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A probabilistic scenario approach for developing improved Reduced Emissions from Deforestation and Degradation (REDD+) baselines

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ABSTRACT

Performance-based payments are widely seen as a promising tool for Reduced Emissions from Deforestation and forest Degradation (REDD+) in tropical forests. Despite great advances in international REDD+ negotiations, there is a lack of consensus around the development of business-as-usual (BAU) reference scenarios or baselines to derive and quantify net carbon emission reductions. In this paper, we explore a novel approach for developing baselines (point forecasts) using exponential smoothing. Further, we introduce the concept of probabilistic BAU scenario ranges developed using this approach. We compare predictive performance with the linear trend and historical averages approaches conventionally used in policy proposals and REDD+ pilots.

We empirically test the relative performance of all three approaches by forecasting BAU baselines and scenario ranges in 36 sites (consisting of 20 countries and 8 Amazonian states with and 8 countries without REDD+ schemes). Based on two predictive performance measures (the root mean squared error and mean absolute percentage error), we find that exponential smoothing outperforms the linear trend and historical average models at predicting forest cover changes. In addition, we show how prediction intervals based on a desired confidence level generated through exponential smoothing can be used in novel ways to determine likely baseline scenario ranges. In this way it is possible to quantify the degree of variability and uncertainty in datasets. Importantly, this also provides a statistical measure of confidence to determine if REDD+ interventions have been effective.

By generating robust probabilistic baseline scenarios, exponential smoothing models can facilitate the effectiveness of REDD+ payments, support a more efficient allocation of scarce conservation resources, and improve our understanding of effective forest conservation investments, also beyond REDD+.

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1. Introduction

Mechanisms to incentivise global conservation and tackle climate change based on payment-for-performance approaches have attracted increased attention, due in large part to the perceived failure of conventional regulation in tackling cross-boundary challenges and environmental externalities (Simpson and Sedjo, 1996; Ferraro, 2001; Ferraro and Kiss, 2002; Ferraro and Simpson, 2002). To be successful, such approaches require a methodology for adequately measuring and verifying performance (Ferraro and Pattanayak, 2006), and this requires a baseline against which performance can be measured. This baseline needs to be defined in a way that is perceived as fair by relevant stakeholders, meaning it needs to be transparently, consistently, and comparably set across sites or countries to provide equitable incentives to those asked to participate (Grassi et al., 2008). Crucially, the baseline methodology needs to provide accurate prediction of what would occur under a BAU scenario (defined as the most likely scenario without implementation of an incentive system) so as to ensure that meeting or outperforming it represents additional positive outcomes (Angelsen, 2008; Olander et al., 2008).

Most prominent among the payment-for-performance systems are a variety of approaches for Reduced Emissions from Deforestation and forest Degradation (REDD+) (Ebeling and Yasué, 2008). REDD+ has become an important part of the broader international climate change debate as forest cover loss accounts for up to 15% of global greenhouse gas (GHG) emissions (Van der Werf et al., 2009). A REDD+ mechanism under the United Nations Framework Convention on Climate Change (UNFCCC), or via bilateral agreements, or though the voluntary carbon markets would reward countries, sub-national jurisdictions, or projects for reducing GHG emissions associated with forest loss (Angelsen, 2008; Olander et al., 2008). REDD+ policies require a sequence of activities including measurements of the carbon density of different types of forests, establishing a plausible BAU baseline for forest cover loss patterns and associated GHG emissions, implementing measures to reduce forest cover loss, and monitoring actual forest cover loss and GHG emissions through time. Incentive payments, for example, through the market-based sale of emission reduction units would be based on avoided GHG emissions compared to the BAU baseline (Angelsen, 2008; Ebeling and Yasué, 2008).

Determining a credible methodology for measuring and verifying performance remains one of the most significant challenges for performance-based conservation schemes such as REDD+. For example, determining a forest baseline against which actual outcomes as a result of policy interventions can be compared, is challenging due to the sheer number of interacting drivers operating across scales that affect future forest cover change. Further, new drivers or factors often create surprises in the form of abrupt and non-linear forest cover loss through time (Ghazoul et al., 2010; Angelsen et al., 2012; Sloan and Pelletier, 2012; Müller et al., 2014). A variety of options for predicting the 'most credible' baseline have been proposed and these are variably used in existing REDD+ pilot schemes. These can be roughly grouped into three types of modelling approaches for baseline setting: (i) extrapolated historical; (ii) forward looking; and (iii) adjusted historical (see below for limitations of each approach).

Currently, most project-based REDD+ mechanisms in voluntary markets, such as the Verified Carbon Standard (VCS), or negotiated multi- and bi-lateral schemes aim to set forest baselines based on extrapolated historical of BAU GHG emissions. For example, The Forest Carbon Partnership Facility Carbon Fund, the Norway–Guyana REDD+ Investment Fund, and the Norway–Amazon Fund favour the use of some sort of historical averages at either regional or global scales. The latter uses a rolling average method among states (Chagas et al., 2013) whilst the VCS uses linear regressions. Ongoing negotiations at the Conference of the Parties (COP) of the UNFCCC suggest that negotiators are leaning towards a mixture of approaches for setting REDD+ baselines (see Griscom et al., 2009 for limitations of baseline setting approaches being proposed under UNFCCC, including Compensated Reductions, Joint Research Center Proposal, Terrestrial Carbon Group, Corridor Approach, Combined Incentives, The Stock Flow approach).

All three baseline setting approaches for REDD+ have limitations. For example, the extrapolated historical methodology assumes that history is the best marker to the future (or its best approximation), and therefore simply extrapolates historical forest cover change data into the future. This applies to historical averages, or a simple linear trend, or exponential smoothing—the focus of this paper. The main issue with extrapolated historical is that it ignores dynamic non-linear interactions among drivers or cannot predict new drivers. For example, the use of linear regression models, as applied in the voluntary markets, with extrapolation to values beyond the observed time periods (also called forecasting in time series modelling) can lead to very misleading and potentially erroneous results (Wood, 2006; Moore et al., 2009). The risk in extrapolation is that the fitted linear trend may wrongly imply a linear future trend (see for example Tatem et al., 2004), and abrupt changes may occur before or within the forecasting period. This can also have severe impacts on prediction intervals associated with forecasted values (Hyndman and Athanasopoulos, 2014).

The second approach proposed for baseline setting, forward looking approach, suggests that the only way to understand future emissions is to model the drivers of land use change. Spatially explicit forward looking models have been the preferred options among those involved in REDD+ at the UNFCCC negotiations (Huettner et al., 2009). However, like extrapolated historical models, forward-looking models cannot predict new drivers nor model the complex and changing interactions among drivers (Sloan and Pelletier, 2012). Further, such models are complex and require various data inputs creating the risk that both the tool and datasets may be inconstantly used by different REDD+ countries or projects. They can also be problematic if the data requirements are too onerous or if the underlying modelling is too complicated and lacks transparency (Huettner et al., 2009). Further, empirical evidence suggest that even sophisticated spatially explicit models have limited ability to anticipate forest-cover change due to non-linear and complex interactions among drivers (Sloan and