Making trees count

Measurement, reporting and verification of agroforestry under the UNFCCC

Working Paper No. 240

CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS)

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Abstract

About half of developing countries express ambition to use agroforestry—the integration of trees with crops, livestock and other non-forest timber products—for adaptation and mitigation of climate change. In order for agroforestry contributions to be recognized and rewarded, however, countries need reliable systems for measurement, reporting and verification (MRV). Here we review, through key informant interviews and examination of official documents, how agroforestry is addressed in national MRV under the United Nations Framework Convention on Climate Change (UNFCCC). Our review highlights significant gaps between national ambition and national action and capabilities. These gaps are smaller in some countries than in others, but not even one country systematically includes agroforestry in all of its relevant MRV systems. Barriers to the inclusion and explicit representation of agroforestry in MRV systems include: (1) technical barriers, such as exclusion of agroforestry from definitions of land use and lack of access to high-resolution satellite imagery; (2) institutional barriers, such as overlapping or contradictory institutional mandates and lack of human capacity to use available tools; and (3) financial barriers that prevent consistent measurement and inclusive processes. The fact that agroforestry often is not counted in UNFCCC MRV systems has serious implications: If agroforestry trees aren't counted in MRV systems, then in many ways they don't count. Only if agroforestry resources are measured, reported and verified will countries gain access to the financial and other support they need to effectively include agroforestry in climate change adaptation and mitigation. Based on emerging lessons, we recommend six ways to support countries to improve MRV of agroforestry.

Keywords

MRV; Trees outside forests; Agroforestry; Agriculture; National GHG inventories; NDCs; NAMAs; REDD+.

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Contents

Acronyms

AFOLU	agriculture, forestry and other land use
AGB	aboveground biomass
APA	Ad Hoc Working Group on the Paris Agreement
BGB	belowground biomass
BAU	business as usual
BFD	Bangladesh Forest Department
BUR	Biennial Update Report
CCAFS CGIAR	Research Program on Climate Change, Agriculture & Food Security
CDM	Clean Development Mechanism
CGE	Consultative Group of Experts
CoP	Conference of Parties
DBH	diameter at breast height
ER-PD	Emission Reduction Program Document
ER-PIN	Emission Reduction Project Idea Note
ETF	enhanced transparency framework
FAO	United Nations Food and Agriculture Organization
FCPF	Forest Carbon Partnership Facility
FRA	Forest Resources Assessment
FREL	Forest Reference Emission Level
FRL	Forest Reference Level
FSI	Forest Survey of India
FSV	Facilitative Sharing of Views

GCF	Green Climate Fund
GEF	Global Environment Facility
GHG	greenhouse gas
GFOI	Global Forest Observations Initiative
GPG	Good Practice Guidance
ICA	International Consultation and Analysis
ICRAF	World Agroforestry Centre
IFI	international financial institution
ILRI	International Livestock Research Institute
IPCC	Intergovernmental Panel on Climate Change
LDN	Land Degradation Neutrality
LEDS	low emissions development strategies
LULUCF	Land Use, Land-Use Change and Forestry
M&E	monitoring and evaluation
MRV	measurement, reporting and verification
NAMA	Nationally Appropriate Mitigation Actions
NC	National Communication
NDC	Nationally Determined Contribution
NFI	national forest inventory
NFMS	National Forest Monitoring System
NSP	NAMA Support Project
OlwTC	other land with tree cover
REDD+	Reducing Emissions from Deforestation and Forest Degradation

R-PP	Readiness Preparation Proposal
SBI	Subsidiary Body for Implementation
SOC	soil organic carbon
ToF	trees outside forests
TTE	team of technical experts
UNCCD	United Nations Convention to Combat Desertification
UNFCCC	United Nations Framework Convention on Climate Change
USAID	United States Agency for International Development

1 Why MRV of agroforestry?

Many developing countries have expressed policy intentions to promote agroforestry—the integration of trees with crops, livestock and other non-forest timber products—for adaptation to climate change and climate variability and for mitigation of greenhouse gases (GHGs) in the atmosphere. Our assessment indicates that 40% of developing countries (59 of 147) explicitly proposed agroforestry as a measure in their Nationally Determined Contributions (NDCs), and that interest is especially high in Africa (71%) compared to the Americas (34%), Asia (21%) and Oceania (7%). Furthermore, seven countries have registered 10 agroforestry-based Nationally Appropriate Mitigation Actions (NAMAs). Out of 73 Reducing Emissions from Deforestation and forest Degradation (REDD+) developing countries, about 62% identify agroforestry as a response measure to combat drivers of forest loss and degradation (see Section 3). The level of stated ambitions for agroforestry found during this assessment was consistent with previous reviews of NDCs and REDD+ (Bernard and Minang 2011, Richards et al. 2015, FAO 2016) and provides additional evidence of national interest through analysis of National Communications (NCs) and NAMAs and through expanded analysis of REDD+ countries.

Despite ambitious government plans, there is still considerable uncertainty surrounding whether agroforestry can be accounted for by countries and programmes responding to climate change (Minang and van Noordwijk 2012). Under the United Nations Framework Convention on Climate Change (UNFCCC), measurement, reporting and verification (MRV) of GHG emissions and removals has several functions. At the country level, improved quantification of emissions and removals enables identification of mitigation actions with sustainable development benefits, and can inform countries about the progress and effects of mitigation actions (Olander et al. 2014). Including agroforestry in MRV thus provides visibility to the contributions that agroforestry makes to national and international climate objectives. Furthermore, robust MRV of agroforestry is a critical step in facilitating access to domestic and international sources of finance and other support. Thus, MRV is a precondition for scaling up of agroforestry to meet countries' climate and development ambitions.

While the UNFCCC and IPCC provide requirements and guidance for MRV, countries have considerable flexibility in the methods they use (IPCC 1996, IPCC 2006 Appendix 2). This is true for international reporting to the UNFCCC in NCs and Biennial Update Reports (BURs), and also for domestic MRV systems for NDCs, Low Emissions Development Strategies (LEDS) and NAMAs. Flexibility has obvious benefits. One consequence, however, is that many countries struggle with design and implementation of MRV systems for agriculture in general and agroforestry in particular (Wilkes et al. 2011, Wilkes et al. 2013, Wilkes et al. 2018). There is an urgent need for guidance on implementation of MRV of agroforestry to improve accounting of GHG emission reductions and removals due to implementation of low-emission, climate-resilient development strategies, especially given the enhanced transparency requirements under the Paris Agreement.

No previous work has specifically examined countries' methods and capacities for MRV of agroforestry under the UNFCCC. However, several previous studies have assessed the capacity of developing countries in tropical regions to undertake forest monitoring for REDD+, and the IPCC inventory guidelines are relevant. Based on the United Nations Food and Agriculture Organization (FAO) Forest Resource Assessment (FRA) country reports for 2005, 2010 and 2015, Romijn et al. (2015) assessed the capacity of non-Annex I countries to produce forest area maps and monitor forest area change; capacities for forest inventories to collect data on species and biomass; and capacities to report biomass and carbon pool changes. The assessment judged that 54 out of 99 countries (55%) had good capacities for detecting forest area change using remote sensing, and that capacities were strong in Latin America and Southeast Asia; capacities in Africa were considerably lower. However, not all the challenges to MRV are technical. Tulyasuwan et al. (2012) surveyed 35 non-Annex I countries across Africa, Asia and the Americas to better understand the institutional arrangements available for MRV of REDD+. The authors analyzed 10 different indicators through a survey of 35 countries and found institutional conditions and readiness varied among regions. A similar pattern was evident for technical capacities, with Africa having the least well-established institutional arrangements and being more externally dependent for technical capacities than other regions. Therefore, lessons from assessment of MRV for REDD+ suggest the potential for technical challenges such as the data compilation, analysis and storage, as well as institutional challenges to coordination and implementation of MRV.

Previous assessments for REDD+ hint at possible challenges and opportunities for MRV of agroforestry. In addition, agroforestry has unique attributes that may increase the challenges of MRV. First, agroforestry occurs on multiple land uses and is not defined by the IPCC as a land-use category in and of itself (IPCC 1996, IPCC 2006). The presence of agroforestry across land uses often presents technical challenges to its treatment in MRV systems (see Section 4), as well as institutional challenges caused by overlapping or unclear institutional mandates (see section 'Factors that constrain or enable MRV of agroforestry'). Second, agroforestry typically occurs over relatively small land areas, making it technically challenging to measure given the diversity of agroforestry systems, the spatial resolution of satellite imagery required to detect small plots or scattered trees, and the lack of existing agroforestry-specific allometric equations, a situation that precludes easy reporting based on either inventory or remote sensing (Schnell et al. 2015, Kuyah et al. 2016). Third, and importantly, unlike forestry and REDD+, agroforestry does not have an international initiative recognized by the UNFCCC that directs attention and resources toward addressing technical and capacity challenges by technical bodies and programs such as the FAO Forest Resource Assessment (FRA), USAID SilvaCarbon and the Global Forest Observations Initiative (GFOI).

With the decision to establish the Koronivia Joint Work on Agriculture, the UNFCCC Conference of Parties (CoP) brought agriculture into international climate negotiations. Agroforestry is relevant to the CoP decision even though it is not explicitly mentioned in it. Agroforestry may generate benefits germane to the topics addressed in the decision, including: building resilience; increasing soil carbon and improving soil health and fertility; providing protein-rich fodder as well as shade, thus reducing heat stress and allowing improved and more sustainable livestock production; and diversifying human diets and income opportunities (see Appendix I). Agroforestry is one of the few mitigation options that also has adaptation benefits. Given the political intent communicated by many developing countries, the technical and institutional challenges, and the importance of agroforestry for Koronivia Joint Work, an agroforestry-focused assessment of MRV is needed to understand current practices and challenges and to identify opportunities for improvement. Such assessment can inform planning so that future work can support countries' use of agroforestry to meet national goals.

This study reviews how developing countries integrate agroforestry in MRV. The MRV systems assessed include NCs and national inventory reports, NDCs, NAMAs and REDD+.

The review is organized around six primary questions: (1) Do countries express intent to use agroforestry to meet national climate goals? (2) To what extent is agroforestry represented in MRV systems—in other words, is agroforestry visible? (3) How do national definitions of agroforestry affect its inclusion in REDD+ MRV systems? (4) What are the opportunities and challenges in aligning different agroforestry MRV systems? (5) What methods of measurement are being used and how do these methods help or hinder representing agroforestry? (6) What factors constrain or enable MRV of agroforestry? We conclude the review by making six recommendations that could help countries improve representation and inclusion of MRV. The appendices include a review of the benefits of agroforestry (Appendix 1), background on MRV under the UNFCCC (Appendix 2), additional information on methods (Appendix 3) and detailed summaries of the assessment of MRV methods currently used in GHG inventories, NDCs, REDD+ and NAMAs (Appendices 4-7).

2 Methods

This assessment primarily focuses on MRV systems at the national level, including measurement and reporting of national GHG inventories through NCs and BURs; measurement and reporting in documents mandated under UNFCCC REDD+ processes; and measurement and reporting of agroforestry NAMAs. The Clean Development Mechanism (CDM) and other voluntary market standards have created considerable experience of agroforestry MRV at the individual project scale (Lee et al. 2018). However, the links between project-scale interventions and MRV of national initiatives under the evolving UNFCCC MRV framework are not yet clear. Therefore, this report focuses on national-level MRV, with discussion of cross-scale issues where relevant.

What is agroforestry?

The problem of defining the term ‘agroforestry’ indicates the central challenge of agroforestry MRV. Does the term encompass trees scattered across Vietnam? Oil palm plantations in Southeast Asia? Coffee farms in Central America? Trees in the rangelands of South America? Current definitions emphasize the roles trees play in integrated ecosystem management connecting trees, forests, farms, livelihoods, landscapes and governance (Noordwijk et al. 2016). Historically, however, narrower definitions focused tightly on trees planted or intentionally managed on croplands and ranches were more common (Nair et al. 2003).

Regardless of the precise definition, there are countless ways agroforestry is practiced, ranging from living fences and home gardens to woodlots and multistrata agroforestry (figure 1). Given the wide range of species (e.g., leguminous versus non-leguminous), planting configurations (e.g., intercropping versus boundary planting) and agro-ecologies, there are countless permutations of agroforestry. Typologies of agroforestry systems typically focus on the parcel level and group agroforestry into categories including the following: agrisilviculture, crop-tree combinations in spaces that include intercrops, parklands and others; silvopastoral, livestock-tree production including rangelands and pasturelands; boundary planting, tree-crop-livestock combinations including living fences, windbreaks, etc.; improved fallows, crop-tree combinations rotated in time; shadow systems, crops grown under shade trees; home gardens, tree-crop-livestock combinations around settlements; and woodlots, tree products that occur within a broader farm matrix of mixed crop-livestock-tree production (Feliciano et al. 2018). Orchards and other monocropped trees are considered agroforestry when they occur within a landscape of mixed products.

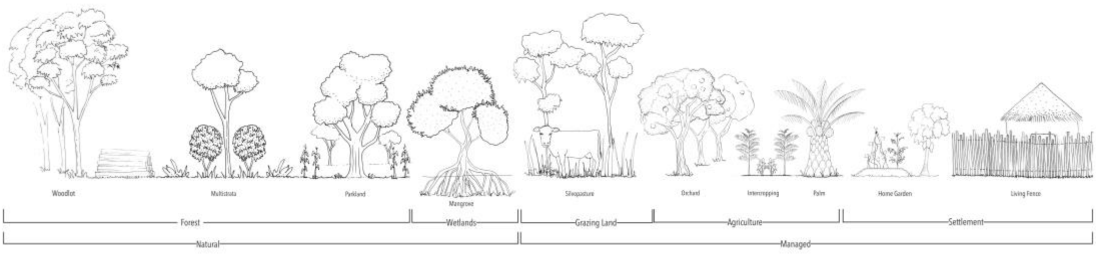


Figure 1: Select types of agroforestry that can extend from managed settlements to planted forests depending on the definition and surrounding landscape.

Conceptual approach

The UNFCCC guidelines for MRV and IPCC guidelines for GHG inventories (which also underlie guidance on MRV for REDD+) are based on the principles of consistency, transparency, accuracy, comparability and completeness. A precondition for assessing the application of these principles to agroforestry is that agroforestry must be explicitly represented in reporting. IPCC guidance on consistent representation of lands is intended to ensure that inventories are able to represent land-use categories and land-use conversions consistently over time for complete representation of all land in a country, with data sources, definitions, methodologies and assumptions clearly described to ensure transparency and to ensure that GHG emissions and removals are neither over- nor underestimated. Given that adherence to these principles can be assessed only if agroforestry is explicitly represented, this review starts by analyzing the visibility of agroforestry in MRV systems in NCs and REDD+. Following the analysis of visibility, we review specific topics, including definitions, and the methods used to represent lands and to convert land uses and land-use changes into emissions estimates.

Data sources

We conducted desk reviews and key informant interviews to answer our research questions. Desk reviews examined developing countries' submissions of NCs (N=147), NDCs (N=147), REDD+ strategies (N=73) and NAMAs (N=264). Countries were considered developing based on World Bank classifications. Documents were read cover-to-cover and examined by keyword search (Appendix 3). Google Translate was used to allow the survey team to interpret the text of documents in other languages as well as possible. Each document was examined against criteria indicating: (1) whether agroforestry was explicitly or potentially mentioned as a climate action; (2) whether agroforestry was explicitly or potentially reported on in MRV systems; and (3) the methods used to quantify and represent agroforestry in each MRV system. The project team had weekly meeting to discuss challenges with data extraction and build coherence in approaches (regarding keywords, data capture, etc.). The dataset is available from ICRAF's Dataverse repository. Data were summarized by descriptive statistics in Microsoft Excel, and maps were made in ArcGIS.

Key informant interviews complemented the desk reviews. Key informants were typically persons who had some responsibility for national MRV systems related to the UNFCCC. Interviews were based on a set of predetermined questions. However, prior to each interview, we used information from the document review and other sources (such as peer-reviewed literature) to provide additional details about the country context and to identify topics of particular relevance to each country and stakeholder interviewed. In total, people from 12 countries were interviewed. Countries that had significant known interest in agroforestry such as a policy (e.g., Nepal), a relevant NAMA submitted or under development (e.g., Colombia) or a considerable number of explicit mentions of agroforestry in NC and REDD+ document review (e.g., Rwanda and Togo) were selected. When countries had known policies or programs and we did not interview a representative, we read secondary literature and case studies to understand ongoing initiatives (e.g., India and China).

3 Agroforestry in UNFCCC reports, policies and programs

This section describes how countries discuss agroforestry in UNFCCC reports (NCs, including GHG inventories), policies (NDCs) and programs (REDD+ and NAMAs). In short, discussion of agroforestry is ubiquitous in all documents, though the prevalence and type of agroforestry varies by region. Results of our review suggest that countries are already using agroforestry now (such as in GHG inventories and REDD+) and have plans to do so in the future (e.g., NDCs) to respond to climate change (figure 2). The level of interest found here generally agrees with earlier assessments that only considered NDCs or a smaller number of REDD+ countries (Richards et al. 2015, Minang et al. 2014). Results are also summarized in the introduction above ('Why MRV of Agroforestry'), with additional information detailed in Appendices 4-7.

National Communications

NCs and BURs submitted to the UNFCCC are the primary channels through which developing countries report national GHG inventories. Of 147 NCs reviewed, 105 either explicitly mention agroforestry or discuss interventions that could include agroforestry (hereafter referred to as 'potential mentions'). More than 80% of those countries (88 of 105) explicitly refer to agroforestry, with 69% (61 of 88) mentioning it as a solution for mitigation, 72% (63 of 88) for adaptation and 41% (36 of 88) mentioning it for both. Interest in agroforestry is particularly evident in Africa, where 36 of the 50 countries (71%) analyzed include agroforestry as a climate response measure. However, interest in agroforestry is also apparent in the Americas, where 34% (11 of 32) of countries mention agroforestry (Appendix 4).

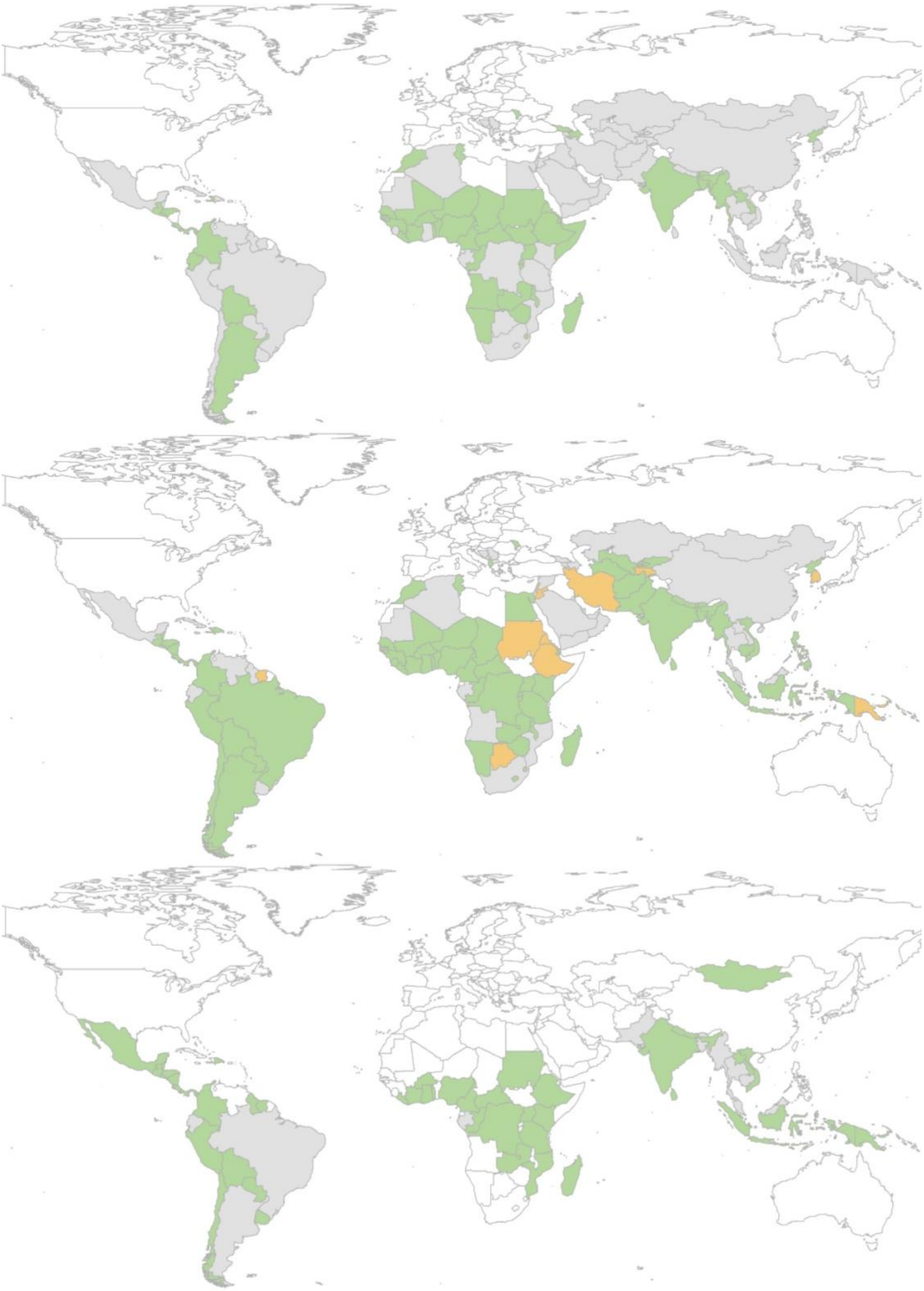


Figure 2: Agroforestry ambitions in a) NDCs, b) NCs and c) REDD+. Colors indicate which countries' documents mentioned agroforestry (green), did not mention agroforestry (grey) and unclear (orange).

Agroforestry is mentioned in 51% of NCs (45 of 88) in non-specific terms, simply as 'agroforestry,' without specifying species or farming system. However, many countries name specific types of agroforestry, such as windbreak trees, fruits and silvopastoral (Djibouti), firewood from orchards and arboriculture (Morocco), perennial plantations (Kyrgyzstan), agrosilvopastoral (Democratic Republic of Congo) and silvofishery (Indonesia).

Many descriptions of land management described in NCs may qualify as agroforestry, though it is not possible to determine this with certainty. The frequency of potential mentions is even greater than the use of the specific term agroforestry, with 78% (115 of 147) of countries reviewed mentioning one or more of the land management activities that potentially involve agroforestry. Each country mentioned an average of two agroforestry-potential activities, with some mentioning as many as eight. When only the GHG inventory sections of NCs are considered, slightly more countries (82%, or 120 of 147) have made potential mentions, with an average of 2.5 potential mentions per country. The larger number of countries with potential mentions indicates the wide net cast with these terms and therefore represents an upper bound of national interest.

The analysis of explicit and potential mentions of agroforestry in NCs clearly illustrates that a significant fraction of developing countries is already including agroforestry in the GHG inventory and mitigation chapters of NCs. Acknowledgement in these documents represents an initial step in including agroforestry in reporting processes of the UNFCCC, though it does not assure fully transparent, accurate, consistent or complete representation.

Nationally Determined Contributions

Many countries are proposing to use national GHG inventories to report on NDC progress. The discussion of agroforestry in NDCs could therefore indicate how it may be included in future reporting.

As in NCs, agroforestry is pervasive throughout developing country NDCs. Out of 147 NDCs examined, 59 (40%) explicitly mention agroforestry as a measure of climate-change mitigation or adaptation. Mentions include: 71% (36 of 50) of African NDCs, 34% (11 of 32) of Americas NDCs, 21% (9 of 44) of Asian NDCs, 7% (1 of 14) of Oceania NDCs and 17% (1 of 6) of European NDCs. How agroforestry practices are mentioned differs by region, with most mentions in Africa focusing on adaptation only and those in Asia and Americas focusing on mitigation only (Appendix 5). A total of 17 countries (10 in Africa, 3 in the Americas, 3 in Asia, 1 in Oceania) propose to use agroforestry for both adaptation and mitigation. Agroforestry is most frequently mentioned using the term ‘agroforestry/agroforestry systems’ (N=44). ‘Assisted natural regeneration’ and ‘agro-silvo pasture/agro-silvo pastoral systems’ are the most common subpractices. Most detailed agroforestry mentions occur in Africa and Asia (including assisted natural regeneration, agro-silvo pasture/silvopasture, protective forestry strips (buffer zones/wind breaks) and social and homestead forestry) and the Americas (including silviculture, assisted natural regeneration and agro-silvo pasture/silvopasture).

The NDCs are specifically intended to direct climate responses. If countries use GHG inventories to report on progress with NDCs, it is paramount for GHG inventories to be able to represent agroforestry.

Reducing Emissions from Forest Degradation and Deforestation

Out of 195 countries, 73 are one or more of the following: UN REDD countries (64), Forest Carbon Partnership Facility (FCPF) countries (47), REDD early mover countries (3), or countries that had made related submissions to the UNFCCC (8). A total of 53 of the 73 countries have submitted 134 REDD+ related documents that were reviewed for this assessment. At the time of the review, 48 countries had submitted REDD+ readiness plans, 34 had submitted their Forest Reference Emission Levels/Forest Reference Levels (FRELs/FRLs), 15 had submitted a REDD+ National Strategy, and two had described their National Forest Monitoring Systems (NFMSs).

Our review of 53 countries’ REDD+ documents found that a majority (42 countries, or 79%) have explicitly mentioned or included agroforestry in their REDD+ efforts (Appendix 6). This percentage is far larger than that from previous assessments, which found between 40% and 44% in an assessment of 43 countries (Salvini et al. 2014, Minang et al. 2014). The difference could in part be an artefact of sampling (e.g., if the countries included in earlier assessments were more limited in the scope of their REDD+ activities), or could reflect that earlier assessments occurred more than four years ago (the study was published in 2014), before some countries submitted new or revised documents.

Africa and the Americas expressed the greatest interest in agroforestry, with 18 and 15 countries represented, respectively. Ten of the 42 specific mentions were generic—'agroforestry' or 'agroforestry system.' The remaining 32 mentions refer to specific types of agroforestry system, such as silvopastoral system, natural regeneration, tree planting on farms, agro-silvo pastoral systems, etc. Two countries note their interest in agroforestry in their national REDD+ strategies but have not yet included it: Costa Rica because of concerns about monitoring costs and Côte d'Ivoire because of land tenure security issues. In addition to the specific and targeted mentions of agroforestry in REDD+ documents, there are several other potential mentions. These include sustainable forest management, afforestation/deforestation, biomass fuels, plantations, cash-crop trees, agropastoral, tree farming, land management and restoration/rehabilitation. Whether these are considered part of forests or outside of forest depends on the national forest definition and the specific practices referred to.

Nationally Appropriate Mitigation Actions

We reviewed the NAMA database (www.nama-database.org) and the UNFCCC NAMA registry (www4.unfccc.int/sites/nama/SitePages/Home.aspx) for agroforestry-based NAMAs (accessed June 2017). Our search yielded 274 NAMAs from 66 developing countries, with roughly 99, 92, 67, 14 and 2 from the Americas, Asia, Africa, Europe and Oceania, respectively. Only 34 of the 274 NAMAs were for the agriculture sector, with 7 from Africa and 13 each from the Americas and Asia. There have been no agricultural NAMAs registered in either Europe or Oceania (Appendix 7).

A fourth of the NAMAs included mentions of agroforestry. Explicit mentions include both general descriptions and specific practices such as hedgerows, silvopastoral systems or short rotation coppicing. NAMAs that potentially include agroforestry but were not in the agriculture sector were proposed in the forest or energy sectors. Only three of the registered NAMAs have developed an MRV system for agroforestry (including Uganda for energy) and one has validated an MRV system (Costa Rica for coffee).

4 Reporting on agroforestry in GHG inventories

This section describes the extent to which agroforestry is currently being reported in national GHG inventories and explores compilation and reporting practices that contribute to greater or lesser visibility of agroforestry. The information presented here is based on a review of the NCs of 147 developing countries in the period 2003 through 2017. We also assessed the inventories of the 105 countries that explicitly mention agroforestry in their NCs.

While we found that virtually all (99 out of 105, or 94%) of the reviewed inventories reported on changes in forest carbon stocks as part of the land-use change and forestry (LUCF) sector inventory, the extent to which agroforestry is specifically visible in national GHG inventories is variable and influenced greatly by reporting approach. Developing countries are not required to submit their national GHG inventories in full detail as part of NCs or BURs. Because NCs and BURs also include a great deal of other information related to climate change and national responses, national GHG inventories are often reported only in summary form in NCs or BURs. The level of detail provided and the transparency of their reporting varies widely (Romijn et al. 2012, Wilkes et al. 2017).

Our review found that 74 of 105 countries (70%) included some non-forest trees in the national inventory. Non-forest trees are, of course, not always agroforestry. However, in some cases they are. More than 229 terms were used to describe non-forest trees. Descriptions included: trees in home gardens (Sri Lanka), commercial tree crops such as fruit orchards and vineyards (Albania), cacao (Cote d'Ivoire), coconut (several Pacific islands) and shrubs in agricultural lands (Indonesia). Mentions that may or may not be agroforestry include descriptions such as trees alongside roads (Myanmar) and mangrove forests (Madagascar). Almost half of the 105 countries included some form of sparse forest in their reporting (e.g., Miombo woodlands in Zimbabwe and Malawi). Overall, the majority of non-forest trees included in NCs are plantation and tree crops (figure 3), though in some cases trees in pastures were mentioned (e.g., in Sierra Leone).

Figure 3. Common descriptors of non-forests trees in NCs. Size of word is relative to the number of mentions of each term out of 229 terms used to describe trees outside forests in 74 NCs. Largest and smallest words have 21 and 1 mentions, respectively.

Relatively few countries provided an estimate of the carbon in non-forest trees in the inventory. Sixteen countries gave a quantitative estimate of either the number of trees (range: 300,000 trees in Nepal to 405,104,918 trees in Niger) or the areal extent of trees outside forests (range: 250 ha in Nauru to 2.2 million ha in Tunisia). Thus, even though many countries mention non-forest trees in the inventory, few provide a quantitative estimate. These findings suggest that there may be a gap between the recognition of trees outside forests (some of which are agroforestry) and their quantitative inclusion in the inventory.

The failure of an inventory to provide explicit numbers for non-forest trees, sparse forest, trees outside forests or agroforestry does not mean, however, that they had not been quantified in the compiling of the inventory. IPCC Guidelines serve as the framework for inventory compilation (and other MRV systems) in the land-use sector. These guidelines include six types of land use: forests, settlements, cropland, grazing, wetland and other lands. It often goes unrecognized that some type of agroforestry can be found on each of these six types of land use (figure 4). The IPCC 1996 Guidelines structure reporting of woody biomass carbon dioxide removals in terms of “forest and other woody biomass.” Trees on lands that do not meet national forest definitions, including various forms of agroforestry, are considered "other woody biomass" and are to be reported in the category 5A5, "other woody biomass." IPCC Good Practice guidance (GPG) and IPCC 2006 use a narrower definition of agroforestry systems as woody biomass on croplands that do not meet national definitions for forest land (reporting category 3B2). This definition is consistent with a narrow definition of agroforestry as trees planted or intentionally managed on farms and ranches (Nair et al. 2003). Woody biomass not occurring on forest land (as defined in national forest definitions) or cropland may be reported under grassland, wetland, settlements or other land categories (reporting categories 3B3-3B6 in the IPCC 2006 Guidelines), but may also have characteristics of agroforestry, i.e. managed trees.

Agroforestry, however, does not occur only on lands outside forests. The IPCC GPG and IPCC 2006 encourage the use of national forest definitions in classifying forests. These vary considerably based on self-determined thresholds for minimum area (measured in ha), tree cover (measured in percent of land surface), and tree height (measured in meters). The consequence is that many types of agroforestry are included in the "forest" category where national forest definitions are met (i.e., reporting categories 5A1-5A3 in the 1996 Guidelines or 3B1 in the IPCC 2006 Guidelines). In addition, some countries' systems for representation of lands distinguish between forested forest land and non-forested forest land (i.e. land considered forest land but without trees meeting national forest definitions, such as recently afforested land). Thus, it is clear that there is an interaction between the type of agroforestry e.g., the type of land use it typically occurs upon) and the definitions of land uses, especially forest definitions, established by countries.

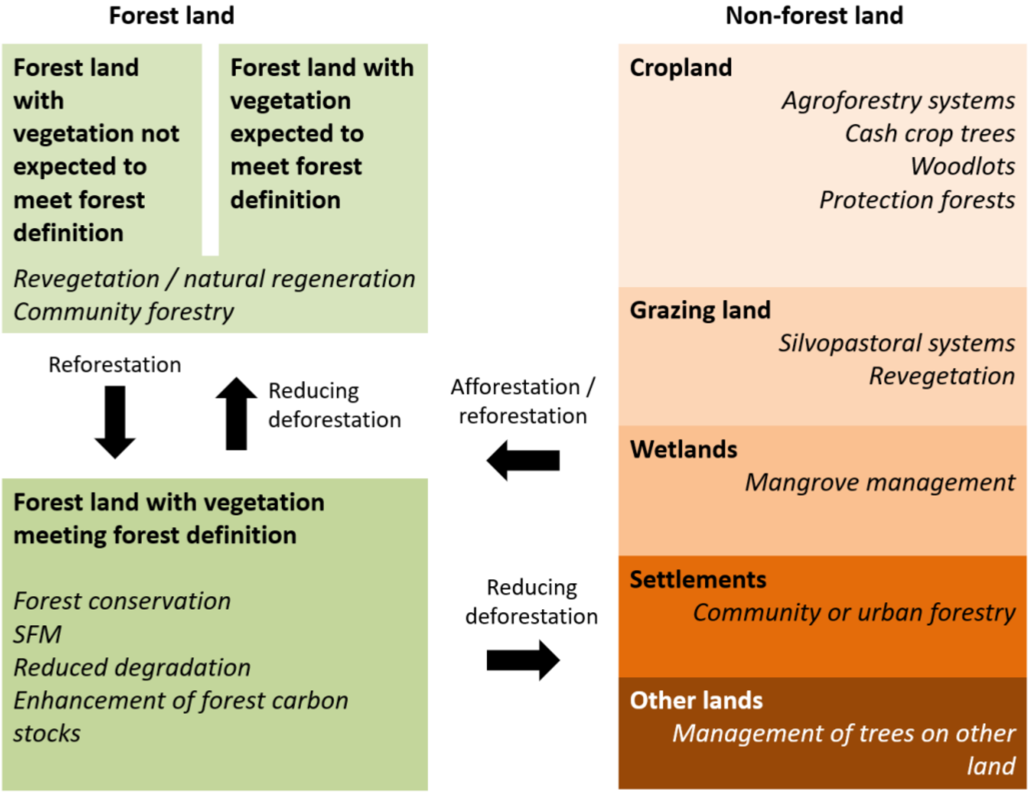


Figure 4: Trees outside forests and agroforestry within the IPCC land-use categories.

Notes: Items in italics are examples of different forms of agroforestry that might be categorized under each land use type. Arrows indicate the potential contributions of agroforestry actions to increasing GHG mitigation by carbon stocks or reducing the loss of forest carbon stocks.

Source: Adapted from Herold and Skutsch (2009)

Because NCs present only a summary of the national GHG inventory, many countries report only aggregate estimates of emissions and removals from LUCF (i.e., reporting category 5 in IPCC 1996), or a summary figure for category 5A, "changes in forest and other woody biomass stocks" (table 1). More than one third of countries (41 of 105) clearly reported estimated carbon removals for some subcategories of 5A, such as "forest remaining forest" or "cropland remaining cropland," and even fewer report detailed subcategories within different types of land use or land-use change. Just over 60% (64 of 105) of countries did not report any carbon removal estimates for subcategories of 5A. However, of these countries, 24 did provide either supplementary tables or narrative explanation that identified trees outside forests (some of which may be agroforestry) as having been included in the estimate of emissions in category 5A.

Table 1. Frequency of countries reporting at different levels of disaggregation for changes in forest and other woody biomass stocks (n=105)

Reporting practice	Number of countries (% of total in parentheses)	
	Reporting this category	Reporting with subcategories thereof
Reporting LUCF total	99 (94%)	88 (85%)
Reporting 5A, forest and woody biomass stocks	90 (86%)	41 (40%)
Reporting forest remaining forest with subcategories	40 (38%)	27 (26%)
Reporting conversion to forest with subcategories	36 (34%)	20 (19%)
Reporting cropland remaining cropland with subcategories	35 (33%)	12 (11%)
Reporting conversion to cropland	28 (26%)	13 (12%)

Thus, for more than half of countries, even if agroforestry had been quantified, it would not appear explicitly within the inventory because LUCF was not presented in a disaggregated way. For countries that did report subcategories of these reporting items, agroforestry is often explicitly mentioned (35 out of 41 countries reporting subcategories of 5A), either in a narrative explanation of methods (18 countries) or in a table presenting disaggregated land-use categories (30 countries). Thus, if countries report subcategories of forest and woody biomass stocks, agroforestry becomes more visible. For other countries, transparency often falls victim to reporting requirements, with the consequence that it is virtually impossible to determine whether agroforestry plays any significant role in the GHG inventories of most countries, even though they are reporting changes in standing stocks of carbon.

Box 1: How are trees outside forests accounted for in Vietnam's national GHG inventory?

Vietnam's 2010 GHG inventory mapped national land-use classifications onto IPCC reporting categories. Within 'forest remaining forest,' various types of forest are reported, including mixed wood and bamboo forests and plantation forests that might fall within the broader definition of agroforestry. Perennial crops on agricultural land are categorized in the GHG inventory as a form of cropland. The inventory presents a land-use change matrix showing that in 2005, there was 59,260 ha of perennial cropland, which increased to 186,302 ha in 2010, mainly due to conversion of forest land and annual cropland to perennial cropland. This was determined on the basis of land-use statistics from the General Statistics Office of Vietnam, which are reported annually.

To estimate the related carbon stock changes, it was assumed—presumably on the basis of expert knowledge of local perennial systems—that perennial cropland planted in the last eight years had an increasing carbon stock, while perennial cropland more than nine years in age had reached a steady state. Since the area of perennial crop increased continuously from 2002 to 2010, the newly planted perennial crop area is estimated simply from the increased area of perennial cropland within the last eight years, which in 2010 was 611,300 ha. The carbon stock change factors used were based on default biomass growth rates in IPCC (2003). The remaining perennial crop area was assumed to be at a steady state, and no biomass increment was attributed to these lands.

In summary, inventory reporting practices that increase the visibility of agroforestry include elaboration of woody biomass types in the narrative content of GHG inventory reports and presentation of subcategories of land-use types and GHG removal sources in supplementary tables. In some cases, lack of reference to agroforestry may be a simple editorial decision in what is included in the synthesis, since there is limited space in national GHG inventory summaries. While this may matter less for reporting to the UNFCCC, GHG inventories are also an important source of information for policy makers and program designers, but editorial simplification can lead to the contribution of agroforestry being overlooked. In addition to these factors, lack of explicit mention is often due to the data sources used (see Section 7).

5 Definition of forest limits inclusion of agroforestry in REDD+ MRV

REDD+ is intended to promote five types of activity: reducing emissions from deforestation; reducing emissions from forest degradation; conservation of forest carbon stocks; sustainable management of forests; and enhancement of forest carbon stocks. The Cancun Agreement set out the framework for REDD+. This framework consists of a National Strategy or Action Plan, a FREL/FRL, a NFMS, and safeguards. Decision 13/CP.19 Warsaw set out the main requirements for FRELs/FRLs, which are benchmarks that represent the assumed trend in deforestation and forest degradation in a country against which progress in REDD+ is to be measured. FRELs/FRLs consist of a forest definition, the scope of REDD+ activities, and carbon pools and gases to be included. Through analysis of data, including historical data, a trend in deforestation and forest degradation in the absence of REDD+ action is established. FRELS/FRLs should be consistent with national GHG inventories, but the Warsaw agreements on REDD+ also allow for improvements over time. FRELs/FRLs may be subject to voluntary technical assessment, but technical assessment is required where countries seek results-based payments.

REDD+ implementation hinges on the concept (and definition) of a forest. The formal definition of a forest adopted by countries defines the scope of activities that will be considered and therefore incentivized. When defining forests for the purpose of REDD+, each country makes its own decisions regarding minimum area, tree height, canopy cover and species/ecosystems (and whether forest must be situated in forest land). What is a forest in one country may not be a forest in another. Forty-five of the 56 countries had communicated a forest definition. Of these, about 18% (8 out of 45) adopted the FAO Forest Resource Assessment definition of forest. Sixteen countries aligned their forest definitions to those of the Clean Development Mechanism (CDM), UNFCCC, United Nations Environmental Program, FAO-FRA or similar, where trees and shrubs greater than 0.5 ha, 10% crown cover and minimum 5 m tall represent forests (table 2).

Table 2. Comparison of common forest definitions

Factor	FAO FRA 2015	IPCC 2003 GPG	CDM
Minimum area (ha)	0.5	0.05–1.0	0.5
Minimum height (m)	5	2–5	5
Crown cover (%)	10	10–30	10
Also includes	–	Young stands expected to reach crown cover and height thresholds; temporarily unstocked forest land	
Excludes	Land predominantly under agricultural or urban land use	–	

Agroforestry may meet the definition in forest and therefore be captured in REDD+ MRV. Agroforestry systems, such as complex multistrata coffee and cocoa, woodlots or palm oil plantations, often meet the area, height and crown cover characteristics of forest definitions. For example, cacao agroforests in Cameroon have as much as 88% tree cover (Bisseleua et al. 2009). By meeting forest definitions, such systems have the potential to be monitored and counted under REDD+. In a few cases, countries identified specific crops or species—such as palm in Mexico, bamboo in India or rubber in Vanuatu—as falling within the REDD+ forest definition, presumably to direct attention and investment toward these systems. However, that was not the norm.

Minimum tree canopy cover is one criterion used to define a forest and therefore include or exclude agroforestry under REDD+ MRV. Thresholds for minimum tree cover range from 10–40%. We found that nearly 80% of countries (45 of 56) have defined their minimum canopy cover threshold within that range, with 22, 3, 3, 16, and 1 establishing thresholds of 10, 15, 20, 30 and 40% minimum tree cover, respectively (figure 5). The relatively low minimum canopy cover for many countries represents an opportunity for agroforestry outside of forests under REDD+. A recent analysis found that 43% of the world's cropland has at least 10% tree cover (Zomer et al. 2016). However, much of the tree cover is not counted toward REDD+ because it occurs on land classified as croplands and not forests, even though it meets the forest definition. Reclassifying land as forests can have significant effects on estimates of the extent of forests. For example, Bastin et al. (2017) estimated that the global extent of forest is 9% greater than previous estimates (an additional 1,079 million hectares) when dryland areas with 10% tree cover, such as the parklands of West Africa, are included (Bastin et al. 2017). Thus, there may be a significant opportunity for countries to widen the scope of lands classified as forest to better realize the potential of agroforestry as a response measure within the context of national REDD+ strategies.

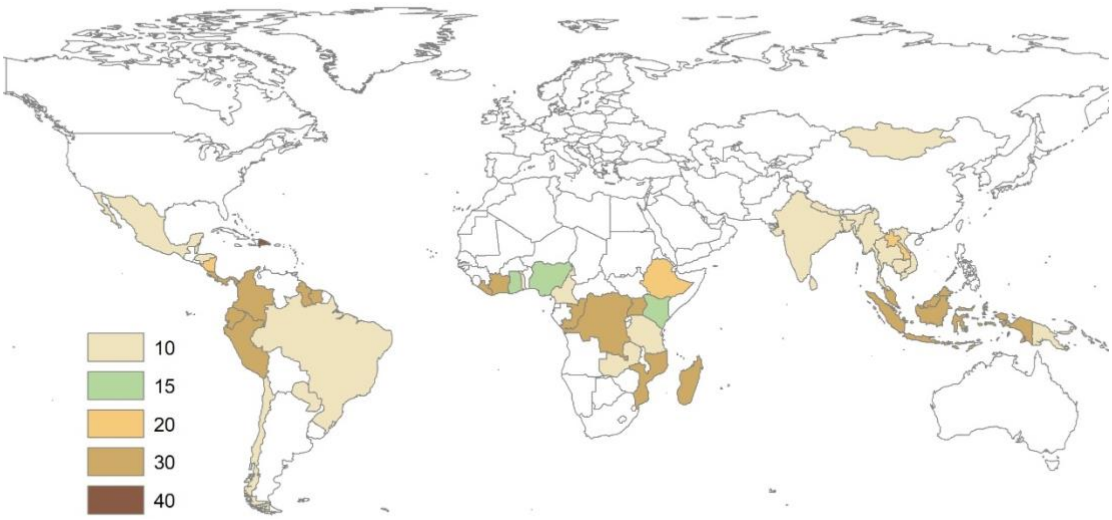


Figure 5: Minimum threshold (%) of tree cover to meet forest definition in REDD+ strategies.

Many countries exclude trees on non-forest land and agroforestry from forest definitions. Forest definitions for 11 countries—Bangladesh, Belize, Colombia, Cote d'Ivoire, Fiji, Ghana, Panama, Paraguay, Sri Lanka, Suriname and Uganda—explicitly exclude agroforestry linked to agricultural land, urban parks, trees for non-wood products, forest plantations, tree crops and fruit plantations (table 3). These systems are excluded despite the fact that all these countries (except Bangladesh) specifically mention agroforestry as a relevant response measure in their REDD+ strategies and the criteria of forest are often met on non-forested lands. Because these systems are excluded from formal definitions, NFMSs used for REDD+ would not necessarily be designed to capture changes in either area or carbon balances from these systems. It should be noted, however, that a few countries use the forest definition to specifically include trees outside forests and agroforestry in REDD+ definitions. Yet only Honduras, Vanuatu and India explicitly include agroforestry on cropland in their forest definitions, although in the REDD+ documents reviewed El Salvador and Pakistan expressed interest in including these systems in the future.

Table 3. Forest definitions adopted by selected countries that have excluded some types of agroforestry from their FREL/FRL

Country	Area (ha)	Height (m)	Canopy cover (%)	Exclusions
Bangladesh	0.5	5	10	Tree stands in agricultural production systems (such as fruit plantations and agroforestry systems), urban parks and gardens
Belize	0.5	5	10	Agroforestry, urban parks and tree assemblages planted for non-wood products.
Brazil	0.5	5	10	Land under agriculture or urban land use
Colombia	1	5	30	Forest plantations, palm crops and planted trees for agriculture
Fiji				Agroforestry listed as agriculture land
Ghana	1	5	15	Tree crops, including cocoa, citrus, oil palm (in smallholder or estate plantations), and rubber are not considered to be forest trees
Malaysia	0.5	5	30	Oil palm and rubber plantations
Mexico	50	4	10	Trees on lands predominately for agriculture or urban
Paraguay	1	3/5	10/30	Urban areas, plantations predominately agricultural, agroforestry, silvopastoral systems
Uganda	1	4	30	Tree stands in agricultural production systems, for example in fruit plantations and agroforestry systems

The definition of agroforestry is central to designating FRELs/FRLs, which provide the benchmark for the performance (emission reductions) of subsequent REDD+ activities. Of the 56 countries reviewed here, 34 (61%) have submitted FRELs/FRLs. Of countries that have submitted them, 59% (20 of 34) have done so within the past two years. One country submitted in 2014, three in 2015, 10 in 2016, nine in 2017 and 11 (two resubmissions and nine new submissions) in 2018.

Whether agroforestry is included or excluded from FRELs/FRLs is strongly influenced by forest definitions and how the definitions are operationalized in the FRELs/FRLs (box 2). For example, in Bangladesh, in-depth studies of trees outside forests (some of which are agroforestry) have been conducted. But with agroforestry likely to be excluded from the current FREL/FRL because of national REDD+ forest definitions, it is not clear whether the availability of improved information on trees outside forests will contribute to REDD+ MRV (Ashraful Haque, SilvaCarbon Bangladesh, pers. comm.). Therefore, a key leverage point to increase the representation of agroforestry in MRV of REDD+ is during the development (and revision) of forest definitions and development of FRELs/FRLs. The provision of data on agroforestry systems alone, however, is insufficient for inclusion of agroforestry in MRV systems, as the definition and the process of forming the forest definition has a large influence on the likelihood of agroforestry inclusion in REDD+.

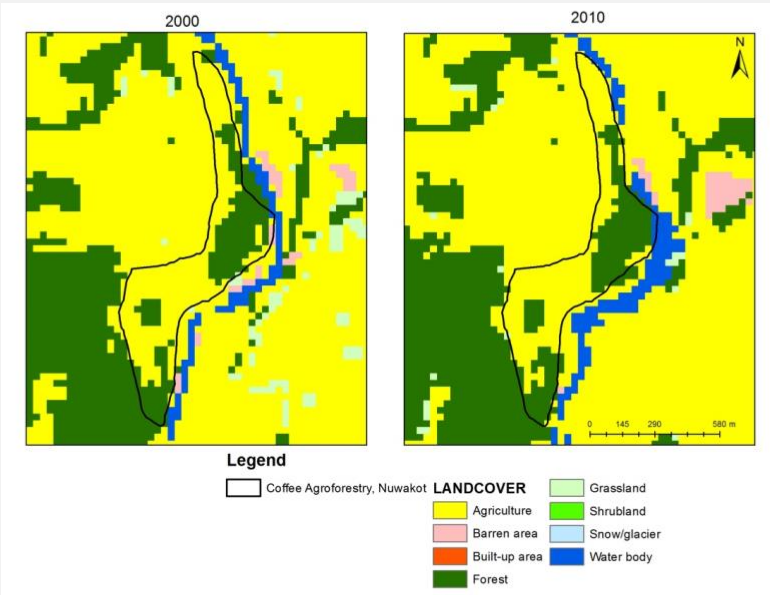
Despite excluding agroforestry or trees outside forests in their current REDD+ forest definitions, 15 countries (about 20% of those reviewed) expressed interest in their REDD+ strategies in monitoring agroforestry/trees outside forests in future evolutions of their REDD+ MRV systems. These countries were Cambodia, Colombia, Democratic Republic of the Congo, Dominican Republic, El Salvador, Ghana, Kenya, Laos, Myanmar, Pakistan, Paraguay, Sudan, Thailand, Togo and Vanuatu. Expressions of interest were direct statements concerning intentions of inclusion in monitoring efforts. This list of countries therefore can be considered potential supporters for the inclusion of agroforestry in REDD+ MRV.

Only eight countries (Côte d'Ivoire, Dominican Republic, Ghana, India, Nepal, Nicaragua, Peru and Thailand) indicated in their submitted REDD+ documents that they have existing pilot experience of monitoring trees outside forests (some of which, though not all, is agroforestry). The methods used in these pilot initiatives ranged from in-field measurements (India) to high-resolution satellite imagery (Ghana), though the submitted documents provide little specific information. Moreover, these efforts have mostly been conducted on a pilot basis. In-depth analysis of these experiences would be useful in the effort to understand challenges and inform approaches to upscaling.

Box 2: Inclusion of agroforestry in Nepal's Forest Reference Level (FRL)

Nepal's REDD Implementation Center (2017) adopted the following definition of forest for developing its FRL: Land with tree crown cover of more that 10 percent, in an area covering more than 0.5 ha, with minimum height of the trees to be 5 m at maturity and in-situ conditions. The land may consist either of closed forest formations where trees of multiple stories and undergrowth cover a high proportion of the ground, or of open forest formations with a continuous vegetation cover in which tree crown cover exceeds 10 percent. Young natural stands and all plantations established for forestry purposes which have yet to reach a crown density of 10 percent or tree height of 5 m are included under forest, as are areas normally forming part of the forest area which are temporarily unstocked as a result of human intervention or natural causes but which are expected to revert to forest. This includes forest nurseries and seed orchards that constitute an integral part of the forest; forest roads, cleared tracts, firebreaks and other small open areas within the forest; forest in national parks, nature reserves and other protected areas such as those of special environmental, scientific, historical, cultural or spiritual interest; windbreaks and shelterbelts of trees with an area of more than 0.5 ha and a width of more than 20 m. Lands predominantly used for agricultural practices are excluded.

Agroforestry was not explicitly mentioned in the FRL document, but agroforestry patches that fulfill the forest criteria were included in analysis, and forest-cover changes on patches above 2.25 hectares were reported in the FRL. The figure below shows an example of coffee agroforestry in Nuwakot, part of which was included as forest in the FRL dataset.



Source: *Case study provided by Bashkar Karky (ICIMOD)*

Joseph et al. (2013) conducted an assessment of MRV capacity for 20 REDD+ projects in six countries, some of which included interventions potentially related to agroforestry. The authors found very good capacity at the project level in terms of data, tools and methods, as well as implementation capacity for MRV across more than 70 indicators (Joseph et al. 2013). The relative strength of project level capacities contrasts with the relatively lack of capacity in national systems, suggesting an asymmetry in MRV capacity at different scales. To date, REDD+ is mostly implemented through subnational projects. The International Database on

REDD+ Projects and Programs[1] list more than 125 REDD+ projects (out of 465) that explicitly mention the term agroforestry. Whether the MRV capacity of the projects is sufficient to document changes in GHG emissions and carbon stocks due to agroforestry requires further study. Equally challenging is whether the appropriate systems are in place for changes at the project level to be accounted for in national accounting, where the protocols may differ (Duchelle et al. 2013)[2]. Even where projects are implemented at a national scale, project-specific MRV systems and methods will be needed to link project and national MRV processes due to the exclusion of agroforestry from REDD+ MRV systems. For example, cocoa and shea REDD+ projects under development in Ghana—whose FREL/FRL was developed with intensive analysis to identify and exclude non-forest trees— illustrate how promotion of commodity tree crop production and other forms of agroforestry will require the development of project-specific monitoring and evaluation and carbon accounting systems to measure the effects of actions on carbon stocks outside forests (box 3).

In summary, the definitions of forest for REDD+ usually exclude agroforestry from REDD+ MRV systems. However, the contribution of agroforestry as a REDD+ response strategy is widely recognized and agroforestry is already widespread in REDD+ project-level activities. This has created a situation in which national REDD+ mechanisms mostly do not include agroforestry, while subnational projects may include it as a project activity. Whether and how project-level agroforestry contributes to national REDD+ MRV and carbon benefits accounting has not yet been determined. Much work has focused on the relationship between project- and national level REDD+ mechanisms, and promising approaches such as nesting have been proposed (Lee et al. 2018). However, the operationalization of such approaches remains a challenge at multiple levels.

[1] http://www.reddprojectsdatabase.org/index.html

[2] http://verra.org/jurisdictional-and-nested-redd-jnr-webinar/

Box 3: Agroforestry initiatives in the context of Ghana's REDD+ strategy

Ghana's REDD+ Strategy (Ghana 2016) identified expansion of cocoa and other tree crops as a key driver of forest degradation and deforestation. Ghana's strategy is to implement large-scale subnational programmes in areas defined by ecological boundaries and major commodity drivers of forest degradation and deforestation. An Emission Reductions Programme for the Cocoa Forest Mosaic Landscape (Cocoa Forest REDD+ Programme) and an Emission Reductions Programme for the Shea Landscape of the Northern Savanna Woodland (Shea Savanna Woodland Programme) have been proposed. In addition to addressing commodity-crop drivers, other drivers (such as mining, illegal logging and charcoal production) will be addressed within each programme in each ecological zone. The Cocoa Programme is being supported by the World Bank Forest Carbon Partnership Facility (FCPF), while the Shea programme has been submitted to the Green Climate Fund, with programme steering committees to link the project/programme level with the National REDD+ Working Group.

Ghana Cocoa Forest REDD+ Program: Support from the World Bank will materialize in a carbon finance transaction under the FCPF Carbon Fund, whereby the World Bank as the trustee of the FCPF Carbon Fund will pay for emission reductions, duly verified over five years in accordance with the Methodological Framework of the FCPF Carbon Fund and resulting from the GCFPR implementation. Proposed programme components include landscape planning, support for climate-smart cocoa production to increase yields, access to finance, and legislative and policy reforms. A reference level for the programme area has been defined following the national forest definition, which excludes tree crops such as cocoa but includes timber plantation species. The programme reference level forms one input into the national FRL submitted to the UNFCCC. The programme MRV system proposes to use high-resolution (Landsat 8) imagery to detect and report forest cover change every two years during the programme period, with specific monitoring methods proposed for tracking the key drivers—fire, illegal logging and timber harvest, and fuelwood collection—and for tracking reforestation and tree survival rates. The GCFRP itself is based on a number of private-sector and civil-society-supported initiatives. For example, private-sector-led promotion of climate-smart cocoa production will aim to increase cocoa yields by providing guidelines to inform on-farm production practices and farmer engagement packages to provide access to planting materials, inputs, extension advice, finance and markets. Within the cocoa landscape, increasing shade trees is one climate-smart option. Some projects embedded in the GCFRP have investigated the potential for using carbon-market methodologies to value the carbon increment in the cocoa landscape. Irrespective of whether carbon-market methodologies are found to be sufficiently economically attractive, the private and public cocoa-promotion initiatives will need to have their own monitoring and evaluation systems to track progress.

The proposed Shea Programme includes components to improve landscape governance; shea yields and incomes; and restoration, reforestation and conservation through community-based forest management, including agroforestry. For the forest management component, the project will work with staff from the Ministry of Food and Agriculture and the Forestry Commission to deliver outreach programmes to support community forest committees to implement community-based actions. In the GCF concept note, mitigation benefits are proposed to be measured by accounting in relation to the national FREL/FRL, as well as accounting for enhancement of carbon stocks in the savannah ecosystem landscape. The project is still under development, but with carbon stock increments due to agroforestry excluded from the FREL/FRL, the project will clearly need to develop additional M&E systems in order to track progress and account for carbon benefits from agroforestry and community forestry that do not meet the national forest definition.

Sources: Ghana and UNDP (2017), Ghana Shea Landscape REDD+ project. FCPF (2016) Emission Reductions Program Document, Ghana Cocoa Forest REDD+ Programme

6 Projects, policies and programs needs for agroforestry MRV

Like REDD+, NAMAs are often implemented through subnational projects and thus raise many of the same challenges to subnational REDD+ projects. NAMAs are not bound by internationally agreed MRV guidelines. Instead, their MRV can be designed and implemented according to their particular needs, goals and desired parameters. As a consequence, NAMA projects and programs often develop stand-alone MRV systems that are thus not always fully aligned with other initiatives or national MRV systems. At best, this situation represents a missed opportunity to generate benefits at multiple scales; at worst, it risks redundancy, inefficiencies and double counting.

Most of the MRV systems for NAMAs are still being developed. Three of the 10 have proposed specific MRV systems (including those for charcoal in Uganda and coffee in Costa Rica). These systems describe indicators, roles and responsibilities of the implementing partners and the results envisaged. Most of the other NAMAs, by contrast, simply note that MRV will be created and mention a few items for consideration. These factors may be aligned with some parts of national MRV (e.g., tiers of measurement or forest inventories) but not all. A fully developed MRV creates an opportunity for alignment with national MRV systems, which will be especially important for NAMAs seeking international finance.

Costa Rica's coffee NAMA, which is initially being supported by finance from the NAMA Facility, illustrates how internationally funded and project-specific MRV approaches are being applied (table 4). The Coffee NAMA highlights that MRV of sinks and sources beyond the farm gate may also be relevant. The NAMA support project (NSP) aims to reduce GHG emissions in both coffee production and processing. The indicator system for the NSP is structured around mandatory indicators required by the NAMA Facility, as well as indicators specific to the project's goals and its main technical and financial components. This example also illustrates how both project and international goals can be tracked within the same MRV system.

Table 4. Indicators in Costa Rica's Coffee NAMA MRV system under the NAMA Facility

Indicators	NAMA Facility	Project Goals
GHG emissions reduced	X	
Emissions intensity of coffee plantations		X
Emissions in coffee production		X
Forest cover per ha of coffee		X
Number of direct beneficiaries	X	
Coffee mills apply low-emission technologies		X
Farmers apply low-emission technologies		X
Farmers applying low carbon technologies receive higher prices		X
Degree of transformational impact	X	
Volume of public finance mobilized	X	X
Volume of private finance mobilized	X	X

Source: http://www.namacafe.org/en/nsp-indicators

Formally registered NAMAs are only part of the story. Anecdotal evidence suggests there may be significant number of agroforestry-relevant NAMAs that countries are developing but have not yet submitted to the UNFCCC's registry. For example, Colombia is developing separate NAMAs on coffee, cattle and forestry. Peru is creating a jurisdictional NAMA that will cover individual NAMAs in cacao, coffee, livestock and palm oil. Kenya is developing a dairy NAMA. Agroforestry is integrated and relevant to each of these. Thus, the existing registry of NAMAs is not comprehensive. More agroforestry-relevant NAMAs are under development too, and these will require MRV.

Domestic policy implementation, outside formal UNFCCC processes, may also drive agroforestry adoption. Countries including India, Nepal and China have all adopted agroforestry-specific and -relevant policies, which are affecting agroforestry and the extent tree cover outside forests. For example, China's Sloping Farmland Conversion Programme is one of the largest programmes promoting tree plantation on cropland (box 4). The programme's international reporting is based on the national GHG inventory, but separate M&E systems serve programme implementation and domestic policymaking needs. Hence, as with subnational REDD+ and NAMAs projects, domestic programs targeting agroforestry demand MRV alignment.

Lastly, agroforestry is an important response in areas beyond climate change. Land and forest restoration efforts globally often promote agroforestry. Significant global action through the United Nations Convention to Combat Desertification (UNCCD) and the implementation of the Land Degradation Neutrality (LDN) goals will increase the reliance on agroforestry for multipurpose land use. These efforts have their own MRV frameworks already established (box 5). Analysis of where UNFCCC and UNCCD MRV can intersect and reinforce each other at various scales could link important issues and create value for investment in MRV.

Much of the implementation effort for agroforestry will be at the subnational level, be it through NAMAs, domestic policies or complementary activities such as LDN. However, the intersection of MRV, both in terms of the practical lessons learned and transaction costs, and politically critical issues such as double-counting for emissions reductions, have not been well elucidated. Much more efforts are needed in the near future to create alignment wherever it is possible.

Box 4: MRV of China's Sloping Land Conversion Program

In recent years, China has reported greater annual tree cover gains than all the rest of the world combined (Ahrends et al. 2017). The Sloped Farmland Conversion Program (SLCP) has been one of the country's major policy measures. Piloted in 1999 and expanded nationwide in 2002, the SLCP finances conversion of sloped (>25°) and degraded cropland and wasteland into forest and grassland. Farmers converting these lands receive subsidies in the form of grain or cash. By 2018 SLCP had been implemented on about 30 million ha of land, with 5.3 million ha planned to be converted in the 2016–2020 period (http://ghzj.forestry.gov.cn/uploadfile/main/2016-6/file/2016-6-22-dc508a08c9ac442ca4202afcf2b5f6b1.pdf). Academic studies have estimated that carbon sequestration due to SLCP can offset about 3%–5% of China's annual carbon emissions (Deng et al. 2017)

SLCP is one of several LULUCF-sector NAMAs highlighted in China's INDC and in successive national GHG emission reduction plans, contributing to the national goal of increasing forest area by 40 million ha and stock volumes by 1.3 billion m^3 by 2020 compared to 2005 (http://www4.unfccc.int/Submissions/INDC/Published%20Documents/China/1/China's%20INDC%20-%20on%2030%20June%202015.pdf) . The effects of the SLCP are monitored and reported through several MRV systems, each of which serve different functions.

M&E for programme management. Implementation of SLCP is governed by implementation regulations (http://www.gov.cn/gongbao/content/2016/content_5139491.htm). Prior to afforestation, contracts are signed between farmers and local governments specifying the planned afforestation area, technical measures and required survival rates. Subsidies are paid after inspection requirements have been met. Local government officials inspect afforestation sites in their areas of jurisdiction and assess compliance against various technical criteria such as tree density and survival rates. The results of field inspection are collated and reported to the province forestry agency, which implements cross-checks before annual reports and any corrective actions are approved. National agencies also cross-check provincial reports by visiting a sample of counties. The resulting data on area and tree stocks provide the basis for national reports on program progress.

M&E of ecological effects. Carbon sequestration is only one of the ecological services targeted by the SLCP. The effects on a range of ecosystem services are measured through a network of 57 monitoring sites and 120 observation sites, with a total of more than 4000 fixed sample plots, where data on hydrology, soil conservation, carbon stocks, air quality and biodiversity are measured (http://lykj.forestry.gov.cn/uploadfile/lykj/2016-1/file/2016-1-29-d915d85316d14aef8ea78c4c8f714531.pdf). The resulting reports inform policy making at the national level.

MRV of climate benefits. For reporting to UNFCCC, China's national GHG inventory uses the results of the national forest inventory (NFI) conducted every five years to estimate carbon removals due to biomass stock changes, with interpolation between inventory years. The NFI uses a combination of remote sensing (with coarser resolution at national level, and higher resolution at provincial level) to determine the sampling frame, and sample plots for field measurement of vegetation characteristics (such as diameter at breast height (DBH), tree height and crown cover). Non-forest plots—including some land converted under the SLCP—are included to capture the effects of land-use conversion. Land classification standards for the NFI require that plots affected by the SLCP are noted, but these are then combined with plots afforested due to other reasons to estimate aggregate change in plantation area and forest volumes in planted forest. For the GHG inventory, data from the NFI and other official sources are used to estimate biomass conversion factors and forest stock volume growth rates with which to estimate carbon stock changes in forests, including those afforested through the SLCP.

7 Can the methods countries use adequately represent agroforestry in MRV systems?

Estimations of GHG emissions and carbon sequestration require two pieces of information (box 6): first, 'activity data' describing the type and areal extent of a land use, and, second, carbon stock change or GHG emission factors relevant to the expected change over time. MRV systems, therefore, rest on the ability to document and represent the extent of agroforestry in ways that are relevant for reporting (i.e., equivalent to or nested within IPCC land uses) and that register the impacts of that agroforestry system on GHG emissions and removals.

Box 6: Guidelines for measurement and reporting

Guidelines for the measurement and preparation of national GHG inventories and NFMSs under REDD+ recommend using the *Revised 1996 IPCC Guidelines for National GHG Inventories* (IPCC 1996), and the *IPCC Good Practice Guidance and Uncertainty Management in National GHG Inventories* (IPCC 2000) for estimating and reporting their national GHG inventories. In addition, in 2003, the IPCC published *Good Practice Guidance for Land Use, Land-Use Change and Forestry (LULUCF)* (hereafter, GPG for LULUCF), which are referred to as a guidance in guidelines for the preparation of BURs (UNFCCC 2011b, annex III). The *Revised 1996 IPCC Guidelines* provide detailed instructions for the application of various methods for the estimation of GHG removals and emissions from sinks and sources across all sectors, and on reporting to the Conference of Parties.

IPCC (2000) provides detailed guidance for procedures used in characterizing activity data and selecting emission factors, in the quantification of uncertainty in GHG inventories and in the analysis of key GHG sources. It also provides guidance on quality control and quality assurance in GHG inventories. The 2003 *GPG for LULUCF* provides guidance on the consistent representation of land areas, and on the measurement and estimation of carbon-stock changes and GHG emissions from different land-use categories. The guidelines also provide templates for reporting of GHG inventories. Developing countries are required to use the IPCC 1996 reporting categories, but some have also begun to use the revised structure of categories in the 2006 IPCC Guidelines. The Warsaw CoP (2013) also set out modalities for NFMSs under REDD+, stating that such systems should use a combination of remote sensing and ground-based forest carbon inventory approaches when estimating forest carbon stock and forest area changes. Such systems should follow IPCC guidance and provide estimates that are transparent, consistent and accurate, and that reduce uncertainties.

The IPCC guidelines provide guidance on, among other things, the identification and quantification of GHG sinks and sources. The *IPCC 1996 Guidelines* and 2003 *GPG for LULUCF* give detailed guidance on the identification of carbon pools and approaches to the quantification of biomass carbon-stock changes in each carbon pool. Both the UNFCCC MRV Guidelines and the more specific guidelines provided by the IPCC set out procedures for countries to follow, and they also provide flexibility for countries to adopt inventory compilation methods suited to their specific country contexts, capacities and resources. It should be noted that the Guidelines are currently undergoing a revision, which will be released in 2019.

Representation of agroforestry

Accounting for agroforestry requires first and foremost an estimate of the areal extent of agroforestry. The 2003 *GPG for LULUCF* identifies six main land-use categories—forest land, cropland, grassland, wetlands, settlements and other lands—which serve as the basis for reporting. These represent the most aggregate or coarsest resolutions. Many countries disaggregate these land uses into subcategories. For example, Indonesia uses 22 subcategories, and agroforestry falls into two of them, plantation and dryland mixed farming.

Multiple data sources (such as satellite imagery, land-use or vegetation maps, land cadastres, etc.) may be required to produce a complete representation of land uses to an appropriate level of detail. The most common data sources used for estimating the areal extent of tree cover in GHG inventories were national forest inventories and analysis of satellite imagery, which were used by 50% and 37%, respectively, of all countries assessed (table 5). Other data sources included aerial photographs, land cadastres, land-use and vegetation maps, and national statistics. Of the 79 countries that reported a data source for LULUCF activity data in GHG inventories, 42 used two or more data sources. For example, some countries (including Chile and Vietnam) used satellite imagery to assess the area of forest and statistics reported by government agencies to estimate the area of cropland under orchards or other trees. With FRELs in REDD+, all 34 countries used satellite imagery, and 85% of those also used vegetation maps. These results suggest that forest inventories may be an important entry point for representation of agroforestry through existing inventory data pipelines.

Table 5. Frequency of countries using different data sources for LULUCF activity data in GHG inventories (n=105)

	Number of countries	**Data sources stated**	**Among countries stating data sources**							
			National forest inventory	Satellite imagery	Global Database	Ministries	Land cadastre	NGO	Peer review	Other
ToF included	65	50	26	18	12	30	4	3	5	17
ToF not included	40	29	11	12	7	19	0	2	8	10

The characteristics of the data sources used to represent lands influence whether and how agroforestry can be included in MRV systems. Certain data sources are unable to capture some configurations of agroforestry (e.g., low-resolution satellite imagery is not able to capture scattered trees) or have uncertain accuracy (e.g., government statistical data). Each data source and its effect on inclusion of agroforestry is discussed below.

National forest inventories are the most common source of LULUCF activity data in GHG inventories. National definitions of forest vary, as does the scope of forest inventories. In some countries, some forms of agroforestry are categorized as forest, while other forms are not. Inclusion of non-forest lands in national forest inventories has been increasing over time, in part because UN FAO has been supporting countries in relation to large-scale assessment of trees outside forests (some of which are agroforestry) since the 1990s. In the FAO classification used for global forest resources assessment, 'trees outside forests' refers to trees growing outside forests that do not fit into the category "Forest or Other Wooded Land" (de Foresta et al. 2013). A category 'other land with tree cover' (OlwTC) was added to FAO's Global Forest Resources Assessment in 2005. Reporting on the area of OlwTC increased from 61 countries in FRA 2005 to 77 in 2010 and 79 in 2015 (FLUDE data set[3]). In addition, in the 2015 Global Forest Resources Assessment (FAO 2015), 167 countries reported on 'other wooded land.'[4] Inclusion of ToF in national forest inventories can therefore support the inclusion of agroforestry in LULUCF estimates in national GHG inventories. Since trees outside forests are still far from universally included in national forest inventories, countries that are revising their inventory methods could learn from countries that already account for such trees. De Foresta et al. (2013) describe the methods used by 17 countries, and the example of India is summarized in box 7. However, as with ToF in other data sources, even where ToF are included in national forest inventories, they may not be explicitly referred to in national GHG inventories. For example, as shown in table 4 above, while 88 countries reported on changes in forest and other woody biomass stocks, only 34 countries reported on biomass stock changes in croplands.

[3] www.fao.org/forest-resources-assessment/explore-data/flude/en/

[4] Land not defined as 'forest,' spanning more than 0.5 ha, with trees higher than 5 m and a canopy cover of 5–10%, or trees able to reach these thresholds; or with a combined cover of shrubs, bushes and trees above 10%. It does not include land that is predominantly under agricultural or urban land use (FRA 2015 terms and definitions).

Box 7: How India does include trees outside forests in its national inventory?

The Forest Survey of India (FSI) undertakes a national forest inventory every two years. The inventory samples 10% of districts in the country, representing different physiographic zones. Areas outside the recorded forest area are termed ToF and are also sampled. For rural ToF, high-resolution satellite data are used to stratify ToF based on whether they are present in the form of blocks (compact groups of trees > 0.1 ha), lines or scattered trees. In each sampled district, 35 0.1 ha plots of blocks, 50 linear formations and 50–95 plots for scattered trees (depending on topography) are sampled. The variables measured include the plot location, topography and irrigation status, category of trees (farm forestry, village woodlots, block plantation, railway, homestead), number of trees sampled, trees species, DBH, crown width and socio-economic information.

Source: http://www.fao.org/docrep/017/aq071e/aq071e03.pdf

Satellite imagery is another common data source for LULUCF reporting in national GHG inventories. Remote sensing data can be categorized into three level of spatial resolution: high (≤ 2.5 m), medium (2.5–60 m) and low (> 60 m). The resolution of the satellite imagery has a significant impact on the ability to identify trees outside forests and agroforestry. The most common sources for satellite data are the Landsat archives (30 m resolution) and RapidEye images (5 m resolution). Landsat has the benefit of a long historic data availability (dating back to 1972) that is accessible free of cost. Thirty-three of the 34 FRELs reviewed used Landsat as at least one of the sources of information. Only six countries noted access to high-resolution data with SPOT 6 & 7, IKONOS or ALOS-PRISM (2.5 m or below). The resolution of imagery analyzed has implications for the ability to identify trees that are in small patches or lines or that are scattered across the landscape. For example, the resolution of imagery necessary for picking up scattered trees may be high (2.5 m or less) while moderate resolution imagery (30 m) may be adequate for picking up stands of trees or those in boundary planting. Some countries (including Bangladesh and Nepal) have made ToF-specific studies using remote-sensing imagery, indicating the high potential of this kind of analysis to contribute to inventory improvements. Where vegetation map layers are overlaid on land-use maps, trees or shrubs outside administratively defined forests (e.g., on croplands or in settlements) may be a clearly distinguishable category of tree cover, enabling quantification of the contributions of agroforestry to carbon-stock changes at the national level (box 8).

Box 8: Analysis of trees outside forests in Bangladesh

Natural forest cover loss has been declining in Bangladesh, while trees outside forests have been increasing and play important roles in national timber and non-timber product supply. With support of the USAID-funded SilvaCarbon project, the Resources Information Management System Unit of the Bangladesh Forest Department (BFD) and Global Land Analysis and Discovery Lab at University of Maryland recently completed a national-level mapping of tree-cover dynamics within and outside of forests.

Landsat data (30 m spatial resolution) was used to implement a stratified random sampling protocol. For a sample of 30 x 30 m Landsat pixels, higher resolution imagery was then used to characterize tree canopy cover, canopy loss and gain over time, and forest type, thus allowing an estimation of national trends. The results showed that total tree canopy cover in 2000 was about 21% of the country area, of which more than half was due to trees outside forests. From 2000 to 2014, trees outside forests increased by almost 13%. In addition, of areas affected by tree loss over the period, 18% had restored tree cover by 2014. These areas include tree rotation within plantations, shifting cultivation and agroforestry systems. Interagency agreements are in place to facilitate provision of information between BFD and agencies responsible for compilation of the national GHG inventory. Although ToF have not been included in current drafts of Bangladesh's FREL for REDD+ accounting, availability of better data on ToF may enable its inclusion in the future.

Sources: Popatov et al. (2017), Ashraful Haque, pers.com.

Land use may be classified either by trees outside forests (e.g., scattered trees), type or configuration of agroforestry system (e.g., hedgerow, silvopastoral) or by specific crop-tree systems. Individual studies of carbon in agroforestry systems typically examine the highest resolution of agroforestry system, quantifying emissions at the crop-tree species level such as intercropped maize and *Gliricidia sepium* (Sileshi et al. 2012). However, it is not typically possible to identify or map national land use at that level, and thus to match data on carbon stocks and stock changes to spatial data. One solution may be to use an intermediate level of land-use classification. Both Feliciano et al. (2018) and Kim et al. (2017) use a more general typology to estimate carbon changes according to categories such as home gardens, intercropping, live fences/boundary planting, parklands, riparian buffers, perennial systems, silvopasture, improved fallows and tree plantations (woodlots). Further studies are required to develop remote-sensing approaches to identification of trees outside forests using classifications that can be easily linked to ground-based classification of types of agroforestry and thus to higher-tier carbon stock change estimates (Schnell et al. 2015).

Satellite imagery of tree cover often provides limited information on agroforestry, forest types and other aspects of land use. Statistical reporting systems and land cadastres are important sources of supplementary information. In particular, where existing satellite imagery analysis has been conducted only for areas defined as forests, alternative information sources may be used to provide information on trees in other land-use types, such as croplands. For example, Chile's GHG inventory uses information on area planted to different fruit tree crops that is collected by the Natural Resources Information Centre primarily to inform development of the horticulture industry. In Vietnam the Ministry of Agriculture and Rural Development collects quarterly data on existence of scattered trees, but this information has not been included in the inventory because of concerns about reliability. This suggests the need for methods that can more objectively identify areas of agroforestry.

Stock change factors

Countries overwhelmingly use Tier 1 approaches to quantify carbon stocks and carbon stock changes in the LULUCF sector. In our assessment, 95 out of 113 countries' NCs reported using Tier 1 approaches for estimating at least some land-use emissions and removals (box 9). Only 18 countries reported using some Tier 2 approaches. In the National REDD+ Strategy documents and the REDD+ FRELs, we found that countries often use a mix of tiers when estimating forest carbon baselines. For example, countries may use locally derived estimates for aboveground biomass (Tier 2) but default ratios for the relationship between above- and belowground biomass for the latter (Tier 1). This finding is consistent with other studies that suggest capacities for reporting carbon pools at higher tiers are limited in tropical developing countries (Romijn et al. 2015). The pattern of using Tier 1 emission factors raises the question of whether these are sufficient to accurately represent agroforestry in MRV systems, and invites assessment of the possibilities of improving accuracy by increasing the tier used for quantification and reporting.

Box 9: Tiered approaches to the quantification of carbon pools

The IPCC uses a tiered system of approaches to quantification. Tier 1 uses global default values given in the IPCC guidelines. Tier 1 emission factors are mostly developed based on syntheses of scientific studies, or available estimates where global data is sparse. Tier 1 factors intend to provide a globally representative and scientifically defensible value when more specific data are unavailable. Tier 2 emission factors are country-specific values that are relevant to the ecological and climate conditions or management practices in a country or an ecosystem within a country. Both Tier 1 and Tier 2 are then applied as empirical models where the users multiply activity data by the appropriate emission factor. Tier 3 uses more complex biophysical process models or high-resolution inventory systems that provide a more highly disaggregated representation of activity data and emission actors at fine scale. For example, in the estimation of tree carbon pools, allometric equations are often used to estimate total aboveground biomass from measurable indicators such as height and DBH, or for estimating belowground biomass from aboveground biomass. Where countries have no data, default biomass estimates presented in the IPCC guidelines can be used (Tier 1). A Tier 2 approach would involve using allometric equations developed or validated in the country or for a specific type of forest.

Source: IPCC (1996)

Stock change factors are included in IPCC guidance according to the land use. When agroforestry meets the forest definition and the land was previously forest, stock change factors relevant for forests remaining forests would be applicable (e.g., tables 4.7-4.12, IPCC 2006) and are provided as ranges of Mg C/ha/yr based on climate, ecological zone and age by continent. Values range from 0.4 Mg C/ha/yr (natural boreal forests) to 15.0 Mg C/ha/yr (tropical forest plantations). When agroforestry occurs on other land uses such as cropland, biomass accumulation rates are lower (table 6). Biomass accumulation ranges from 1.8–10.0 Mg C/ha/yr depending on climate and moisture.

Table 6. Default values for aboveground woody biomass in cropland that includes perennials.

Climate region	Aboveground biomass at harvest (t C ha-1)	Harvest cycle (yr)	Biomass accumulation rate (t C ha-1)	Biomass carbon loss (t C ha-1)	Error range (± %)
Temperate (all moisture regimes)	63	30	2.1	63	75
Tropical, dry	9	5	1.8	9	75
Tropical, moist	21	8	2.6	21	75
Tropical, wet	50	5	10.0	50	75

Source: IPCC 2006

Tier 1 stock change factors in the IPCC generally cover the range of values found in specific studies on aboveground carbon accumulation by different species. One recent meta-analysis looking at carbon sequestration (e.g., stock change) rates in agroforestry systems globally found that rates average 8.4 Mg C/ha/year, with approximately 75% being biomass (above and belowground) (Kim et al. 2017). Another meta-analysis suggested that stock change rates could be either lower or higher, ranging between 0.52–12.63 Mg C/ha/yr for aboveground biomass C depending on the climate and system (Feliciano et al. 2018). However, there is significant variation in the rate of C stock change by region and systems (table 7). For example, data on agrisilviculture systems in Asia show rates of C accumulation beyond the range of that found in the same system in Africa. In some systems, the variance is 100% of the mean, suggesting significant uncertainty when using values derived from other locations. High variability increases the uncertainty in estimates of agroforestry carbon stock changes where Tier 1 estimates are used, and highlights the potential benefits of using national data for carbon stock change factors (Tier 2) when possible.

The utility of using a higher carbon stock change factor is clear only if the land use is classified at a resolution to match the emission factors. Analysis of national GHG inventory capacities suggests that many developing countries still face challenges with the adequate and consistent representation of lands due to a combination of technical constraints (e.g., lack of available data, tools and skills) and institutional constraints (e.g., lack of coordination between institutions) (Tulyasuwan et al. 2012). This indicates that countries could improve the accuracy of GHG estimates for agroforestry by adopting Tier 2 carbon stock change factors. However, the representation of land uses at an appropriate resolution is a precondition for the application of more accurate carbon stock change estimates. Compared to other constraints on the representation of agroforestry and trees outside forests in inventories (e.g., lack of transparent reporting), improved accuracy of emission estimates may represent a relatively marginal improvement in making trees count.

Table 7. Mean aboveground carbon accumulation by agroforestry type and region (Mg C/ha/yr).

Continent	Agroforestry system	Mean	Variance	*N*
Africa (n = 60)	Agrisilvicultural	0.88	0.14	5
	Home garden	.52	0.07	5
	Improved fallows	12.95	20.12	17
	Shadow systems	2.27	2.36	18
	Silvopastoral	0.15		1
	Woodlots	3.36	1.85	14
Asia (n = 50)	Agrisilvicultural	1.13	2.52	4
	Home garden	2.77	5.8	27
	Improved fallows	2.9	0.08	2
	Silvopastoral	2.65	4.35	7
	Woodlots	6.28	26.57	10
Latin America (n = 45	Agrisilvicultural	2.94	5.56	6
	Boundary planting	9.14	54.72	5
	Home garden	3.25		1
	Improved fallows	5.55	5.45	2
	Shadow systems	2.87	2.79	22
	Silvopastoral	2.29	0.29	3
	Woodlots	12.63	8.57	6

Source: Feliciano et al. (2018)

Technically, the IPCC guidelines propose Tier 1 approaches to reduce the data demands of GHG inventory compilation. However, guidance suggests that Tier 1 should be used only for those sinks and sources whose sum accounts for less than 5% of the total GHG inventory. The relative size of the carbon pool of agroforestry varies among countries, and therefore it is not possible to generalize as to whether estimating agroforestry warrants greater accuracy. However, as a first step countries should estimate whether they are above the 5% threshold, so they know whether they should aim to move toward Tier 2. Countries generally should follow guidelines to use higher-level tiers when specifically targeting action such as agroforestry. Although forests in many countries are likely to be the main land use with significant carbon stock changes, the IPCC guidelines note that trees outside forests “should be included when they are a significant component of total changes in biomass stocks” (IPCC 1996, 5.13). Irrespective of whether agroforestry meets the 5% of GHG inventory threshold, countries may still need to increase the tiers of measurement. With so many countries including agroforestry in their NDCs, it remains unclear whether the MRV systems in use are capable of tracking changes in carbon stocks due to agroforestry-based actions.

Our assessment of the representation of lands and stock change factors also identifies some concerns with transparency and completeness, two key principles highlighted in UNFCCC agreements on MRV. For example, 75% of countries report the methods used for representing lands in the inventories, but 25% do not. The lack of reporting by 25% of the countries makes it difficult to know what was included. By contrast, 100% of the countries that had submitted FRELs for REDD+ implementation by November 2017 had reported the methods used to delineate forests and establish the FREL. This difference can likely be attributed to the FRELs being focused on only one IPCC land-use type, while national GHG inventories cover all land uses as well as other sectors. However, if agriculture, forestry and other land use (AFOLU) response options are undertaken as part of countries’ NDCs and reported on through national GHG inventory summaries in NCs, transparency in representation of land uses is imperative in order to represent the changes attributed to climate actions over time.

8 Factors that constrain or enable MRV of agroforestry

Key informants identified ten factors that either constrain or enable MRV of agroforestry (table 8). Many of the factors were common across countries, calling attention to certain more universal issues, while others were identified by only one country. The fact that ten unique factors were identified in only 12 interviews speaks to the diversity of challenges countries face in attempting to better represent agroforestry in MRV. Despite challenges, many countries also noted areas of progress. Below we discuss both constraints and enabling conditions. It should be noted that the discussions with key informants were based on semi-structured interviews that were tailored specifically to each country's context. Because the interviews were similar but not standardized, mention or omission of any specific barrier or enabler by a country should be interpreted with caution.

Constraints

Country representatives identified a significant number of constraints involving finance, institutions and technical capacity.

Finance remains a persistent challenge for developing countries' MRV activities, with most countries interviewed mentioning funding as a constraint. Countries lacked sufficient funds to organize meetings to build consensus around definitions and methods (Rwanda), purchase high-resolution satellite imagery capable of capturing scattered trees (Vietnam, Bolivia, Namibia) or retain staff after donor-funded MRV projects come to an end (St. Lucia). Some MRV of trees outside forests clearly benefited from the support of internationally supported programmes, such as USAID's SilvaCarbon (Bangladesh, Democratic Republic of Congo), or where funds were available for development of specific investment proposals (Ghana, Costa Rica). GHG inventory preparation often has been funded by the Global Environment Facility (GEF), and additional funds have become available through the GEF-managed Capacity Building Initiative for Transparency. However, in the near-term finance may be the key practical constraint for MRV of agroforestry.

Table 7. Factors that constrain and enable MRV of agroforestry mentioned during country interview. Constraints = orange, Enablers = green, Items identified as both at different points in the interview = grey.

Factor	Ethiopia	Bangladesh	Bolivia	Chile	Colombia	Indonesia	Nepal	Peru	Rwanda	St. Lucia	Togo	Vietnam
Institutional arrangement and enabling environment												
Political support												
Definitions of forest												
Changes in government mandates and interest												
Conflicting or unclear mandates												
Technical facilities and capacities												
Clear representation of land												
Resolution of available satellite imagery												
Availability of locally relevant stock change factors												
Human capacity for data collection or processing												
Project-level experience with MRV												
Finance												
Sustained funding or cost of MRV												

A number of respondents noted challenges related to the institutional and political environment surrounding MRV of agroforestry. Policies in Bangladesh, for example, do not highlight agroforestry or trees outside forests, so despite the provision of information about the extent and carbon benefits of such trees, there is only a limited chance that they will be integrated into national MRV in the short term. Bolivia and Rwanda cited concerns that no single agency is responsible for agroforestry, making it vulnerable to changes in government policies, structures and mandates. Institutional arrangements have been identified as a key factor for success of MRV of REDD+ (Romijn et al. 2012, Ochieng et al. 2016, Neef et al. 2017). Tulyasuwan et al. (2012) report on the key factors and institutional arrangements that constrain REDD+ monitoring (figure 4). A follow-up survey, specific to the unique challenges for MRV of agroforestry, would help provide detailed guidance on leverage points.

Technical capacity was one of the most widely stated constraints on the inclusion of agroforestry in MRV systems. Specific constraints mentioned included lack of access to costly high-resolution satellite imagery (Bolivia) and unreliable statistical reporting methods (Vietnam). Multiple countries also cited the definition of forest as a significant influence, both positive and negative. Nepal mentioned that a relatively low forest threshold (0.5 ha, 10% tree cover) facilitates the inclusion of agroforestry in MRV. The opposite was the case in Bangladesh, where trees outside forests (some of which are agroforestry) were excluded from the forest definition. Meanwhile, inconsistencies among the local definition, FAO definition and IPCC definition caused confusion and asymmetry with international programs in Ethiopia.

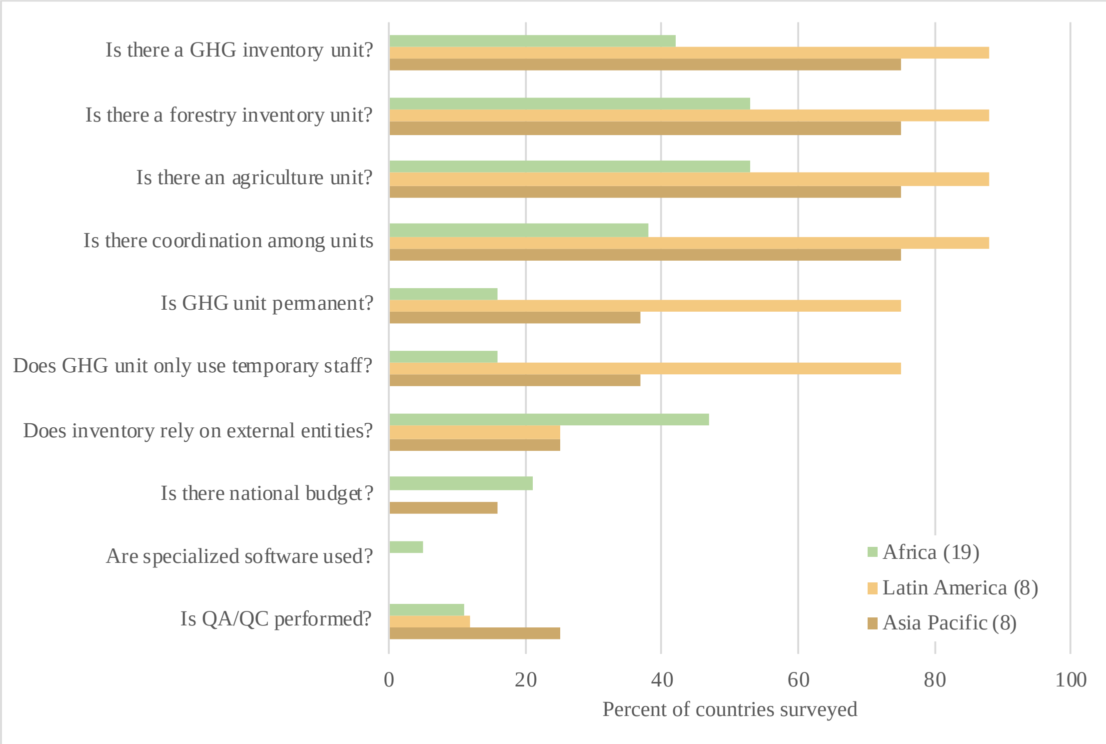


Figure 4: Institutional arrangements that enable MRV under REDD+

Source: Adapted from Tulyasuwan et al. (2012).

Enabling factors

Where countries have made progress in including agroforestry in GHG inventories, a number of enabling factors were reported. Inclusion of agroforestry in regular statistical reporting, availability of high-resolution satellite imagery, and the use of multiple data sources for different types of forests can provide data to ensure that trees outside forests are included in GHG inventories, according to interviews in Vietnam, Chile and Peru. In Colombia, creation of a time series for land-use transitions was a significant step forward in the inventory process because it enabled the country to move from simple reporting of annual land-use classes to a land-use transition matrix, and also highlighted where significant uncertainties lie, thus providing the basis for future inventory improvements.

Beyond data and techniques, inventory improvement requires a supportive institutional environment. Multi-institution coordination around land use and a supportive legal and policy environment for integrative land use provide political impetus for the GHG inventory to improve the quantification of biomass stocks on different land-use types, according to interviews conducted in Bolivia, Peru, Colombia and Vietnam. In Peru and Colombia, inventory improvements for agroforestry-related land use have also been facilitated by the involvement of diverse stakeholders in developing NAMAs and by the focus on low-emission development provided by the NDCs. Political will, the involvement of research organizations as well as farmer and producer organizations, and the delegation to ministries of responsibilities for monitoring progress towards NDC targets were all cited as factors that improve interest in collecting and sharing data that can inform the national inventory alongside specific mitigation actions. Political interest is inspired not only by mitigation benefits but also by non-carbon benefits, such as tackling land degradation, preserving biodiversity and supporting producers, according to interviews in Bangladesh, Chile, Nepal and Colombia.

Collaboration among researchers in a country—including networking around inventory improvement issues with colleagues in the wider region—was cited by interviewees in Bolivia and Peru as an important enabler of inventory improvement. As illustrated by the study on agroforestry in Bangladesh, international funding and technical support can also play key roles in delivering on inventory improvements defined by national needs

The interviews suggested, in particular, that inclusion of agroforestry in MRV systems and improvement in MRV of agroforestry can be supported when there is a supportive legal and policy environment for integrative land use; when mandates for GHG quantification are clear; when stakeholders clearly perceive the benefits of investing in MRV; and when institutional arrangements are put in place to support collaboration.

9 Recommendations: Opportunities for improvement

Our review of MRV practices under the UNFCCC illustrates both the technical and institutional challenges to measuring progress of agroforestry and trees outside forests, and highlights the frequent gaps between national ambitions and national capabilities. That gap is smaller in some countries than in others, but no developing country has succeeded in fully closing it. A few countries have taken steps to address the major challenges and move toward integration of agroforestry into UNFCCC MRV systems, but no country has yet put all the pieces together. Major challenges include but are not limited to the following: clarifying and refining land-use definitions to include agroforestry; defining institutional mandates as they relate to agroforestry; strengthening technical capacities and resources for data collection and management; and improving transparency in reporting. Further research and investment are needed to operationalize broad-scale MRV of agroforestry. Here we make six recommendations to improve the state and representation of agroforestry in MRV under the UNFCCC (not listed in order of importance):

1. *Develop accessible approaches for representation of lands with agroforestry*. Costs, time, capacity and complexity stand in the way of countries including agroforestry in MRV in a consistent and comprehensive way. Development of cost-effective and lower-technology ways to represent lands with agroforestry will be essential. Recent progress with remote sensing is promising (Schnell et al. 2015). However, many of the advances in representing and documenting the extent of agroforestry are still far beyond the capacities of many countries. Approaches that can leverage freely available high-resolution imagery and local knowledge such as Collect Earth online should be further explored (Bey et al. 2016, Kelley et al. 2018). Capacity building of technicians and institutions will be needed irrespective of the technological methods advanced.

2. *Create guidelines for agroforestry reporting to improve transparency*. We found that even if agroforestry had been quantified, it would not have been visible in 60% of the inventories due to the way the inventories and NCs were structured. This represents a missed opportunity when the contributions of agroforestry are being quantified and included, and an imperative for change when they are not. Both situations require adjustments soon given the calls for consistency and completeness in the preparation of inventories and the need for reporting on NDCs. Development of guidelines building on the finding of this assessment that outlines ways to increase transparency is needed. The guidelines should be designed to align with commonly used reporting software and IPCC Guideline revisions.

3. *Develop carbon stock change and emission factor data and databases relevant for reporting requirements*. Many countries report using Tier 2 emission factors within REDD+ MRV and often state that much of the information is available not in scientific literature but rather in grey literature. These data are often at the lowest level of species allometries which do not match the ways countries (and projects) need to apply them, which is typically aggregated to the course level of the typology, if not to the land-use level. Recent meta-analyses by Feliciano et al. (2018) and Kim

et al. (2017) compiled the available stock change and emission factors using a consistent typology of agroforestry systems. These analyses could be built upon. Investment in compiling information from countries' grey literature and linking the data to climate, agroecosystem and agroforestry systems would provide a readily available resource and encourage international collaboration for more consistent and transparent reporting.

4. *Assess the institutional arrangements needed to include agroforestry in MRV*. Interviewees called attention to a range of institutional conditions that support or discourage the inclusion of agroforestry in MRV systems. Much more information is needed to be able to provide guidelines on best practices to improve MRV. A follow-up study at the global level examining a large number of countries (perhaps 50) with a standard questionnaire may help illuminate key leverage points and preconditions for change.

5. *Research and practical guidelines on linking national and project-level MRV*. While agroforestry is rarely visible in MRV at the national level, project-level applications are prevalent. There are major concerns about whether and how the project-level contributions might count toward national goals. Lessons are starting to emerge (Lee et al. 2018), but there is a long way to go to make the two work together in ways that reduce transaction costs, build trust and share benefits. With the increase in funding to climate responses (such as through the Green Climate Fund) and projects serving as vehicles for action, alignment of goals and tools for integration will be paramount. What is needed, however, is more than a strictly technical approach. Countries and their development partners must be sure that the design of products matches the needs and goals of all parties. An assessment of alignment with REDD+, emerging NAMAs and domestic policies could help illuminate opportunities.

6. *Create mechanisms that increase the likelihood of continued funding for continuity of MRV activities*. MRV is often low on the list of implementation activities. Many countries called attention to the fact that funding for MRV development is often tied to specific projects and thus ends with the project. This is an issue not only for agroforestry but for agriculture and land use in general. It is necessary to support the integration of MRV for agroforestry with more general MRV under the UNFCCC in

order to create synergies and economies of scale. In this way, MRV processes could be formally included within national budgets for ministries of environment or other institutions responsible for reporting to UNFCCC. Dedicated funding to increase the transparency, consistency and completeness of agroforestry MRV would generate a great deal of information that could have a catalytic effect on improvements in the large number of countries expressing interest in agroforestry as a climate response measure.

10 Conclusions

This assessment represents a first appraisal of the gap between countries' ambitions and abilities to include agroforestry and trees outside forests in MRV systems under the UNFCCC. A large number of developing countries—particularly in Africa—have expressed an interest in promoting agroforestry as a climate-change adaptation or mitigation measure. Much like previous assessments of MRV of forests and other GHG sources, this study found that institutional, financial and technical challenges stand in the way of including agroforestry in MRV systems. But these problems are further compounded by challenges specific to agroforestry, including the definition of forest; the fact that agroforestry is not a land-use in and of itself; and sometimes contradictory agricultural and forestry mandates. The result of this situation is that agroforestry is not clearly captured and represented in a systematic way.

This review also found, however, that agroforestry is not completely absent from current MRV systems. There are examples of countries that do include and represent agroforestry in national GHG inventories, REDD+ MRV systems and NAMA MRV. Their experiences point to potential solutions to technical and institutional issues that might be relevant to other countries with an interest in promoting agroforestry. Process and people drive the inclusion or exclusion of MRV. It is important to target key leverage points to improve MRV. Countries' experiences suggest that if there is political will and if capacity building and research innovation is targeted to this issue, agroforestry can be better integrated into national MRV processes to help make trees count toward countries' commitments.

References

Bastin J-F et al. 2017. The extent of forest in dryland biomes. *Science* 356(6338), pp.635–638. Available at: http://www.sciencemag.org/lookup/doi/10.1126/science.aam6527.

Bernard F, Minang PA. 2011. Strengthening Measurement, Reporting and Verification

(MRV) for REDD+. London. Available at: http://www.asb.cgiar.org/PDFwebdocs/redd_strengthening_mrv_kenya.pdf.

Bey A et al. 2016. Collect earth: Land use and land cover assessment through augmented visual interpretation. *Remote Sensing* 8(10).

Bisseleua DHB, Missoup AD, Vidal S. 2009. Biodiversity conservation, ecosystem functioning, and economic incentives under cocoa agroforestry intensification. *Conservation Biology* 23(5), pp.1176–1184.

Climate Investment Funds. 2014. Greenhouse gas analysis and harmonization of methodology.

Dawson IK et al. 2014. Agroforestry, livestock, fodder production and climate change adaptation and mitigation in East Africa: issues and options. ICRAF Working paper 178. Nairobi: World Agroforestry Centre. Available at: http://dx.doi.org/10.5716/WP14050.PDF

Dawson IK et al. 2014. The management of tree genetic resources and the livelihoods of rural communities in the tropics: Non-timber forest products, smallholder agroforestry practices and tree commodity crops. *Forest Ecology and Management,* 333, pp.9–21. Available at: http://dx.doi.org/10.1016/j.foreco.2014.01.021.

Dinesh D et al. 2017. 10 Best Bet Innovations for Adaptation in Agriculture: A supplement to the UNFCCC NAP Technical Guidelines. CCAFS Working Paper 215. Wageningen, The Netherlands: CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS). p.70. Available at: https://cgspace.cgiar.org/bitstream/handle/10568/89192/CCAFSWP215.pdf?sequence=3&isAllowed=y.

Duchelle AE, Herold M, de Sassi C. 2013. Monitoring REDD+ Impacts: Cross Scale Coordination and Interdisciplinary Integration. In: Latawiec A, Agol D. Sustainability Indicators in Practice. Available at: https://doi.org/10.1515/9783110450507-009

FAO. 2015. Global Forest Resources Assessment. Rome: Food and Agriculture Organization of the United Nations.

FAO. 2016. The Agriculture Sectors in the Intended Nationally Determined Contributions. Rome: Food and Agriculture Organization of the United Nations.

de Foresta H, Somarriba Chávez E, Temu A, Boulanger D, Feuily H, Gauthier M. 2015. Towards the Assessment of Trees Outside Forests. Forest Resources Assessment Working Paper 183. Rome: Food and Agriculture Organization of the United Nations. Available at: http://www.fao.org/docrep/017/aq071e/aq071e00.htm

GCF. 2016. Insight: an introduction to the Green Climate Fund. Korea: Green Climate Fund.

Feliciano D et al. 2018. Which agroforestry options give the greatest soil and above ground carbon benefits in different world regions? *Agriculture, Ecosystems and Environment* 254, pp.117–129. Available at: https://doi.org/10.1016/j.agee.2017.11.032.

Ickowitz A et al. 2014. Dietary quality and tree cover in Africa. G*lobal Environmental Change* 24, 287–294. Available at: http://linkinghub.elsevier.com/retrieve/pii/S0959378013002318.

IPCC 2014. Climate Change 2014 Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, 1–151.

Jamnadass RH et al. 2011. Improving livelihoods and nutrition in sub-Saharan Africa through the promotion of indigenous and exotic fruit production in smallholders' agroforestry systems: a review. *International Forestry Review* 13(3) 338–354.

Joseph S. et al. 2013. REDD+ readiness: Early insights on monitoring, reporting and verification systems of project developers. *Environmental Research Letters* 8(3), p.034038.

Kelley LC, Pitcher L, Bacon C. 2018. Using google earth engine to map complex shade-grown coffee landscapes in northern Nicaragua. *Remote Sensing* 10(6), 952. Available at: http://www.mdpi.com/2072-4292/10/6/952.

Kim D-G, Kirschbaum M, Beedy T. 2016. Carbon sequestration and net emissions of CH_4 and N_2O under agroforestry: Synthesizing available data and suggestions for future studies. *Agriculture, Ecosystems and Environment* 226, 65–78. Available at: http://dx.doi.org/10.1016/j.agee.2016.04.011.

Kuyah S. et al. 2012. Allometric equations for estimating biomass in agricultural landscapes: II. Belowground biomass. *Agriculture, Ecosystems & Environment* 158, 225–234. Available at: http://linkinghub.elsevier.com/retrieve/pii/S0167880912001880.

Kuyah S. et al. 2016. Quantifying tree biomass carbon stocks and fluxes in agricultural landscapes. In: Rosenstock et al. Methods for measuring greenhouse gas balances and evaluating mitigation options in smallholder agriculture. Available at: http://link.springer.com/10.1007/978-3-319-29794-1.

Lee DL, Llopis P, Waterworth RM, Roberts G, Pearson TRH. 2018. *Approaches to REDD: nesting lessons learned from country experiences.* Washington, D.C.: World Bank Group. http://documents.worldbank.org/curated/en/670171523647847532/Main-report

Minang PA, van Noordwijk M. 2012. Design challenges for achieving reduced emissions from deforestation and forest degradation through conservation: Leveraging multiple paradigms at the tropical forest margins. *Land Use Policy* 31, 61–70. Available at: http://linkinghub.elsevier.com/retrieve/pii/S0264837712000944 [Accessed November 7, 2012].

Minang PA et al. 2014. Prospects for agroforestry in REDD+ landscapes in Africa. *Current Opinion in Environmental Sustainability* 6(1), 78–82. Available at: http://dx.doi.org/10.1016/j.cosust.2013.10.015.

Njenga M et al. 2014. Additional cooking fuel supply and reduced global warming potential from recycling charcoal dust into charcoal briquette in Kenya. *Journal of Cleaner Production* 81, 81–88. Available at: http://dx.doi.org/10.1016/j.jclepro.2014.06.002.

van Noordwijk M et al. 2014. Pricing rainbow, green, blue and grey water: tree cover and geopolitics of climatic teleconnections. *Current Opinion in Environmental Sustainability* 6, 41–47. Available at: http://linkinghub.elsevier.com/retrieve/pii/S1877343513001383 [Accessed February 5, 2014].

van Noordwijk M, Coe R, Sinclair F. 2016. Central hypotheses for the third agroforestry paradigm within a common definition. Working paper 233, Bogor, Indonesia: World Agroforestry Centre (ICRAF) Southeast Asia Regional Program. Available at: http://dx.doi.org/10.5716/WP16079.PDF

Olander LP et al. 2014. Synthesis and review: Advancing agricultural greenhouse gas quantification. *Environmental Research Letters* 9(7), 075003. Available at: http://stacks.iop.org/1748-9326/9/i=7/a=075003?key=crossref.f08f8ef5100c56564169f394b759920b.

Ovalle-Rivera O et al. 2015. Projected shifts in Coffea arabica suitability among major global producing regions due to climate change. *PLoS ONE* 10(4), pp.1–13.

Reed J et al. 2017. Trees for life: The ecosystem service contribution of trees to food production and livelihoods in the tropics. *Forest Policy and Economics*. Available at: http://dx.doi.org/10.1016/j.forpol.2017.01.012.

Richards M et al. 2015. Agriculture’s prominence in the INDCs. CCAFS Info Note. Copenhagen: CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS). Available at www.ccafs.cgiar.org.

Romijn E et al. 2012. Assessing capacities of non-Annex I countries for national forest monitoring in the context of REDD+. *Environmental Science & Policy* 19–20, .33–48.

Available at: http://linkinghub.elsevier.com/retrieve/pii/S1462901112000202 [Accessed November 1, 2012].

Rosenstock T et al. 2014. Agroforestry with N2-fixing trees: sustainable development's friend or foe? *Current Opinion in Environmental Sustainability* 6, 15–21. Available at: http://linkinghub.elsevier.com/retrieve/pii/S1877343513001218.

Salvini G. et al. 2014. How countries link REDD+ interventions to drivers in their readiness plans: implications for monitoring systems. *Environmental Research Letters* 9(7), p.074004.

Schnell S, Kleinn C, Stahl G. 2015. Monitoring trees outside forests: a review. *Environmental Monitoring and Assessment*. Available at: http://dx.doi.org/10.1007/s10661-015-4817-7.

Sileshi GW, Debusho LK, Akinnifesi FK. 2012. Can integration of legume trees increase yield stability in rainfed maize cropping systems in southern Africa? *Agronomy Journal* 104(5), 1392–1398. Available at: https://www.agronomy.org/publications/aj/abstracts/104/5/1392 [Accessed November 3, 2012].

Thornton PK et al. 2017. A qualitative evaluation of CSA options in mixed crop-livestock systems in developing countries. In Lipper L et al., Climate-Smart Agriculture: Building resilience to climate change. Netherlands: Springer. Available at: https://www.springer.com/us/book/9783319611938

Thornton PK, Herrero M. 2015. Adapting to climate change in mixed crop and livestock farming system in sub-Saharan Africa. *Nature Climate Change* 5(9), 830–836. Available at: http://dx.doi.org/10.1038/nclimate2754.

Tulyasuwan N. et al. 2012. Issues and challenges for the national system for greenhouse gas inventory in the context of REDD+. *Greenhouse Gas Measurement and Management* 2(2–3), pp.73–83. Available at: http://www.tandfonline.com/doi/abs/10.1080/20430779.2012.716298%5Cnhttp://dx.doi.org/10.1080/20430779.2012.716298.

Wilkes A. et al. 2011. Agricultural monitoring and evaluation systems: What can we learn for the MRV of agricultural NAMAs? ICRAF Working Paper No. 126, Beijing, China: World Agroforestry Centre.

Wilkes A, Reisinger A, Wollenberg E, Van Dijk S. 2017. Measurement, reporting and verification of livestock GHG emissions by developing countries in the UNFCCC: current practices and opportunities for improvement. CCAFS Report 17. Wageningen, the Netherlands: CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS) and Global Research Alliance for Agricultural Greenhouse Gases (GRA).

Wilkes A, Tennigkeit T, Solymosi K. 2013. National planning for GHG mitigation in agriculture: A guidance document. Mitigation of Climate Change in Agriculture Series 8, Rome: FAO.

Zomer R et al. 2016. Global tree cover and biomass carbon on agricultural land: The contribution of agroforestry to global and national carbon budgets Supplementary Information. *Scientific Reports*.

Appendix 1. A brief review of the benefits of agroforestry

Trees are ubiquitous features of landscapes, occurring on practically every land use. Obviously, forests are composed of trees. But the drylands of West Africa are peppered with scattered trees (e.g., parklands), perennial crops lie under multistrata tree systems (e.g., shade coffee) and trees dot ranches of Latin America (e.g., silvopastoral systems). At the global scale, 43% of farmland had at least 10% tree cover in 2010, a 10% increase since 2000 (Zomer et al. 2016). When considering the national importance of trees, it is also apparent that trees are prevalent on land uses other than forest land, with some countries identifying trees occurring on as much as 28% of the land area (table A1.1). Given the global extent of trees outside forests and the growing trend in recent years, trees outside forests offer an important opportunity for both mitigation of and adaptation to climate change.

Table A1.1. Select examples of common types of trees outside forests inventoried and their areal extent.

Country	Lead institution	Categories of trees covered	Extent (million ha)	Proportion of country land area (%)
Bangladesh	Bangladesh Forest Department of Ministry of Environment and Forest with Bangladesh Space Research and Remote Sensing	Annual crops with trees, perennial crops with trees, shifting cultivation, rural settlements with trees range land	4.1	27.7
Cameroon	Ministry of Forests and Fauna	Grassland, wetland, perennial crop, pasture land, built-up areas	13.3	28
India	Ministry of Environment & Forests	Large orchards, non-forestry tree plantation, agroforestry system with appropriate area and tree cover	Forest cover 69, non-forest cover 255.5	
Morocco	High Commission for Water, Forests and the Control of Desertification	Fruit tree cops, silvopasture	1.0	
Nicaragua	Instituto Nacional Forestal	Coffee, cocoa, fruit crops, silvopastoral, urban trees	2.1	6.2
Philippines	Forest Management Bureau	Perennial crops, grassland, marshland,	1.9	6.4

Compiled from de Foresta et al. (2015)

Trees confer mitigation and adaptation benefits under some conditions (Kim et al. 2016, Reed et al. 2017 see Appendix I for review). Trees can increase the carbon in soils and biomass; buffer climate change, variability and extreme events by creating microclimates, conserving soil moisture, stabilizing landscapes and reducing erosion; and diversify farming systems by creating new ecological niches, increasing resource use efficiency, and providing new marketable products such as firewood and fruits. For all of these reasons, trees increase the resilience of livelihoods and landscapes (Dinesh et al. 2017). This diversity of benefits makes trees attractive for farmers, land managers and policy makers.

Trees on farms can help mitigate climate change by increasing carbon storage in biomass and in soils, as well as through substitution for products that have higher emissions (e.g., firewood and construction materials). Globally, trees on farms were estimated to contain greater than 2 Pg C in 2015, which represents a 2% increase over the previous decade (Zomer et al. 2016). At the plot level, agroforestry systems accumulate between 0.3 and 7.7 Mg C/ha/year in biomass and between 1.0 and 7.4 Mg C/ha/year in soils (Kim et al. 2016). When leguminous trees and shrubs are used, agroforestry systems tend to produce similar levels of nitrous oxide emission from the soil that occurs when farmers use chemical fertilizer (1% of available nitrogen) (Rosenstock et al. 2014), while avoiding the environmental emissions from energy use during fertilizer production and transport, which account for roughly 1% of annual global emissions (IPCC 2014).

In terms of farm, landscape and livelihood resilience, trees buffer climate change and variability and diversify land use and farming systems, providing additional livelihood and environmental benefits not delivered through land management without trees. Appropriately managed tree shade over crops reduces ambient temperature by up to 2^{o} C, allowing temperature-sensitive crops like coffee to continue to be grown at locations where temperatures are increasing (Ovalle-Rivera et al. 2015). Tree shade can also lead to higher yields of staple food crops by reducing heat stress and extending the grain-filling period. Tree shade in silvopastoral systems also increases animal production by reducing heat stress (Thornton et al. 2017, Thornton and Herrero 2015). Shade also reduces bare-soil evaporation and improves the water-use efficiency of crops, making better use of water during drought periods. In many circumstances, trees increase water infiltration, thereby reducing soil erosion and flood risk. Tree cover plays an important role in water cycles at both landscape and continental scales: groundwater recharge in the seasonally dry tropics is maximized with an intermediate level of tree cover, and changes in tree cover in one place (such as the East African highlands) impact rainfall elsewhere (such as the Sahel) through re-precipitation of transpired water transferred over large distances in the atmosphere (van Noordwijk et al. 2014).

Trees diversify livelihoods both directly (such as through tree products that may be consumed or sold such as fruit, nuts, timber, firewood and fodder) and indirectly (such as through sustainable intensification involving interactions with other components). For example, producing firewood and charcoal, which are the main energy sources for cooking for 760 million people in Africa alone, reduces labor required for collection that can be redirected to other livelihood options, while on-farm fodder production supports livestock husbandry (Dawson et al. 2014, Njenga et al. 2014). Trees are often complementary to other components of farming systems. They produce fodder and food at times when annual crops or grasses do not, diversify diet through provision of key micronutrients and vitamins (notably A, C and B6) not provided sufficiently by crop staples, and stabilize income through product diversification (Dawson et al. 2014, Jamnadass et al. 2011). A positive relationship between indicators of dietary quality of children under five and landscape-scale tree cover has been found in Africa, and it is associated with maximum fruit and vegetable consumption at an intermediate level of tree cover (Ickowitz et al. 2014).

Appendix 2. MRV in the UNFCCC

This section gives an overview of the main components of MRV systems in the UNFCCC context and the requirements for each (table A2.1). It discusses (1) GHG inventories reported in NCs and BURs and (2) MRV of mitigation actions, including REDD+ and NAMAs.[5]

Table A2.1. Overview of measurement, reporting and verification requirements for developing countries in the UNFCCC

MRV component	Country progress on NDCs*	National GHG inventory	REDD+	NAMAs
Measurement	Account for emissions and removals in a transparent, accurate, complete, comparable and consistent way	IPCC Guidelines	IPCC Guidelines	Self-determined
Reporting	NDC reported to UNFCCC National inventory and information for tracking progress in implementing NDC to be reported	NCs and BURs	FRELs/FRLs reported in BURs	NCs and BURs
Verification	Technical expert review	National verification procedures (inventory and NCs) International consultation and analysis (BURs)	FRELs/FRLs verified through ICA of BURs. For countries seeking results-based payments, verification by team of technical experts	Technical analysis of information submitted in BURs. Additional verification depending on funding source

**At the time of writing (early 2018), specific requirements for NDC accounting were still under discussion in the UNFCCC.*

[5] The Clean Development Mechanism established under the Kyoto Protocol is a related MRV system, and several methodologies are applicable to different forms of agroforestry (see https://cdm.unfccc.int/methodologies/index.html). However, since there are few examples of agroforestry CDM projects that reach a scale commensurate with countries' ambitions for agroforestry, this paper does not provide further analysis.

The key role of national GHG inventories

NCs and BURs are important components of MRV for developing countries under the UNFCCC (table 2). Guidelines for NCs (UNFCCC 2002) state that they should report information on several topics, including the national GHG inventory and information on policies, programs or other steps implemented or planned to mitigate climate change (box A2.1). Developing countries are also encouraged to report information on institutions and procedures for the establishment of a regular national GHG inventory process, and on efforts undertaken to develop emission factors and activity data. BURs should include updates to the most recent NC in areas including the national GHG inventory, mitigation actions and their effects, and domestic arrangements for MRV (box A2.2) (UNFCCC 2009).

Box A2.1: Main contents of National Communications

Guidelines highlight that National Communications shall include:

"(f) A national inventory of anthropogenic emissions by sources and removal by sinks of all greenhouse gases not controlled by the Montreal Protocol, to the extent its capacities permit, using comparable methodologies to be promoted and agreed upon by the Conference of the Parties;

(g) A general description of steps taken or envisaged by the non-Annex I Party to implement the Convention;

(h) Any other information that the non-Annex I Party considers relevant to the achievement of the objective of the Convention and suitable for inclusion in its communication, including, if feasible, material relevant for calculations of global emissions trends."

Source: UNFCCC 2002

Box A2.2: Approaches to quantification of carbon stock changes in agroforestry due to land-use change

Quantification of carbon stock changes due to land-use and land-cover change (LULCC) is among the most uncertain components in carbon budgets and calculations in developing countries. Available methods are poorly suited to smallholder agriculture and agroforestry, where land parcels are smaller than the resolution of readily and cheaply available satellite imagery and trees are scattered throughout the landscape without relevant allometric equations (proxies to translate measureable tree parameters to carbon content). Yet estimates still must be made. Generally, estimation follows a few basic steps: (1) identify major land uses, (2) compile or develop estimates of carbon content of five carbon pools (see box 4) via existing data, field inventories or remote sensing, (3) calculate biomass carbon for each land use, and (4) scale the biomass calculated for each land use relevant to the land-use transition matrix between time points.

Source: samples.ccafs.cgiar.org

The national GHG inventory section of the BUR should consist of a national inventory report "as a summary or as an update," including two overview tables required in the NC guidelines. Additional or supporting information, such as sector-specific information—including technical information relating to REDD+ (UNFCCC 2013b)—may be supplied in a technical annex to the BUR.

Table A2.2. Overview of reporting requirements for developed and developing countries

Requirement	Developed countries	Developing countries
National Communications	Every 4 years	Every 4 years, with flexibility
Biennial report	Every 2 years	Every 2 years, with flexibility
GHG inventory	Annually	

Guidelines for the measurement and preparation of national GHG inventories by developing countries (UNFCCC 2002) recommend using the *Revised 1996 IPCC Guidelines for National GHG Inventories* (IPCC 1996), and the *IPCC Good Practice Guidance and Uncertainty Management in National GHG Inventories* (IPCC 2000) for estimating and reporting their national GHG inventories. In addition, in 2003, the IPCC published *Good Practice Guidance for Land Use, Land-Use Change and Forestry (LULUCF)* (hereafter, GPG for LULUCF), which are referred to as a guidance in guidelines for the preparation of BURs (UNFCCC 2011b, annex III). The *Revised 1996 IPCC Guidelines* provide detailed instructions for the application of various methods for the estimation of GHG removals and emissions from sinks and sources across all sectors, and on reporting to the CoP. IPCC (2000) provides detailed guidance for procedures used in characterizing activity data and selecting emission factors, in the quantification of uncertainty in GHG inventories, and in the analysis of key GHG sources. It also provides guidance on quality control and quality assurance in GHG inventories. The 2003 *GPG for LULUCF* provides guidance on the consistent representation of land areas, and on the measurement and estimation of carbon-stock changes and GHG emissions from different land-use categories. The guidelines also provide templates for reporting of GHG inventories. Developing countries are required to use the IPCC 1996 reporting categories, but some have also begun to use the revised structure of categories in the 2006 IPCC Guidelines.

Verification of information in both NCs and BURs may be conducted domestically at the national level before submission to the UNFCCC. NCs are not subject to international verification, but information from the NCs submitted by developing countries is compiled and synthesized by the UNFCCC Secretariat. The Consultative Group of Experts (CGE) provides technical support and advice to developing countries on the preparation of their NCs. This work involves analysis of NCs and recommendations for the improvements of NCs. These tasks, however, are not part of the formal verification framework under the UNFCCC (UNFCCC 2002). But regarding BURs, a verification framework has been agreed, which is referred to as International Consultation and Analysis (ICA). The aim of ICA is to increase the transparency of information reported in the BURs, including information on mitigation actions and their effects. ICA is conducted through technical analysis of BURs by teams of technical experts (TTEs), followed by facilitative sharing of views (FSV) in a workshop convened by the Subsidiary Body for Implementation (SBI) (UNFCCC 2011b, annex III).

Under the Paris Agreement (CoP 21 2015), both developed and developing countries agree to undertake and communicate their efforts to hold the increase in the global average temperature to well below 2°C above preindustrial levels and to pursue efforts to limit the temperature increase to 1.5°C above preindustrial levels (UN 2016, Article 2). Parties to the agreement must submit NDCs, which are statements of intended reductions in GHG emissions that are to be updated every five years and that should reflect progressive ambition (UN 2016, Article 4).

The Paris Agreement also commits to establish "an enhanced transparency framework (ETF) for action and support, with built-in flexibility which takes into account countries' different capacities" (UN 2016, Article 13). The decision to establish the ETF represents a significant step in the evolution of the MRV framework under the UNFCCC. The ETF will eventually supersede the existing modalities, procedures and guidelines for MRV, although it is planned to build on and enhance existing transparency arrangements under the UNFCCC, including NCs, BURs and related verification processes. In terms of GHG mitigation, the purpose of the ETF is to provide a clear understanding of mitigation actions, to track progress towards NDCs, and to inform a global stocktake to be undertaken every five years to assess collective progress towards the objectives of the Paris Agreement. Modalities, procedures and guidelines for the ETF will be developed by the Ad Hoc Working Group on the Paris Agreement (APA) and presented for consideration at CoP 24 (2018).

In terms of reporting on GHGs and GHG mitigation for developing countries, the key provisions of the Paris Agreement are that: (1) all parties shall regularly submit national inventory reports and information on implementation and achievement of NDCs; (2) all parties shall account for their NDCs; and (3) developing country parties should regularly communicate progress made on implementing capacity-building plans, policies, actions or measures. Parties' NDCs are currently communicated through a registry maintained by the UNFCCC Secretariat (unfccc.int/focus/ndc_registry/items/9433.php), and the SBI is undertaking work to develop modalities and procedures for operation and use of the registry.

In terms of verification, information on GHG inventories and on implementation and achievement of NDCs will be subject to technical expert review. While ICA of BURs submitted by developing countries considers only transparency, under the ETF implementation and achievement of NDCs by all countries will be subject to "facilitative, multilateral consideration," the modalities, procedures and guidelines for which have yet to be developed under the APA. For those developing countries that need it in the light of their capacities, the review process shall include assistance in identifying capacity-building needs (UN 2016, Article 13, par. 2).

The most significant departure from the current MRV framework will be the need to report progress on implementation and achievement of NDCs. There is significant diversity among existing NDCs. For example, some specify targeted reductions in absolute emission levels, while others target reductions in GHG emission intensity (e.g., GHG per unit GDP); some are economy-wide targets, while others specify certain sectors only; baseline and target years also vary among countries. There is little existing agreement on methods for measurement and reporting of progress in implementing these diverse forms of NDC. The Paris Agreement calls for "methodological consistency, including on baselines, between the communication and implementation of" NDCs and refers to "consistency between the methodology communicated in the NDCs and the methodology for reporting on progress made towards achieving NDCs." However, no further definition has been given of what consistency means. When the Paris Agreement states that all parties shall account for their NDCs, it refers to existing guidance adopted under the UNFCCC, which includes guidance published by the IPCC.

The IPCC guidelines provide guidance on, among other things, the identification and quantification of GHG sinks and sources. The 2003 *GPG for LULUCF* identifies six main land-use categories: forest land, cropland, grassland, wetlands, settlements and other lands (Milne et al. 2003). Forests and grasslands are further categorized by ecosystem type, and distinctions between closed (crown cover >40%) and open (crown cover 10–40%) forests

(IPCC 1996, ch. 5). The *2006 IPCC Guidelines* further stratify forest and other land uses based on climate, ecosystem, soil type and management practices in order to apply the most appropriate emission and stock change factors. The IPCC categorization is designed to harmonize with FAO classifications, but they are not identical. In practice, however, specific definitions of each land-use category, including forest, may be given by national definitions. The IPCC guidelines encourage countries to use data with higher levels of detail on subcategories of land uses that are then aggregated to the national level. Although in many countries forests are likely to be the main land use with significant carbon stock changes, the IPCC guidelines note that trees outside forests "should be included when they are a significant component of total changes in biomass stocks" (IPCC 1996, 5.13).

MRV of mitigation actions through REDD+ and NAMAs

Countries report on mitigation actions in their NCs and BURs. However, the reporting requirements are relatively general. The NC guidelines state: "Based on national circumstances, non-Annex I Parties are encouraged to provide, to the extent their capacities allow, information on programmes and measures implemented or planned which contribute to mitigating climate change…including, as appropriate, relevant information by key sectors on methodologies, scenarios, results, measures and institutional arrangements" (UNFCCC 2002).

The BUR guidelines are more explicit on the information that must be reported for mitigation actions (box A2.3).

Box A2.3: Reporting on mitigation actions in BURs

"Developing country Parties shall provide the following information to the extent possible:

Name and description of the mitigation action, including information on the nature of the action, coverage (i.e., sectors and gases), quantitative goals and progress indicators;

Information on methodologies and assumptions;

Objectives of the action and steps taken or envisaged to achieve that action;

Information on the progress of implementation of the mitigation actions and the underlying steps taken or envisaged, and the results achieved, such as estimated outcomes (metrics depending on type of action and estimated emission reductions, to the extent possible;

Information on international market mechanisms.

13. Parties should provide information on the description of domestic measurement, reporting and verification arrangements."

Source: UNFCCC (2011b), annex III

For measurement of the effects of NAMAs, there is limited methodological guidance under the UNFCCC. Guidance for BURs requires that "information on methodologies and assumptions" is given "to the extent possible" and that domestic measurement, reporting and verification arrangements are described (UNFCCC 2011b, annex III). Where such information is submitted as part of BURs, it is subject to verification through ICA (UNFCCC 2011b). In general, it is expected that quantification methodologies will be consistent with guidance from the IPCC and other organizations (UNFCCC 2014).

International climate funds (such as Global Environment Fund and Green Climate Fund) and international financial institutions (IFIs) are likely to be among the main financial supporters of mitigation actions in many developing countries. In recent years, these institutions have been developing internal policies and procedures to account for GHG emissions and emission reductions from projects they support (Climate Investment Funds 2014). These policies and procedures, including agreements among a number of IFIs to harmonize their GHG accounting policies, are not within the scope of the UNFCCC. However, the Green Climate Fund (GCF), which is one of the main financing vehicles for climate action under the UNFCCC, has issued documents specifying performance indicators for projects and programmes that it funds. Further guidance on methods, baseline setting and performance measurement has not yet been developed (GCF 2016).

For REDD+—which for some countries is also a form of nationally appropriate mitigation action—a more elaborate MRV framework has been agreed. REDD+ is intended to promote five types of activity: reducing emissions from deforestation; reducing emissions from forest degradation; conservation of forest carbon stocks; sustainable management of forests; and enhancement of forest carbon stocks. The Cancun Agreement set out the framework for REDD+. This framework consists of a National Strategy or Action Plan, a FREL/FRL, an NFMS and safeguards. FRELs/FRLs may be subject to voluntary technical assessment, but technical assessment is required where countries seek results-based payments. The Warsaw CoP (2013) also set out modalities for NFMSs, which should use a combination of remote sensing and ground-based forest carbon inventory approaches when estimating forest carbon stock and forest area changes. They should follow IPCC guidance and provide estimates that are transparent, consistent and accurate, and that reduce uncertainties. Both FRELs/FRLs and subsequent estimates of carbon removals in comparison to the FREL/FRL may be reported in a technical annex to a country’s BUR. While BURs are subject to ICA as a form of verification, these technical annexes are subject to additional verification by teams of technical experts.

Appendix 3. Additional information on methods

Keywords

Explicit mentions

Agroforestry, hedgerows, silviculture, protective forestry strips, buffer trees, wind breaks, social and homestead forestry, agro-silvo pasture, agro-silvo pastoral systems, arboriculture, assisted natural regeneration, woodlots, on-farm ligneous species, on-farm trees, farmer managed, intercropping with trees, alley cropping, parklands, boundary planting, multistrata

Potential mentions

Afforestation, agriculture land/cropland management, alternative forest management, aromatic trees, assisted phytostabilization, avoided deforestation, cash crop tree production, community forest, conserve biodiversity in coffee–forest landscape, fire management, forest cover, forest management, forest plantation, forest renewal, forest restoration, fruit trees (include including individual species e.g. mango, palm; orchards), growing biomass, fuelwood, grasslands management/restoration, greenbelts, green wall, growing biomass, increase carbon sequestration capacity, increase forest/tree cover, increase tree coverage, increasing forested area, land protection, logging management, mangrove management, mangrove restoration, medicinal trees, mg of pastoral/agropastoral land, management for carbon stocks of landscapes, management for forest carbon stocks, miombo woodlands management, non-extractive forest use, overcutting, participatory/native/community forest management, pasture and gazing land management, peatland, peatland management /restoration, private forests, protect area management, rangeland, reduce loss of woodlands, reduced clearing, reduced deforestation, regeneration, rehabilitation, revegetation, riparian management, savanna and shrub management, silvopasture, steppe management, sustainable charcoal production, sustainable forest management, private forests, sustainable timber production/logging, sustainable use of forest products, sustainable charcoal and firewood, timber, tree management, tree planting in non-forest/non-protected, tree use, urban forest, watershed management/restoration, woodland management.

Appendix 4: Agroforestry in National Communications

We reviewed 147 non-Annex I countries' NCs for evidence (mentions) of agroforestry, including 50 countries in Africa, 33 in the Americas, 44 in Asia, 6 in Europe and 14 in Oceania. The most recent document for each country was reviewed. The average and medium year was 2013, but the publication dates ranged from 2000 to 2017. Of the 146 NCs reviewed, 71% (N=105) were reviewed in detail because of explicit or potential mentions of agroforestry or possible agroforestry-related management techniques.

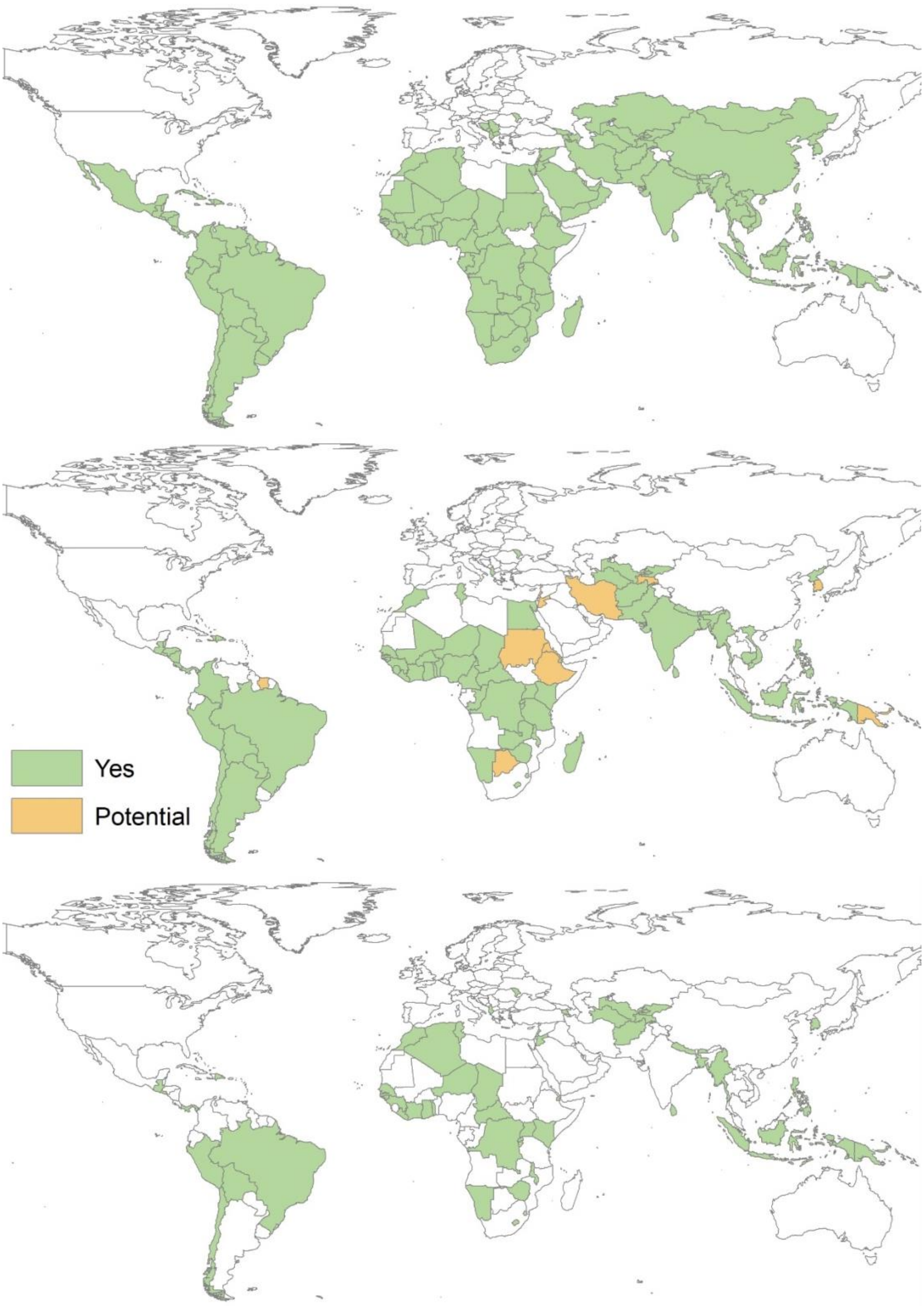


Figure A4.1. National Communications reviewed (top). National Communication explicitly or potentially mentions agroforestry (middle). National Communication potentially mentions trees outside forests (bottom).

Table A4.1. Number of countries with explicit mentions of agroforestry in National Communications and the sections where they are mentioned

Region	Explicitly mention	Mitigation only	Adaptation only	Adaptation & mitigation
Africa	36	29	28	21
Americas	20	13	13	6
Asia	20	10	13	3
Europe	4	4	2	2
Oceania	8	5	7	4
Total	**88**	**61**	**63**	**36**

Table A4.2. Agroforestry practices specifically named in National Communications

Agroforestry categories	Africa	Americas	Asia	Europe	Oceania
Agroforestry	21	11	8	2	3
On-farm trees	1		1		
Agro-silvo pasture / Agro-silvo pastoral systems	3	3		1	
Silviculture	3	1	1	2	2
Regeneration	6	1	2	1	0
Alley/hedgerow	2		1		
Woodlots	1			1	2
Protective forestry strips (buffer zones/wind breaks)				1	

Table A4.3. National Communications that include agroforestry in the inventory section or where the mitigation analysis includes agroforestry

Regions	Country	Description in inventory	Practices mentioned in mitigation analysis
Americas	Bolivia	Specifically include agroforestry in the inventory	
Africa	Chad	Trees outside forests inventoried included what is most likely agroforestry	Agroforestry; silviculture; alley/hedgerow; arboriculture
Africa	Democratic republic of Congo	Trees outside forests inventoried included what is most likely agroforestry; NAMAs suggested also cover agroforestry	Agroforestry; agro-silvo pasture; agro-silvo pastoral systems
Africa	Djibouti	Inventory includes windbreak trees and fruit (cash-crop trees)	Silvopasture
Americas	El Salvador	Included coffee under shade trees	
Asia	India	Inventory for $C0_2$ emissions included perennials tree biomass in croplands	Regeneration
Asia	Indonesia	Mix agriculture shrubs included in inventory in cropland	Silvofishery
Africa	Kenya	Trees on farms included	
Asia	Kyrgyzstan	Settlements trees and shrubs included; perennial plantations included	

Asia	Lebanon	Growth of cropland (perennial crops) included	
Africa	Malawi	Included agroforestry in analysis of mitigation options (p. 232)	Agroforestry
Oceania	Marshall Islands	Agroforestry identified as a sector vulnerable to climate change; agroforestry treated as a sector	Agroforestry
Africa	Morocco	Forest firewood, firewood from orchards and arboriculture included in inventory	
Asia	Pakistan	Agroforestry identified as the best mitigation option and analysis done on costs and potential	
Asia	Philippines	Inability to account for millions of hectares of upland farms, tree plantations and grasslands	
Africa	Rwanda	Included trees scattered in the field (agroforestry). Mitigation through agroforestry is detailed including species of trees recommended	Agroforestry regeneration
Americas	Saint Vincent & Grenadines	Agroforestry major component of mitigation efforts	Agroforestry
Asia	East Timor	Agriculture mixed with shrub taken into account in inventory; agroforestry factored into mitigation scenarios	On-farm trees
Oceania	Tonga	Took into account boundary planting in the 2000 inventory; forestry department promotes agroforestry	Agroforestry
Africa	Tunisia	Included arboriculture plantation, olive groves and urban forestry	Alley/hedgerow

Table A4.4. National Communications with potential mentions of agroforestry

Potential mentions	Africa	Americas	Asia	Europe	Oceania	Grand Total
Afforestation/reforestation	45	24	35	5	10	119
Rangeland/pastoral/agropastoral/steppe mgmt	17	8	15	1	1	42
Sustainable forest mgmt	43	24	31	6	9	113
Wetland/peat/watershed/riparian	27	22	28	2	10	89
Urban forestry	6	2	9	0	0	17
Fire	14	8	15	2	4	43
Land mgmt	20	10	12	2	4	48
Biomass energy	18	2	10	1	4	35
Cash-crop trees	10	3	8	2	7	30
Sustainable use of forest products	9	3	4	1	1	18
Miombo/savannah2	2	0	0	0	0	2
Cropland	0	0	0	1	0	1

Table A4.5. National Communications with potential mentions of agroforestry in the mitigation chapter of inventory

Systems	Africa	Americas	Asia	Europe	Oceania	Total
Afforestation/reforestation	40	22	30	5	6	103
Rangeland/pastoral/agropastoral/steppe mgmt	7	5	7	1	1	21
Sustainable forest mgmt	33	17	24	2	6	82
Wetland/peat/watershed/riparian	8	7	9	1	3	28
Urban forestry	5	0	3	0	0	8
Fire	10	5	6	2	4	27
Land mgmt	12	5	6	1	0	23
Biomass energy	14	1	6	1	4	26
Cash crop trees	5	3	4	1	4	17
Sustainable use of forest products	6	2	2	1	1	12
Miombo/savannah	2	0	0	0	0	2

Table A4.6. Tiers of measurement reportedly used GHG inventories of agriculture and other land use

Region	Total countries in region	NCs reviewed	Reported using IPCC Tier 1	Reported using IPCC Tier 2
Africa	54	50	37	2
Americas	33	33	19	2
Asia	45	44	15	5
Europe	6	6	2	1
Oceania	14	14	7	0
Total	**152**	**147**	**80**	**10**

Appendix 5. Agroforestry in (Intended) Nationally Determined Contributions

NDCs set the targets for climate action in the Paris Agreement signed at CoP 21. Many countries are proposing to use national GHG inventories to measure progress in their climate and development goals through reporting on the NDCs. This makes practical sense as the frameworks and methods are typically agreed upon, reporting is clearly established and verification protocols clearly set out. We read 147 developing countries' NDCs. Methods were the same as used for other documents and explained above.

Figure A5.1. Nationally Determined Contributions reviewed (*N*=147) (top). Explicit mentions of agroforestry (bottom).

Table A5.1. Number of countries with explicit mentions of agroforestry in NDCs

Region	Mitigation only	Adaptation only	Adaptation & mitigation
Africa	10	12	27
Americas	9	4	10
Asia	9	13	11
Europe	1	1	1
Oceania	3	2	1
Total	**32**	**32**	**60**

Table A5.2: Explicit agroforestry practices/sub-practices per continent

Explicit mention	Africa	Americas	Asia	Europe	Oceania	Total
Agroforestry	28	9	6	0	1	44
Hedgerows	1	0	0	0	0	1
Silviculture	2	2	0	0	0	4
Protective forestry strips (buffer zones/wind breaks)	0	0	1	1	0	2
Social and homestead forestry	0	0	1	0	0	1
Agro-silvo pasture/agro-silvo pastoral systems	7	3	1	0	0	12
Arboriculture	5	0	0	0	0	5
Assisted natural regeneration	7	1	2	0	0	10
Woodlots	1	1	0	0	0	2
Ligneous species	1	0	0	0	0	1

Table A5.3. Potential mentions of agroforestry in NDCs per continent

Potential mention	Africa	Americas	Asia	Europe	Oceania	Total
Rangeland/steppe/grassland/pastoral	17	4	6	0	0	27
Wetland/peat/watershed/riparian/marine vegetation/mangrove	19	14	14	2	3	51
Crop/cropland/agriculture	1	0	0	0	0	1
Fire	6	0	0	0	0	6
Miombo/savannah	8	0	0	0	0	7
Urban forest	2	0	1	0	0	3
Sustainable use of forest products	9	1	4	1	0	15
Cash-crop trees	6	0	1	0	1	8
Afforestation/reforestation	29	12	17	2	0	57
Sustainable forest management	31	17	24	0	2	74
Biomass energy	15	2	3	2	0	22
Land	13	6	10	0	1	30

Appendix 6. MRV of agroforestry in REDD+

Out of 195 countries, 73 are either UN REDD countries (64), FCPF countries (47), REDD early mover countries (3), or had made submissions to the UNFCCC (8) (as posted on UNFCCC website). A total of 53 countries submitted 134 REDD+ related documents that were reviewed for this assessment. The documents reviewed were obtained from FREL/FRL (www.forestcarbonpartnership.org/redd-countries-1), Readiness Preparation Proposal (R-PP), Emission Reduction Program Document (ER-PD) and (Emission Reduction Project Idea Note (ER-PIN) (redd.unfccc.int/submissions.html?mode=browse-by-country) and the REDD desk (theredddesk.org). At the time of the review, 48 countries have submitted REDD+ readiness, 34 have submitted their FREL, 15 have submitted a National Strategy, and only two have an NFMS system.

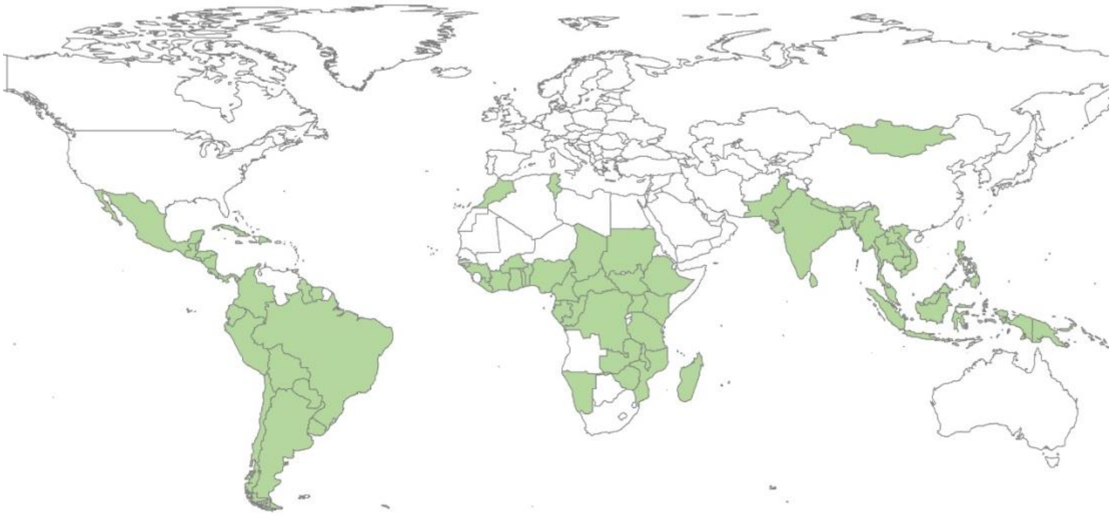


Figure A6.1: Countries having at least 1 REDD+ document assessed

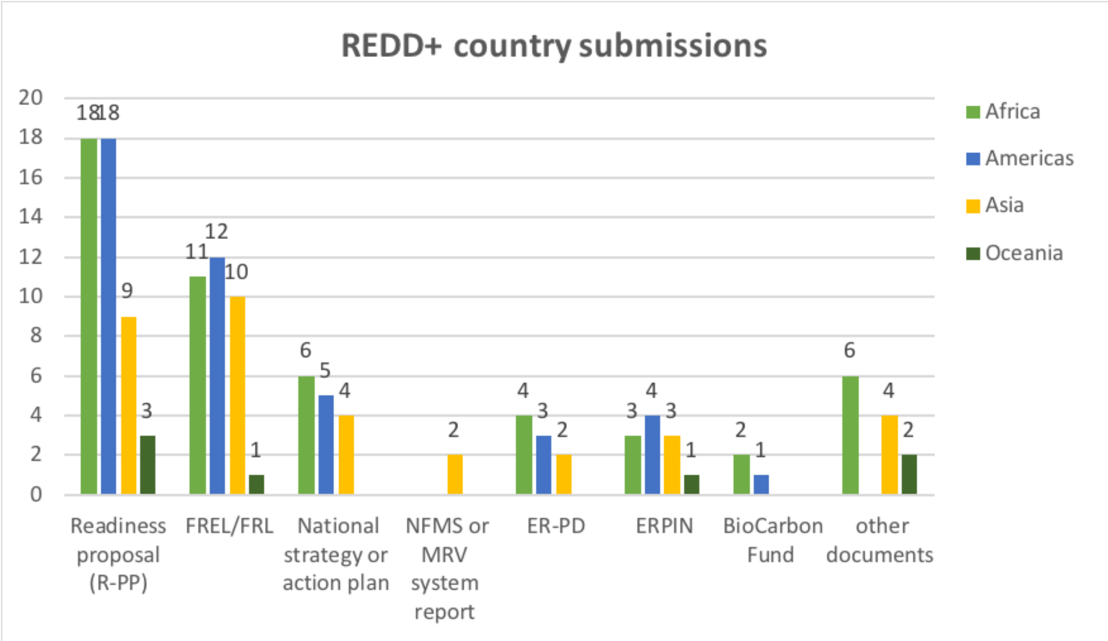


Figure A6.2: Types of REDD+ documents assessed by continent

Table A6.1. Number of countries with explicit mentions of agroforestry in NDCs

Region	Explicit mention	Potential mention
Africa	18	21
Americas	15	17
Asia	6	11
Oceania	3	3
Total	42	52

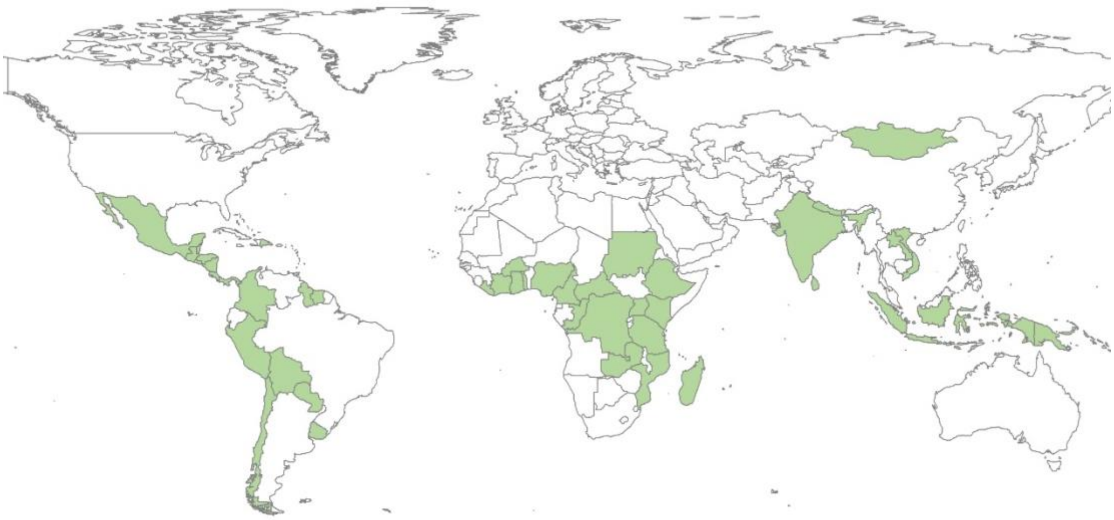


Figure A6.3: Countries that mention agroforestry in REDD+ strategies

Table A6.2: Explicit mentions of agroforestry in 56 REDD+ strategies

Keyword	Number of countries
Explicit	
Agroforestry/agroforestry system	38
Woodlots	5
Hedgerows	2
Cocoa agroforestry	3
Coffee agroforestry	2
Buffer strips	1
Silvopastoral systems	9
Agrosilvopastoral	5
Planting trees on farms	6
Multi-tree cropping systems	4
Agro-silviculture	1
Silviculture	4
Natural regeneration	7
Enrichment planting	2
Potential mentions	
Sustainable forest management	52
Afforestation/reforestation	53
Biomass fuels	22
Sustainable use of forest resources	8
Plantations	17
Cash crop trees	9
Agropastoral/pastoral	8
Tree farming	1
Land management	13

Table A6.3. Countries' interest and experience in monitoring tees outside forest (some of which are agroforestry). Interest expressed in REDD+ documents

Country	Past/present policies promoting ToF	Includes AF in its forest definition	AF as specific mention	Has expressed interest in monitoring of ToF	Has experience monitoring ToF
Cambodia				Yes	
Columbia			Yes	Yes	
Côte d'Ivoire			Yes		Yes
Democratic Republic of the Congo			Yes	Yes	
Dominican Republic			Yes	Yes	Yes

El Salvador	Yes		Yes	Yes	
Ghana	Yes		Yes	Yes	Yes
India	Yes	Yes	Yes		Yes
Kenya	Yes		Yes	Yes	
Laos			Yes	Yes	
Myanmar				Yes	
Nepal	Yes		Yes		Yes
Nicaragua	Yes		Yes		Yes
Pakistan	Yes			Yes	
Paraguay	Yes		Yes	Yes	
Peru	Yes		Yes		Yes
Sudan			Yes	Yes	
Thailand	Yes			Yes	Yes
Togo	Yes		Yes	Yes	
Vanuatu		Yes	Yes	Yes	
Total	11	2	16	15	8

Table A6.4. Status of FREL/FRL submissions for 56 REDD+ countries reviewed (as of November 2017)

Country	FREL Submission
Bangladesh	No
Bhutan	No
Bolivia	No
Brazil	Yes
Central African Republic	No
Chad	No
Chile	Yes
Costa Rica	Yes
Côte D'Ivoire	Yes
Democratic Republic of the Congo	Yes
Dominican Republic	No
El Salvador	No
Ethiopia	Yes
Fiji	No
Ghana	Yes
Guatemala	No
Guinea	No
Guinea Bissau	No
India	Yes

Country	FREL Submission
Kenya	No
Liberia	No
Madagascar	Yes
Malawi	No
Morocco	No
Myanmar	Yes
Namibia	No
Nepal	Yes
Panama	Yes
Papua New Guinea	Yes
Peru	Yes
Philippines	No
Saint Lucia	No
Samoa	No
Solomon Islands	No
Sri Lanka	Yes
Togo	No
Tunisia	No
Uganda	Yes
Vanuatu	No

Table A6.5. Resolution of satellite imagery used in REDD+ MRV

Region	Use of IPCC default values for EF/AD	No. countries using high resolution = < 2.5 m	No. countries using medium resolution, 2.5 - 60 m	No. countries using low resolution > 60 m
Africa	8	3	17	5
Americas		1	10	2
Asia	3	1	10	2
Europe	1	1	2	0
Oceania	3	0	6	0
Total	**15**	**6**	**45**	**9**

Appendix 7. MRV in proposed agroforestry NAMAs

We reviewed the NAMA database (www.nama-database.org) and the UNFCCC NAMA registry (www4.unfccc.int/sites/nama/SitePages/Home.aspx) for agroforestry-based NAMAs. Our search yielded 274 NAMAs from 66 developing countries (accessed June 2017), with roughly 99, 92, 67, 14 and 2 from the Americas, Asia, Africa, Europe and Oceania, respectively. Only 34 of the 274 NAMAs were for the agriculture sector, with 7, 13 and 13 being from Africa, the Americas and Asia, respectively. There have been no agricultural NAMAs proposed in either Europe or Oceania. Though only 34 NAMAs were from the agriculture sector, 42 NAMAs included explicit (10) or potential (32) mentions of agroforestry. Explicit mentions include both general descriptions and specific practices such as hedgerow, silvopastoral systems or short-rotation coppicing. NAMAs that potentially include agroforestry but were not in the agriculture sector were typically conducted in the forest or energy sectors.

Table A7.1. Explicit mentions of agroforestry

Country	Number	Sector	Mentions	Status
Costa Rica	2	Agriculture[6, 7]	Hedgerow (live fences)	Seeking support for implementation
			Silvopastoral system	
		Agriculture	Coffee agroforestry systems	Seeking support for implementation
Colombia	1	Agriculture	Silvopastoral system	Seeking support for preparation
Dominican Republic	1	Agriculture/waste/energy[7]	Agroforestry systems	Not submitted
Indonesia	2	Agriculture/forestry[8]	Agroforestry	Not submitted
		Energy[9]	Trees mixed with rotation crops	Not submitted
			Short-rotation coppice	
Kenya	1	Agriculture[10, 11]	Agroforestry	Not submitted
Rwanda	1	Energy[12]	Agroforestry sources of wood fuel	Seeking support for preparation
			Short rotation coppice	
Uganda	2	Agriculture[13]	Agroforestry species for livestock feed	Seeking support for preparation
		Energy[14]	Woodlots	Not submitted
			On-farm trees	

[6]http://www.lowemissiondevelopment.org/lecbp/docs/NAMA_Concept_Livestock_Costa_Rica_Nov_2014.pdf

[7]http://www.nama-database.org/index.php/Eco-competitive_Livestock_sector

[8]http://www4.unfccc.int/sites/nama/_layouts/un/fccc/nama/NamaSeekingSupportForImplementation.aspx?ID=90&viewOnly=1

[9]http://www4.unfccc.int/sites/nama/_layouts/un/fccc/nama/NamaSeekingSupportForPreparation.aspx?ID=150&viewOnly=1

[10]http://www4.unfccc.int/sites/nama/_layouts/un/fccc/nama/NamaSeekingSupportForPreparation.aspx?ID=173&viewOnly=1

[11]http://www.nama-database.org/index.php/Agroforestry_for_Rehabilitation_of_Degraded_Land

[12]http://www.gelamai.org/files/MediaPublication/Concept%20Paper%20-%20LAMA%20Mine%20Reclamation%20for%20Rural%20Renewable%20Energy%20in%20East%20Kalimantan%20(LAMA-MORRE).pdf

[13]https://ccafs.cgiar.org/nationally-appropriate-mitigation-actions-kenya%E2%80%99s-dairy-sector#.WcIJDrIjGUl

[14]http://www.nama-database.org/index.php/NAMA_for_the_Dairy_sector

[15]http://documents.worldbank.org/curated/en/938251468027639371/pdf/830370WP0v10P10Box0379822B00PUBLIC0.pdf

[16]http://www4.unfccc.int/sites/nama/_layouts/UN/FCCC/NAMA/Download.aspx?ListName=NAMA&Id=87&FileName=Livestock%20Emissions%20NAMA.docx

[17]http://www.undp.org/content/dam/undp/library/Environment%20and%20Energy/MDG%20Carbon%20Facility/CharcoalNAMAStudy_9Jan2013.pdf

Table A7.2. Description of intended MRV under the select NAMAs

Country	Sector	Practices covered	MRV
Gambia	Energy	Biomass energy Rangeland/steppe/grassland/pastoral Sustainable forest management Fire management Rangeland/steppe/grassland/pastoral	UNFCCC Focal Secretariat and the Department of Energy will conduct national level monitoring and evaluation; external monitoring and evaluation will be based on the MRV system in place according to CoP decisions and procedures
Uganda	Agriculture	Afforestation/reforestation Rangeland/steppe/grassland/pastoral Agroforestry species for livestock feed	MRV begins from farm records. Research NAMA will gather baseline data and attempt to calculate the emission reductions of specific abatement actions; activity data collected population size, type of livestock, emission factor of type of feeds
Uganda	Energy	Afforestation/reforestation Sustainable forest management Urban forestry Woodlots	MRV will be based on records such as registration of all charcoal producers and indicators of impact of project suggested, such as quantities of products and persons involved. UNFCC factors applied CDM SSC methodology, AMS-III.BG: Emission reduction through sustainable charcoal production and consumption (UNFCCC 2012)
Georgia	Forestry	On-farm trees Afforestation/reforestation Sustainable forest management	Data obtained from 2013 forest inventory; above-ground biomass calculated using biomass conversion and extension factor for growing stock (IPCC); difference in total biomass stock estimated using Stock-Difference Method (IPCC 2006 on AFOLU)
Indonesia	Agriculture/forestry	Land rehabilitation Sustainable forest management Mangrove/wetland/peat/watershed/riparian	Indonesia has the most detailed MRV for the NAMA. Data continuously measured; bodies to be considered UNFCC through CDM, J-VER and VCS. VCS methodolofgyVM0004: Methodology for Conservation Projects that Avoid Planned Land Use Conversion in Peat Swamp Forests used for most of the MRV work presented
Chile	Forestry	Afforestation/reforestation	The Strategy is also interlinked with the REDD+ Chilean proposal to the FCPF, where social and environmental safeguards are being fully considered. The MRV system being developed for the National Strategy will also include indicators related to biodiversity, gender equality and adaptation issues, among others.

RESEARCH PROGRAM ON
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