Food and Agriculture Organization of the United Nations

Better data, better decisions

Towards impactful forest monitoring

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Cover photo: Aerial view of the Amazon rainforest, near Manaus, capital of the state of Amazonas, Brazil. ©CIFOR/Neil Palmer

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Abbreviations and acronyms

CAR	Cadastro Ambiental Rural/Rural Environmental Registry (Brazil)
CIFOR	Center for International Forestry Research
DETER	Sistema de Detecção de Desmatamento em Tempo Real/Real-Time System for Detection of Deforestation (Brazil)
FRA	Global Forest Resources Assessment
IFRI	International Forestry Resources and Institutions Network
INPE	Instituto Nacional de Pesquisas Espaciais/National Institute for Space Research (Brazil)
MRV	measurement, reporting and verification
NFMA	National Forest Monitoring and Assessment
NGO	non-governmental organization
PRODES	Programa de Cálculo do Desflorestamento da Amazônia/Programme for the Calculation of Deforestation in the Amazon
REDD+	Reducing Emissions from Deforestation and Forest Degradation and the role of conservation, sustainable management of forests and enhancement of forest carbon stocks in developing countries
UNFCCC	United Nations Framework Convention on Climate Change
USAID	United States Agency for International Development
WRI	World Resources Institute

Executive summary

Decisions based on data and analysis are often deemed to produce a better outcome and providing decision-makers with information is seen as an important development strategy. The adoption of the Sustainable Development Goals reinforces the importance of science-policy linkages. In the forestry sector, efforts to reduce emissions from deforestation and forest degradation (REDD+) have created opportunities for forest monitoring capacity development over the past decade, which can support forest management and domestic policy-making in addition to international reporting. This paper explores country examples, and considers how forest monitoring can inform problem-solving, especially on public policy.

Where and when does forest monitoring inform problem-solving?
While it may seem natural that information on forests *could* (and *should*) contribute to decision-making, a set of case studies demonstrates that this does happen in practice. To examine the factors that determine whether or not forest monitoring results inform problem-solving efforts, a set of positive cases was selected for in-depth analysis. These illustrate problem-solving in both a public policy and a corporate setting, and cover a diverse range of geographical contexts.

For example, **Viet Nam** underwent a forest transition in the early 1990s, as a result of policy efforts to accelerate the agricultural transition and to expand a self-sufficient forest industry. After data had shown serious forest decline, the government took on ambitious forest-area targets and launched a new monitoring campaign to track progress. Vast tree plantings were undertaken. Also, the government enacted several partial logging and export bans and used the results of a national forest inventory to tightly control logging.

Another example is **Cameroon** where important steps were taken to reform the forest concessions regime in the 1990s and 2000s. A fiscal crisis and the need to enhance government revenues triggered efforts to lay the basis for orderly forest management and to clamp down on corruption. Upgraded forest management planning required concession-level inventories. Independent forest monitoring became a basis for management oversight. Forest policy progress could be transparently evaluated based on independent forest monitoring results.

The past decade has seen progressive mainstreaming of deforestation concerns into **corporate decision-making**. Alarming data on global forest area trends have contributed to creating momentum, providing evidence for non-governmental organization (NGO) campaigning. In response, procurement by consumer goods companies, plantation management by agribusinesses, and lending decisions by financial firms are being

reoriented to address deforestation risks, all drawing on forest monitoring results for operational decision-making.

In the cases examined in this paper, diverse types of data and analysis on forests contributed to solving problems in public policy and corporate activities. Information was tailored to the issues at hand and to those involved in decision-making.

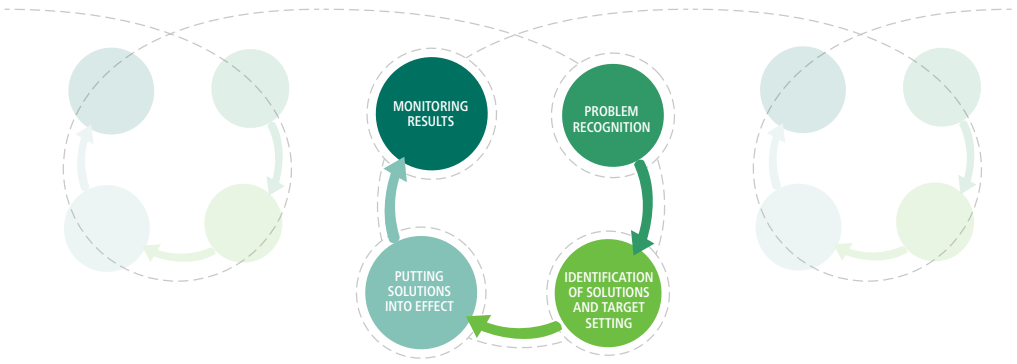
Forest monitoring data and analysis underpinned clear and intuitive messaging to place issues on the agenda of policy-makers. Thematically rich datasets became the basis for detailed analysis, including through modelling, to identify solutions. Operational decision-making used locally specific data, collected and analysed in a timely manner for the decisions at hand. Datasets compiled by reputable institutions with long time series and at a more aggregate scale permitted the monitoring of results.

How can forest monitoring inform problem-solving – and what enabling conditions are needed?

The above examples of public policy-making and corporate activities illustrate that forest monitoring can be a key input to effective problem-solving. Exploring these dynamics yields lessons for the design of capacity-development strategies. It also explains why such positive uptake is not universal – because policy change requires a window of opportunity combined with the political will that data and analysis can catalyse but not create.

Forest monitoring results can contribute to all stages of efforts to solve problems (ES-Figure 1). When data and analysis highlight problems that need to be addressed in public policy or corporate activities, windows of opportunity for change can open. Forest monitoring can then enable problem **recognition**, therefore helping to engage people and setting an agenda for change. While some problems grow until they are glaringly evident, in other cases detailed analysis is required to make them visible to decision-makers.

ES-FIGURE 1
Applied problem-solving cycle



Source: modified from Howlett, Ramesh and Perl, 2009.

Once a problem is recognized, bold solutions can be identified and targets can be set. Forest monitoring can help to provide the analytical backdrop for building agreement among diverse stakeholders. Forest monitoring can also be the basis for identifying entry points for action, as well as setting quantitative targets and tracking how they are achieved.

Once decisions have been taken and targets have been set, **solutions need to be put into effect**. Governments operate policy instruments, such as fiscal or regulatory actions, which forest monitoring can underpin. Similarly, forest monitoring can support decision-making in government programmes and corporate operations. There is ample opportunity in public policy-making and corporate activities to solve problems using forest monitoring results. Policy instruments can be built around available datasets and create incentives or disincentives that lead to change.

Monitoring the results of policy implementation can support the evaluation of government efforts, provide accountability (especially if data are accessible to civil society) and be a basis for learning. Monitoring can also reduce the risk of ill-informed, ineffective or wasteful actions. Data and analysis are essential for sound monitoring of policy progress.

An indicator-based assessment of public policy-making in 38 developing countries highlights both the need and the opportunity to replicate positive experiences. In most countries forest monitoring results are already instrumental in setting the agenda of decision-makers, defining solutions and evaluating outcomes – increasingly so in the context of REDD+ and mitigation policy and more broadly in domestic and global sustainable development agendas. The assessment shows that forest monitoring could be better leveraged in policy implementation, to guide decision-making in government programmes or to underpin fiscal incentive schemes.

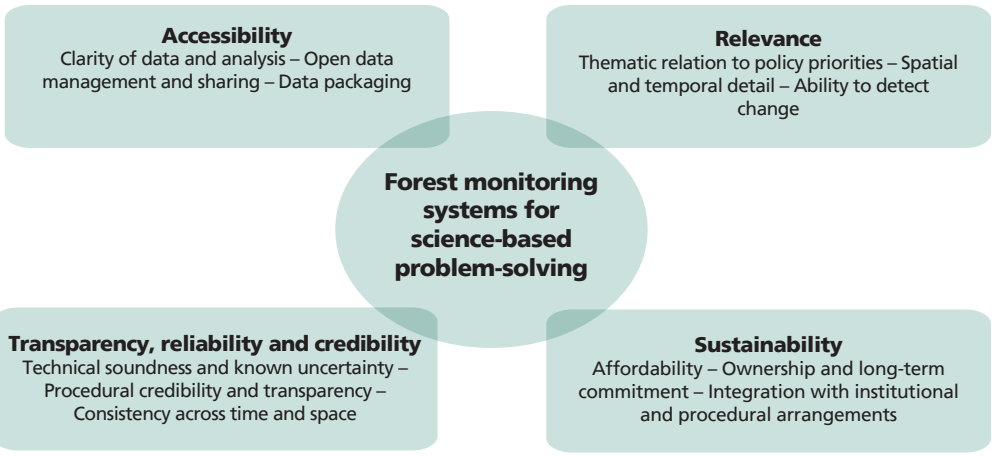
How can forest monitoring systems be structured to inform problem-solving?

The case studies, as well as further examples from the literature, yield lessons on what has made forest monitoring suitable for informing decision-making. These could guide the design of forest monitoring systems, as well as related technical assistance programmes. Prior work suggests that monitoring systems and their results need to be accessible, transparent, reliable and credible, relevant, and sustainable to inform forest policy-making (ES-Figure 2, page xi).

To influence policy-making, information needs to be **accessible** to its users. Data sharing among government agencies is not universal, and even less so in civil society or among the general public. It is important that data should be conceptually accessible; excessively complex information will not easily be taken up by potential users. Data must be communicated in an understandable way and analysis must be presented to its audience through purposeful, tailor-made communication.

Transparent, reliable and credible forest monitoring can inform decision-making. Data need to be technically sound, consistent across time and space, and uncertainties need to be known. But credibility is also a matter of perception, not least regarding

ES-FIGURE 2
A framework for understanding forest monitoring systems for science-based problem-solving



Source: authors' elaboration.

the reputation of data providers and third-party reviewers. Credibility stems from transparency, both in the methods applied and the people involved, especially when others are supplying the data.

Information on forests that is **relevant** to decision-making has adequate thematic and spatial detail, is collected at appropriate time intervals, enables assessment of change, speaks to thematic policy priorities and is aggregated at relevant scales.

Countries are more likely to operate forest monitoring systems in a **sustainable** manner if they are affordable and respond to policy needs. Where there is a strong linkage to policy needs, governments are more likely to take full ownership and integrate forest monitoring into their regular institutional and procedural arrangements. Additionally, nationally designed, funded and operated forest monitoring may more easily link to policy-making, simply because governments are more likely to trust "home-grown" data.

The analysis of country case studies and the literature has yielded information on enabling conditions between forest monitoring and policy-making. The indicator-based assessment of public policy-making in developing countries highlights that for many countries there is a need for further capacity development. More investment has gone into the transparency, reliability and credibility of forest monitoring than into making sure that it is relevant and accessible to policy-makers. In most countries, sustainability of forest monitoring systems is at risk. Capacity development efforts should aim at supporting forest monitoring systems that are accessible, transparent, reliable and credible, relevant, and thus suitable for direct linkages to policy-making. Where a linkage to policy-making can be established, it can become a starting point for governments to take the necessary decisions that create sustainable forest monitoring systems.

Conclusions and recommendations

In conclusion, forest monitoring can create momentum and inform change *if the conditions are right*. A window of opportunity for policy change needs to be open, and forest monitoring data need to be suitable to inform policy-making. This conclusion can be the basis for designing and operating forest monitoring systems and for targeting capacity development strategically.

The forest monitoring investments of the past decade have enhanced many countries' capabilities and thus offer an opportunity for improved problem-solving. While recent investments have often been oriented towards international reporting, many countries could still undertake further work to link forest monitoring closely to domestic policy priorities. The countries that have had most success in reducing deforestation offer lessons on structuring forest monitoring systems for informing policy design, underpinning policy instruments and enabling learning.

FAO believes that working towards impactful forest monitoring requires the pursuit of a set of interlinked outcomes. Governments, donors and technical support agencies can all contribute.

- Enhancing the suitability of forest monitoring to inform problem-solving, by the private or the public sector, starts by making data and analysis available in an easily accessible and understandable format. To develop impact, forest monitoring initiatives focus on the dissemination of results for diverse audiences, not as an afterthought but as the core objective.
- Significant progress already achieved through past and ongoing capacity development needs to be secured and remaining gaps need to be addressed so that robust forest monitoring systems can cater both for domestic needs for data and analysis and international reporting and REDD+.
- Forest monitoring systems that governments design jointly with other stakeholders will be trusted.
- Impactful forest monitoring generates datasets for multiple purposes that help countries to advance towards national sustainable development objectives through all stages of the problem-solving cycle.
- For developing countries, funding national forest monitoring will be much easier if the monitoring system is affordable.
- A fit-for-purpose forest and land-use monitoring system that is closely linked into policy-making and caters for domestic needs for data will have strong ownership by the government and naturally embed into national institutions.

FAO envisages that forest monitoring capacity development, by taking on board the thinking in this paper, could make a crucial contribution to global efforts to achieve transformational change surrounding forests and land use in the decade to come. The governments of developing countries, their donors, and those providing technical assistance can leverage current opportunities and bring forest monitoring to the next level, **where better data lead to better decisions**.

1. Introduction

Do better data lead to better decisions? Decisions based on data and analysis are often perceived to be "better" and providing decision-makers with information is seen as an important development strategy. The adoption of the Sustainable Development Goals reinforces the importance of science-based policy-making. Momentum on Reducing Emissions from Deforestation and Forest Degradation (REDD+) as a mitigation option has created opportunities for forest monitoring capacity development over the past decade. Explicitly or implicitly, such efforts have often also aimed to inform forest management and policy-making. This paper explores how forest monitoring can inform problem-solving, especially in public policy.

The goal of informing decision-making is not new. It has long guided forest monitoring efforts, but a renewed focus on opportunities is timely since the past decade has seen investments in REDD+-driven forest monitoring capacity development (FAO, 2018a; Kleinn, 2017; Neeff and Piazza, 2019). Capacity development support has focused on forest monitoring systems that could become a basis for potential results-based payments, and for international reporting against the 2015 Paris Agreement mitigation goals (FAO, 2018b, 2019). The result has been sweeping enhancements to national forest monitoring systems (FAO, 2018a; Neeff and Piazza, 2019), and improvements in forest data which can provide a basis for improved decision-making. *FAO's Voluntary guidelines on forest monitoring* reflect this goal, and it has been the topic of much other work at FAO over the years (Arnold, Rametsteiner and Kleinn, 2014; FAO, 2007, 2014, 2017a). One of the motivations for writing this paper was the observation that capacity development in forest monitoring may enable informed decision-making in forestry and other land uses in a way that would not have been possible ten years ago.

Although it may seem evident that information on forests could contribute to decision-making, it is much less evident that this does happen in practice. This paper opens by discussing: **Where and when does forest monitoring inform problem-solving?** A set of positive case studies covers both public policy and corporate activities in diverse geographical contexts: Viet Nam's forest transition, Cameroon's forest concessions regime, Brazil's efforts to reduce deforestation, and the current mainstreaming of deforestation concerns into corporate activities.

But beyond providing confidence that forest monitoring can, in fact, catalyse progress, positive cases also provide lessons on how decision-makers leverage forest monitoring. Concerning problem-solving dynamics, this paper offers a broad view on activities of the public and private sectors. When investigating types of information, it discusses both the measurement of forest properties in the field (as part of a national forest inventory) and through remote sensing (satellite land monitoring systems), as well as the analysis of resulting data, including through modelling.

The analysis of positive cases leads to a follow-up question: **How can forest monitoring inform decision-making – and what enabling conditions are needed?** The discussion also clarifies that forest monitoring should not in itself be expected to drive change, but should be thought of as a catalytic element facilitating problem-solving – where windows of opportunity are open. Relating to a conceptual discussion, the paper provides information from a country assessment on current science-policy linkages in developing countries.

With this limitation in mind, what made the reported positive cases possible? Although a comprehensive answer is difficult, as there are many factors beyond information that also induce action, the paper investigates **How can forest monitoring systems be structured to inform problem-solving?** To provide an answer, the paper looks into the current suitability of forest monitoring to inform policy-making in developing countries around the world.

Finally, **Conclusions and recommendations** on impactful forest monitoring are directed at governments operating forest monitoring systems, especially in developing countries, at donors and at agencies providing technical assistance.

2. Where and when does forest monitoring inform problem-solving?

Information on forests *can* contribute to decision-making, as demonstrated by four cases in very different contexts.[1] Viet Nam's concerted efforts to achieve a forest transition would not have been possible without forest monitoring. In Cameroon, forest information was instrumental in restructuring the concessions regime in a difficult governance context. Brazil has built several policy instruments from its forest datasets that have helped to dramatically reduce deforestation. New private-sector commitments to sustainability have been motivated by forest monitoring results and use data to underpin decision-making.

2.1 VIET NAM'S FOREST TRANSITION

Viet Nam underwent a forest transition in the early 1990s, as a result of policy efforts to accelerate the agricultural transition, to address rural poverty and to expand a self-sufficient forest industry. After data had shown serious forest decline, the government took on ambitious forest-area targets and launched a new monitoring campaign to track progress. Vast tree plantings were undertaken. Also, the government enacted several partial logging and export bans and used the results of a national forest inventory to tightly control logging.

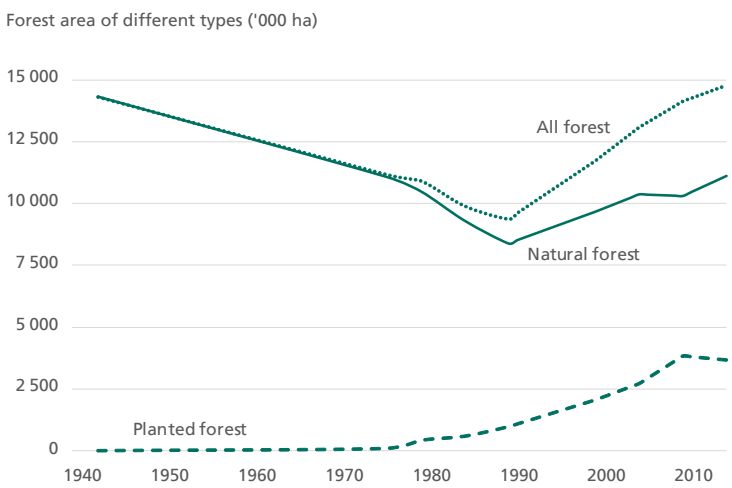
Viet Nam's forest transition of the early 1990s was a net, national-scale shift from deforestation to reforestation (Figure 1).

The forest transition occurred along with dramatic societal changes after Viet Nam adopted its Doi Moi reform policy in 1986 to introduce a decentralized, market-oriented economy. The government reformed land tenure, laying the basis for the agricultural transition, and enacted a range of policies to address rural poverty and to expand a self-sufficient forest industry (McElwee, 2004; Meyfroidt and Lambin, 2008).

The turnaround in the forest and land-use sector came hand-in-hand with new efforts to collect data on forest area, forest quality and changes. Since 1991, Viet Nam has been one of the few developing countries to continually operate a national forest inventory. Its data underpinned target setting and enabled decision-making, notably in setting logging quotas and informing tree-planting campaigns. Moreover, Viet Nam developed a system to monitor forest area, which made it possible to track progress towards ambitious forest-area targets from the Viet Nam Forestry Development Strategy 2006–2020 (Government of Viet Nam, 2007).

[1] More detail on the four example cases in this section will be published separately and is available on request from the authors at FAO. (Neeff and Piazza, 2020; Neeff et al., 2020)

FIGURE 1
Viet Nam's forest transition in the early 1990s



Source: FAO, undated; FAO, 2009.

Logging was greatly reduced through a combination of bans and shrinking quotas (Meyfroidt and Lambin, 2009). The forest monitoring system underpinned these efforts because it was designed to enable tightly controlled logging. The data-collection efforts were developed to mirror the hierarchical system for setting logging quotas and generate information on growing stock and yields – not only at national level but also disaggregated by province, and at a relatively high frequency of five-year intervals. The system has generated estimates of growing stock, yields and growth tables – all the specific data items that classical approaches for sustainable management of timber stocks require (Box 7, page 21).

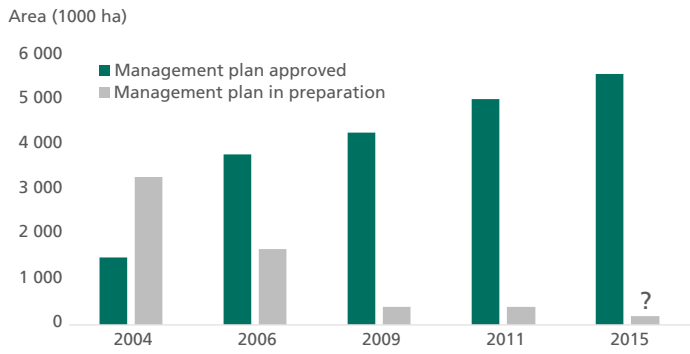
In addition, large-scale tree planting helped to increase forest area. An initial campaign was launched in 1993, and its successor, the Five Million Hectare Reforestation Program, started in 1998. Although Viet Nam collected information on forest area, which helped to track aggregate targets, the national-scale forest monitoring results are not sufficiently granular for a robust evaluation of the tree-planting campaigns themselves. A widely cited evaluation report of the programme concluded with a recommendation to "*arrange [for] the establishment of a performance-based monitoring and evaluation system*" (MARD, 2001). Nonetheless, the campaigns are widely seen as having been instrumental in achieving the forest transition (Meyfroidt and Lambin, 2008).

2.2 CAMEROON'S FOREST CONCESSIONS REGIME

Cameroon took important steps to reform its forest concessions regime in the 1990s and 2000s. A fiscal crisis and the need to enhance government revenues triggered much effort to lay the basis for orderly forest management and clamp down on corruption. Upgraded forest management planning required concession-level inventories to be collected. Independent forest monitoring became a basis for management oversight. Forest policy progress could be transparently evaluated based on independent forest monitoring results.

During the 1990s and 2000s, Cameroon introduced a structured approach to managing the country's forest resources. Although admittedly from a rather low base, those years saw forest governance improve markedly. Irregular logging was reduced, while the revenues from allocating forest concessions have multiplied (Topa *et al.*, 2009). Especially remarkable is how the area with approved forest management plans has increased (Figure 2). (In Figure 2, the 2015 area with management plan in preparation is rather small, but the exact amount is not known.)

FIGURE 2
Forest units under forest management plans in Cameroon, 2004–2015



Source: FAO and CIFOR, 2016; Mertens *et al.*, 2012.

A reform milestone was a new forest law that Cameroon adopted in 1994 under pressure from international donors (Ekoko, 2000). It created a regime for large-scale forest concessions with revamped title allocation processes, as well as forest management planning and enforcement. From 1998, independent observers took a role in the forest concessions regime and often relied on forest monitoring data (Topa *et al.*, 2009).

One of the ground-breaking novelties in the 1994 forestry law was a bidding process for the allocation of forest concessions. This has been credited with increasing revenues from allocation. Independent observers made an important contribution to the bidding, helping to ensure its credibility (Cerutti and Tacconi, 2006).

Where bids are successful, concessionaires need to develop forest management plans. Management plans separate production areas from set-asides and define fundamental silvicultural parameters to ensure a continuous supply of timber. From a technical perspective, the key parameters to be defined are the boundaries of areas for annual timber harvests and the minimum cutting diameter of trees, which can only be reliably established through a management inventory. Moreover, at the time of harvesting, much more detailed harvesting inventories are conducted (Box 10, page 23).

For ongoing monitoring of compliance with forest management plans, Cameroon's Ministry of Forests and Environment maintains forest control brigades that routinely carry out spot-check missions. As independent observers, teams by international NGOs (initially Global Witness and later Resource Extraction Monitoring) have participated in hundreds of such missions (Topa *et al.*, 2009). They have extensively used information available in Cameroon's *Interactive Forest Atlas* (Mertens *et al.*, 2012), itself an independent monitoring product. For example, maps of logging permits and locations of roads can help to pinpoint illegal logging. Having such analytical products available has improved the ability to detect illegal logging activities – and therefore to enforce laws (Cheung *et al.*, 2014).

To evaluate progress in forest reform (as well as underpinning enforcement), the *Interactive Forest Atlas* regularly makes available map-based data with support from the World Resources Institute. Rather than generating new data, the atlas mainly makes existing data publicly available in an easily accessible format. For example, it brings together information on forest allocation, certification status, mining permits, volume of timber logged in concession areas, and location and capacity of sawmills. Not all of these datasets had been made publicly available before (Cheung *et al.*, 2014) and available data were scattered and their formats incompatible.

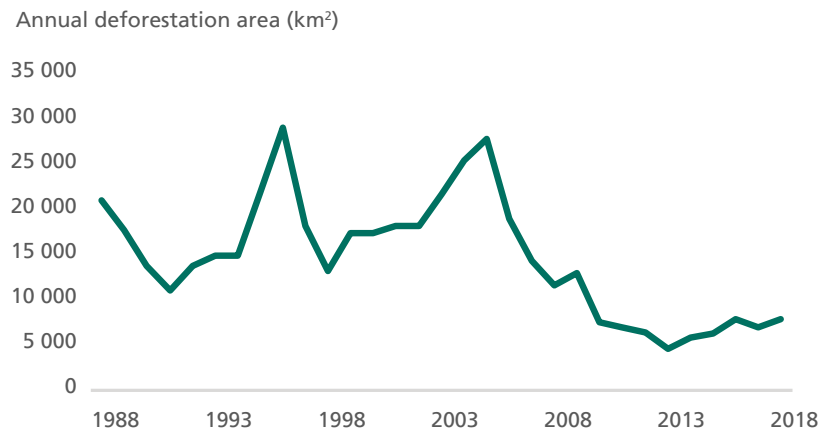
2.3 BRAZIL'S EFFORTS TO REDUCE DEFORESTATION

New fiscal and regulatory instruments and improved law enforcement helped Brazil to cut deforestation by over two-thirds between 2005 and 2014. Forest monitoring results were not only instrumental in creating the necessary political momentum, but became an integral part of several policy instruments – as well as private-sector action. Moreover, forest monitoring allowed Brazil and its resource partners to keep track of progress, and to operate the results-based Amazon Fund.

During 2005–2014, Brazil successfully lowered deforestation rates (Figure 3).

There are multiple reasons for Brazil's success in reducing deforestation in the Amazon (Moutinho, Guerra and Azevedo-Ramos, 2016). Next to changing global market patterns, the government put in place fiscal and regulatory incentives, stepped up law enforcement, and expanded protected areas. There was supply-chain action to address deforestation. Brazil attracted international funding for improved forest governance and reduced deforestation.

FIGURE 3
Reduction of deforestation in Brazil's Amazon, 1988–2018



Source: INPE, undated.

Forest monitoring was critical to some of these efforts. At the National Institute for Space Research (INPE), the Programme for the Calculation of Deforestation in the Amazon (PRODES) (INPE, undated) collects and annually updates deforestation maps and statistics and makes these publicly available through an easily accessed geoportal, TerraBrasilis. [2] In parallel, the Rural Environmental Registry (CAR) enabled compliance monitoring with minimum forest cover requirements for individual properties ("legal reserve") through mandatory, digital, self-declaratory registration of landowners (Souza Costa Neves and Whately, 2016).

Together, PRODES and CAR became the basis for several fiscal and regulatory mechanisms. In 2008, access to agricultural soft loans was made contingent on registration with the CAR and compliance with legal reserve requirements. A public list of irregular rural estates was compiled that were consequently embargoed. Also, from 2008 onwards municipalities with the highest levels of deforestation according to PRODES were included in a list of priority municipalities for enforcement action, and had access to funding restricted. Staying off these lists became important to landowners and municipal administrations alike (Souza Costa Neves and Whately, 2016).

The PRODES data and the CAR were also integral to the private sector's efforts to address deforestation. The much-acclaimed voluntary moratoria, most prominently for soy as of 2006 and beef as of 2009, prompted some agribusinesses to set up supply-chain monitoring systems of deforestation risk using PRODES deforestation maps, which enabled checks to be made when their supplying producers had converted land. The CAR became evidence for due diligence of agribusinesses because it revealed producers' compliance with legal reserve requirements, which could create legal liability to agribusinesses (Azevedo *et al.*, 2017; Azevedo, Stabile and Reis, 2015; Gibbs *et al.*, 2015).

[2] http://terrabrasilis.dpi.inpe.br/en/home-page/

Brazil also stepped up law enforcement to reduce illegal land conversion. The CAR played a role here, as it provided a forest cover record of individual properties (Azevedo *et al.*, 2017; Azevedo, Stabile and Reis, 2015). In addition, since 2004 the Real-Time System for Detection of Deforestation (DETER) has provided satellite-based alerts on deforestation hotspots. Its near real-time alerts allow the identification, close monitoring and therefore rapid action on illegal deforestation events. The ability to act quickly is significant, because Brazil's legal setup is such that offenders in illegal forest clearings can be punished more easily when caught red-handed (Assunção, Gandour and Rocha, 2017).

Finally, the robust forest monitoring system allowed Brazil to demonstrate success in reducing deforestation during 2005–2014. This was essential not only to evaluate policy action, but also to attract large amounts of international REDD+ funding, especially results-based finance under the Amazon Fund since 2008 and more recently from the Green Climate Fund.

2.4 MAINSTREAMING DEFORESTATION CONCERNS INTO CORPORATE ACTIVITIES

The past decade has seen progressive mainstreaming of deforestation concerns into corporate decision-making. Alarming data on global forest area trends have stoked much of the momentum, providing evidence for vigorous NGO campaigning. In response, procurement by consumer goods companies, plantation management by agribusinesses and lending decisions by financial firms are being reoriented to address deforestation risks, all drawing on forest monitoring results for operational decision-making.

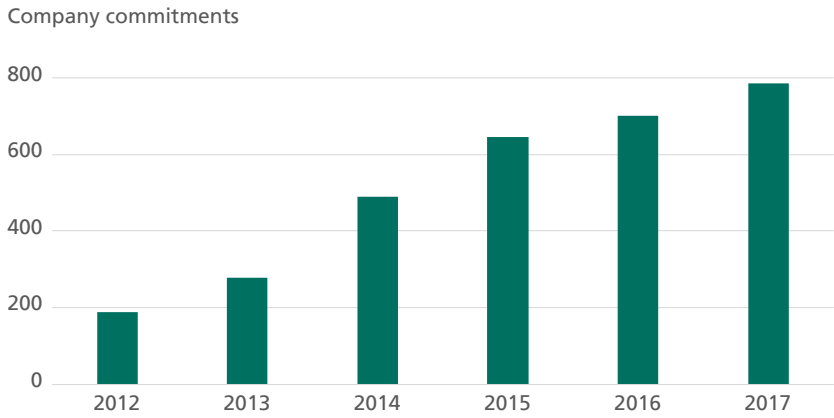
Over the past decade, hundreds of companies that take part in global agricultural supply chains — particularly for palm oil, soy, beef, pulp and paper, cocoa and rubber — have made commitments to reduce or avoid deforestation related to their activities (Figure 4). These commitments include consumer goods companies' sourcing of such raw materials, lending by financial firms and production by agribusinesses.

International datasets on forest area trends were instrumental in creating the global momentum around deforestation concerns. Both WWF's influential call for "zero net deforestation" from 2008 and the 2013 New York Declaration on Forests start with a reference to forest-loss estimates from FAO's Global Forest Resources Assessments (FAO, 2015; United Nations, 2015a; WWF, 2008).

To nudge firms to update corporate policies, NGOs built up public pressure through campaigns. As a fact base, such NGO campaigning typically draws on detailed research reports. For example, one of Greenpeace's campaigns, *Eating up the Amazon*, which contributed to momentum towards the trailblazing Brazilian Soy Moratorium, starts by discussing "*destruction by numbers – the key facts*". The report uses publicly available official data: forest-loss statistics from Brazil's PRODES, in combination with socio-economic data from other sources (Greenpeace, 2006).

International datasets are also key to continual monitoring of the state of global forests, for example, the regular assessments of the goals stated in the New York Declaration on

FIGURE 4
Growth of supply-chain commitments identified in a broad review of corporate policies, 2012–2017



Source: based on data from Forest Trends, 2017.

Forests (United Nations, 2015a), as well as the closely related Sustainable Development Goal 15 – Life on Land.[3] FAO's Global Forest Resources Assessments and the World Resources Institute's Global Forest Watch also enable aggregate impact evaluation that looks beyond anecdotal evidence on supply-chain action.

Corporate policies translate the zero-deforestation commitment into actionable guidance by referring to hard criteria, such as the product's origin and the presence of certification (FAO, 2017b). Forest monitoring data partially underpin such criteria, especially regarding the origin of commodities and associated deforestation risks. The high-risk jurisdictions listed in corporate guidelines are largely those where international datasets show high deforestation (Box 8, page 21).

But, ultimately, any push through global supply chains to reduce deforestation will need to be implemented by producers and agribusinesses. Producers have begun to mainstream zero-deforestation concerns when undertaking site selection and developing management plans. Both national and local forest monitoring data are required for this – similar to those used in forest management planning (Box 10, page 23). Agribusinesses have taken to collecting information on producers and their deforestation behaviour using a variety of datasets. In these processes, governments with effective forest monitoring will be well placed to evaluate corporate action.

[3] SDG 15 – Life on Land: Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss.

Table 1: Data and analysis used for problem-solving in the four example cases

	Problem recognition	Proposal and choice of solutions	Putting solutions into effect	Monitoring results
Viet Nam's forest transition	When forest data showed dramatic forest decline, tree planting campaigns were launched and logging reduced	The 43 percent forest-area target reflected historical records	National forest inventory informed the setting of logging quotas. Forest area monitoring helped to identify areas for planting	Forest area monitoring enabled tracking forest health, a quantitative forest-area target and demonstrated the forest transition
Cameroon's forest concessions regime			The *Interactive Forest Atlas* helped to guide spot-checks of forest control brigades. Management plans used concession-level inventories	The *Interactive Forest Atlas* compiled diverse information to evaluate progress in forest reform
Brazil's efforts to reduce deforestation	Policy-making became possible when PRODES data showed crisis levels of deforestation	PRODES and CAR underlaid a list of "priority municipalities", the most critical municipalities for action	DETER alerts supported law enforcement Agribusinesses used CAR for due diligence Monitoring results supported the identification of protected areas	PRODES data on deforestation trends helped to evaluate policy progress PRODES data demonstrated deforestation reduction for the Amazon Fund
Mainstreaming deforestation concerns into corporate activities	NGO campaigning drew on forest-loss statistics to call public attention to corporate activities and deforestation	Evidence on the predominant drivers of deforestation catalysed broad-based agreement on the role of agricultural commodity production Targets were set in terms of "zero-deforestation" slogans	Sourcing guidelines used deforestation data for rating country risk Supply-chain management relied on Global Forest Watch data Agribusinesses used detailed inventories for management planning	Progress monitoring against targets, e.g. in New York Declaration on Forests, used global datasets, notably FAO's Global Forest Resources Assessment

2.5 WHAT TYPE OF INFORMATION FOR WHAT PURPOSE?

Forest monitoring contributed to problem-solving in all four cases. But there are different types of problems to be solved and different types of data and analysis being leveraged (Table 1).

Problem recognition. To enable stakeholders' problem recognition and to set the public policy agenda, evidence and science-based messaging must be clear and intuitive. For example, large-scale forest-area change datasets played a key role in campaigning to improve sustainability of agricultural commodity production. Picking out the deforestation impacts from among the many other possible sustainability dimensions enabled a strong narrative that developed much traction – especially when forest monitoring demonstrated crisis levels. Large-scale intuitive analysis, however, can also result in major simplifications, making them insufficient as a basis for judgement of responsible business practices or complex environmental and social impacts, for example.

Proposal and choice of solutions. Identifying solutions and formulating policies and targets accordingly requires forest data and analysis with more thematic detail. For example, Brazil's PRODES was used to identify municipalities with the most rapid deforestation, which became a priority for law enforcement action and fiscal measures. Where evidence with rich thematic detail can help to broker agreements between actors about the causes of observed problems, significant momentum can result. For example, growing evidence on the predominant drivers of deforestation catalysed broad-based consensus on the impacts of agricultural commodity production, which then became the target for environmental campaigning around the world.

Putting solutions into effect. Operational decision-making based on information with the same spatial, temporal and thematic detail is necessary when implementing solutions. The examples above illustrate that managing landholdings, whether running forestry concessions in Cameroon, operating a protected area in Brazil, or producing agricultural commodities anywhere, demands locally specific datasets, potentially collected through one-time, focused data-collection efforts. In the same vein, Viet Nam structured its forest inventory to generate information matching its hierarchical administrative setup, which could thus effectively support setting logging quotas.

Monitoring results. Because policy targets also often refer to entire countries, results monitoring typically draws on information at larger aggregate scales and over longer time series. Assessing progress against targets or a baseline is only possible if measurable targets are defined and a coherent time series provides data for analysing change. Where datasets are widely perceived as reliable, the analysis built from them will inherit some of this credibility. FAO's Global Forest Resources Assessment is a good example of a reputable effort to collect information on forests, which has become the preferred source to take stock of global-scale forest policy progress.

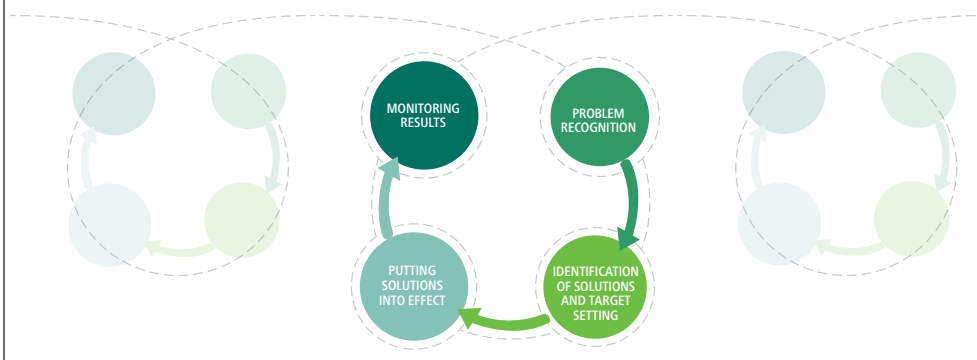
Flexibly built datasets can contribute to several problem-solving phases. The above examples also describe ways in which various robust monitoring systems are being put to use to identify problems, to set targets, to underpin implementation, and to monitor results. There is great value in maintaining high-quality and versatile datasets on the staple parameters of forest inventories: forest area and forest structure and their changes over time, with due spatial and temporal detail.

3. How can forest monitoring inform problem-solving – and what enabling conditions are needed?

Chapter 2 presented a diverse set of cases where forest information has been an important ingredient for change. But what dynamics are at play when evidence contributes to effective decision-making? Understanding such dynamics could lead to strategies for designing development interventions and forest monitoring.

Although the examples on contributions of forest monitoring and the evidence they generate are diverse, thinking in terms of an applied problem-solving cycle with four stages may provide some structure (Figure 5). Political science uses such cyclical models to understand public policy-making (Howlett, Ramesh and Perl, 2009). They have also been found to be well-suited to facilitate an understanding of policy-making for forests and land use (FAO, 2006, 2010) and mitigation issues (Andersson, Evans and Richards, 2009). This section discusses the four stages of the problem-solving cycle.[4]

FIGURE 5
Applied problem-solving cycle



Source: modified from Howlett, Ramesh and Perl, 2009.

[4] This model gives structure and detail to the assessment of how countries link forest monitoring to policy-making. In political science the concept is also contested because it portrays policy-making as a somewhat rational problem-solving process. For example, mapping the actual practice of policy-making in Indonesia uncovered a rather more disorganized reality (Blomkamp *et al.*, 2017). Despite such limitations, the model was useful in this paper's assessment of linkages between forest monitoring and policy-making.

For better information on forests to lead to better decisions and better policy-making, enabling conditions are needed. Information is but one out of many factors at play in problem-solving. To explore how information contributes to decision-making, this paper has benefited from a compilation of case studies, especially on public policy, a broad literature review and interviews with a wide range of forest-sector experts and development professionals. Not all were positive in their views of forest governance, and some looked at forest information more as an arena for exerting power, rather than for reaching optimal decisions (Box 1). While the following discussion of the problem-solving cycle highlights the importance of information, it also highlights that political interests may get in the way of science-based policy-making.

Box 1: A view by two independent researchers on "the politics of statistics"

"The degree of commitment [to improving the statistical base] is influenced by many factors. One important consideration in this context is that knowledge is power. The authorities in many countries may not want the truth to be known. They may have vested interests or things to hide or they may want to make claims that are not supported by the statistics. For example:

- In some countries with high deforestation rates the authorities may not want to publish the real figures in order to avoid criticism.
- Conversely, in other countries they may want to show as high a deforestation rate as possible, in order to obtain increased support for forestry.
- They may not always want to bring results of plantations in the open, because there are many failures that they want to hide. Also, subventions to plantations may have been misused.
- There may be much illegal felling, often with the connivance of the forest authorities, and therefore there is only limited interest in finding out the true actual rate of use of the forests.
- Planning based on information usually leads to changes, but there are often many groups that benefit from the existing system."

Source: quote from Janz and Persson, 2002

Box 2: How a forest resource assessment helped to set the agenda for reforming Armenia's forest policy

By the early 1990s, Armenia's forest inventory database still relied on stand-based forest inventories from the time of the former Soviet Union. Results were increasingly outdated, prone to systematic errors, and thus unsuitable for informing decision-making (Sayadyan and Moreno-Sanchez, 2006). The need for reliable information on wood volumes and increments to enable the management of timber stocks became obvious during the energy crisis, when uncontrolled fuelwood cutting led to severe overcutting and forest degradation. In 1998–1999, a forest resource assessment was carried out for a part of the country to obtain data that could support decision-making (Thuresson, 2002).

Newly obtained growth estimates were much larger than previous official figures (2.86 versus 1.4 m^3 per hectare per year), while stump measurements indicated that cuttings far exceeded the official maximum allowable cut (600 000 versus 100 000 m^3 per year) (based on Thuresson, 2002).

Despite some initial reluctance to accept the large differences between the previous official figures and the new results (Sayadyan and Moreno-Sanchez, 2006), the new evidence helped to inform the discourse among Armenia's foresters. During a seminar held for this purpose, participants concluded that illegal and often unsustainable cuttings were a problem to be addressed (Thuresson, 2002). Such thinking contributed to the discussion surrounding work towards a new forest code that the country adopted in 2005 (Burns *et al.*, 2017).

3.1 PROBLEM RECOGNITION

Data and analysis can enable problem recognition, thereby helping to engage actors and setting an agenda for change. While some problems grow until they are evident, in other cases detailed analysis can help to make them visible to decision-makers. For example, logging moratoria in Viet Nam became possible after senior politicians saw degraded forest first-hand in the field (Section 2.1). In Armenia, conversely, a national-scale inventory first provided foresters with reliable evidence of irregular activities (Box 2). In Brazil, a window of opportunity for policy-making opened when forest monitoring showed increasing levels of deforestation (Section 2.3). FAO's Global Forest Resources Assessment provided the necessary backdrop to place deforestation concerns high on the international environmental agenda (Box 3).

However, to place a problem prominently on the agenda of decision-makers in such a way that it triggers action, more is required than data and analysis. There also needs to be a clear motivation to push for change, as well as possible solutions. Analysts of public policy think of windows of opportunity for change when a problem has been recognized,

Box 3: How FAO's Global Forest Resources Assessment helped to set the agenda for a concerted response to deforestation concerns

The results of the first Global Forest Resources Assessment were published in 1948 and five-yearly or ten-yearly updates have been produced to the present day. Since the Global Forest Resources Assessment 2005, the reporting is based on official statistics that FAO compiles from member governments through a global network of national correspondents. To guarantee consistency, a common reporting template is used and data are reviewed and quality checked by FAO.

Although the Global Forest Resources Assessment has had innumerable other applications, its contribution to a globally concerted response to deforestation illustrates well how forest monitoring can inform agenda-setting and stock-taking of policy progress. Its results, complemented by other sources, are part of the background for important policy milestones that positioned forests and deforestation on the global development agenda. The 2008 call for "zero net deforestation by 2020" by the World Wildlife Fund (WWF) and the 2014 New York Declaration on Forests both started out with a reference to forest-loss estimates from Global Forest Resources Assessment (United Nations, 2015a; WWF, 2008).

The Global Forest Resources Assessment enables aggregate impact evaluation and progress assessment. The regular assessments of the Sustainable Development Goals (SDGs) (United Nations, 2015b) draws on the Global Forest Resources Assessment, notably the goals stated in SDG 15 (Life on Land), including Indicators 15.1.1 (forest area) and 15.2.1 (sustainable forest management).

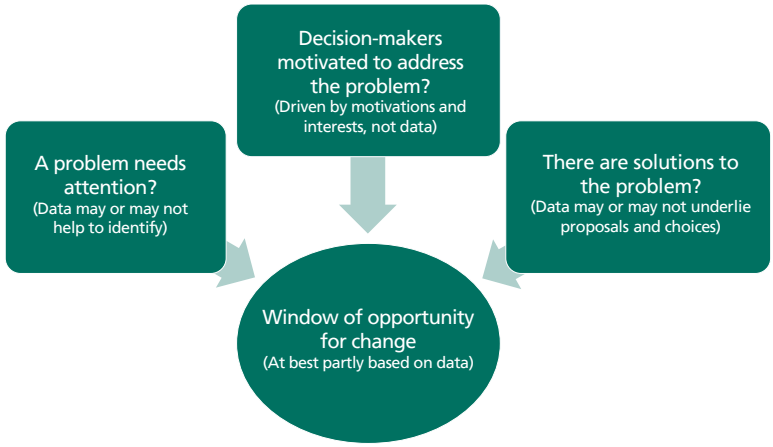
Going forward, data collection, analysis and presentation will further evolve to enhance the potential impact that the Global Forest Resources Assessment can generate. For example, FAO will introduce annual or biennial reporting for key variables, such as forest area and its changes, which is expected to make results more relevant for fast-paced policy processes. Also, the reporting tools and database interface will be improved to reduce the reporting burden, improve data quality and enhance accessibility to all users. With such commitment to continual improvement, while protecting time-series consistency, the Global Forest Resources Assessment is expected to continue to be critical for taking stock of global-scale forest policy progress.

when decision-makers are motivated to address it, and when solutions are on the table (Figure 6, page 17). A plethora of problems in the forest sector go unchecked, often for long time frames – and the availability of data and analysis is not always the bottleneck.

3.2 IDENTIFICATION OF SOLUTIONS AND TARGET SETTING

Once a problem is recognized, possible solutions can be identified and targets can be set. Forest monitoring can help to provide the analytical backdrop for building agreement among diverse stakeholders. Forest monitoring can also be the basis for identifying entry points for action as well as for setting quantitative targets.

FIGURE 6
Ingredients of windows of opportunity for (policy) change – and the possible contribution of data and analysis



Source: based on thinking included in Howlett, Ramesh and Perl, 2009.

Devising effective action requires an understanding of the root causes of observed problems, and data can support the necessary analysis. Efforts towards cross-sector collaboration typically require a level of agreement between stakeholders on diagnosed policy issues and options to address them, which could then be the basis for action. Forest monitoring results can be instrumental in building a shared understanding (Neeff, von Lüpke and Hovani, 2018). For example, Turkey used a combination of biophysical forest inventory and household survey to investigate rural livelihoods in order to explore possible solutions for reducing rural out-migration (Box 4).

Subsequently, forest information can identify entry points for policy action. For example, Canada leverages a sophisticated forest carbon budget model to identify and assess mitigation options in forestry (Box 5). Similarly, forest products statistics guided development of sustainable land and forest management practices in Uganda (Box 6).

To guide action, high-level goals are often set quantitatively, creating a demand for data to track progress towards goals. For example, many consumer goods companies concerned about responsible supply chains set a target of "zero deforestation" by 2020 (Section 2.4). Similarly, much of Viet Nam's forest policy has been driven by a target to achieve 43 percent forest cover by 2010 – i.e. a return to the 1943 post-colonial level, according to historical records (Section 2.1). Such goal-setting requires monitoring systems for evaluating actual development against the target (Section 3.4, page 22).

In spite of such encouraging examples of science-based policy-making, political

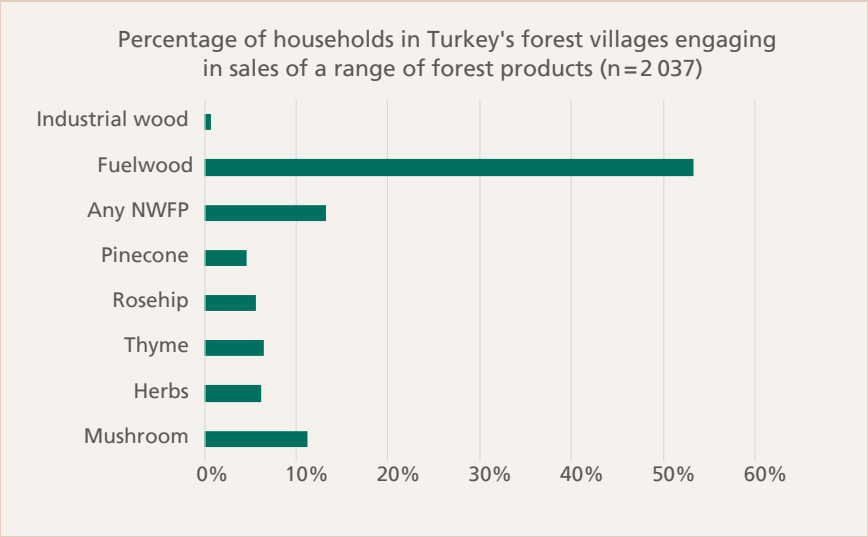
Box 4: Using the results of Turkey's multipurpose forest inventory to set rural development priorities

A large part of Turkey's rural population lives in forest villages, where income generation opportunities are limited, prompting millions to move to urban areas. To better understand the socio-economic conditions of forest villagers, in 2016, the General Directorate of Forestry carried out a household survey as part of a multipurpose national forest inventory.

The results highlighted the great importance of a diverse range of non-wood forest products (NWFPs) for the poorest rural households (Figure 7). Only a small share of NWFPs undergoes any form of value-added processing before export, which revealed that value chains may be an underexploited entry point for enhancing the welfare of forest villagers.

FIGURE 7

Evidence on the importance of non-wood forest products for Turkey's rural livelihoods



The new evidence attracted much attention. A Forest Policy Note to Turkey's General Directorate of Forestry recommended a concerted approach for data collection, and prioritization of investment and legal reforms to promote NWFPs. A new department was established in the General Directorate of Forestry that took charge of matters related to NWFPs to maximize the socio-economic condition of the forest villagers. The new department was entrusted with overseeing the inventory, planning, production and marketing of a great variety of NWFPs.

Source: Republic of Turkey, 2016; World Bank, 2017.

Box 5: Canada's analysis of forestry mitigation options for public-sector investment planning

In late 2016, Canada's First Ministers adopted the Pan-Canadian Framework on Clean Growth and Climate Change, an action plan to achieve its target of reducing greenhouse gas emissions by 30 percent below 2005 levels by 2030 (Government of Canada, 2016). Among other factors, the action plan identifies priority interventions for mitigating climate change.

Identifying priority mitigation actions in the forest sector required quantitative analysis of options and scenarios. The Canadian Forest Sector undertook supporting analytical work using a scalable carbon budget model (CBM-CFS3) that is also used to calculate the national greenhouse gas inventory (Kurz *et al.*, 2018). The model connects forest properties and management parameters to greenhouse gas results, enabling scenario calculations for modified input parameters (for example harvesting levels).

A set of forest-sector mitigation options was analysed in detail to identify optimal strategies, both with a view to greenhouse gas results (Smyth *et al.*, 2014) and their economic implications (Xu *et al.*, 2018). The analysis was taken up when formulating the Pan-Canadian Framework on Clean Growth and Climate Change

Box 6: Forest product data to guide development of sustainable land and forest management practices in Uganda

A national charcoal survey was commissioned in Uganda in 2015 to build a baseline on charcoal production, supply and usage. Data from a Global Environment Facility (GEF)-funded project was intended to aid informed decision-making by authorities involved in the management of the charcoal industry and to heighten public awareness of the charcoal value chain and trade. The data were also intended to feed into national statistics on forest products.

A wide variety of information on charcoal consumption was collected using various methods, including household and institutional surveys. These surveys revealed trends surrounding charcoal consumption and also indicated that the charcoal sector was poorly regulated and unsustainable.

This analysis provided the basis for a follow-up project to address the challenges of both unsustainable utilization of biomass for charcoal and poor land management practices. The data-driven project improved the capacity of stakeholders in targeted districts to establish and manage dedicated woodlots leading to accumulated yields of 368 770 million tonnes of renewable biomass by year five, as well as 50 000 hectares of forest land across four pilot districts brought under improved multifunctional forest management, leading to enhanced carbon sequestration of 2 100 000 tonnes of carbon dioxide equivalent.

Source: based on MEMD, 2016; Republic of Uganda, 2005.

preference plays a role in setting targets or proposing a course of action. Although targets may be quantitative and time bound, the forest monitoring system used for tracking the targets cannot always be assumed entirely free from political interference (Box 1, page 14).

3.3 PUTTING SOLUTIONS INTO EFFECT

Once decisions have been taken and targets have been set, solutions need to be implemented. Governments operate policy instruments, such as fiscal or regulatory actions, which forest monitoring results can underpin. Similarly, forest monitoring can support decision-making in government programmes and corporate operations.

Entire policy instruments can be built around available datasets and create incentives or disincentives that lead to change. For example, Brazil's action towards reducing deforestation uses the PRODES deforestation statistics in multiple ways; municipalities with high rates of deforestation are prioritized so that they become targets for law enforcement crackdown (Section 2.3). The resulting incentive to remove the municipalities from the list is very real. India's ecological fiscal transfers draw on subnational forest-area data to allocate fiscal and regulatory incentives (Box 16, page 35). Firms involved in supply chains for forest risk commodities see themselves as targets of NGO campaigning, incentivizing a move towards responsible sourcing (Section 2.4). There is ample opportunity in public policy-making and corporate activities to solve problems using forest monitoring results.

Data and analysis can be the basis for operational decision-making in government programmes. For example, Viet Nam's low logging quotas in natural forests over recent decades reflect a push to allow forests to recover – resulting from standard, data-driven approaches to setting annual allowable cuts (Section 2.1 and Box 7).

Forest monitoring results also support private-sector action, both on company operations and jurisdictional-scale information. For example, while forest management plans are based on detailed concession-level inventories, the planning may also use species-level incremental information from national forest inventories or be cross-checked against it (Box 10, page 23). For example, while consumer goods companies sourcing agricultural commodities will naturally focus attention on their own supply chain, some procurement decisions may also be based on country of origin and its deforestation risk rating, relating to national-scale monitoring results (Box 8).

However, putting solutions into effect will not always be guided by the science base; in some cases, policy instruments and government programmes are guided more by political preference than by data and analysis. For example, much of Cameroon's forest reforms during the 1990s and early 2000s were designed to introduce transparency into the concessions regime as a way to reduce corruption (Section 2.2). Or, as Armenia's foresters discovered in the late 1990s, harvesting levels had little to do with information on growth or ongoing activity levels, indicating a need for legal reform (Box 2, page 15).

Box 7: Data and analysis for setting logging quotas and sustainably managing timber stocks

Managing timber stocks and sustainable yields requires balancing annual allowable cuts with forest increment. To achieve this objective, there are several classical approaches. The choice of approach for setting annual allowable cuts depends, among other factors, on the data available.

Even relatively simple methods will require a demanding set of forest inventory results as input, for example:

$$\textit{Annual allowable cut} = \frac{\textit{Forest net increment} + \textit{Net increment of a "normal forest"}}{2} + \frac{\textit{Forest volume} - \textit{Volume of a "normal forest"}}{\textit{Adjustment period}}$$

Forest inventories can deliver the necessary information for setting logging quotas accordingly. Inventories commonly deliver volume and increment information for the forest units (e.g. for provinces or even for the entire forest estate) that require the determination of annual allowable cuts, and inventories also deliver the growth tables, which reflect increment and volume of an idealized forest in standard conditions, the so-called "normal forest".

Source: based on FAO, 1998.

Box 8: Evidence-guided identification of high-risk origin of wood products in corporate policies

Corporate policies of consumer goods companies, retailers and banks increasingly aim to exclude deforestation risk, for example by checking on the origin of wood products or on certification. Where products originate in regions of high risk, corporate due diligence will be especially stringent. The Consumer Goods Forum guidelines for sourcing fibre include a list of high-priority countries where the low risk of controversial sources contributing to deforestation should be verified or at least monitored, such as through user certification. The countries listed as high priority are the following: Indonesia, Malaysia, China, Thailand, Colombia, Myanmar, Viet Nam, Papua New Guinea, Cambodia, Democratic Republic of the Congo, Cameroon and Ghana. The underlying risk ratings are based on a range of variables related to timber legality – as well as to forest monitoring results of deforestation trends.

Source: based on FAO, 2017b.

3.4 MONITORING RESULTS

Monitoring the results of policy implementation can support the evaluation of government efforts, provide accountability and be a basis for learning. It can also reduce the risk of ill-informed, ineffective or wasteful action. By the nature of the monitoring task, evidence is essential.

Because of this, in some cases monitoring efforts may be specifically set up for tracking the effects of policy-making. Germany, for example, operates a system for monitoring forest conditions that provides a backdrop for policy-making on air pollution. This system was put in place only once efforts to reduce air pollution became high priority to policy-makers in the early 1980s (Box 18, page 37).

The evaluation of forest-related policies and targets requires monitoring results. For example, REDD+ programmes devote much attention to tracking results. Countries implement a REDD+ strategy, which is then evaluated by a national forest monitoring system, quantifying REDD+ results through comparison with a forest reference (emission) level (Box 9).

Other than such impact evaluation, forest monitoring can also support accountability when using its results to check for implementation of plans. The case of Cameroon's concessions regime explains how data are being used in the zoning of land, developing forest management plans, planning cutting interventions – and checking on compliance with the approved plan (Box 10 and Section 2.2).

However, policy-making is not universally underpinned by strong monitoring and evaluation efforts. It is not unusual to find cases where policy-makers are reluctant to offer full transparency. When discussing the politics surrounding statistics and monitoring, the Center for International Forestry Research (CIFOR) has pointed to vested interests and the concealment of facts, or the pronouncement of claims that are

Box 9: Forest monitoring results for setting targets in national REDD+ programmes

Developing countries voluntarily work to submit forest reference levels and REDD+ results reports to the United Nations Framework Convention on Climate Change (UNFCCC). Uptake has been almost universal: as of early 2020, 45 countries have submitted reference levels and 10 countries have reported REDD+ results to the UNFCCC. Reported results total more than 8 billion tonnes of carbon dioxide equivalent.

Countries' forest monitoring capacities have developed markedly to enable tracking REDD+ results. Many countries have benefited from capacity-development support for their forest monitoring systems from technical agencies such as FAO. A recent scorecard-based progress assessment for 16 countries indicated that despite starting at a rather low base around 2008, in 2018 countries had established significant forest monitoring capacities.

Source: FAO, 2018a, 2019.

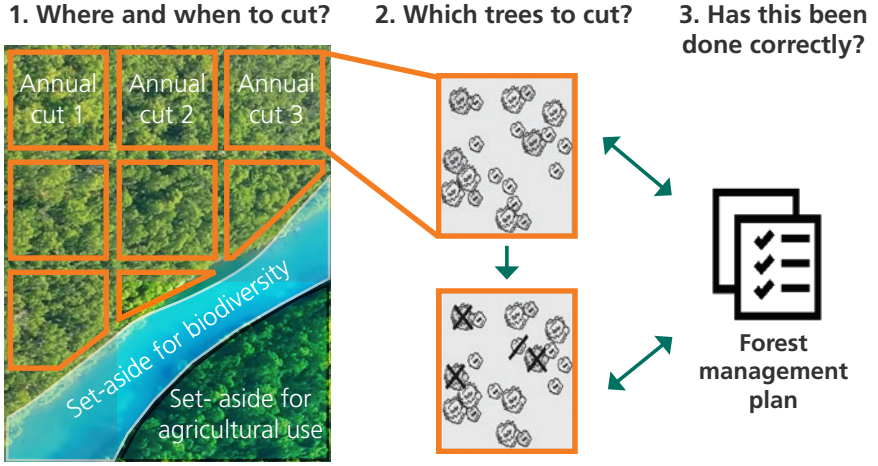
Box 10: Data and analysis in Cameroon's forest concessions regime

Forest monitoring results play a key role in concessions regimes around the world, and Cameroon's forest sector is no exception.

1. A production forest management plan begins with topographical, biological and socio-economic surveys. The surveys guide the identification of set-asides for biodiversity, such as along rivers, and for agroforestry where farmers continue cropping. The remaining forest production series is divided into annual cuts. A forest management inventory covers 0.5–1 percent of commercial trees to allow recovery to be modelled during the 30-year period that a forest is left to recover after a logging intervention.
2. Ahead of the annual cut, companies conduct a harvesting inventory, completing tree-by-tree measurement of all commercial trees. Selective harvesting then involves felling only a few trees per hectare and making sure that enough trees of all commercial species remain for those species to regenerate to a target diameter and maintain long-term presence in the ecosystem.
3. Forest control brigades regularly visit all concessions to conduct spot checks. Checks focus on compliance with forest management plans, especially regarding the boundaries of areas for annual timber harvests and the minimum cutting diameter of trees (Figure 8).

FIGURE 8

Forest management inventory, harvesting inventory and information for management oversight in Cameroon's concessions regime



Source: based on interviews.

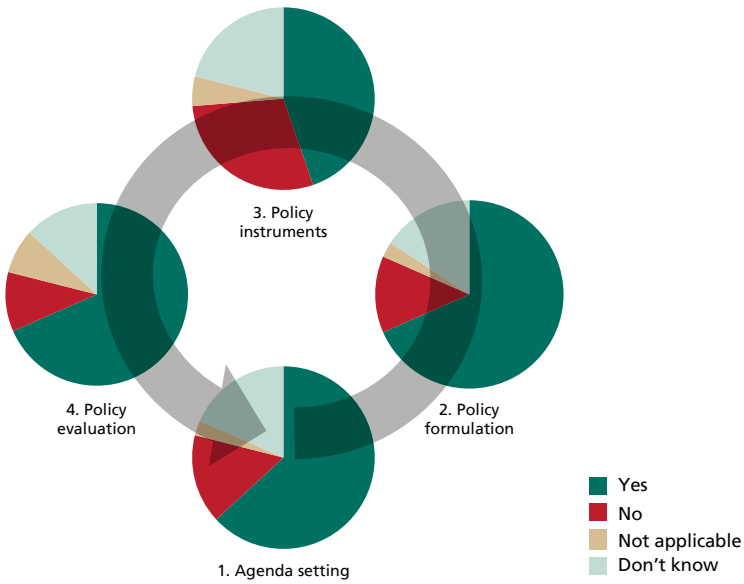
not fully supported by a science base (Box 1, page 14). For example, while Viet Nam's tree-planting efforts have been acclaimed as instrumental in achieving forest transition and have consumed large amounts of resources, there is still scope to improve the data for evaluating these tree-planting campaigns (Section 2.1). Significantly, an independent forest monitor was installed in Cameroon to collect information for, among other factors, a credible evaluation of forest policy-making (Section 2.2).

3.5 CURRENT USE OF FOREST MONITORING TO INFORM POLICY-MAKING

An indicator-based assessment of a representative set of developing countries was undertaken in early 2019 in order to understand the status quo of linkages between forest monitoring and policy-making.

Information was collected on 38 countries using FAO's wide network of in-country technical staff as well as government counterparts involved in international reporting (Figure 9). Assessment methods are described in detail in a separate publication, available from FAO on request (Neeff and Piazza, 2020). Since the assessment aimed chiefly at understanding the contribution of forest monitoring to public policy-making, a particular case of the applied problem-solving cycle (Figure 5, page 13) was used as a reference. Such a policy-making cycle begins, for a policy issue, when it attracts the attention of decision-makers, which can lead up to defining solutions through formulating policy

FIGURE 9
Current use of forest monitoring information in policy-making, according to an assessment of 38 countries



instruments, and implementing these solutions. The cycle concludes with an evaluation of action undertaken, potentially providing the basis for improved policy-making.

In most countries, forest monitoring is already instrumental in setting the agenda of decision-makers, defining solutions and evaluating outcomes. However, evidence could still be better leveraged in policy implementation, such as by guiding decision-making in government programmes or by underpinning fiscal incentive schemes.

In more than half of the 38 countries, forest monitoring contributes to **agenda setting** and **formulating policy instruments**. Examples provided include the establishment of import/export regulations and logging moratoria, discussions surrounding impacts of mining concessions, and efforts to define forest-sector targets. The contribution of forest monitoring results to country strategies on REDD+ and climate change was most frequently referred to.[5]

There may be an underused opportunity for forest information to directly inform the **implementation of policy instruments**, which was only found in about a quarter of the countries. The examples referred to include the use of forest monitoring results for setting silvicultural parameters, law enforcement, payment-for-environmental-services schemes and designating protected areas. In addition to these, numerous cases are reported throughout this paper on how data can underpin strong policy instruments. Enhanced sharing of experiences across countries might find a ready audience.

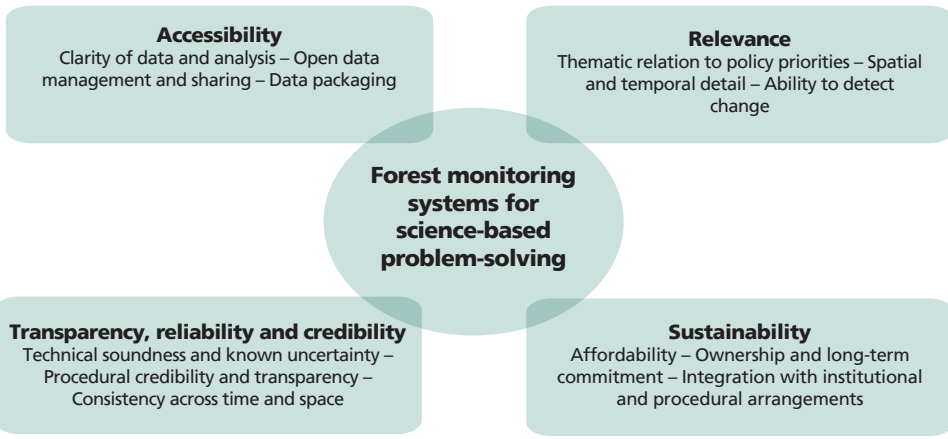
Frequently, forest monitoring results are used to **evaluate government policy** and its outcomes. This comes through in the assessment most prominently with regard to REDD+, surely because the assessment was framed around satellite land monitoring systems and national forest inventories – large-scale datasets as they are promoted in a REDD+ context, where forest reference (emission) levels are established to track forest mitigation results. But for several countries it was also reported that forest monitoring tracks progress against forest-area targets.

[5] The policy-making discussed in this paper includes the processes surrounding country strategies on REDD+ and climate change. Although it has been pointed out that these may have been integrated with sector policy surrounding forestry and agriculture to varying extents (Korhonen-Kurki *et al.*, 2016; Nepstad *et al.*, 2013), this paper includes REDD+ among the important contexts for forest monitoring. It has triggered much international funding and capacity development (Neeff and Piazza, 2019; Neeff *et al.*, 2017).

4. How can forest monitoring systems be structured to inform problem-solving?

Chapter 3 illustrated diverse cases where forest monitoring results have contributed to problem-solving, especially in a public policy context. But what characteristics of the forest monitoring system made this positive contribution possible? Prior work suggests that monitoring systems and their results need to be accessible, transparent, reliable and credible, relevant, and sustainable to inform forest policy-making[6][7] (Arnold, Rametsteiner and Kleinn, 2014; FAO, 2014) (Figure 10).

FIGURE 10
A framework for understanding forest and land-use monitoring systems for science-based decision-making



Source: authors' elaboration.

This section explains the framework and provides examples that illustrate how forest monitoring can provide a science base for diverse problem-solving efforts. The discussion focuses on the context of public policy.

6 The principles of FAO's *Voluntary guidelines on national forest monitoring* (FAO, 2017a) also largely map to the same criteria.

7 The discussion in this paper focuses on data and analysis for forest policy-making and therefore draws on prior work at FAO on this topic. However, it is useful to note that scholars more generally interested in knowledge systems for sustainable development have reached similar conclusions and suggested that scientific information likely to be impactful is that which relevant stakeholders perceive to be credible, salient and legitimate (Cash *et al.*, 2003; Clark *et al.*, 2016). Such ideas largely match the thinking of this paper.

4.1 ACCESSIBILITY

To inform policy-making, data and analysis need to be accessible to users. Clearly, only data that are technically available, i.e. can be downloaded or otherwise obtained, can be used. But information also needs to be accessible conceptually; too complex analysis will not easily be taken up, simply because potential users may not have the technical background to fully understand it.

Open data management and sharing. Willingness to make forest monitoring results available for use by others is by no means universal or widespread. Both the private sector and governments often keep tight control of information, and forest agencies sometimes charge for use of official data. The case of Cameroon's *Interactive Forest Atlas* (Mertens *et al.*, 2012) illustrates how openly available information can enhance public-sector accountability (Section 2.2).

Crucially, information must be available in a user-friendly format. The Cameroon case also illustrates how otherwise disjointed datasets, e.g. on the road network and forest loss, were made available in a coherent format. This established spatial correspondence and thus provided a powerful means of detecting irregular activity patterns (Section 2.2).

Simplicity of data and analysis. Only clear analysis can convince and develop impact. The simplest metrics can be the clearest. Stakeholders who are not forest monitoring specialists will prefer intuitively understandable data and analysis (Neeff, von Lüpke and Hovani, 2018). The case of mainstreaming deforestation concerns into corporate activities demonstrates the immense influence acquired by a hugely simplified view of supply chains (Section 2.4). Whether supply chains are "deforestation free" is a huge simplification of the environmental and social concerns that zero-deforestation protagonists may have had at heart – but "deforestation free" is also incredibly cogent in its simplicity (FAO, 2018c).

Data packaging. Even where datasets have a certain complexity, efforts can be made to package information to be accessible. Especially where the target is policy-makers, who may not be fully aware of all the technical intricacies, the data and analysis must be communicated in an understandable way. Strategies that have been found effective include the use of knowledge brokers between science and policy, tailoring evidence to its audience (e.g. through blogs, summaries, simple language, open access, policy briefs, infographics), as well as promoting the work of scientists in mainstream media to engage policy-makers and the public (Rose *et al.*, 2018).

4.2 TRANSPARENCY, RELIABILITY AND CREDIBILITY

Transparent, reliable and credible forest monitoring can inform decision-making. Data and analysis need to be technically sound, consistent across time and space, and remaining uncertainties need to be known. Credibility is a matter of perception, not least regarding the reputation of data providers and third-party reviewers. Credibility depends on transparency, both in the methods applied and the people involved. This is especially important when others are supplying the information, as trusting data and analysis is more difficult then.

Over the past decade, FAO in collaboration with over 70 countries and partners have developed innovative solutions for forest and land-use monitoring under the Open Foris initiative. These technical tools facilitate rapid technology transfer and allow countries to operate transparent, reliable and credible forest monitoring systems at reduced cost (Box 11).

Box 11: FAO's Open Foris initiative as an enabler of transparent, reliable and credible forest monitoring

With over 20 000 installations, the Open Foris initiative has catalysed significant progress in the measurement and monitoring of forests. Many countries have used these tools for developing their reports to the UNFCCC and other international bodies, including for REDD+ purposes.

Open Foris SEPAL – the System for Earth Observation Data Access, Processing and Analysis for Land Monitoring – was developed with the vision that innovative, accurate and transparent forest monitoring data can unlock the huge potential of forests for climate action. A key feature of SEPAL is accessibility and ease of use, which enables effective capacity-building and technology transfer for the creation of critical forest information by those who manage forests, and are at the front line in mitigating and adapting to climate change. SEPAL now has more than 4 300 active users from 160 countries, offering easy-to-use cloud-based access to satellite data and supercomputing power, including from mobile devices. The SEPAL platform is built on collaboration and partnerships with those who share the FAO vision for collective action, inclusive of donors, universities, technology and international partners.

During 2019, access via mobile phones was introduced as well as access to daily high-resolution data from Planet Labs for eight forest countries: Chile, Colombia, Costa Rica, the Democratic Republic of the Congo, Ghana, Indonesia, Mexico and Mozambique.

Increasingly, SEPAL is being deployed in new and novel applications, such as peatland monitoring, landscape restoration monitoring, and near real-time fire assessment and alerts. For the future, the accessibility and functionality of the platform will be continually improved for supporting the generation of accurate forest information at all scales. Keys to success have been innovation and partnerships, and partnerships with public- and private-sector entities, universities, technology and international partners will be further strengthened and expanded in the future.

Open Foris Collect Earth Online, developed in collaboration with the National Aeronautics and Space Administration (NASA), provides crowd-sourcing functionality to data collection. Collect Earth Online is the online implementation of Collect Earth, eliminating the need for desktop computer requirements and installations. It allows users to collect reference data using high-resolution satellite images. Multiple users can simultaneously collect information. Users do not need to worry about software installation and data management. Everything runs online and users can focus on applications.

Not only are transparency, reliability and credibility preconditions for use of evidence to inform problem-solving, but when forest monitoring informs problem-solving, its reliability is enhanced. This is because allocating the necessary funds to produce datasets will be much easier to justify if these datasets inform problem-solving, especially in a public policy context.

Technically sound data with known uncertainty. Data can be "wrong" in several ways. First, where uncertainty is great, data do not yield clear conclusions. Second, data can be biased, usually to an unknown degree. Potentially most problematic is the case where uncertainties are unknown.

In the context of REDD+, a particular effort is often made to quantify and duly account for uncertainties, because forest monitoring can become the basis for climate finance and for allocating results-based payments (Neeff and Lee, 2018). For example, the Forest Carbon Partnership Facility Carbon Fund has built an approach to measurement, reporting and verification of emission reductions that is meant to create trust among its investors (Box 12).

Box 12: Efforts to create trust in monitoring results under the Forest Carbon Partnership Facility Carbon Fund

The Forest Carbon Partnership Facility Carbon Fund, a trust fund at the World Bank, was designed to pilot performance-based payments to countries with REDD+ programmes. There are two tranches, or types of buyers, in the fund: one is allowed the unrestricted use of emission reductions, while the other excludes the use of emission reductions for offsetting or resale. The Carbon Fund has built an approach that aims to ensure reliability of emission estimates and to provide the Carbon Fund donors with the trust they need to purchase emission reductions.

- Measurements of emissions and emission reductions need to be as precise as possible and remaining error needs to be known. A methodological framework provides technical guidance.
- Estimates need to be consistent across time and space and therefore support comparability of emission-reduction estimates across countries. The guidance in the methodological framework is designed to promote this.
- Country data undergo an independent evaluation. The reference levels are assessed by a technical advisory panel and the results are verified by auditing firms.

Complying with all such methodological requirements is greatly demanding for many developing countries. Those countries with less than fully developed forest monitoring capabilities have frequently found it necessary to seek international support.

Despite the methodological framework's rigour, applying it also requires a good degree of judgement. Partly because of this, the assessments leave room for political decision-making among the Carbon Fund donors.

Source: Neeff and Lee, 2018; World Bank, undated.

There are cases in this paper, however, where forest monitoring data and analysis have had a great impact despite doubts surrounding their technical soundness. The example of Germany shows how forest damage monitoring created huge momentum, although the underlying methods have been criticized (Box 18, page 37). Though technical correctness and impartial analysis may therefore not be universally decisive, incorrect evidence is prone to be debunked, putting in jeopardy any policy initiatives based on it. The case of Indonesia's forest moratorium highlights how inconsistencies between spatial information at several government agencies became the entry point for restructuring decision-making authority (Box 13).

Box 13: Indonesia's forest moratorium and the need for consistent spatial information

Since 2011, Indonesia has had a forest moratorium blocking the issue of new concession licences in primary forests and peatlands for oil palm and fast-growing tree plantations, as well as logging. Although experts have varied views on its effectiveness, it has been pointed out that deforestation might have been higher in the absence of a moratorium. Some studies suggest that several hundred million tonnes of carbon dioxide equivalent may have been avoided (Busch *et al.*, 2015; Wijaya *et al.*, 2017), while others have expressed doubts about the moratorium's impact (Greenomics Indonesia, 2016).

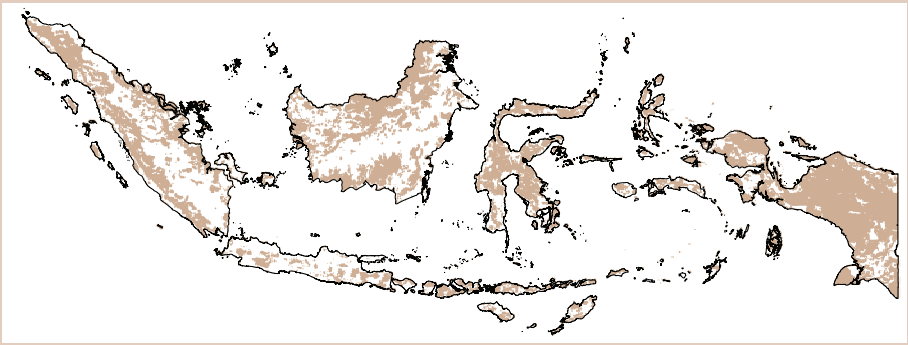
The forest moratorium substantially shifted control over natural resources, as it suspended the autonomy of government agencies in allocating licences. To legitimize such a change, highlighting discrepancies in official datasets was an important means of discrediting Indonesia's concessions regime. During a crucial cabinet meeting in 2010, the then-President Yudhoyono was presented with two starkly inconsistent official maps of forest cover in Papua province, produced by the Ministry of Forestry and the Ministry of Environment. The forest moratorium was portrayed as a solution that could overcome the fragmentation of spatial information and knowledge (Astuti and McGregor, 2015).

The "moratorium map" is a cornerstone of the forest moratorium (Figure 11). It identifies which areas contain primary forests and/or peatlands and are therefore off limits to new permits. The Ministry of Forestry first published the indicative moratorium map in 2011 and has since updated it regularly. With notorious discrepancies in spatial information at Indonesia's agencies, the moratorium map for the first time created an agreed spatial database (Astuti and McGregor, 2015).

The push for improving spatial information and the coordination between agencies was later consolidated in the One Map Initiative. This policy is aimed at standardizing and unifying spatial data across the Indonesian archipelago, creating a base map for all agencies to use, and making spatial data free and readily accessible for Indonesian citizens (Shahab, 2016). The initiative has been seen to correspond to an important step towards increased transparency, public participation and government coordination (Mulyani and Jepson, 2017).

In 2019, after repeated extensions, President Jokowi made the moratorium permanent. This decision consolidated a decade-long process where evidence played a key role in Indonesia's natural resource governance.

FIGURE 11
Indonesia's indicative moratorium map showing areas off limits for issuing new concessions in brown



Consistency across time and space. Comparisons across time or between similar units need consistent datasets. Where consistency is not ensured, changes – which are especially relevant to policy-making – cannot be assessed (Section 4.1). Without comparability, jurisdictions cannot be benchmarked, losing a key entry point for policy instruments. The example of Brazil shows how a prioritization list of municipalities was an effective tool to reduce deforestation, which was based on a consistent dataset of municipalities (Section 2.3).

Procedural credibility and transparency. Where there is a lack of transparency on the methods applied and the people involved in forest monitoring, credibility will be harder to build. Transparency on methods is the basis for any sound review. But even beyond technical parameters, transparency will be essential for the relationships of those involved in forest monitoring systems. Anything other than full transparency may create (justified or unjustified) suspicion.

Trusting your own data may often be easier than trusting those of other people, especially in the public sector. In most cases reported in this paper, those involved used a science base that they generated themselves, potentially jointly with others. When using information from others that may have vested interests, it may be harder to be fully comfortable that such vested interests do not introduce bias into data and analysis (Box 1, page 14). Because of this, participatory processes have proven effective for vetting datasets and analysis, especially where these have wide-ranging implications. For example, Argentina designed an approach to forest zoning that was both data-driven and participatory, which helped to greatly reduce deforestation (Box 14).

Box 14: Argentina's land-use planning, combining spatial analysis and participatory approaches

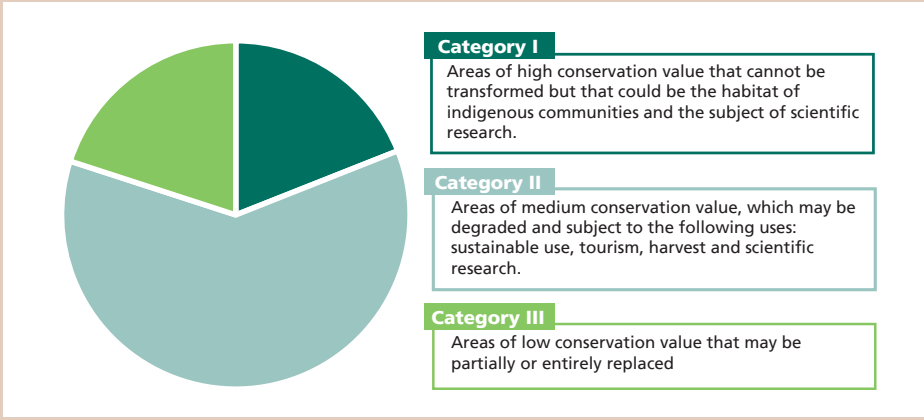
During the 1990s and 2000s, Argentina's native forests suffered from conversion to soybean monoculture and from a high degree of degradation, driven by investment in infrastructure and technological changes, as well as the increasingly globalized commodity markets.

In 2007, new legislation (Minimum Provisions for the Environmental Protection of Native Forests, Act No. 26.331) established a minimum level of environmental protection. Accordingly, all jurisdictions should carry out the spatial planning for land covered by native forests. The act also recognized environmental services and introduced a funding mechanism to compensate for their protection.

The Argentine spatial planning classifies native forests in three conservation categories, which determine the activities that can be carried out (Figure 12).

FIGURE 12

Argentina's three forest zones by percentage of total natural forest area



To assign these categories, the provinces generated a native forest map and combined it with information on ten environmental sustainability criteria (e.g. connectivity between protected areas, potential agricultural productivity) in a geographic information system. Moreover, the participatory processes engaged local land-users and helped to build ownership. The zoning concludes with adoption through provincial law and is then presented in a web-based National Registry of Plans, which facilitates monitoring and verification of compliance.

A national forest monitoring system provides information on compliance with the plans. Since 2018 an early warning system of deforestation detects clearings on a 16-day lapse using satellite imagery and notifies local authorities so that they can verify legality or impose any sanctions.

The participatory zoning and deforestation monitoring have, together with external factors, helped to reduce deforestation by more than half. Since the enactment of these reforms in 2007, forest loss has dropped from approximately 0.80 percent per year, and stabilized around 0.35 percent per year since 2014.

Source: MAyDS, 2017.

Credibility can derive from the engagement of a reputable institution without vested interests, either in producing and analysing the evidence or in vetting it. The case of REDD+ illustrates how independent reviews serve this purpose (Box 12, page 29). The case of Cameroon's forest concessions regime shows how independence made the observer credible (Section 2.2). The case of Germany's forest-damage monitoring illustrates how the reputation of research institutions was more decisive than the impartiality of data analysis in developing policy momentum (Box 18, page 37).

There can be trade-offs between the reliability of forest monitoring and system sustainability, and relevance to policy-making. Efforts to boost the reliability of data might drive up costs (Andersson, Evans and Richards, 2009) and may therefore be difficult to reconcile with a decent amount of thematic or spatial detail, which would be key to making forest monitoring relevant to policy-making (Section 4.3). On the other hand, where forest monitoring is not seen as credible, it is hard to imagine that national budgets would be allocated and forest monitoring integrated into the institutional setup.

4.3 RELEVANCE

Data and analysis that are relevant to decision-making have thematic and spatial detail, are produced at frequent time intervals, enable assessment of change, and speak to thematic policy priorities. Such evidence will provide more entry points for decision-makers than static forest monitoring systems with data at aggregate scales, for scant time intervals and without thematic detail.

Quite obviously, where information on issues of policy concern is available, policy-makers will explore using it to underpin narratives. Where relevant datasets are unavailable, policy needs can prompt the setting up of new monitoring systems or trigger modifications to existing systems. This was the case with Germany's forest damage inventories (Box 18, page 37) and Indonesia's forest moratorium (Box 13, page 30).

But the opposite is also true: available evidence and its data structure can shape policy-making. For example, in the case of mainstreaming deforestation concerns into corporate activities, a powerful policy agenda across public and private sectors was set in terms of a (somewhat questionable yet intuitive and measurable) indicator: whether supply chains are "deforestation free" or not (Section 2.4).

Similarly, Brazil's PRODES was set up in the late 1980s, decades before it helped to put deforestation high on the political agenda and became the basis for several policy instruments in the 2000s. Although the eventual use of deforestation statistics could not have been foreseen at the time, the system was designed to deliver data in a way that made them relevant to subsequent policy-making: on a spatial, temporal and thematic

scale, with a robust quantification approach, with sustained national funding and with an open data policy (Section 2.3).

Thematic relation to policy priorities Influential data and analysis speak to policy actors' thematic priorities. Because of this, thematic disaggregation of information can sometimes enhance policy relevance and highlight entry points for policies. For example, international assistance funds can be used more effectively when forest monitoring (with thematic detail) supports targeting the recipients in greatest need (Box 9, page 22). To ensure that forest monitoring systems deliver information on the appropriate topics, structured information needs assessments have commonly been conducted at the onset of forest monitoring programmes, especially where technical assistance providers are involved (Box 15).

Box 15: Information needs assessment for the Gambia's national forest inventory

At the onset of forest monitoring efforts, information needs assessments are commonly undertaken to help to guide the data collection. FAO has developed a standardized approach to support such information needs assessments. When in 2009 the Gambia embarked upon a national forest inventory with FAO support, a detailed information needs assessment was the first step.

The assessment included a set of interviews and questionnaires, as well as a three-day workshop in Bijilo, which brought together a cross-section of stakeholders including experts in various natural resources institutions. As only sparse, outdated and scattered information on the forestry sector existed up to the date of the inventory, the stakeholders approved that the information needs were numerous, covering as many as 109 expected query results.

In a follow-up to the assessment, draft field forms were compiled to gather the requested information and to facilitate prioritized data-processing.

Source: based on Nget *et al.*, 2011.

Spatial and temporal detail. To have an impact, forest monitoring needs to deliver the "right" degree of spatial and temporal detail to make results timely and relevant to specific locations of interest. For example, the case of Brazil's DETER shows how near real-time information can powerfully support law enforcement action (Box 16 and Section 2.3). Some policies affect entire countries (e.g. trade, many fiscal and regulatory interventions), but operational land management often needs data at more granular scales (e.g. for managing land holdings). For example, India's ecological fiscal transfers (Box 17) draw on subnational forest-area data to allocate fiscal and regulatory incentives, while managing forests in Cameroon requires several types of concession-level forest inventories (Box 10, page 23, and Section 2.2).

Box 16: Brazil's Real-Time System for Detection of Deforestation (DETER)

DETER began working in early 2004 at Brazil's National Institute for Space Research. It provides satellite-based alerts on deforestation hotspots throughout the Brazilian Amazon on an approximately monthly basis. Alerts are sent to the Brazilian Institute of the Environment and Renewable Natural Resources when changes are detected. Law enforcement officials can then be dispatched. The ability to act quickly is significant because Brazil's legal setup is such that offenders in illegal forest clearings can be punished more easily when caught red-handed.

Source: based on Assunção, Gandour and Rocha, 2017.

Box 17: India's ecological fiscal transfers

From 2015 to 2019, India's central government distributed some of its tax revenue to states in proportion to their 2013 forest cover. At the time of planning the scheme, transfers were expected to amount to about USD 6.9–12 billion per year, which is around USD 174–303 per hectare of forest per year.

Indian states depend on such transfers from the central government for a large share of their revenue. The India Finance Commission sets a formula every five years that determines the funding each state receives, drawing on variables such as population, poverty or fiscal situation. The 14th India Finance Commission decided that 7.5 percent of the total revenue will be allocated based on forest cover.

India's forest monitoring system makes the transfer scheme possible. Since 1987, the country's Forest Survey has produced biannual State of Forest Reports that include detailed maps of forest cover. Crucially, the methodology monitors forests in a consistent way across vast areas and it delivers estimates that are comparable between states and sufficiently robust to form a basis for fiscal transfers.

Source: based on Busch and Mukherjee, 2018.

Whether coarser-scale datasets can be used at more granular scales depends on the forest monitoring approach. For example, Brazil's Green Municipality Programme (Section 2.3) and Argentina's data-driven approach to land-use planning (Box 14, page 32) illustrate the versatility of map-based monitoring approaches to enable consistent analysis on both coarser and more detailed scales.

Ability to detect change. Forest monitoring's ability to detect change spans three levels with increasing policy relevance. First, some datasets are a snapshot of the status quo (forest cover, growing stock, etc. at any given point in time). Second, data may reflect changes to that status quo and observed or expected future trends (deforestation,

growth rates, emission reductions, projections, etc.). For example, the national forest inventory's increment estimates helped to set Viet Nam's logging quotas (Box 7, page 21, and Section 2.1). Third, analysis can highlight the drivers of forest change, which has taken centre stage especially for REDD+ (Rautner, Leggett and Davis, 2013). For example, the case of Armenia highlights how clear information on the causes of forest degradation, i.e. illegal logging, was a catalyst for change (Box 2, page 15).

4.4 SUSTAINABILITY

Countries are more likely to operate forest monitoring systems in a sustainable manner if they are affordable and respond to policy needs. Where this linkage to policy needs is strong, governments will want to take full ownership and integrate forest monitoring into the institutional and procedural arrangements. Additionally, such nationally designed, funded and operated forest monitoring may more easily link to policy-making, simply because governments are more likely to trust "home-grown" data.

Ownership and long-term commitment. Long-term commitment to forest monitoring derives from specific needs for information. Even where resources are available in principle, they will only be allocated where governments need the forest monitoring outputs. The case of Viet Nam's forest transition illustrates that, once management of the forest resource had become high priority and was seen as critical to the country's sustained economic development, an admittedly costly national forest inventory could be financed because the data outputs were a core requirement for setting logging quotas (Section 2.1 and Box 7). Similarly, in Germany, it was fear of forest dieback from air pollution that led to the building of a whole new monitoring system (Box 18).

Moreover, when evidence is to be used in domestic policy-making, especially on potentially contentious issues such as land governance and fiscal allocations, there is no question that governments will aim to control the process. The case of Brazil illustrates, among other factors, strong leadership through the entirely domestically funded PRODES, which became the basis for a range of fiscal incentive schemes (Section 2.3). Conversely, when international assistance funds data collection, international advisors not only oversee spending but often dictate technical and conceptual inputs (Box 19).

Integration with institutional and procedural arrangements. Where governments are committed to sustained forest monitoring, including the use of domestic resources, integrating such monitoring into processes and institutions can make sense. First, using a permanent government infrastructure and staff could be operationally more efficient than ad hoc implementation through projects, which is the default modus operandi for international funding. Second, comparative advantages of specialized government agencies can then be accessed, i.e. national forest inventories can be carried out by government staff, mapping by dedicated divisions or surveyor's offices, etc.

Box 18: Monitoring acid rain damage to Germany's forests

In the late 1970s and 1980s, Germany introduced a series of environmental reforms that helped to reduce air pollution. Forest monitoring results and their scientific analysis were instrumental in drawing attention to the issue.

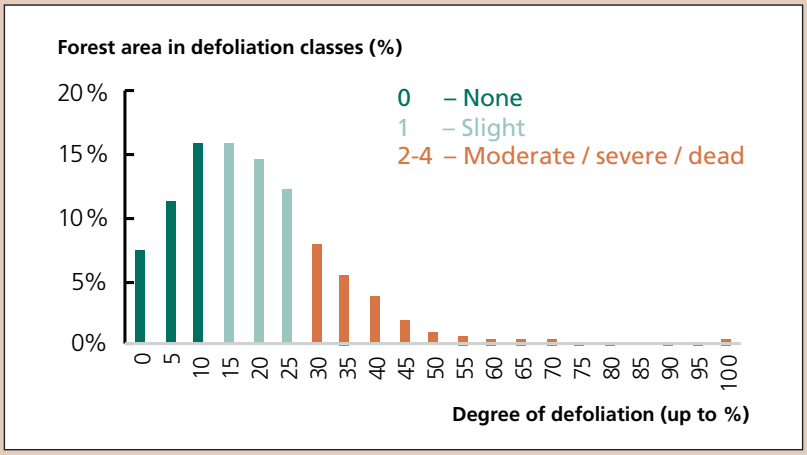
A group of scientists from Göttingen and Munich universities first investigated acid-rain impacts in the forests of Solling and Sauerlach. Although only based on localized observations made by a small group of scientists, the research was associated with high-profile scientific institutions. The media picked this up using the evocative term "Waldsterben" (forest dieback). In 1982, Germany introduced a systematic forest damage inventory. Annual reports on the state of forests fuelled a continuing public debate, especially during the mid and late 1980s, around the necessity for further action on air pollution.

Unlike common national forest inventories with decade-long remeasurement intervals and cryptic summary indicators, such as "growing stock", the results of the forest damage inventories were available annually and were intuitively understandable to the general public: national-scale aggregates of foliage loss.

The underlying methods for gauging forest damage have also been criticized. One line of criticism has focused on the underlying assumption that foliage losses would indicate compromised tree health (Figure 13). Tree phenology differs by site. For example, comparing the foliage of a tree growing in mountain conditions against a tree growing at lower altitude could lead to diagnosing foliage losses that reflect more the growing conditions than health.

FIGURE 13

Results of the 2017 forest damage inventory with red and green bars indicating damage classes



Source: based on BMEL, 2017; Schäfer, 2012.

Affordability. Affordability of monitoring systems varies significantly. Notably, national forest inventories have been designed and carried out that require significant effort, whereas others demand much fewer resources (Box 19). But beyond absolute cost levels, affordability depends on the issues that forest monitoring addresses. A costly monitoring effort may be commensurate with the reach of decisions based on its results. Moreover, affordability of forest monitoring depends on the resources that a given government (or other actor) has at its disposal – and who pays for forest monitoring. Nonetheless, where costs are prohibitive, monitoring cannot be continual, at least not using domestic funding in resource-constrained countries.

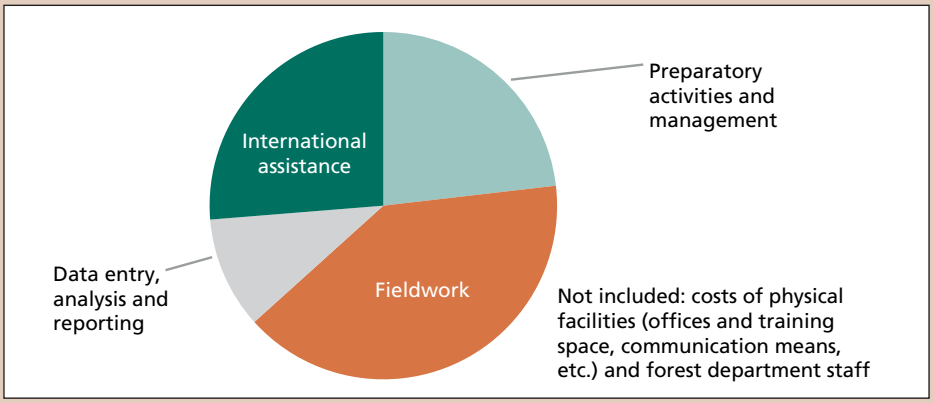
Box 19: Costs of national forest inventories

In 2008, FAO collected information on the time and cost of a set of national forest inventory campaigns (from around 1998–2008). For a set of 18 forest inventories, the total cost ranged from less than USD 0.5 million to almost USD 4 million, with an average of USD 0.8 million. Such variation is due to the differences in total forest area, number of samples, variables collected, targeted uncertainty, and existing capacity, among other factors.

More detailed analysis of several forest inventories revealed that the largest costs are for fieldwork. International assistance and preparatory activities/management are also expensive (Figure 14).

FIGURE 14

Average cost breakdown in five national forest inventory campaigns conducted with FAO support before 2008



Since the above figures on costs were compiled before 2008 with FAO support, the requirement in a REDD+ context of low uncertainties for estimates of carbon stocks and changes of stocks may have resulted in large sample sizes and thereby more expensive inventories.

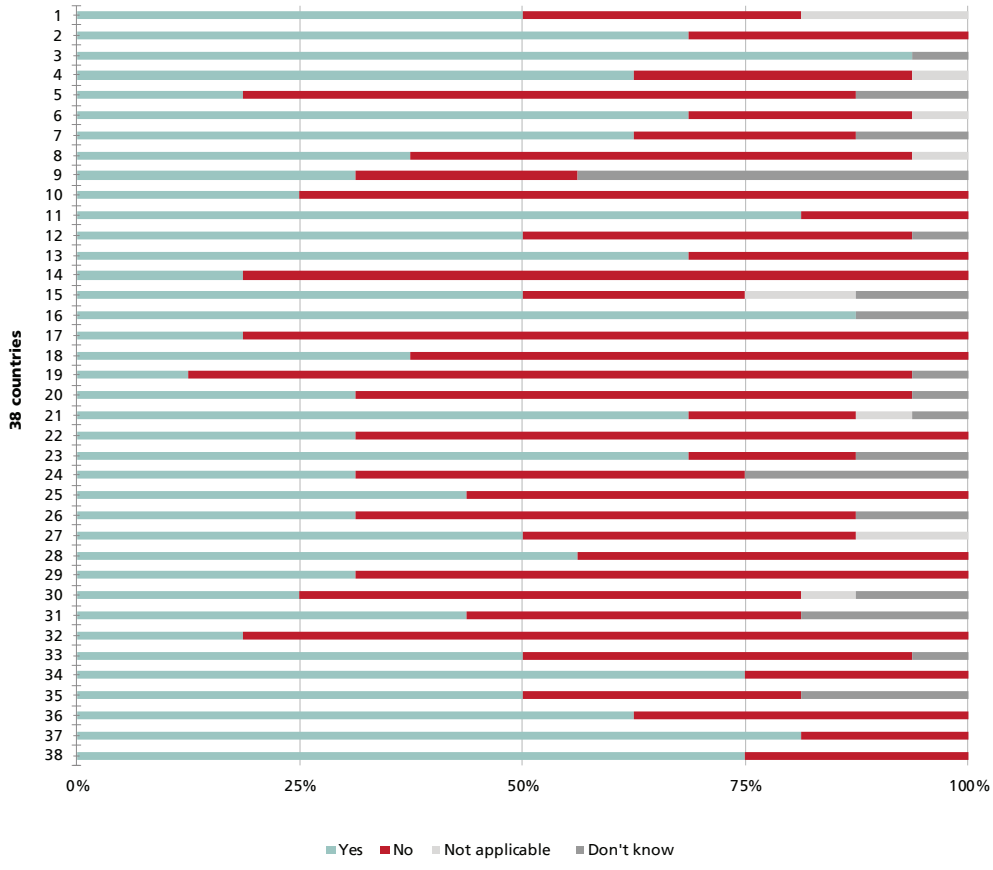
Source: based on FAO, 2008.

4.5 CURRENT SUITABILITY OF FOREST MONITORING TO INFORM POLICY-MAKING

The assessment of linkages between public policy-making and forest monitoring in 38 countries (Section 3.5), highlighted that in many countries there is a need for further capacity development. More investment has gone into the transparency, reliability and credibility of forest monitoring than into making sure it is relevant and accessible to policy-makers. Often, the sustainability of forest monitoring systems is at risk.

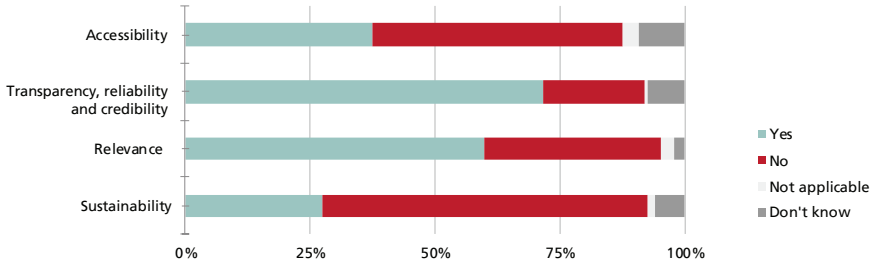
The assessment suggests that only in a small group of countries could forest monitoring systems be seen to be broadly suitable for informing policy-making. In most countries, there are significant gaps (Figure 15).

FIGURE 15
Assessment results for 38 countries on suitability of forest monitoring systems and their data and analysis to inform policy-making



Aggregating the assessment results by aspects of suitability reveals some further differences. More than half of the indicators of transparency, reliability and credibility, and relevance, of forest monitoring yielded a "yes". But the share of "yes" assessments was smaller for the indicators of accessibility and sustainability of forest monitoring systems (Figure 16).

FIGURE 16
Assessment results on accessibility, transparency, reliability and credibility, relevance, and sustainability of forest monitoring systems and their data and analysis



There is ample room to improve the accessibility of forest monitoring systems and their results, as only about one-third of indicators were assessed as a "yes". Among the suggestions made, the need for web portals was prominent as a means for making information accessible. Moreover, efforts to present evidence in a format and language targeted at decision-makers were highlighted.

The transparency, reliability and credibility of forest monitoring emerged as the strongest among the four factors of suitability for policy-making, assessed as "yes" in close to three-quarters of cases. This result is unsurprising because the need to generate robust emission estimates has driven much of the recent REDD+ capacity development. But gaps remain, and suggestions addressing them related mainly to improving documentation of methods and approaches.

More than half of the indicators on the relevance of forest monitoring to policy-making yielded a positive "yes" assessment. When asked what could be undertaken to improve relevance, respondents pointed to issues surrounding data accessibility (Box 20) – which the assessment framework sees as a determinant in its own right of suitability to inform policy-making. Accordingly, information is often not being made available, not even to policy-makers, and even where sharing occurs, efforts are not made to communicate monitoring results in terms understandable to decision-makers.

According to the assessments, sustainability of forest monitoring systems is not secured, as only about a quarter of the indicators were rated as "yes". In part, this may be a consequence of abundant donor funding for REDD+ capacity development. When asked what could be done to address this situation, many respondents highlighted the lack of budgetary and regulatory flexibility as a constraint, largely echoing the

Box 20: Selected set of suggestions (actual quotes) on making forest monitoring more relevant to policy-making

"What could be done to make forest monitoring more relevant to forest policy-making?"

- "Countries need to make the data freely and quickly available in a user-friendly way."
- "Improve communication on forest information for decision-makers, with simple language and using media such as infographics, key messages, etc."
- "More awareness in a language which is relevant for policy-makers on the opportunities generated by this forest monitoring data."
- "Produce communication material with the main results, bridging the gap between technical and political understanding."
- "Make the forest monitoring data easily accessible to decision-makers."
- "Consult the policy-makers and raise awareness of the potential of data."
- "Involve policy-makers more in construction of data and parameters so that they understand what can be measured."

assessment criteria. Only a handful of answers attempted to diagnose what prevents such budgetary and regulatory reforms at the root (Box 21). From these, making forest monitoring relevant to decision-makers emerges as a strategy to achieve sustainability of forest monitoring systems – again the assessment framework has its own set of indicators for this.

Box 21: Selected set of suggestions (actual quotes) on improving sustainability of forest monitoring systems

"What key decision or action would need to be taken to enhance the sustainability of forest monitoring?"

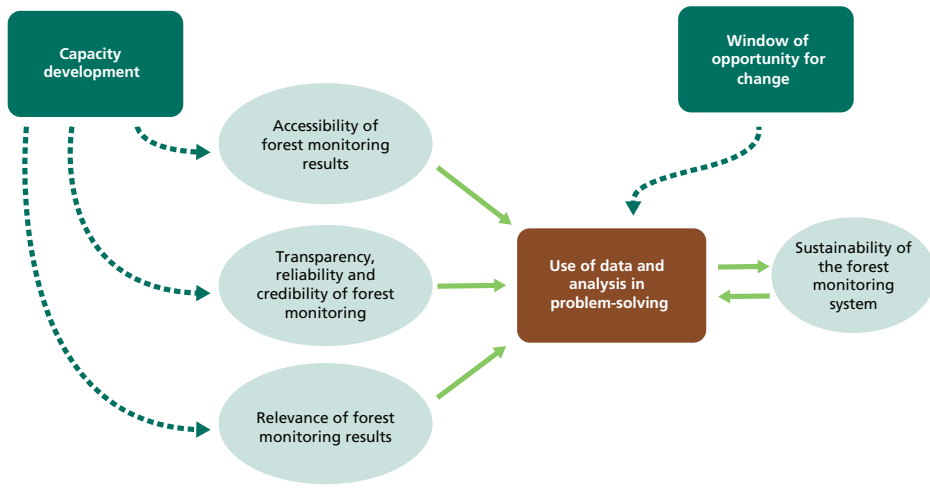
- "Increase awareness by civil society and government of the importance of the data generated."
- "... make the data as useful as possible for daily operations and decisions."
- "The national forest monitoring system should provide information beyond climate-related data, which will allow the continual production of relevant forest information for decision-makers."
- "Make sure the national forest monitoring system is not exclusively linked with REDD+, give access to the private sector."
- "If revenues came from managed forests this would probably give an incentive for the country to invest more in forest monitoring."

5. Conclusions and recommendations

5.1 A PATHWAY TOWARDS IMPACTFUL FOREST MONITORING

So, how can better data lead to better decisions? This paper leads to the conclusion that information can enable change *if the conditions are right*. A window of opportunity for policy change needs to be open, and forest monitoring needs to be suitable to inform policy-making. This conclusion can be the basis for strategically operating forest monitoring systems and targeting related capacity development (Figure 17).

FIGURE 17
Summary view of how suitable forest monitoring can enable policy change



The point of departure for those interested in better problem-solving, whether for operating monitoring systems or for providing and funding technical assistance, needs to be a window of opportunity for change. This paper explains that policy-making is really driven by a host of other factors beyond its science base, such that information can catalyse change but not cause it. The interviews that underlie this study have also revealed discouraging cases of isolated data-collection efforts with no clear connection to policy-making. Regardless of their technical sophistication, forest monitoring results risk not being used, unless data and analysis are generated in response to specific demand.

The positive case studies are equally strong and reveal that forest monitoring systems can be a powerful entry point to policy change. While information cannot directly drive better decisions, it can co-create change by serving as a vital input to decision-making. For this to happen, forest monitoring systems must be structured to be accessible, transparent, reliable and credible, relevant, and sustainable. Along these lines, technical assistance can support forest monitoring and help to ensure it is suitable for informing policy-making.

The past decade has seen a forest monitoring boom with plenty of technical assistance, much of it driven by international investment for REDD+. In some countries and sectors, policy-making progress has been impressive and would not have been possible without forest monitoring. In particular, much progress has been made towards the transparency, reliability and credibility of forest monitoring, because data and analyses have to gain investors' trust. More effort is still needed to make sure forest monitoring is relevant to policy questions, i.e. have spatial and temporal detail, speak to the right thematic priorities and deliver information on changes. The information also has to be more accessible, i.e. stepping up communication with the general public and decision-makers, implementing data-sharing policies, and building smooth-running geoportals that anyone can use.

Moreover, as in many developing countries the current forest monitoring systems are at risk of being unsustainable, this paper argues that sustainability could be achieved by using monitoring results in policy-making. Much capacity has been developed using international funding, but continuity is not ensured should donor interest wane. It is unsurprising that many developing countries seem to be reluctant to allocate scarce resources to forest monitoring systems that are largely geared towards international reporting but lack linkages to the concerns of national policy-makers. Although this finding may be sobering, it also offers a strategy towards sustainability: promoting linkages to policy-making. Integrating forest monitoring into institutions and processes, domestic funding and national ownership may all make practical sense once monitoring does connect with national policy-making, informs the policy dialogue, underpins operational decision-making, and supports the evaluation of forest policy.

The forest monitoring boom of the past decade has enhanced the capacity of many countries and thus offers an opportunity for improved decision-making. As recent investments have often been oriented towards REDD+ and international reporting, many countries will still need to undertake further work to link forest monitoring more closely to policy-making. Enhancing the accessibility, transparency, reliability and credibility, and relevance of forest monitoring will be the starting point for this.

5.2 RECOMMENDATIONS FOR IMPACTFUL FOREST MONITORING

Governments that operate forest monitoring systems, international donors and technical support agencies need to work together to promote accessible, transparent, reliable, credible, relevant, and sustainable forest monitoring that can satisfy multiple needs and impact policy-making.

FAO believes that working towards impactful forest monitoring requires the pursuit of four interlinked outcomes (below and Table 2). Governments, donors and technical support agencies all need to contribute.

Data are available in an easily accessible and understandable format; analytical results are tailored to diverse audiences and widely published.
Enhancing the suitability of forest monitoring to inform problem-solving, by the private or the public sector, starts by making data and analysis available in an easily accessible and understandable format. Governments should rigorously commit to making data publicly available and donors should consider including commensurate requirements when funding forest monitoring. Support agencies can provide technical, as well as legal and administrative, solutions for making data available.

To develop impact, forest monitoring initiatives should focus on the dissemination of results for diverse audiences, not as an afterthought but as the core objective. This will require donors to fund detailed follow-up for analysis and outreach and relevant agencies to provide capacity development support, also on communication and outreach linked to forest monitoring.

Key government agencies, civil society and academia work together through all phases of forest monitoring to continually improve transparency and quality of data and analysis.
Significant progress already achieved through past and ongoing capacity development needs to be secured, and remaining gaps need to be addressed, such that robust forest monitoring systems can cater both for domestic needs for data and analysis and international reporting and REDD+. Governments need to commit to continual improvement through a rigorous focus on remaining uncertainties and the use of technical support on new technologies and approaches from technical agencies. Donors should continue questioning data and analysis using accepted good practice guidance and fund the necessary review processes.

Forest monitoring systems that governments own jointly with other stakeholders will be trusted. Governments should involve key government agencies and civil society in forest monitoring, and technical support agencies should encourage this. Donors may selectively decide to fund some applications of data and analysis by civil society, NGOs or academia.

Governments play a leading role in building forest monitoring systems that generate data with spatial, temporal and thematic detail to respond to the need for data and analysis of multiple stakeholders throughout all stages of public policy-making.
Impactful forest monitoring generates datasets for multiple purposes that help countries to advance towards national sustainable development objectives through all stages of the problem-solving cycle. Governments should produce datasets with spatial, temporal and thematic detail that detect changes. Decision-makers need to engage in forest monitoring.

Table 2: Recommendations to governments with national forest monitoring systems, donors and technical support agencies

	What can governments do?	What can donors do?	What can technical support agencies do?
Accessibility	**Outcome:** Data are available in an easily accessible and understandable format; analytical results are tailored to diverse audiences and widely published		
	• Provide open access to data in easily accessible formats where possible • Widely publish analytical results tailored to diverse audiences	• Require governments receiving support to provide open access to data • Fund detailed follow-up after data collection for analysis and outreach, leading up to strategic recommendations and policy uptake	• Encourage open access and develop technical solutions for making data open and accessible • Develop and support data sharing protocols • Provide capacity development for communication and outreach
Transparency, reliability and credibility	**Outcome:** Key government agencies, civil society and academia work together through all phases of forest monitoring to continually improve transparency and quality of data and analysis.		
	• Involve key government agencies, civil society and academia in all phases of forest monitoring • Commit to continually improve data through robust quality management	• Selectively fund data users beyond forest services • Rigorously question data quality following agreed good practice guidance, and fund third-party reviews	• Encourage governments to work through existing cross-sectoral platforms, where available • Provide technical assistance to enhance data quality, guided by capacity needs assessments • Continually monitor and evaluate data quality
Relevance	**Outcome:** Governments play a leading role in building multipurpose forest monitoring systems that generate data with spatial, temporal and thematic detail to respond to the need for data and analysis of multiple stakeholders throughout all stages of public policy-making.		
	• Build multipurpose datasets with spatial, temporal and thematic detail that detect changes • Engage decision-makers and take a strong lead on identifying priorities for forest monitoring together with relevant stakeholders.	• Fund monitoring that coherently builds on existing systems • Fund detailed preparatory work before data collection to identify priorities and needs	• Provide capacity development for contextualized data analysis • Periodically conduct data needs assessments with diverse stakeholders that place forest monitoring in a policy context
Sustainability	**Outcome:** National administrations operate resource-efficient forest monitoring systems using domestic funding with strategic international support.		
	• Be resource-efficient when using donor funding • Use regular government staff for forest monitoring, and create incentives for their retention • Develop businesses cases for forest monitoring	• Fund with a long-term perspective and aiming for low-cost solutions • Require an exit strategy whenever possible • Build on lessons learned and evaluations of previous work	• Develop technical low-cost solutions for countries that build on existing successful systems • Provide functional capacity development on processes and procedures • Work through in-country partners for delivery whenever possible • Engage with local universities and support curriculum development

Where donors fund work to build on existing systems in a coherent manner, this will greatly facilitate the production of long, consistent time series. Moreover, donors should fund technical support agencies to conduct detailed preparatory work before data collection to identify priorities and specific needs for data.

National administrations operate resource-efficient forest monitoring systems using domestic funding with strategic international support.
For developing countries, funding national forest monitoring will be much easier if the forest monitoring system is affordable. Governments should be resource-efficient even when donor funding may be available. Donors, in turn, should fund with a long-term outlook, and promote low-cost solutions that can potentially be funded from domestic sources. Technical support agencies may be helpful here by developing tools that countries can use at low cost.

A fit-for-purpose forest and land-use monitoring system that is closely linked to policy-making and caters for domestic needs for data will have strong ownership by the government and will naturally embed into national institutions. Governments should promote this integration by using regular government staff for forest monitoring. Donors should, whenever possible, consider their exit strategy before engaging in forest monitoring support. Capacity development should look beyond technical support and extend towards advice on process and procedures, as well as the budgetary and legal aspects of forest monitoring. For delivery, local partners should be used whenever possible, and local universities should receive support for building capacities for the long term.

5.3 AN FAO APPROACH TO FOREST MONITORING CAPACITY DEVELOPMENT

FAO's approach to forest monitoring and related capacity development is guided by its *Voluntary guidelines on national forest monitoring* (FAO, 2017a). FAO advocates that multipurpose national forest monitoring systems should be linked to policy frameworks and instruments. This ensures that the improved information results in improved land-use decisions and evidence-based actions in the forest and land-use sector. It also ensures that national forest monitoring systems underpin REDD+ and enable mitigation actions in the forest and land-use sectors as a distinct contribution to global commitments to hold the increase of average global temperature to well below 2 degrees Celsius by 2025 (FAO, 2018b).

Much progress has already been achieved on forest monitoring over the past decade but significant capacity gaps remain. FAO has reported almost universal participation of developing countries in forest monitoring for REDD+ (FAO, 2019). Recent FAO work has highlighted that, especially on technical aspects, forest monitoring has much improved, while institutional and procedural aspects of forest monitoring need further strengthening (FAO, 2018a; Neeff and Piazza, 2019). This paper shows that there is potential to strengthen the contribution of forest monitoring to policy processes – and that this could enable ownership and institutional uptake.

Working towards impactful forest monitoring requires tailoring the theory of

change to the individual country's context and for governments to work closely with donors and technical assistance providers (Section 5.2). The countries that have had most success in reducing deforestation offer lessons on structuring forest monitoring systems and potentially replicable experience on how data can inform policy design, underpin policy instruments and enable learning. FAO envisages that forest monitoring capacity development that takes on board the thinking in this paper could make a crucial contribution to global efforts to achieve transformational change surrounding forests and land use in the decade to come. Governments of developing countries, their donors, and those providing technical assistance can then leverage current opportunities and bring forest monitoring to the next level, **where better data lead to better decisions**.

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