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Assessing audit impact and thoroughness of VCS forest carbon offset projects

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ABSTRACT

Voluntary markets transacted over $66 million USD of forest carbon offsets in 2016, according to Forest Trends, and over 99% of those offset projects were audited to a standard, primarily the Verified Carbon Standard (VCS). We provide a table characterizing all 70 validated and verified forest carbon projects employing the VCS version 3.0 currently-in-use (December 2011–July 2017). We also examine two separate aspects of the audit process—impact and thoroughness—to assess the effectiveness of the costly audit process, which can consume up to one-third of offset revenue. Audit impact we measure in terms of reduction in the number of offsets from *ex ante* estimated to *ex post* approved. Audit thoroughness we measure both directly in terms of the number of auditor hours worked per project and also indirectly in terms of the total number of Corrective Action Requests (CARs)/Non-Conformity Reports (NCRs) auditors prescribe. In terms of impact, we find that Afforestation/Reforestation/Restoration (A/R/R) and Improved Forest Management (IFM) projects, though only constituting 5% of total verified offsets, demonstrate significant ($p <= 0.05$) reductions from *ex ante* estimated to *ex post* approved offsets, likely because auditors can easily scrutinize carbon stocks/emission factors for the commercial tree species involved in these project types. In terms of thoroughness, we find that higher *ex ante* estimates correlate with more total auditor hours worked and total CARs/NCRs prescribed for three of four project activity types, likely because auditors perceive larger *ex ante* projects as higher risk. We conclude with recommendations for the VCS to empower auditors to scrutinize carbon stocks/emissions factors from avoided deforestation projects, and also to continue to flag high *ex ante* projects as higher risk.

1. Introduction

Forest emissions constituted approximately 10–15% of the 52 gigatons of greenhouse gases emitted (in carbon dioxide equivalents (CO_2e)) from anthropogenic sources in 2015 (UNEP, 2016), with the lower 10% estimate including only deforestation net regrowth and the upper 15% estimate also including emissions from degradation and drained peat soil (Pearson et al., 2017). In response to these emissions from the forestry sector, the United Nations Framework Convention on Climate Change (UNFCCC) (see Table 1 for acronyms) Paris Agreement of 2015 states: "Parties are encouraged to take action to implement and support…activities relating to Reducing Emissions from Deforestation and forest Degradation, [plus] the role of conservation, sustainable management of forests, and enhancement of forest carbon stocks (REDD +)." Indeed, REDD+ initiatives provide up to a quarter of the intended nationally determined contributions planned by tropical countries under the Paris Agreement (Grassi et al., 2017).

REDD+ initiatives differ from historic integrated conservation and development projects primarily by their conditionality of payment-for-performance of carbon storage conducted via measurement, reporting and verification (MRV) (Blom et al., 2010) that effectively convert fund-based initiatives into market-based initiatives.[1] Publicly funded REDD+ initiatives from the United Nations and World Bank highlighted by the Paris Agreement are years away from this payment-for-performance conditionality, but privately funded REDD+ initiatives are already there. In 2016, over $66 million USD of forestry offsets were purchased in the voluntary market, primarily for the demonstration of corporate socio-environmental responsibility (Hamrick and Gallant, 2017).

Compliance markets have required audits against protocols and methodologies for transacted projects since their inception, with the audit process effectively converting abstract offsets into credible market

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[1] Salles et al. (2017) identified four major differences between private, market-based and public, fund-based forest carbon initiatives in Brazil: (1) results-based vs. effort-based financial compensation; (2) decadal vs. annual project timeframes; (3) project vs. state/provincial spatial scales; and (4) standardized quantitative reporting with third-party auditor inspections vs. differentiated qualitative reporting with second-party agency or foundation inspections.

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Table 1
Acronyms (in alphabetical order) used in the research article and their full referents with additional descriptions in parentheses.

Acronym	Full referent
AENOR	Asociación Española de NORmalización y certificación (auditing firm)
APD	Avoided Planned Deforestation (project activity stratum)
A/R/R	Afforestation/Reforestation/Revegetation (project activity stratum)
AUDD	Avoided Unplanned Deforestation & Degradation (project activity stratum)
CAR/NCR	Corrective Action Request/Non-Conformity Report (type of auditor finding)
CCB	Climate, Community, and Biodiversity (standard)
CDM	Clean Development Mechanism (standard)
CEC	China Environmental united certification Center (auditing firm)
DNV	Det Norske Veritas (auditing firm)
ERA	Extension of Rotation Age or cutting cycle (sub-stratum of IFM)
ESI	Environmental Services International (auditing firm)
FSC	Forest Stewardship Council (organization & standard)
IFM	Improved Forest Management (project activity stratum)
IPCC	Intergovernmental Panel on Climate Change (organization)
LtPF	Logged to Protected Forest (sub-stratum of IFM)
MR	Monitoring Report (document against which auditors conduct verification)
MRV	Monitoring, Reporting & Verification
NIR/CL	New Information Request/CLarification request (type of auditor finding)
PD	Project Document (document against which auditors conduct validation)
RA	Rainforest Alliance (auditing firm)
REDD+	Reducing Emissions from Deforestation & forest Degradation [+] the role of conservation, sustainable management of forests & enhancement of forest carbon stocks
SCS	Scientific Certification Systems (auditing firm)
UNFCCC	United Nations Framework Convention on Climate Change (organization)
VCS	Verified Carbon Standard (organization & standard)
VVB	Validation & Verification Body (analogous to "auditing firm")

goods (Kelly and Schmitz, 2016). Voluntary markets have increased their use of the audit process over time: from fewer than 50% of transacted projects audited against standards in 2005 to over 99% in 2016 (Hamrick and Gallant, 2017). Voluntary forest carbon offsets are covered by three major international standards: the Gold Standard; Plan Vivo; and the Verified Carbon Standard (VCS). A separate co-benefit/safeguard standard, Climate, Community and Biodiversity (CCB), is occasionally employed in combination with the VCS to demonstrate the conservation of biodiversity and the improvement of socio-economic welfare. We focus on the VCS because: (1) the VCS is applicable, through specific methodologies,[2] to the entire range of REDD+ project types, making it the most widely used standard in more than two-thirds of voluntary forest carbon offsets by total transacted volume (Goldstein, 2016); (2) the VCS, among all global standards, involves the most comprehensive (Merger et al., 2011) and the most conservative (Galik et al., 2009) calculation of forest carbon offsets; and (3) the VCS does not employ a pre-validation/pre-verification assessment by standards personnel, so publicly available VCS audit reports contain all findings.

All VCS offset projects must prove additionality by demonstrating that the projects are unique and face significant barriers in the absence of carbon finance (including, among other offset types, landfill methane conversion, machinery fuel substitution, and sun, water, and wind power). We focus on forest carbon offsets due to additional challenges they must overcome to make them equivalent with other offset types, adding greater weight to the auditing process. These challenges include: (1) risk of impermanence (reversal of sequestered carbon to the atmosphere) due to natural disturbances and also anthropogenic cutting and burning; (2) error-prone extrapolation from small measurement plots to large forest tracts to calculate carbon stocks/emission factors; (3) reliance on hypothetical, counter-factual baselines to calculate activity data; and (4) susceptibility to negative spillage or leakage[3] by displacing current land uses (Agrawal et al., 2011).

Offset project proponents typically go through seven steps,[4] including two audits, from project initiation to selling their first tranche of offsets on a VCS-sanctioned offset registry. On the registry, vintages are recorded to specify the date of carbon emission reduction/removal and also identification numbers are assigned to reduce the risk of double-counting. The first audit involves a qualitative validation of project design based on the Project Document (PD). Concurrent with or subsequent to validation, a second audit involves a quantitative verification of offset quantities produced over the monitoring period based on the Monitoring Report (MR). Typically, validation is only conducted once at project initiation (unless project specifications change significantly), whereas the VCS requires verification at least every five years to confirm offset quantities during the minimum 30 year required project length (else impermanence risk buffer credits are put on hold and potentially cancelled). Forest carbon projects often require at least two years from conception to audit readiness, and the audit process typically lasts an additional six months (*Ibid*). Figs. 1 and 2 illustrate how forest carbon auditors conduct field audits, including observing a project inventory team following its standard operating procedures for carbon stock/emission factor measurement, and assessing project activity implementation in terms of reforestation progress.

The VCS is considered a legitimizing institution[5] as it transforms the invisible commodity of carbon into a credible market good (Corbera and Brown, 2010) via standard development, auditor (Validation and Verification Body (VVB)) accreditation, and credible market access via the VCS registry. In terms of accreditation, VCS audit firms are subject to oversight from the American National Standards Institute or the Clean Development Mechanism (CDM) Accreditation Panel. In addition, to reduce the risk of client capture, the VCS requires projects to rotate with at least one other auditing firm during successive verification audits after the first validation and verification.

REDD+ projects involve two major explicit costs: implementation costs of activity administration and realization; and transaction costs of

[2] VCS forest carbon offset methodologies provide instructions for: (1) Identifying the project boundary; (2) Determining the baseline scenario; (3) Demonstrating additionality; (4) Quantifying net greenhouse gas emission reductions and/or removals; and (5) Specifying monitoring procedures to track emission reductions and/or removals. Methodologies also provide guidance on which of the seven stocks are eligible for quantification including: (1) Live aboveground tree; (2) Live aboveground non-tree; (3) Coarse and fine roots; (4) Standing and downed dead wood; (5) Litter; (6) Soil; and (7) Harvested wood products. To date, the VCS has approved 13 forestry methodologies, four Clean Development Mechanism (CDM) A/R/R methodologies, and one forestry performance method for reduced impact logging. Each of these 18 methodologies and performance methods is specific to a defined project activity and in some cases a particular location.

[3] Leakage is defined by the VCS as "the net change of anthropogenic emissions by GHG sources that occur outside of the project/program boundary, but are attributable to the project/program." The VCS recognizes negative leakage arising from activity-shifting drivers, ecological factors, and/or economic market forces.

[4] The seven project development steps in chronological order are: (1) Completing a PD for auditors; (2) Undergoing a validation audit based on the PD; (3) Registering the validated project with the VCS; (4) Completing an MR for auditors; (5) Undergoing a verification audit based on both the PD and the MR; (6) Registering the verified project with the VCS; (7) Issuing the first tranche of offsets via a VCS-approved registry, then repeating steps 4–7 often called Monitoring, Reporting and Verification (MRV) (Olander and Ebeling, 2011).

[5] The VCS Requirements version 3.0 provides six principles to guide the institution's legitimizing role: "(1) Relevance: Select the GHG sources, GHG sinks, GHG reservoirs, data and methodologies appropriate to the needs of the intended user; (2) Completeness: Include all relevant GHG emissions and removals and include all relevant information to support criteria and procedures; (3) Consistency: Enable meaningful comparisons in GHG-related information; (4) Accuracy: Reduce bias and uncertainties as far as practical; (5) Transparency: Disclose sufficient and appropriate GHG-related information to allow intended users to make decisions with reasonable confidence; and (6) Conservativeness: Use conservative assumptions, values and procedures to ensure that net GHG emission reductions or removals are not overestimated."

Fig. 1. ESI auditors off-camera scrutinize standard operating procedures for carbon stock/emission factor measurement conducted by the inventory crew for an AUD project in Brazil (courtesy: ESI).

Fig. 2. ESI auditor Eric Jaeschke inspects tree growth and survival for the reforestation component of a REDD+ project in Indonesia (courtesy: ESI).

audit preparation and execution (White and Minang, 2011). The total transaction costs to sellers from auditing, monitoring, and report preparation is 5–35% (Rendon-Thompson et al., 2013; Bellassen et al., 2015) of offset revenue with implementation costs at approximately the same amount (Rakimata et al., 2017). Transaction costs are justified by enabling access to credible markets (White and Minang, 2011) but they also increase the economies of scale (Cashore et al., 2007) for REDD+ projects, essentially making smaller projects non-viable financially at less than 1000 HA at offset prices of \$8 USD/tCO_2e and less than 2000 HA at offset prices of \$4 USD/tCO_2e (Pearson et al., 2014).

The international voluntary offset market currently suffers from low demand, likely from pre-compliance buyers no longer participating due to diminished prospects (Liang et al., 2016). The total volume of forest carbon offsets transacted has dropped by approximately 25% from 17 million tons CO_2e in 2011 (when VCS version 3.0 was introduced) to 13 million tons CO_2e in 2016. The average price has fallen even more sharply, by nearly 50%, from an average price of \$10.12 USD/tCO_2e in 2011 to an average price of \$5.10 USD/tCO_2e in 2016 (Peters-Stanley et al., 2012; Hamrick and Gallant, 2017).

In the face of falling demand, transaction costs can only be sustained if they support market credibility, for example by ensuring that buyers driving demand receive at least as many offsets as they pay for. Recent research, however, questions the credibility of international voluntary forest carbon offsets. Seyller et al. (2016) and Van Kooten et al. (2015) demonstrate how baselines may have been gamed in avoided unplanned deforestation projects in Africa and Canada by using reference areas with dense populations and addressable markets to project future deforestation for relatively unpopulated and inaccessible project areas.

Our research builds on these studies by examining whether the VCS audit process builds credibility by minimizing the potential "hot air" of inflated offsets (due to either inadvertent miscalculation or intentional misrepresentation) so that buyers receive at least as many offsets as they pay for. Specifically, we ask the following two questions: (1) *Audit impact:* Does the audit process have a statistically significant impact in reducing the total number of project offsets from *ex ante* estimated to *ex post* approved?; and (2) *Audit thoroughness:* Do projects with the largest *ex ante* offsets (and associated risk of "hot air") receive more thorough audits than projects with smaller estimated offsets?

2. Methods

We derived our data from publicly available audit reports, which is an approach similar to Newsom et al. (2006) (who used Forest Stewardship Council (FSC) certification audit reports), and also to Lawlor et al. (2013) (who used CCB validation audit reports). We accessed all VCS audit reports (www.vcsprojectdatabase.org) as of 01 July 2017 and selected all projects in sectoral scope 14 (agriculture, forestry, and other land use), bringing up a total listing of 145 projects internationally. Only projects employing the current VCS version 3.0 were selected to provide a time period where auditors used a consistent and modern standard. This filter reduced the number of projects from 145 to 124, from a validation date of 22 December 2011 ("TIST Program in Kenya-005") to a verification date of 03 May 2017 ("Lacandon-Forest for Life"). Only projects that passed not only validation but also first verification to approve offset quantities were selected, because this study considers not only project design but also offset calculation. This filter reduced the total number of projects from 124 to 77. Finally, two reforestation projects were phased in, with three phases in Kenya and six phases in Uganda. We aggregated these nine projects into one in Kenya and one in Uganda so as not to weight our results disproportionately with any one identical project participant group in any one specific location. This final filter reduced the total number of projects from 77 to 70.

We stratified our findings by VCS project activity type using abbreviations from Shoch et al., 2013. The VCS has developed three major project types based on the project activity or intervention—Afforestation/Reforestation/Revegetation (A/R/R), Avoided Deforestation and Degradation (ADD), and Improved Forest Management (IFM)—which correspond to the Intergovernmental Panel on Climate Change (IPCC) land use change categories of: converting non-forest to forest land; avoiding conversion of forest to non-forest land; and maintaining forest as forest land. A/R/R (n = 20) projects involve shrub or woody grass planting (revegetation) or tree planting in project areas with a minimum 30 year (afforestation) or 10 year (reforestation) history of

being continuously below country-applicable CDM forest land definitions.[6] ADD projects involve both avoided deforestation (conversion of forest land to non-forest land per CDM forest land definitions)[7] and also degradation (reduction in carbon stocks while still remaining forest land). ADD activities include: border enforcement inside legally protected project areas, often combined with tenure establishment outside; certified partial timber harvesting and non-timber forest product collection inside unprotected project areas; and various land use intensification activities outside project areas to alleviate conversion pressure. The VCS further divides ADD projects into either Avoided Unplanned Deforestation and Degradation (AUDD, n = 31), with baselines forecast from models and reference areas, and Avoided Planned Deforestation (APD, n = 9), with baselines forecast from legal documents of imminent conversion. Avoided planned degradation is categorized by the VCS in the IFM category (n = 11), which includes the project activities of Logged to Protected Forest (LtPF) and Extended Rotation Age (ERA) or cutting cycle. In the rare cases where a single project covered multiple activities, we categorized the project by the activity consuming the majority of the land area.

We used both qualitative and quantitative factors to describe all 70 projects in Table 2. The qualitative factors obtained from the PD included: project name and country location; CCB co-benefit/safeguard standard validation and first verification status; name and number of the VCS methodology employed to calculate offsets; predominant vegetation types, including assignment of United Nations Food and Agriculture Organization (FAO) global ecological zone abbreviations (Iremonger et al., 2015); and project participants. These participants included: financial proponents (funding the project); technical developers (contractually responsible to financial proponent for completing the PD and MR); local implementers (contractually responsible for realizing project activities); and auditors (contractually responsible for conducting validation and verification audits). The quantitative factors obtained from the PD, MR, and verification report included: estimated *ex ante* and approved *ex post* offsets on an annual basis over the first monitoring period; project area size in hectares; normalized *ex post* offsets based on project area size; *ex post* percent leakage risk deductions; and *ex post* percent impermanence risk buffers (which may be partially released over time).

We conducted a paired *t*-test between total estimated *ex ante* and total approved *ex post* offsets to evaluate audit impact. We predicted that audits would significantly reduce total offsets, since without the audit process, inexperienced or unscrupulous project developers would attempt to sell the entirety of *ex ante* offset estimates. We calculated *ex post* offsets on an annual basis from the first verification report, confirmed those numbers from the MR, and then calculated *ex ante* offsets for the same time period from the PD. Our comparisons of *ex ante* versus *ex post* offsets were conservative but not necessarily accurate. Comparisons were straight-forward when the monitoring period began on March 15, for example, of a past year and ended on March 15 or December 31 of a future year. Comparisons became complicated when the monitoring period began on March 15 of a past year and ended on October 31, for example, of a future year. In this case, to be conservative, we reduced the corresponding calendar year *ex ante* estimate in the PD by 0.17.

To evaluate audit thoroughness, we obtained information on the total number of auditor hours worked per project. We contacted the three audit firms that dominated our study—ESI (Environmental Services International), RA (Rainforest Alliance), and SCS (Scientific Certification Systems)—in June 2017 and provided them with a summary of our research and a list of projects with dates in which those firms conducted VCS validation and first verification audits. All three agreed to provide the total hours worked (hours billed plus excess) on the condition of signed nondisclosure agreements and payments for administrative fees (up to $500 USD per firm) for 33 projects from our sample size of 70.

We used the total number of audit findings called Corrective Action Requests (CARs)/Non-Conformity Reports (NCRs) from the publically available validation and first verification reports as indirect measures of audit thoroughness. CARs/NCRs are required to be addressed to auditor satisfaction in order for the project proponents to achieve validation or verification.[8] Some auditing firms also report New Information Requests (NIRs) or Clarification requests (CLs). NIRs/CLs are comparable to CARs/NCRs in that they are required to be addressed to auditor satisfaction, but are administrative as opposed to operational. We counted CARs, NCRs, NIRs, and CLs together as "CARs/NCRs" both because of auditing firm inconsistencies in reporting, and also because NIRs/CLs may have significant impacts on offset calculation (for example by requesting clarification on whether the most recent version of a methodology was employed). We excluded altogether from our CAR/NCR counts three types of findings from audit reports: (1) CARs/NCRs that are duplicated on both validation and first verification reports; (2) CARs/NCRs that pertain specifically to the CCB co-benefit/safeguard standard tangential to offset calculation; and (3) all findings that are optional for clients to address prior to validation/verification and are therefore often postponed—called observations, opportunities for improvement, or forward action requests by auditing firms.

We conducted linear regressions to test audit thoroughness. We predicted that the auditors would more closely scrutinize larger absolute offset estimates, as opposed to normalized per area offset estimates. This expectation derived from larger projects being viewed as more material to climate change in terms of the amount of GHG emissions they would offset (the VCS specifically requires disclosure of large offset projects producing more than 300,000 tons of CO_2e annually) and also audit fees, above a threshold, rising for larger projects so auditors could afford to spend more time on larger projects.

We used the traditional $p <= 0.05$ as our statistical significance threshold for audit impact in *t*-tests and $p <= 0.10$ as our statistical significance threshold for audit thoroughness in regressions. Another study based on CCB audit reports reported only percentages and not significance (Lawlor et al., 2013), while a study based on FSC audit reports reported significance using the traditional $p <= 0.05$ (Newsom et al., 2006).

3. Results and discussion

3.1. Qualitative and quantitative overview of all project activity types

Table 2 (with data on all 70 of the VCS validated and verified forest carbon projects over a five and a half year period) should be useful to project proponents and developers whom, whether novice or experienced, lack complete information to quickly answer common questions: where are other VCS REDD+ projects located and who are the participants involved?; how common is CCB co-benefit/safeguard validation and first verification?; which VCS methodologies are most widely employed for various project activities?; which tree species are typically planted in A/R/R projects and what forest types are used for other

[6] Country-specific CDM definitions of forest land range from 0.05-1.0 HA contiguous area, 10–30% crown cover, and 2–5 m average tree height.

[7] The VCS further categorizes deforestation by its spatial pattern: (1) Mosaic deforestation with multiple forest patches less than 1000 HA in an anthropogenic landscape; or (2) Frontier deforestation with contiguous forest patches and penetrating waterways or roads.

[8] CARs/NCRs commonly address these 12 issues (in alphabetical order): (1) Appropriate calculation, mensuration, and modelling techniques; (2) Appropriate deductions for impermanence risk buffer, negative leakage risk and calculation uncertainty; (3) Completeness and format of documentation; (4) Credibility of baseline; (5) Determination of deforestation drivers; (6) Determination of eligible sinks and sources; (7) Determination of project length; (8) Engagement with stakeholders; (9) Establishment of boundaries; (10) Evidence of additionality; (11) Evidence of legal ownership; and (12) Evidence of project activity implementation.

Table 2
Characteristics of all 70 international validated and verified forest carbon projects under VCS version 3.0 from December, 2011 to July, 2017 and t-test results of audit impact. Note that the projects have been stratified by VCS project activity type and listed from small to large in terms of *ex ante* annual offset estimates calculated during the first verification period. Quantitative variables are listed in the first five columns after the project name and country. Qualitative variables are listed in the final four of 10 columns total. VCS methodology number and FAO vegetation code are defined at their first occurrence in columns eight and nine respectively. Auditing firm name acronyms used in column 10 are defined in Table 1.

Avoided Planned Deforestation (APD) stratum (n = 9)									
Project name & country	*Ex ante* (1st row) & *ex post* annual offsets (2nd row) during first verification period (t CO2e/yr)	Offset crediting area (HA)	*Ex post* normalized annual offsets during first verification period (t CO2e/yr/HA)	*Ex post* leakage deduction (%)	*Ex post* impermanence risk buffer (%)	CCB validation & first verification achieved (Yes/No)	VCS methodology employed	Predominant vegetation type (1st row) & FAO code (2nd row)	Project participants (1st row) & audit dates (2nd row)
Paraguay Forest Conservation Project: La Amistad, Paraguay	794	–	–	–	–	Y	VM0007: REDD + methodology framework	Tropical mixed semi-deciduous angiosperm forests	Swire Pacific Offshore Operations (financial proponent); World Land Trust (technical developer); Guyra Paraguay (local implementer); Tuv Sud (auditor)
	609	72	8.5	7%	21%	–	–	Tropical moist forests (TAwa)	28 Oct. 2015 (validation); 12 Feb. 2016 (verification)
Paraguay Forest Conservation Project: Chaco-Pantanal, Paraguay	7,601	–	–	–	–	Y	VM0007	Tropical mixed semi-deciduous angiosperm forests	Swire Pacific Offshore Operations (financial proponent); World Land Trust (technical developer); Guyra Paraguay (local implementer); RA (auditor)
	7,601	4,745	1.6	40%	19%	–	–	TAwa	24 Nov. 2012 (validation); 13 March 2013 (verification)
Avoiding Planned Deforestation & Degradation in the Valdivian Coastal Reserve, Chile	64,980	–	–	–	–	Y	VM0007	Temperate southern beech forests	The Nature Conservancy (financial proponent & local implementer); TerraCarbon & Serval (technical developers); ESI (auditor)
	58,000	1,273	45.6	5%	10%	–	–	Subtropical montane forests (SM)	06 April 2014 (validation); 01 May 2014 (verification)
APD stratum									
Protection of the Bolivian Amazon Forest, Bolivia	71,102	–	–	–	–	N	VM0007	Tropical degraded mixed evergreen forests	REDD Services Ltd. (financial proponent, technical developer & local implementer); ESI (auditor)
	58,170	235	247.5	0%	16%	–	–	Tropical angiosperm forests (TAr)	22 March 2012 (validation); 07 June 2013 (verification)
Bull Run Overseas Forest Carbon Project, Belize	169,287	–	–	–	–	N	VM0007	Tropical pine savannah, mixed semi-deciduous angiosperm & gallery forests	Bull Run Overseas (financial proponent & local implementer); Forest Carbon Offsets & Conservation Management Institute (technical developers); ESI (auditor)
	122,028	567	215.2	0%	23%	–	–	Tropical dry forests (TAwb)	14 March 2012 (validation & verification)
Rio Bravo Climate Action Project, Belize	184,473	–	–	–	–	N	VM0007	Tropical mixed semi-deciduous angiosperm forests	Forestland Group (financial proponent & local implementer); ERA/Offsetters (technical developer); ESI (auditor)
	184,473	6,296	29.3	28%	14%	–	–	TAwa	30 March 2016 (validation); 23 May 2016 (verification)
APD stratum									
Laguna Seca Forest Carbon Project, Belize	234,994	–	–	–	–	N	VM0007	Tropical mixed semi-deciduous angiosperm & freshwater swamp forests	CKVB Forestal Inc. (financial proponent & local implementer); 33 Forest Capital & TerraCarbon

(*continued on next page*)

Table 2 (*continued*)

Avoided Planned Deforestation (APD) stratum (n = 9)									
Project name & country	*Ex ante* (1st row) & *ex post* annual offsets (2nd row) during first verification period (t CO2e/yr)	Offset crediting area (HA)	*Ex post* normalized annual offsets during first verification period (t CO2e/yr/HA)	*Ex post* leakage deduction (%)	*Ex post* impermanence risk buffer (%)	CCB validation & first verification achieved (Yes/No)	VCS methodology employed	Predominant vegetation type (1st row) & FAO code (2nd row)	Project participants (1st row) & audit dates (2nd row)
									(technical developers); RA (auditor)
	162,699	8,432	19.3	12%	27%	–	–	TAwa	17 May 2012 (validation); 20 June 2012 (verification)
Cikel Brazilian Amazon REDD, Brazil	1,080,071	–	–	–	–	N	VM0007	Tropical mixed evergreen angiosperm forests	CarbonCo & Carbon Securities (financial proponents); TerraCarbon & TECMAN (technical developers); EIRELI (local implementer); ESI (auditor)
	1,094,951	27,934	39.2	22%	16%	–	–	Tropical rain forests (TAr)	6 April 2015 (validation); 8 March 2016 (verification)
The Envira Amazonia Project- A Tropical Forest Conservation Project in Acre, Brazil	1,974,430	–	–	–	–	Y	VM0007	Tropical mixed semi-deciduous angiosperm forests with palm & bamboo components	Forestland Group (financial proponent & local implementer); Offsetters (technical developer); ESI (auditor)
	1,964,962	39,300	50.0	18%	23%	–	–	TAwa	30 March 2016 (validation); 23 May 2016 (verification)
APD stratum summary	**Totals**:	**Medians**: 4,745	39.2	12%	19%	**Means**: No (56%)	VM0007: REDD + methodology framework (100%)	Tropical vegetation (89%)	ESI (66%)
	3,787,682 *ex ante*; 3,653,493 *ex post* (−3%)								
	2-tailed t-test: n/s	(**Ranges**: 72–39,300)	(1.6–247.5)	(0–40%)	(10–27%)				

Avoided Unplanned Deforestation & Degradation (AUDD) stratum (n = 31)

Project name & country	*Ex ante* (1st row) & *ex post* annual offsets (2nd row) during first verification period (t CO2e/yr)	Offset crediting area (HA)	*Ex post* normalized annual offsets during first verification period (t CO2e/yr/HA)	*Ex post* leakage deduction (%)	*Ex post* impermanence risk buffer (%)	CCB validation & first verification achieved (Yes/No)	VCS methodology employed	Predominant vegetation type (1st row) & FAO code (2nd row)	Project participants (1st row) & audit dates (2nd row)
Mjumita Community Forestry Project (Lindi), Tanzania	29,956	–	–	–	–	Y	VM0015: Avoided unplanned deforestation	Tropical brushlands & mixed deciduous angiosperm forests, including Baobab trees	MJUMITA & Tanzania Forest Conservation Group (financial proponents & technical developers); Ten village assemblies & councils (local implementers); SCS (auditor)
	39,896	41,924	1.0	0%	10%	–	–	TAwb & tropical shrublands (TBSh)	6 May 2015 (validation & verification)
Choco-Darien Conservation Corridor REDD Project, Colombia	39,622	–	–	–	–	N	VM0009: Avoided mosaic deforestation of tropical forests	Tropical mixed evergreen & semi-deciduous angiosperm forests	Anthrotect (financial proponent); Eco-implementers, Carnegie Institute & Medellin Botanical Garden (technical developers); Cocomasur & Fund for Environmental Action (local implementers); DNV (auditor)
	49,799	13,465	3.7	0%	16%	–	–	TAr & TAwa	27 Aug. 2012 (validation); 14 Nov. 2012 (verification)
Maisa REDD + Project, Brazil	40,496	–	–	–	–	N	VM0007	Tropical mixed evergreen angiosperm forests	Biofilica Investimentos Ambientais (financial proponent); Instituto Peaviru, Eco-Logica Consultoria Ambiental, & Amazonia Gestao Ambiental (technical developers); Maisa-Moju Agroindustrial & Sipasa-seringa Industrial do Para (local implementers); RA (auditor)
	52,109	28,752	1.8	0%	19%	–	–	TAr	29 Dec. 2014 (validation); 13 Feb. 2015 (verification)
AUDD stratum									
Russas Project, Brazil	59,878	–	–	–	–	Y	VM0007	Tropical mixed semi-deciduous angiosperm forests with palm & bamboo components	ISRC & Freitas International/ CarbonCo (financial proponents); TerraCarbon, William Flores & TECMAN (technical developers); SSBEA, SOS, Amazonia & CEFLORA (local implementers); ESI (auditor)
	70,225	41,976	1.7	16%	10%	–	–	TAwa	15 May 2014 (validation); 22 Dec. 2014 (verification)
Purus Project, Brazil	63,258	–	–	–	–	Y	VM0007	Tropical mixed semi-deciduous angiosperm forests with palm & bamboo components	CarbonCo & Freitas International (financial proponents); TerraCarbon & TECMAN (technical developers); EMBRAPA (local implementer); SCS (validation auditor); ESI (verification auditor)
	81,528	34,702	2.3	19%	10%	–	–	TAwa	28 Dec. 2012 (validation); 10 Dec. 2013 (verification)
Ecomapua Amazon REDD Project, Brazil	67,435	–	–	–	–	N	VM0015	Tropical mixed semi-deciduous angiosperm & freshwater swamp forests	Ecomapua (financial proponent & local implementer); Sustainable Carbon & Agencia Verde (technical developers); Tuv (validation

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Table 2 (*continued*)

Avoided Unplanned Deforestation & Degradation (AUDD) stratum (n = 31)									
Project name & country	*Ex ante* (1st row) & *ex post* annual offsets (2nd row) during first verification period (t CO2e/yr)	Offset crediting area (HA)	*Ex post* normalized annual offsets during first verification period (t CO2e/yr/HA)	*Ex post* leakage deduction (%)	*Ex post* impermanence risk buffer (%)	CCB validation & first verification achieved (Yes/No)	VCS methodology employed	Predominant vegetation type (1st row) & FAO code (2nd row)	Project participants (1st row) & audit dates (2nd row)
									auditor); RINA (verification auditor)
	144,833	86,270	1.7	0%	32%	–	–	TAwa	6 March 2013 (validation); 22 Jan. 2015 (verification)
AUDD stratum									
Kulera Landscape REDD + Program for Co-Managed Protected Areas, Malawi	72,355	–	–	–	–	Y	VM0006: Carbon accounting for mosaic & landscape-scale REDD + projects	Tropical Miombo savannahs & mixed deciduous angiosperm forests	Government of Malawi & Terra Global Capital (financial proponents & technical developers); Care International & Total Land Care (local implementers); DNV (auditor)
	210,404	169,026	1.2	0%	10%	–	–	TAwb & TBSh	4 July 2014 (validation & verification)
Biocorredor Martin Sagrado REDD+, Peru	80,929	–	–	–	–	Y	VM0015	Tropical mixed semi-deciduous & evergreen montane cloud angiosperm forests including bamboo & palm	Pur Projet (financial proponent & technical developer); Fundacion Amazonia Viva (local implementer); SCS (validation auditor); Group EcoCert (verification auditor)
	29,206	295,654	0.1	0%	10%	–	–	TAwa & tropical montane forests (TM)	22 Jan. 2013 (validation); 13 May 2016 (verification)
REDD in Community Forests, Oddar Meanchey, Cambodia	84,411	–	–	–	–	Y	VM0006	Tropical mixed evergreen & semi-deciduous angiosperm forests	Forestry Administration of Cambodia & Clinton Climate Initiative (financial proponents); Community Forestry International & Terra Global Capital (technical developers); PACT, Children's Development Association & Monks' Community Forestry (local implementers); Tuv Sud (validation auditor); SCS (verification auditor)
	184,428	56,050	3.3	14%	17%	–	–	TAr & TAwa	22 Aug. 2012 (validation); 29 Aug. 2013 (verification)
AUDD stratum									
Carbon Emissions Reduction in the "COFAV," Madagascar	87,919	–	–	–	–	Y	VM0015	Tropical mixed evergreen angiosperm forests	Madagascar Director Generale des Forets (financial proponent); Conservation International (technical developer & local implementer); SCS (auditor)
	407,503	285,500	1.4	0%	10%	–	–	TAr	7 Oct. 2013 (validation & verification)
Lacandon Forest for Life REDD + Project, Guatemala	102,321	–	–	–	–	Y	VM0015	Tropical mixed evergreen & semi-deciduous angiosperm forests	Fundacion Defensores de la Naturleza (financial proponent); South Pole Carbon & Oro Verde (technical developers); Union Maya Itza Coop., La Lucha Coop. & La

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Table 2 (*continued*)

Project name & country	*Ex ante* (1st row) & *ex post* annual offsets (2nd row) during first verification period (t CO2e/yr)	Offset crediting area (HA)	*Ex post* normalized annual offsets during first verification period (t CO2e/yr/HA)	*Ex post* leakage deduction (%)	*Ex post* impermanence risk buffer (%)	CCB validation & first verification achieved (Yes/No)	VCS methodology employed	Predominant vegetation type (1st row) & FAO code (2nd row)	Project participants (1st row) & audit dates (2nd row)
Avoided Unplanned Deforestation & Degradation (AUDD) stratum (n = 31)									
									Tecnica Agropecuaria Coop. (local implementers); AENOR (auditor)
	123,327	45,288	2.7	0%	10%	–	–	TAr & TAwa	8 June 2016 (validation); 2 Nov. 2016 (verification)
Lower Zambezi REDD + Project, Zambia	102,754	–	–	–	–	N	VM0009	Tropical Miambo savannahs & Mopane woodlands	BioCarbon Implementers (financial proponent & technical developer); Sable Transport Limited & others (local implementers); DNV (auditor)
	102,754	40,128	2.6	0%	14%			TAwb & TBSh	4 April 2014 (validation & verification)
AUDD stratum									
Jari/Amapa REDD + Project, Brazil	102,822	–	–	–	–	N	VM0015	Tropical mixed evergreen & semi-deciduous angiosperm forests	Grupo Jari (financial proponent & local implementer); IMAZON & IPE (technical developers); SCS (auditor)
	202,004	65,980	3.1	0%	17%	–	–	TAr & TAwa	10 May 2013 (validation); 10 July 2013 (verification)
Valparaiso Project, Brazil	111,120	–	–	–	–	Y	VM0007	Tropical mixed semi-deciduous angiosperm forests with palm & bamboo components	Manoel Batista Lopes, Freitas International & CarbonCo (financial proponents); TerraCarbon, William Flores & TECMAN (technical developers); SSBEA, SOS, Amazonia & CEFLORA (local implementers); ESI (auditor)
	153,387	28,096	5.5	9%	12%	–	–	TAwa	23 Sept. 2014 (validation); 22 Dec. 2014 (verification)
The Makira Forest Protected Area, Madagascar	120,286	–	–	–	–	Y	VM0007	Tropical mixed evergreen angiosperm forests	Government of Madagascar (financial proponent & local implementer); Wildlife Conservation Society (technical developer & local implementer); RA (auditor)
	166,154	360,060	0.5	0%	16%	–	–	TAr	28 Sept. 2012 (validation & verification)
AUDD stratum									
Surui Forest Carbon Project, Brazil	121,852	–	–	–	–	Y	VM0015	Tropical degraded mixed evergreen angiosperm forests	Metarelia Association of Surui (financial proponent); Forest Trends & IDESAM (technical developers); Kide & ACT Brazil (local implementers); RA (auditor)
	62,882	31,944	2.0	2%	16%	–	–	TAr	29 Feb. 2012 (validation); 15 July 2013 (verification)
REDD in Tambopata National Reserve Madre de Dios Region, Peru	165,972	–	–	–	–	Y	VM0007	Tropical mixed semi-deciduous angiosperm & freshwater swamp forests	Aider & BAM (financial proponents); PUCP & Aider (technical developers); SERNANP (local implementer); RA (validation

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Avoided Unplanned Deforestation & Degradation (AUDD) stratum (n = 31)									
Project name & country	*Ex ante* (1st row) & *ex post* annual offsets (2nd row) during first verification period (t CO2e/yr)	Offset crediting area (HA)	*Ex post* normalized annual offsets during first verification period (t CO2e/yr/HA)	*Ex post* leakage deduction (%)	*Ex post* impermanence risk buffer (%)	CCB validation & first verification achieved (Yes/No)	VCS methodology employed	Predominant vegetation type (1st row) & FAO code (2nd row)	Project participants (1st row) & audit dates (2nd row)
									auditor) AENOR (verification auditor)
	165,992	573,300	0.3	0%	13%	–	–	TAwa	21 June, 2012 (validation); 9 April, 2013 (verification)
ADPML Portel-Para REDD Project, Brazil	250,892	–	–	–	–	N	VM0015	Tropical mixed evergreen angiosperm forests	Oak Trust & ADMPL (financial proponents); Ecosystem Services (technical developer & local implementer); DNV (auditor)
	159,204	148,975	1.1	0%	14%			TAr	15 Feb. 2013 (validation); 10 Nov. 2014 (verification)
AUDD stratum									
Resex Rio Preto-Jacunda REDD+, Brazil	259,262	–	–	–	–	Y	VM0015	Tropical mixed evergreen & semi-deciduous angiosperm forests	Biofilica Investimentos Ambientais (financial proponent & technical developer); ASMOREX (local implementer); RA/IMAFLORA (auditor)
	403,842	35,222	11.5	0%	10%	–	–	TAr & TAwa	14 June 2016 (validation); 20 June 2016 (verification)
Isangi REDD + Project, Democratic Republic of Congo	312,829	–	–	–	–	Y	VM0006	Tropical mixed semi-deciduous angiosperm & freshwater swamp forests	Jadora (financial proponent); ECO implementers (technical developer); Safbois (local implementer); RA (auditor)
	278,325	187,571	1.5	0%	15%	–	–	TAwa	9 Sept. 2014 (validation); 18 Dec. 2014 (verification)
Carbon Emissions Reduction in the "CAZ," Madagascar	342,629	–	–	–	–	N	VM0015	Tropical mixed semi-deciduous & evergreen angiosperm forests	Government of Madagascar (financial proponent & local implementer); Conservation International (technical developer & local implementer); RA (auditor)
	978,874	370,032	2.6	0%	10%	–	–	TAr & TAwa	23 Oct. 2013 (validation & verification)
AUDD stratum									
Gola REDD Project, Sierra Leone	398,218	–	–	–	–	Y	VM0007	Tropical mixed semi-deciduous & evergreen angiosperm forests	Royal Society for Protection of Birds (financial proponent); Winrock International (technical developer); Welthungerlife, Government of Sierra Leone, & Conservation Society of Sierra Leone (local implementers); RA (auditor)
	325,008	68,515	4.7	20%	10%	–	–	TAr & TAwa	16 Oct. 2015 (validation); 25 Nov. 2015 (verification)
Alto Mayo Conservation Initiative, Peru	455,529	–	–	–	–	Y	VM0015	Tropical mixed semi-deciduous & evergreen cloud angiosperm forests	Conservation International (financial proponent); Aider, CI & SPDA (technical developers); SERNANP, ECOAN & CI (local implementers); SCS (auditor)

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Avoided Unplanned Deforestation & Degradation (AUDD) stratum (n = 31)									
Project name & country	*Ex ante* (1st row) & *ex post* annual offsets (2nd row) during first verification period (t CO2e/yr)	Offset crediting area (HA)	*Ex post* normalized annual offsets during first verification period (t CO2e/yr/HA)	*Ex post* leakage deduction (%)	*Ex post* impermanence risk buffer (%)	CCB validation & first verification achieved (Yes/No)	VCS methodology employed	Predominant vegetation type (1st row) & FAO code (2nd row)	Project participants (1st row) & audit dates (2nd row)
	710,712	187,000	3.8	0%	10%	–	–	TAwa & tropical montane forests (TM)	30 July 2012 (validation); 11 Dec. 2012 (verification)
RMDLT Portel-Para REDD Project, Brazil	488,637	–	–	–	–	N	VM0015	Tropical mixed evergreen angiosperm forests	Allcot Group/RMDLT (financial proponent); Ecosystem Services (technical developer & local implementer); DNV (auditor)
	445,649	194,403	2.3	0%	14%	–	–	TAr	16 April 2013 (validation); 16 Feb. 2015 (verification)
AUDD stratum									
Florestal Santa Maria Project, Brazil	889,204	–	–	–	–	N	VM0007	Tropical mixed semi-deciduous & evergreen angiosperm forests with palm component	Florestal Santa Maria (financial proponent & local implementer); Plant Intelegensia, BUNGE, & Avix (technical developers); RA (auditor)
	857,564	71,714	12.0	3%	16%	–	–	TAwa & TAr	4 May 2012 (validation); 6 Dec. 2012 (verification)
Cordillera Azul National Park REDD Project, Peru	901,857	–	–	–	–	Y	VM0007	Tropical mixed semi-deciduous & evergreen montane cloud angiosperm forests	CIMA-Peru (financial proponent & local implementer); TerraCarbon & The Field Museum (technical developers); SCS (auditor)
	1,443,018	1,351,964	1.1	0%	10%	–	–	TAwa & TM	1 Feb. 2013 (validation & verification)
Madre de Dios Amazon REDD Project, Peru	1,115,793	–	–	–	–	Y	VM0007	Tropical mixed semi-deciduous angiosperm with bamboo component & freshwater swamp forests	Maderacre & Maderyja (financial proponents & local implementers); GreeNoxx, BAM & AIDER (technical developers); SCS (auditor)
	1,124,090	97,817	11.5	0%	10%	–	–	TAwa	20 Sept. 2012 (validation); 21 May 2013 (verification)
AUDD stratum									
Mai Ndombe REDD+ Project, Democratic Republic of Congo	1,435,703	–	–	–	–	Y	VM0009	Tropical degraded mixed semi-deciduous angiosperm & freshwater swamp forests	Wildlife Works (financial proponent, technical developer & local implementer); DNV (auditor)
	1,392,741	248,956	5.6	0%	25%	–	–	TAwa	6 Dec. 2012 (validation & verification)
REDD Project in Brazil Nut Concessions in Madre de Dios, Brazil	2,209,667	–	–	–	–	N	VM0007	Tropical mixed semi-deciduous angiosperm with bamboo component & freshwater swamp forests	BAM (financial proponent); BAM & CDI (technical developers); FEPROCAMD & CAMDE PERU (local implementers); SCS (auditor)
	1,859,943	290,696	6.4	0%	11%	–	–	TAwa	13 June 2012 (validation); 14 Nov. 2013 (verification)
Kantingan Peatland Restoration & Conservation Project, Indonesia	3,043,081	–	–	–	–	Y	VM0007	Tropical mixed evergreen angiosperm forests with peat soils	PT Rimba Makmur Utama (financial proponent & local implementer); Yayasan Puter Indonesia, Wetlands International & Permian Global (technical developers); SCS (auditor)
	2,833,025	149,800	18.9	0%	10%	–	–	TAr	

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Avoided Unplanned Deforestation & Degradation (AUDD) stratum (n = 31)									
Project name & country	*Ex ante* (1st row) & *ex post* annual offsets (2nd row) during first verification period (t CO2e/yr)	Offset crediting area (HA)	*Ex post* normalized annual offsets during first verification period (t CO2e/yr/HA)	*Ex post* leakage deduction (%)	*Ex post* impermanence risk buffer (%)	CCB validation & first verification achieved (Yes/No)	VCS methodology employed	Predominant vegetation type (1st row) & FAO code (2nd row)	Project participants (1st row) & audit dates (2nd row)
Kariba REDD + Project, Zimbabwe	3,448,457	–	–	–	–	Y	VM0009	Tropical Miombo savannahs & Mopane woodlands	6 May 2016 (validation); 14 Oct. 2016 (verification) Carbon Green Investments (financial proponent); South Pole Carbon & Black Crystal Consulting (technical developers); Environment Africa (local implementer); ESI (auditor)
	2,751,549	748,987	3.5	0%	17%	–	–	TBSh & TAwb	19 Aug. 2013 (validation & verification)
AUDD stratum summary	**Totals:** 17,005,114 *ex ante*; 17,809,975 *ex post* (+5%)	**Medians**: 97,817	2.6	0%	12%	**Means**: Yes (68%)	VM0007: REDD+ methodology framework (39%) VM0015: Avoided unplanned deforestation (39%)	Tropical vegetation (100%)	SCS (32%) RA (29%)
	2-tailed t-test: n/s	(**Ranges**: 13,465–1,35-1,964)	(0.1–18.9)	(0–20%)	(10–32%)				
Afforestation, Reforestation, and Revegetation (A/R/R) stratum (n = 19)									
Project name & country	*Ex ante* (1st row) & ex post annual offsets (2nd row) during first verification period (t CO2e/yr)	Offset crediting area (HA)	*Ex post* normalized annual offsets during first verification period (t CO2e/yr/HA)	*Ex post* leakage deduction (%)	*Ex post* impermanence risk buffer (%)	CCB validation & first verification achieved (Yes/No)	VCS methodology employed	Predominant vegetation type (1st row) & FAO code (2nd row)	Project participants (1st row) & audit dates (2nd row)
Jatropha Agroforestry, Senegal	81	–	–	–	–	N	AR-ACM0003: Afforestation & reforestation of lands except wetlands	Jatropha curcas	African National Oil Corporation (financial proponent); Carbon Sink Group (technical developer); Agroils Technology (local implementer); DNV (auditor)
	120	574	0.2	0%	18%	–	–	–	29 Nov. 2013 (validation); 20 May 2014 (verification)
Reforestation of Degraded Forest Reserves in Ghana	4,612	–	–	–	–	N	AR-ACM0001: Afforestation & reforestation of degraded land	Tectona grandis	FORM International (financial proponent & technical developer); FORM Ghana (local implementer); SCS (auditor)
	1,127	1,500	0.8	0%	11%	–	–	–	17 Jan. 2013 (validation); 29 Jan. 2013 (verification)
TIST Program in India, VCS 001	6,035	–	–	–	–	Y			

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Table 2 (*continued*)

Afforestation, Reforestation, and Revegetation (A/R/R) stratum (n = 19)									
Project name & country	*Ex ante* (1st row) & ex post annual offsets (2nd row) during first verification period (t CO2e/yr)	Offset crediting area (HA)	*Ex post* normalized annual offsets during first verification period (t CO2e/yr/HA)	*Ex post* leakage deduction (%)	*Ex post* impermanence risk buffer (%)	CCB validation & first verification achieved (Yes/No)	VCS methodology employed	Predominant vegetation type (1st row) & FAO code (2nd row)	Project participants (1st row) & audit dates (2nd row)
							AR-ACM0001S: Simplified baseline & monitoring methodologies for small-scale A/R CDM project activities	Gmelina arborea, Mangifera indica & Tectona grandis	TIST (financial proponent & technical developer); TIST India (local implementer); ESI (auditor)
	1,696	672	2.5	0%	10%	–	–	–	7 March 2013 (validation & verification)
A/R/R stratum									
India Sunderbans Mangrove Restoration, India	7,185	–	–	–	–	N	AR-ACM0014: Afforestation & reforestation of degraded mangrove habitats	Mangroves primarily Avicennia spp.	Livelihoods Fund (financial proponent); UNIQUE forestry (technical developer); NEWS (local implementer); SCS (auditor)
	14,522	4,404	3.3	0%	15%	–	–	–	10 June 2013 (validation); 8 Sept. 2015 (verification)
Bukaleba Forest Project, Uganda	8,366	–	–	–	–	N	AR-ACM0001S	Pinus caribea & Eucalyptus spp.	Green Resources (financial proponent & technical developer); Busoga Forestry (local implementer); DNV (auditor)
	3,380	2,062	1.6	0%	29%	–	–	–	20 Feb. 2012 (validation & verification)
Araku Valley Livelihood Project, India	12,874	–	–	–	–	N	AR-ACM0003	Mangifera indica & Tectona grandis	Livelihoods Fund (financial proponent); UNIQUE forestry (technical developer); Nandi Foundation (local implementer); SCS (auditor)
	8,567	6,002	1.4	0%	10%	–	–	–	24 Nov. 2014 (validation & verification)
A/R/R stratum									
Jubilacion Segura, Peru	14,298	–	–	–	–	N	AR-ACM0001S	Agroforestry for Theobroma cacao & Caffea arabica with 22 angiosperm tropical tree species	Pur Projet (financial proponent & technical developer); Oro Verde, Acopagro, COOPARM, & AFCA (local implementers); Group EcoCert (auditor)
	5,895	1,062	3.7	0%	10%	–	–	–	12 Jan. 2016 (validation); 9 Feb. 2016 (verification)
Mitigation of GHG: Rubber Based Agro-Forestry System in Pakkading, Bolikhamsay Province, Lao PDR	16,493	–	–	–	–	N	AR-ACM0003	Hevea brasiliensis	Lao Thai Hua Rubber Company (financial proponent & local implementer); Prince Consulting (technical developer); Tuv Sud (validation auditor); Rina (verification auditor)
	4,162	661	6.3	0%	10%	–	–	–	01 June 2015 (validation); 02 April 2017 (verification)
	26,416	–	–	–	–	N	AR-ACM0014		

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Table 2 (*continued*)

Afforestation, Reforestation, and Revegetation (A/R/R) stratum (n = 19)									
Project name & country	*Ex ante* (1st row) & ex post annual offsets (2nd row) during first verification period (t CO2e/yr)	Offset crediting area (HA)	*Ex post* normalized annual offsets during first verification period (t CO2e/yr/HA)	*Ex post* leakage deduction (%)	*Ex post* impermanence risk buffer (%)	CCB validation & first verification achieved (Yes/No)	VCS methodology employed	Predominant vegetation type (1st row) & FAO code (2nd row)	Project participants (1st row) & audit dates (2nd row)
Mangrove Restoration & Coastal Green Belt Protection in the East Coast of Aceh & North Sumatra Province, Indonesia								Mangroves primarily Rhizophora spp.	Livelihoods Fund (financial proponent); UNIQUE forestry (technical developer); YAGASU (local implementer); SCS (auditor)
	26,398	5,000	5.3	0%	13%	–	–	–	10 June 2013 (validation); 8 Sept. 2015 (verification)
A/R/R stratum									
Alto Huayabamba, Peru	34,906	–	–	–	–	N	AR-ACM0001S	Agroforestry for Theobroma cacao & Caffea arabica with 11 angiosperm tropical tree species	Pur Projet (financial proponent & technical developer); Acopagro, Fonde Bosque & Reforesta Peru (local implementers); RA (validation auditor); Group EcoCert (verification auditor)
	7,612	1,728	4.4	0%	10%	–	–	–	14 Dec. 2011 (validation); 4 July 2014 (verification)
Agroforestry & Forest Restoration for Ecological Connectivity, Poverty Reduction & Biodiversity Conservation in Cerro San Gil, Guatemala	36,511	–	–	–	–	N	AR-ACM0003	Agroforestry for Theobroma cacao & Caffea arabica with Pinus patula & Alnus acuminate	Livelihoods Fund (financial proponent); Fundaeco (technical developer & local implementer); SCS (auditor)
	15,652	1,758	8.9	0%	13%	–	–	–	17 Nov. 2016 (validation & verification)
Livelihoods' Mangrove Restoration Grouped Project, Senegal	36,671	–	–	–	–	N	AR-ACM0014	Mangroves primarily Rhizophora spp.	Livelihoods Fund (financial proponent); Agresta Coop & Pole Carto (technical developers); Oceanium (local implementer); SCS (auditor)
	26,572	10,415	2.6	0%	10%	–	–	–	16 July 2014 (validation & verification)
A/R/R stratum									
Forestry Project for the Basin of the Chinchina River (Procuenca Project), Colombia	37,681	–	–	–	–	N	AR-ACM0003	Agroforestry for Theobroma cacao & Caffea arabica including Pinus patula & Alnus acuminate	Infimanizales (financial proponent); South Pole Group (technical developer); Agroforestal (local implementer); Tuv Sud (validation auditor); Icontec (verification auditor)

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Table 2 (*continued*)

Afforestation, Reforestation, and Revegetation (A/R/R) stratum (n = 19)									
Project name & country	*Ex ante* (1st row) & ex post annual offsets (2nd row) during first verification period (t CO2e/yr)	Offset crediting area (HA)	*Ex post* normalized annual offsets during first verification period (t CO2e/yr/HA)	*Ex post* leakage deduction (%)	*Ex post* impermanence risk buffer (%)	CCB validation & first verification achieved (Yes/No)	VCS methodology employed	Predominant vegetation type (1st row) & FAO code (2nd row)	Project participants (1st row) & audit dates (2nd row)
	22,604	2,030	11.1	0%	19%	–	–	–	12 Jan. 2010 (validation); 10 May 2015 (verification)
TIST Program in Uganda, VCS 001-006 (grouped project), Uganda	54,848	–	–	–	–	Y	AR-ACM0001S	Cupressus spp., Eucalyptus grandis & Pinus patula	TIST of CAAC & Berkeley Re-afforestation Trust (financial proponents); TIST (technical developer); TIST & Institute for Environmental Innovation (local implementers); ESI (auditor)
	22,355	2,493	9.0	0%	10%	–	–	–	20 March 2012 (validation-001); 27 Oct. 2014 (verification-001)
El Arriero Afforestation on Degraded Grasslands under Extensive Grazing, Uruguay	91,211	–	–	–	–	N	AR-ACM0001	Pinus elliotti & Pinus taeda	El Arriero SA (financial proponent); Carbosur (technical developer); Cambium Forestal Uruguay (local implementer); SCS (auditor)
	6,983	4,988	1.4	0%	10%	–	–	–	14 Jan. 2013 (validation); 7 April 2014 (verification)
A/R/R stratum									
Reforesting Degraded Lands in Chile through the Use of Mycorrhizal Inoculation, Chile	96,652	–	–	–	–	N	AR-ACM0003	Eucalyptus globulus & Pinus radiata	Mikro-Tek (financial proponent & local implementer); TerraCarbon (technical developer); ESI (auditor)
	44,804	3,007	14.9	0%	10%	–	–	–	23 April 2013 (validation); 26 Feb. 2015 (verification)
Fresh Breeze Afforestation Project, Mexico	100,313	–	–	–	–	N	AR-ACM0003	Tectona grandis	Proteak (financial proponent & local implementer); Carbon Solutions de Mexico (technical developer); AENOR (auditor)
	40,992	3,959	10.4	0%	14%	–	–	–	9 July 2014 (validation); 22 July 2016 (verification)
TIST Program in Kenya, VCS 005-006,009 (grouped project), Kenya	241,368	–	–	–	–	Y	AR-ACM0001S	Cupressus spp., Eucalyptus grandis & Grevillea robusta	TIST of CAAC & USAID (financial proponents); TIST (technical developer); TIST & Institute for Environmental Innovation (local implementers); ESI (auditor)

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Table 2 (*continued*)

Afforestation, Reforestation, and Revegetation (A/R/R) stratum (n = 19)

Project name & country	*Ex ante* (1st row) & ex post annual offsets (2nd row) during first verification period (t CO2e/yr)	Offset crediting area (HA)	*Ex post* normalized annual offsets during first verification period (t CO2e/yr/HA)	*Ex post* leakage deduction (%)	*Ex post* impermanence risk buffer (%)	CCB validation & first verification achieved (Yes/No)	VCS methodology employed	Predominant vegetation type (1st row) & FAO code (2nd row)	Project participants (1st row) & audit dates (2nd row)
	36,830	12,700	2.9	0%	10%	–	–	–	16 Dec. 2011 (validation-005); 22 Dec. 2011 (verification-005)
Forteko Afforestation on Degraded Grasslands under Extensive Grazing, Uruguay	347,498	–	–	–	–	N	AR-ACM0001	Pinus taeda	Forestal Tekoayhu (financial proponent); Carbosur (technical developer); Cambium Forestal Uruguay (local implementer); SCS (auditor)
	46,348	16,553	2.8	0%	10%	–	–	–	14 Jan. 2013 (validation); 07 April 2014 (verification)
A/R/R stratum summary	**Totals**:	**Medians**: 2,493	3.3	0%	10%	**Means**: No (84%)	AR-ACM001S: Simplified baseline & monitoring methodologies for small-scale A/R CDM project activities (54%)	Eucalyptus spp. & pinus spp (32%)	SCS (42%)
	1,174,019 *ex ante*; 336,619 ex post (−71%)							Tectona grandis (21%)	
	2-tailed t-test: p = 0.03	(**Ranges**: 574–16,553)	(0.2–14.9)	(0)	(10–29%)				

Improved Forest Management (IFM) stratum (n = 11)

Project name & country	*Ex ante* (1st row) & *ex post* annual offsets (2nd row) during first verification period (t CO2e/yr)	Offset crediting area (HA)	*Ex post* normalized annual offsets during first verification period (t CO2e/yr/HA)	*Ex post* leakage deduction (%)	*Ex post* impermanence risk buffer (%)	CCB validation & first verification achieved (Yes/No)	VCS methodology employed	Predominant vegetation type (1st row) & FAO code (2nd row)	Project participants (1st row) & audit dates (2nd row)
Ecotrust IFM Project, United States	4,816	–	–	–	–	N	VM0003: IFM through extension of rotation age	Temperate hemlock-sitka spruce forests	EcoTrust Forest Management (financial proponent); EcoPartners & Terra Verde (technical developers); Garibaldi Forest Management (local implementer); RA (auditor)
	3,764	397	9.5	44%	43%	–	–	Temperate oceanic forests (TeDo)	4 Dec. 2014 (validation & verification)
Lock Haven IFM Project, United States	14,854	–	–	–	–	N	VM0003	Temperate oak-hickory & oak-hemlock-pine forests	Lock Haven City Authority (financial proponent); BlueSource & SIG (technical developers); Appalachian Forest Consultants (local implementer); RA (auditor)
	14,854	4,906	3.0	0%	12%	–	–	Temperate continental forests (TeDe)	30 Dec. 2014 (validation); 23 Jan. 2015 (verification)
	22,027	–	–	–	–	N	VM0003		

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Table 2 (*continued*)

Improved Forest Management (IFM) stratum (n = 11)									
Project name & country	*Ex ante* (1st row) & *ex post* annual offsets (2nd row) during first verification period (t CO2e/yr)	Offset crediting area (HA)	*Ex post* normalized annual offsets during first verification period (t CO2e/yr/HA)	*Ex post* leakage deduction (%)	*Ex post* impermanence risk buffer (%)	CCB validation & first verification achieved (Yes/No)	VCS methodology employed	Predominant vegetation type (1st row) & FAO code (2nd row)	Project participants (1st row) & audit dates (2nd row)
Bethlehem Authority IFM Project, United States								Temperate northern hardwood forests (beech, birch & maple) & mixed pine forests (jack, red & white)	Bethlehem Authority (financial proponent); BlueSource & SIG (technical developers); The Nature Conservancy & Woodlands Management Service (local implementers); RA (auditor)
	22,027	7,265	3.0	20%	10%	–	–	TeDe	11 April 2013 (validation); 18 April 2013 (verification)
IFM stratum									
New Leaf Carbon Project, Australia	43,106	–	–	–	–	Y	VM0010: Conversion of logged to protected forest	Tropical eucalypt forests	Tasmanian Land Conservancy (financial proponent); Forests Alive (technical developer & local implementer); ESI (auditor)
	36,856	12,143	3.0	0%	15%	–	–	Subtropical humid forests (SCf)	20 March 2014 (validation & verification)
Yunnan Kunming Liangqu IFM Project, China	44,725	–	–	–	–	N	VM0010	Subtropical mixed angiosperm & pine gymnosperm forests	Kunming Yuming Investment Development Co. (financial proponent & local implementer); CITIC Environment Investment Group & China Green Carbon Foundation (technical developers); CEC (auditor)
	43,556	6,879	6.3	0%	33%	–	–	Subtropical dry forests (SCs)	8 Jan. 2016 (validation); 22 March 2016 (verification)
Fujian Yong'an IFM Project, China	48,358	–	–	–	–	N	VM0010	Subtropical Chinese fir, pine & mixed angiosperm forests	Yong'an Forestry Bureau (financial proponent & local implementer); CITIC Environmental & China Green Carbon Foundation (technical developers); CEC (auditor)
	47,878	7,186	6.7	0%	35%	–	–	SCs	6 Dec. 2016 (validation & verification)
IFM stratum									
Inner Mongolia Chao'er IFM Project, Mongolia	78,102	–	–	–	–	N	VM0010	Temperate lowland birch & mountain pine forests	Chao'er Forest Bureau of Inner Mongolia Autonomous Region (financial proponent & local implementer); CITIC Environment Investment Group and China Green Carbon Foundation (technical developers); CEC (auditor)
	76,050	355,622	0.2	0%	30%	–	–	Temperate montane forests (TeM)	12 Dec. 2014 (validation); 13 Jan. 2016 (verification)
Jiangxi Province Le'an County Forest Farm Carbon Sink Project, China	86,680	–	–	–	–	N	VM0010	Temperate Chinese fir & slash pine forests	Beijing Shendanhuitong Carbon Management (financial proponent & local implementer); DTM Energy Technology Development (technical developer); Bureau Veritas (auditor)
	22,637	7,747	2.9	0%	23%	–	–	TeDe	24 April 2014 (validation & verification)
North Pikounda REDD+, Republic of Congo	88,896	–	–	–	–	N	VM0011: Estimating GHG emissions from planned degradation	Tropical mixed semi-deciduous angiosperm & freshwater swamp forests	CIB/Olam International (financial proponent & local implementer); Carbon Conservation (technical developer); DNV (auditor)
	56,209	55,950	1.0	0%	21%	–	–	TAwa	26 Aug. 2013 (validation & verification)

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Table 2 (*continued*)

Improved Forest Management (IFM) stratum (n = 11)									
Project name & country	*Ex ante* (1st row) & *ex post* annual offsets (2nd row) during first verification period (t CO2e/yr)	Offset crediting area (HA)	*Ex post* normalized annual offsets during first verification period (t CO2e/yr/HA)	*Ex post* leakage deduction (%)	*Ex post* impermanence risk buffer (%)	CCB validation & first verification achieved (Yes/No)	VCS methodology employed	Predominant vegetation type (1st row) & FAO code (2nd row)	Project participants (1st row) & audit dates (2nd row)
IFM stratum									
Afognak Forest Carbon Project, United States	116,126	–	–	–	–	N	VM0012: IFM in temperate and boreal forests	Temperate mature & regenerating spruce forests	American Land Conservancy & Rocky Mountain Elk Foundation (financial proponents); Camco International & 3GreenTree (technical developers & local implementers); RA (validation auditor); SCS (verification auditor)
	100,528	3,327	30.2	13%	11%	–	–	TeDe	13 June 2012 (validation); 21 Nov. 2014 (verification)
April Salumei REDD Project, Papua New Guinea	279,467	–	–	–	–	N	VM0010	Tropical mixed semi-deciduous angiosperm tropical forests with Kauri pine component	Rainforest Project Management (financial proponent); Environmental Accounting Services (technical developer); Pacific Forest Alliance (local implementer); ESI (auditor)
	227,446	204,343	1.1	16%	10%	–	–	TAwa	8 Oct. 2013 (validation & verification)
IFM stratum summary	**Totals**:	**Medians**: 7,265	3.0	0%	21%	**Means**: No (90%)	VM0010: Conversion of Logged to Protected Forest (55%)	Temperate vegetation (72%)	RA (32%)
	827,157 *ex ante*; 651,805 *ex post* (−21%)								CEC (27%)
	2-tailed t-test:	(**Ranges**: 397–355,62-2)	(0.2–30.2)	(0–44%)	(10–43%)				
	p = 0.05								

Table 3
Positive regression relationships with associated significance (p value) and coefficient of determination (adj. R^2) as tests of audit thoroughness. Outcome variables are labeled "y" and explanatory variables are labeled "x." See Table 1 for definitions of project activity strata acronyms.

Project activity strata (n = 33)	(a) Total number of VCS CARs (y) vs. Total number of hours worked on audits (x), y = f(x)
APD (n = 6)	p = 0.01, adj R^2 = 0.78
AUDD (n = 13)	n/s
A/R/R (n = 9)	p = 0.03, adj. R^2 = 0.47
IFM (n = 5)	p = 0.04, adj. R^2 = 0.74
Project activity strata (n = 33)	**(b) Total number of hours worked on audits (y) vs. *Ex ante* offset estimates (x), y = f(x)**
APD (n = 6)	n/s
AUDD (n = 13)	p = 0.03, adj. R^2 = 0.29
A/R/R (n = 9)	p = 0.10, adj. R^2 = 0.25
IFM (n = 5)	p = 0.01, adj. R^2 = 0.88
Project activity strata (n = 70)	**(c) Total number of VCS CARs (y) vs. *Ex ante* offset estimates (x), y = f(x)**
APD (n = 9)	n/s
AUDD (n = 31)	n/s
A/R/R (n = 19)	p = 0.04, adj. R^2 = 0.2
IFM (n = 11)	p < 0.01, adj. R^2 = 0.7

activity types?; what is a realistic REDD+ project size by activity type?; what is a realistic expectation for CO2e offset generation per hectare per year?; and what percentage of offsets will likely need to be set aside permanently for negative leakage risk and temporarily for impermanence risk?

CCB was most commonly employed in the APD and AUDD project activity types (applying to 44% and 68% of the projects respectively) where project activities typically overlap with biodiversity conservation and socio-economic welfare improvement. In terms of methodologies: "VM0007: REDD+ methodology framework" was used for all APD projects; VM0007 and "VM0015: Avoided unplanned deforestation" were the most popular AUDD methodologies; "AR-ACM0001S: Simplified baseline and monitoring methodologies for small-scale A/R CDM project activities" was the most popular methodology for A/R/R projects; and "VM0010: Conversion of logged to protected forest" was the most popular methodology for IFM projects. In terms of vegetation: tropical vegetation dominated nearly all APD and AUDD projects; A/R/R projects involved primarily fast-growing tree species with commercial timber value, *Eucalpytus* spp. and *Pinus* spp. (32%) or *Tectonia grandis* (21%); and temperate forests constituted nearly three-quarters of IFM projects. Proponents, developers, implementers, and auditors were all diverse with no single auditing firm accounting for more than 42–66% of the projects in any one strata.

In terms of median project areas: APD had 4,745 HA; AUDD had the largest 97,817 HA; A/R/R had the smallest 2,493 HA; and IFM had 7,265 HA. In terms of normalized *ex post* offset volumes: APD had the most 39.2 tons CO_2e/HA/yr by approximately 13 x due to a temporal bias of claiming most of the project offsets at first verification; AUDD had 2.6 tons CO_2e/HA/yr; A/R/R had 3.3 tons CO_2e/HA/yr; and IFM had 3.0 tons CO_2e/HA/yr. In terms of median leakage risk deductions: APD had the highest at 12% and all of the remaining project activity types had 0%. In terms of median impermanence risk buffers: IFM had the highest at 21% and A/R/R the lowest at 10%.

3.2. Impact: audits significantly reduced offsets from estimated to approved for A/R/R and IFM project activity types

The total *ex ante* estimated and *ex post* approved offset quantities are listed in the second column of Table 1. In terms of total *ex post* offsets during the monitoring period for all 70 projects: APD had 16% of the total with 3,653,493 tons of CO_2e/yr; AUDD projects had the most 79% of the total with 17,809,975 tons of CO_2e/yr; A/R/R had the least 2% of the total with 336,619 tons of CO_2e/yr; and IFM had 3% of the total with 651,805 tons of CO_2e/yr. A/R/R has high direct implementation costs of planting trees and IFM has high indirect opportunity costs of foregone historical harvesting, which may explain their lower contributions to the total number of approved offsets.

Only A/R/R and IFM projects demonstrated audit impact in terms of significant reductions from *ex ante* to *ex post* offset quantities (p = 0.03 and p = 0.05, with 71% and 21% reductions respectively). A/R/R projects with the greatest reductions were Alto Huayabamba in Peru, El Arriero in Uruguay, and Reforestation in Ghana, where estimated offsets were reduced by 78%, 92%, and 76% respectively. Verification report findings suggest that the downward adjustments were directly due to the audit process: Alto Huayabamba CARs/NCRs involved an adjustment downward for a smaller planted project area, an exclusion of trees less than 1.3 m tall erroneously included, and the replacement of a more conservative allometric biomass equation for the appropriate climate zone (moist (> 2000 mm/yr) instead of wet (> 4000 mm/yr)); El Arriero CARs/NCRs involved a more conservative calculation for soil carbon based on an updated methodology version; and Reforestation in Ghana CARs/NCRs involved corrections of errors identified in plot remeasurement, as well as a cap on the maximum number of offsets based on the long-term project average including planned harvests.

AUDD had the smallest *ex post* decrease in offsets so that the total approved with all projects was an insignificant 5% greater than the total estimated. AUDD projects with the greatest increases from *ex ante* to *ex post* were two projects in Madagascar: Carbon Emissions Reduction in the "COFAV" (463% increase) and Carbon Emissions Reduction in the "CAZ" (286% increase). Both projects involved international conservation organizations working with the national government of Madagascar to enforce protected area boundaries against encroachment from small-scale swidden agriculture, called "tavy" locally. With both COFAV and CAZ, the verification reports indicated that the project activities of boundary enforcement were more effective than predicted in the PD, and furthermore that the rates of deforestation in the activity level/baseline reference areas were more rapid than projected.

Auditors do not calculate offsets independently during verification, but rather provide critical comments on the basis of the MR. The Madagascar cases involving adjustments in activity level/baselines relative to projections were common in AUDD MRs, however these adjustments (based on expensive remote imagery collection and analysis) may further isolate project claims from auditor scrutiny. In contrast, in the two project activity strata where audit impact was significant (A/R/R and IFM) verification report findings focused on carbon stocks/

emission factors, which can be inexpensively checked in monitoring plots during verification field audits. Since carbon stocks/emission factors are more difficult to measure and calculate in naturally-regenerated tropical forests in APD and AUDD projects relative to planted A/R/R and temperate IFM projects, we recommend that the VCS make four changes to its verification report and methodology guidance to drive greater scrutiny of carbon stocks/emission factors for potentially greater future audit impact in avoided deforestation projects. First, to enable quick and accurate comparisons between *ex ante* and *ex post* offsets, the VCS should modify its verification report format so that auditors are required to assign *ex post* offsets to full calendar years in the verification report to correspond to full calendar years in the PD. Second, the VCS should require that auditors reveal in their verification reports their sampling plan for emission factor plots re-measured during field visits, with an explicit emphasis on risk by re-measuring large and dense trees that can disproportionately affect total project offset calculation (Rifai et al., 2015), followed by emphases on accessibility and unbiased selection. Third, the VCS should add a methodological requirement that the chosen allometric equations be demonstrably more conservative that at least one other methodologically eligible equation option, and thereby empower auditors to scrutinize allometry choice. Shettles et al. (2016) and Picard et al. (2015) report that 65–70% of total emission factor error is attributed to modelling error, primarily from allometric equations, rather than from sampling and measurement error. Fourth, the VCS should require that the most recent allometric equation references be used by project developers and proponents, and thereby further empower auditors to scrutinize outdated references. Methodologies typically provide extensive guidance on allometric equations,[9] but allometric equations can become outdated between methodological revisions (for example, Chave et al., 2005 recommended in VM0007 has been updated by Chave et al., 2015).

3.3. Thoroughness: audit thoroughness increased with offset estimates for *almost* all project activity types

Table 3a shows that the total number of CARs/NCRs are a useful indirect measure of audit thoroughness as they are correlated with the total number of hours worked on audits, with both low p significance values (p = 0.01-0.04) and high adjusted R^2 correlations (R^2 = 0.47-0.78). The one project activity strata that was insignificant, AUDD, was retested in terms of total number of CARs/NCRs including not only VCS but also CCB. Almost three-quarters of the 11 AUDD projects reported by the three audit firms included CCB and audit firms aggregated their CCB and VCS work time. This supplementary analysis for AUDD had a p value of 0.05 and an adjusted R^2 of 0.23.

Table 3b and c show that auditors perceived larger *ex ante* estimates to be a primary risk factor for determining the thoroughness of their audits (both directly in terms of number of hours worked and indirectly in terms of number of CARs/NCRs identified) in all strata except APD. In Table 3c (as in a), the AUDD strata was insignificant until we included both VCS and CCB CARs/NCRs to get a supplementary analysis p value of 0.05 and an adjusted R^2 of 0.27.

We examined APD more closely to determine why larger *ex ante* estimates do not trigger more thorough audits. APD projects had a median project area in-between other project activity types. But in terms of median time spent on audits per area: APD had the most 0.12 hrs./HA (range 0.02–0.38); AUDD had the least 0.004 hrs./HA (range 0.001–0.022); A/R/R had 0.04 hrs./HA (range 0.01–0.12); and IFM had 0.06 hrs./HA (range 0.01–0.94). In terms of the median number of CARs/NCRs per project for VCS validation and first verification from the 70 projects: APD again had the most 54 (range 6–360); AUDD had 35 (range 2–146); A/R/R had 32 (range 1–58); and IFM had the least 17 (range 4–283). Therefore, APD projects of all sizes appear to undergo more thorough audits compared to other project activity types, likely due to auditors thoroughly examining the legitimacy of the imminent legal deforestation baselines.

To support continued audit thoroughness weighted by risk, we recommend that the VCS lower the threshold in the PD for large scale offset projects for A/R/R and IFM projects only. The threshold is currently 300,000 tons CO_2e/yr, which is appropriate for avoided deforestation projects, but we found that only 150,000 tons CO_2e/yr is *ex ante* offset mean plus one standard deviation (thus including two thirds of projects) for A/R/R and IFM activity strata.

3.4. Recommendations for offset buyers and auditors based on impact, and offset sellers based on thoroughness

Most international voluntary forest carbon offset buyers today are corporations fulfilling socio-environmental responsibility mandates for positive publicity (Lee et al., 2017). Those buyers should be drawn to AUDD projects which often provide unique stories regarding biodiversity conservation and socio-economic welfare improvement through CCB co-benefit/safeguard validation and first verification. However, if buyers are more interested in offsetting specific quantities of GHG emissions, those buyers should be drawn to A/R/R and IFM projects where they are least likely to encounter "hot air" (either intentional or inadvertent), according to our results on audit impact. Offset sellers, based on our results on audit thoroughness, could minimize the potential number of CARs/NCRs (for all project activity types except APD) by making conservative *ex ante* offset estimates in the PD, thereby reducing project risk from an auditor's perspective. At the same time, auditing firms should apply a surcharge based on the number of CARs/NCRs above medians to force the development of *ex ante* estimates which are not only conservative, but also realistic.

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[9] The current eligibility guidelines for allometric equation selection under methodology VM0007 used for all APD and numerous AUDD projects are: "(1) Equations must have been derived using a wide range of measured variables (e.g. DBH, height, etc.) based on datasets that comprise at least 30 trees; (2) Equations must be based on statistically significant regressions and must have an R^2 value greater than or equal to 0.8; and (3) The source of equation(s) shall be chosen with priority from higher to lower preference, as available, as follows: (a) National species-, genus-, family-specific; (b) Species-, genus-, family-specific from neighboring countries with similar conditions; (c) National forest-type specific; (d) Forest-type specific from neighboring countries with similar conditions; and (e) Pan-tropical forest type-specific such as those provided in Pearson et al., 2005 or Chave et al., 2005."

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