The digital globe is our oyster

June 2011 marked 6 years since the mainstream release of Google Earth™, together with other "digital globes", revolutionized the public use of geospatial information by providing a vast database of freely accessible, high-resolution imagery. Geospatial information is crucial in environmental research to make temporal and spatial linkages between features at the landscape scale and to better inform policies for the conservation of imperiled ecosystems. Yet established geospatial software is often expensive, analysis requires substantial training, and freely available satellite imagery (such as Landsat), though welcomed, may be at a resolution too coarse for many applications. High-resolution image use is therefore restricted to researchers with specialized tools, expertise, and funding (Tanser and le Sueur 2002). In this regard, the arrival of freely accessible, high-resolution geospatial data through digital globes has marked a new era in the "democratization of geospatial science" (Butler 2006). Digital globes can increase access to high-resolution imagery and simple spatial analysis tools, and could be one instrument to help narrow the recognized knowledge, funding, and capacity gaps between researchers in developed and developing nations (Tanser and le Sueur 2002).

Despite the "treasure trove" of high-resolution imagery available, it is surprising that little academic research in high-impact environmental journals has explicitly utilized this geospatial resource (with the exception of Begall *et al.* 2008). The wider use of digital globes can address the critical need for inexpensive mapping tools, often recognized by the public health and disaster management communities (inter alia Tanser and le Sueur 2002; Nourbakhsh *et al.* 2006). Digital globes can strengthen environmental research in both developing and developed nations, where facilities and image access may be lacking, or in situations where simple spatial analysis is not the focus of, but would greatly benefit, ongoing research. The broader application of digital globes could be better realized by the academic environmental community; so far, it is predominantly non-peer-reviewed sources and environmental blogs that have encouraged their use in ecological and conservation research.

Several factors may constrain the greater academic use of digital globes. First is perceived inaccuracy; for example, Google Earth™ provides inadequate metadata regarding image processing and spatial accuracy. However, analysis (Potere 2008; Friess *et al.* unpublished) shows that geocorrection accuracy is not an issue, in some locations at least. Accuracy is also scale-dependent; some inaccuracy may be acceptable if broad observations are required on the landscape scale. Secondly, digital globes may be perceived as unsuitable for academic research because they are a freely accessible resource with features that allow extensive contributions from the general public. Thirdly, researchers may not be fully aware of the capability of digital globes: the available literature suggests that digital globes are used for study site selection or to reference other imagery types, though spatial statistics can also be extracted via Google Earth Pro™ or associated shareware plugins.

Such constraints are unproven, surmountable, or outweighed by the need for, and the benefits of, the increased use of digital globes for basic spatial applications. Some constraints can be addressed by increased acceptance, awareness, and scientific contributions ("evidence" of its use) from researchers. Digital globes can cost-effectively increase spatial data capacity to the great benefit of researchers, decision makers, and students lacking expertise, training, or access to specialist spatial software and high-resolution imagery sources.

Six years after the mainstream introduction of digital globes, it is time to unleash the research potential stored within their vast database of high-resolution geospatial data.

Daniel A Friess[1*], Enoka P Kudavidanage[1,2], and Edward L Webb[1]
[1]National University of Singapore, Singapore [*](dan.friess@nus.edu.sg); [2]Sabaragamuwa University of Sri Lanka, Belihuloya, Sri Lanka

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Overestimating conservation costs in Southeast Asia

Peer-reviewed letter

It is important to moderate the often exaggerated expectations about the potential for carbon payments to secure tropical forest conservation, but pessimism also needs to be kept in check. On the pessimistic side, Fisher *et al.* (*Front Ecol Environ* 2011; **9[6]**: 329–34) estimated that the opportunity costs of conserving forests in Southeast Asia range between US$9860 and US$12 750 per hectare from logging and a further US$11 240 per hectare from subsequent conversion to oil-palm (*Elaeis guineensis*) plantations. We agree with the authors that these costs exceed any likely payments from international programs for Reducing Emissions from Deforestation and Forest Degradation and enhancement of carbon stocks (REDD+), but we do not think that these figures apply generally across Southeast Asia.

In our opinion, the costs-of-conservation estimates presented by Fisher *et al.* are derived from above-average timber yields and prices, lower-than-normal harvesting costs, and exaggerated oil-palm profits. Moreover, the authors apparently disregarded government policies that preclude forest conversion. Finally, the assumption that carbon payments must compete directly with extractive industries overlooks options for enhancing carbon stocks and cutting conservation costs through the use of reduced-impact logging techniques and other well-known improved forest management methods.

Across the Southeast Asian region to which Fisher *et al.* extrapolate their results, forests differ substantially in structure and composition but reach some of their highest commercial timber volumes in Sabah, in northeastern Borneo (Putz *et al.* 2001). Indeed, the historical timber yield from the site upon which Fisher *et al.* base their estimated 152 m^3 ha^{-1} is double the norm. Elsewhere in Borneo, primary forests typically yield only 40–65 m^3 ha^{-1} (WebTable 1). For example, the mean harvest volume (1990–2008) from five concessions, covering 271 255 ha of primary dipterocarp forest in Kalimantan (Indonesian Borneo), was only 44.2 m^3 ha^{-1} (WebTable 2). Furthermore, given that most of the lowland forests in Borneo have already been logged at least once and recognizing that much of the forest on level terrain has already been converted to other land uses, harvestable volumes are now typically even lower.

In Indonesia, the largest producer of timber in the region, policies designed to promote local industries – including a log export ban in effect since 1985 – have depressed log prices (Manurung 2008). For example, the 2007–2009 price of US$153 m^{-3} for *Shorea* spp (meranti) timber used by Fisher *et al.* is substantially higher than the US$122 m^{-3} paid in Indonesia in 2009 (MoF 2010; WebPanel 1).

Timber harvesting in Kalimantan costs an average of US$80 m^{-3} (WebTable 3), which is 33% more than the Fisher *et al.* estimate of US$60 m^{-3}. Higher costs in Kalimantan are due primarily to the inclusion of a license fee, the costs of log grading and preparation of annual harvest plans, and funds for local social welfare projects (WebPanel 2).

Based on (1) harvests of 54 m^3 ha^{-1}, which is the mean harvest level from other studies in Southeast Asia (WebTable 1) plus our figures from five concessions in Kalimantan (WebTable 2), (2) log prices of US$122 m^{-3}, and (3) logging costs of US$80 m^{-3}, we calculate the net present value (NPV) of a logging operation in Indonesian Borneo to be US$2268 per hectare, which is much less than that reported by Fisher *et al.* (WebPanel 3).

Oil palms do not yield a constant quantity of fruit throughout their life cycle, as assumed by Fisher *et al.* Indeed, oil palms produce no harvestable fruit during their first 2 years and require about 7 years to reach full yield. Coupling their economic model with the average standardized oil-palm yield curve presented by Butler *et al.* (2009), the NPV of a well-run oil-palm plantation is US$6766, about half of the estimate of Fisher *et al.* (WebPanel 4).

Plugging our estimated logging and oil-palm rents into Equation 4 from Fisher *et al.*, we calculate an equilibrium carbon price of US$17.97 per ton of carbon dioxide equivalent (tCO_{2eq}) averted, which is substantially lower than their estimate of US$46–48 per tCO_{2eq}. Our figure is comparable with the US$10–33 per tCO_{2eq} estimated in a previous study on the opportunity and transaction costs of REDD+ in Kalimantan's planned oil-palm plantations (Venter *et al.* 2009). Although our estimate accounts for the profits from conversion of lowland forest into oil-palm plantations, much of the remaining forests in Southeast Asia are legally zoned as permanent forest estate (WebPanel 5) and are therefore not eligible for such profits.

Not considered in our analysis is improved forest management as a cost-effective means of reducing carbon emissions and promoting forest conservation (Putz *et al.* 2008). Selectively logged forests retain most of their carbon and biodiversity (Berry *et al.* 2010) and, if logging is carried out by trained crews using reduced-impact logging techniques, the savings are even greater (Pinard and Putz 1996; Putz *et al.* 2008).

Our results suggest that the opportunity costs of retaining forests in Southeast Asia are generally much lower than those reported by Fisher *et al.*, which is good news for conservation. Nevertheless, the potential for REDD+ to conserve imperiled forests hinges on more than just opportunity costs. Equally important will be overcoming institutional inertia, winning over forest-exploiting communities and companies, accurately monitoring forest carbon stocks across large areas, and convincing investors that emissions reductions are authentic. The heights of these hurdles are hard to gauge, but the emergence of large-scale REDD+ programs across the tropics (www.forestcarbonportal.com) gives us reason for cautious optimism.

Ruslandi[1], Oscar Venter[2,3], and Francis E Putz[4*]
[1]Tropical Forest Foundation, Asia and Pacific Regional Office, Jakarta, Indonesia; [2]School of Biological Sciences, University of Queensland, Brisbane, Australia; [3]School of Marine and Tropical Biology, James Cook University, Cairns, Australia; [4]Department of Biology, University of Florida, Gainesville, FL, and Southern Cross University, Brisbane, Australia
[*](fep@ufl.edu)

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Underestimating the costs of conservation in Southeast Asia

In their letter, Ruslandi *et al.* raise some interesting points but also make several misleading statements, which overall make us confident that the cost of protecting the primary rainforests of Southeast Asia is indeed very high.

Ruslandi *et al.* promote the use of carbon payments to enhance carbon stocks, fund reduced-impact logging, and improve forest management, arguing that such payments could prevent highly destructive logging practices and forest conversion – an analysis that they suggest was lacking from Fisher *et al.* (2011a). However, the explicit aim of our paper was to evaluate the use of REDD+ to protect the remaining *primary* (ie *un*logged) forests of Southeast Asia. Although we agree with Ruslandi *et al.* that carbon payments have important roles to play in the protection of degraded forests (eg Edwards *et al.* 2010, 2011), by definition, payments for reduced-impact logging cannot provide any protection for primary forests.

We welcome the publication of Tropical Forest Foundation timber records and extraction costs in the Ruslandi *et al.* letter; these new data clearly show that, in their study area, logging is more costly, timber yields are smaller, and profits are lower than those in Sabah, Borneo, where we worked. Ruslandi *et al.* take these data, plus timber yields from seven other studies, and compare them with our yields. However, the authors overlook many other relevant studies. Here, we conduct a more exhaustive review of extraction data from 25 study locations (including those in Ruslandi *et al.*) across Southeast Asia. Extraction rates are highly variable, ranging from 25 m^3 in Sarawak, Borneo, to 205 m^3 in the Philippines (mean ± standard error [SE] = 84.9 ± 9.0; WebTable 1). All studies present yields from operations with 50–60-cm diameter at breast height (dbh) cutting limits, but there is additional timber value beneath this limit – consisting of both the most valuable and different (eg *Octomeles* spp, *Neolamarckia* spp, and *Duabanga* spp) tree species – that must also be offset. In Fisher *et al.* (2011a), this value (representing logging trees of between 40- and 60-cm dbh as well as the growth before the second cut, discounted at 10% over a 16-year span between cuts) was roughly $1000 per hectare, a value missed in Ruslandi *et al.* (but explored in Fisher *et al.* 2011c); note: all monetary values in this letter, unless noted otherwise, are expressed in 2009 US dollars.

For each timber harvest listed in WebTable 1 – combined with price and extraction costs for harvests in Malaysia (Fisher *et al.* 2011a), Indonesia (Ruslandi *et al.*), and elsewhere (taken as the midpoint of the two studies) – we find that profits from logging operations in tropical Southeast Asia could fall in the range of $1260 to $13 840 per hectare (mean ± SE = $5563 ± 757; WebTable 1). But again, this estimate disregards the values below 50–60-cm dbh. Ruslandi *et al.*'s estimate of $2268 is thus much less than half the regional average timber value.

We appreciate the use of the average standardized oil-palm yield curve by Ruslandi *et al.*, which they use to derive a net present value (NPV) of $6766 per hectare of oil palm (versus $11 240 in our paper). But – importantly – the NPV of agricultural yield rents is heavily determined by (1) the discount rate used and (2) the price of the crop. In WebTable 2, we vary these two factors to calculate the NPVs for a non-optimized oil-palm plantation using the same yield curves as those in Ruslandi *et al.*, and we show a huge range of potential values.

Two things are evident. First, lower discount rates (toward 5%) shift the $6766 estimate upward; since the Malaysian bond market rate is 4–10%, these higher values seem more reasonable. Second, since we conducted our analysis, the price per metric ton of crude palm oil increased from $788 to $1048 (22 Jul 2011; www.palmoilhq.com/crude-palm-oil-cpo-futures/), which has a large positive impact on profits. Combining July's price with 5% and 10% discount rates suggests that oil-palm profits are as high or higher than those presented in our paper (WebTable 2).

High estimates for oil-palm profits are supported by the financial reports of large plantation companies. Industrial Oxygen Incorporated's (IOI's) 2010 Annual Report gives an operating profit per hectare of mature oil palm of Malaysian Ringgit (RM) 8148 (= $2400; 2009 exchange rate where US$1 = RM 3.39) (p28 in IOI 2010) per year, which equates to an NPV of $15 800 ($r$ = 10%, production years 4–25). Wilmar International's 2009 Annual Report calculates the NPV of one hectare of oil palm as ranging from $9250 to $20 710 (Wilmar's accounting discount rate ranges from 7.36% to 15.9%; Wilmar International 2009). While the NPV used by Fisher *et al.* (2011a) – $11 240 – falls within the range of values reported by Wilmar International and below IOI's valuation, Ruslandi *et al.*'s NPV of $6766 and Venter *et al.*'s (2009) NPV of $5510 largely underestimate profits from oil-palm production, as reported by major palm producers themselves.

Ruslandi *et al.* also incorrectly use Fisher *et al.*'s (2011a) Equation 4 to calculate a breakeven price for carbon based on their estimates. In our paper, the carbon emitted from logging was explicitly tied to the magnitude of timber removed (and hence the value of the timber). Ruslandi *et al.* remove only a fraction of the timber, at higher cost, and therefore reap a much lower potential rent. They then divide this rent by the total amount of carbon that would be liberated if they were logging 152 m^3 ha^{-1} and then converting to oil palm. Surely the carbon emissions from a Ruslandi *et al.* forest of 54 m^3 ha^{-1} cannot liberate the same levels of carbon as the primary forests analyzed in Fisher *et al.* (2011a), but in using our equation, they take a small profit and divide it by a huge carbon emissions profile, greatly (and erroneously) driving down the breakeven price to just $18 per metric ton of CO_2.

For the reasons discussed above, we are confident that the breakeven price for carbon remains much higher than Ruslandi *et al.*'s estimate. The key question is whether lower breakeven prices than the $44–46 per metric ton of CO_2 in our paper can compete on a global carbon market. In Brazil, 90% of deforestation might be thwarted by carbon prices of $2.80 per metric ton C (~$10 per metric ton CO_2; Nepstad *et al.* 2007), while in East Africa, a carbon payment of $6.50 per metric ton CO_2 has the potential to stop deforestation (Fisher *et al.* 2011b). Both of these studies indicate that carbon can be stored much more cheaply in tropical regions other than Southeast Asia. The reasons for this disparity are simple: Southeast Asia is a nexus of high timber yield, high timber prices across tree species, and high-value agriculture. Fisher *et al.* (2011a) and this further analysis thus suggest that intrinsic, cultural, and social values, rather than carbon payments, are most likely to protect Southeast Asia's remaining primary lowland forests. We caution against underestimating the costs of protecting Southeast Asian versus other primary forests, lest conservation planning rely too heavily on unrealistic outcomes.

David P Edwards[1*†], Brendan Fisher[1], Xingli Giam[2], and David S Wilcove[1,2]
[1]*Woodrow Wilson School of Public and International Affairs, Princeton University, Princeton, NJ;* [†]*current address: School of Marine and Tropical Biology, James Cook University, Cairns, Australia*
[*]*(dave.edwards@jcu.edu.au);*
[2]*Department of Ecology and Evolutionary Biology, Princeton University, Princeton, NJ*

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