The Promise of Digitalisation

Case study: Social Impact of a Digital App for Community-based Deforestation Monitoring in the Peruvian Amazon

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Introducing new digital technologies in 'low-tech' environments can affect the dynamics between stakeholders, and the distribution of costs and benefits among them. As part of Peruvian forest conservation activities, forest monitoring (vigilance) committees have been formed, consisting of local community members who are responsible for patrolling the forest, verifying deforestation alerts, and reporting. In recent years, several government agencies and NGOs involved in forest conservation have started to use digital technologies for forest monitoring, such as smartphone apps and drones. The social impacts of such digital technologies are not well understood. A tool has been developed to assess the social impact of a digital innovation, and to serve as an entry point for discussion between stakeholders.

Key words: community-based monitoring, social impacts, high-tech tools, low-tech environment, social impact feedback framework, deforestation, multi-stakeholder, Peruvian Amazon

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P.O. Box 88, 6700 AB Wageningen, The Netherlands, T +31 0317 48 48 88, E info.wser@wur.nl, http://www.wur.eu/social-and-economic-research. Wageningen Social & Economic Research is part of Wageningen University & Research.

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Cover photo: Cover photo taken by Christina Cappello, Wageningen Environmental Research, during a combined visit with colleagues (from WSER and WEnR) to the Native Community Tres Islas, Madre de Dios, Peru, on 1-12-2023.

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Preface

As part of Peruvian forest conservation activities, forest monitoring (vigilance) committees have been formed, consisting of local community members who are responsible for patrolling the forest, verifying deforestation alerts, and reporting. In recent years, several government agencies and NGOs involved in forest conservation have started to use digital technologies for forest monitoring, such as smartphone apps and drones. The social impacts of such digital technologies are not well understood.

Approaches such as ELSA (Ethical, Legal and Social Aspects) and RRI (Responsible Research and Innovation) have been applied before to ensure responsible development of technology. However, these approaches have mainly focused on a European or North American context. Introducing new digital technologies in 'low-tech' environments can affect the dynamics between stakeholders, and the distribution of costs and benefits among them, in different ways. This case study assesses the social impacts of a specific digital technology innovation in a low-tech environment: the case of community-based deforestation monitoring with a digital app in the Peruvian Amazon.

The authors would like to express their appreciation and gratitude for the support received from the National Forest Conservation Program (PNCB) of the Peruvian Ministry of Environment (MINAM), and from colleagues from Wageningen Environmental Research (WEnR). Furthermore, the team is grateful for the efforts of the community forest monitors for their committed efforts to conserve the forest of their communities. The team would also like to particularly thank the interviewees who provided their valuable insights and opinions and dedicated precious time to the interviews and/or FGDs. They demonstrated not only their knowledge and experience, but also their commitment to forest protection and conservation.

Ir. O. (Olaf) Hietbrink
Institute Manager Wageningen Social & Economic Research
Wageningen University & Research

Summary

In Peru, although 60% of the land cover is tropical forest, deforestation is a major problem. In recent years, several government agencies and NGOs involved in forest conservation have started to use digital technologies for forest monitoring, such as smartphone apps and drones. The social impacts of this digital technology are not well understood. Introducing new digital technologies in 'low-tech' environments can a affect the dynamics between stakeholders, and the distribution of costs and benefits among stakeholders. The objective of this study is therefore *to understand the social impact on stakeholders of a high-tech solution for community-based forest monitoring in a low-tech environment, specifically the Peruvian Amazon. A secondary objective was to develop a coherent analytical tool to analyse the social impact of a digital innovation in a low-tech environment.*

The Peruvian Ministry of Environment (MINAM) committed to reduce deforestation and established the National Forest Conservation Program for Climate Change Mitigation (PNCB-MCC) in 2010. As part of forest conservation activities, forest monitoring (vigilance) committees have been formed in a total of 274 communities across the country (as of 2020), consisting of local community members who are responsible for patrolling the forest, verifying deforestation alerts, and reporting back to PNCB. Community-based forest monitoring in the Peruvian Amazone is done with low-tech methods, e.g., forest patrols, ocular inspection, and with paper forms to be filled out and sent over long distances to centralised PNCB offices. This is a labour-intensive process, with a long lead time, which is prone to human error. WUR developed a smartphone app to facilitate community-based forest monitoring. This new app was tested during two years in four communities in the Madre de Dios department (Amazone region). A social impact analysis has been performed, to contribute to a (more) responsible innovation process.

We built a consistent Social Impact Feedback Tool (SIFT), based on a combination of deduction (RRI[1] and ELSA[2] principles) and induction (case-specific social impact elements). For the development and first application of the SIFT, we used a combination of grey literature review, stakeholder mapping, interviews and focus group discussions. The following social impact dimensions are considered in the analysis: ethics & anticipation; inclusion & interactivity; responsiveness; solutionism & negotiation; and participation & interdisciplinarity. A sixth dimension that preceded the other five was a factual review of the digital tool and the implementation process. The SIFT framework consists of 14 evaluative questions that can be scored on a Likert scale by respondents, and complemented by qualitative reflections.

Based on the findings, it can be concluded that the use of the app for forest monitoring has been perceived as beneficial by all stakeholders, as it facilitates forest monitoring operations and forest data management. However, data confidentiality issues may potentially increase risks for forest monitors, particularly in relation to illegal mining activities. With increased use of digital technologies (apps and drones), the composition of forest monitoring committees has been subject to change. In Peru's current community-based monitoring system, forest monitors rely on paper-based satellite deforestation alerts provided by the government to carry out their activities. Feedback from the government to forest monitors about collected data and insights that follow from the data is rather limited. Thus far, the introduction of the smartphone app has not changed this dynamic. This leads to information asymmetry and dependency, which may affect the sense of ownership of the app. For the continued use of the app, long-term institutional and financial support is needed to sustain the communities' forest monitoring activities.

In the Peru case, the SIFT framework proved to be a valuable and effective tool to assess the social impact of a digital innovation. The Likert scores can be used as an entry point for discussion between stakeholders. Prior to the application of the SIFT framework, an initial quick scan of the project context - including a stakeholder mapping - is required, to customise the 14 evaluation questions. The SIFT framework can also

[1] Responsible Research and Innovation (RRI) has been introduced by the European Commission to improve the alignment of research goals and outcomes with societal needs and challenges.
[2] ELSA refers to research activities that consider Ethical, Legal and Social Aspects of science.

be applied to discuss social impact in a multi-disciplinary setting with social and technology experts, both in academia and by technology implementing organisations. From this first experience, the research team expects the SIFT framework to be sufficiently robust to be applied to very different types of digital innovations in low-tech environments, in different kinds of projects. Such a replication in other situations will need to be tested in practice.

The SIFT framework could be further developed in a variety of manners. First, the SIFT analysis can be repeated with the same stakeholders to assess digital innovation developments over time. Second, the SIFT analysis can be deployed at a national scale in Peru, e.g., in connection to the new digital app for community forest monitoring that is being developed by PNCB. Lastly, WUR can continue to develop the SIFT framework, for example as an app-based tool, which can subsequently also be used for other digital innovation projects.

List of abbreviations

Acronym	Full name in Spanish a)	Full name in English b)
ACCA	Conservación Amazónica Perú	Amazone Conservation Peru
AFIMAD	Asociación Forestal Indígena Madre de Dios (afiliada a FENAMAD)	Indigenous Forestry Association of Madre de Dios (affiliated to FENAMAD)
AIDESEP	Asociación Inter-Étnica de Desarrollo de la Selva Peruana	Interethnic Association for the Development of the Peruvian Rainforest
ANECAP	Asociación Nacional de Ejecutores de Contrato de Administración	National Association of Implementing agencies of [protected area] Administration Contracts
APAFA	Asociación de Padres de Familia	Association of School Parents
COHARYIMA	Consejo Harakmbut, Yine y Matsiguenga (afiliada a FENAMAD)	Council of Harakmbut, Yine y Matsiguenga peoples (affiliated to FENAMAD)
COINBAMAD	Consejo Indígena de bajo Madre de Dios (afiliada a FENAMAD)	Indigenous Council of the lower Madre de Dios (affiliated to FENAMAD)
ECA	Ejecutora de Contrato de Administración	Implementing agency of a [protected area] Administration Contract
FENAMAD	Federación Nativa del Río Madre de Dios y Afluentes (afiliada a AIDESEP)	Native Federation of the Madre de Dios river and its affluents
FIP-BID	Programa de Incentivos Forestales del BID (administered by PNCB/MINAM)	Forest Investment Program of the Inter-American Development Bank
JICA	Agencia de Cooperación Internacional del Japón	Japan International Cooperation Agency
MIDAGRI	Ministerio de Desarrollo Agrario y de Riego	Ministry of Agricultural Development and Irrigation
MINAM	Ministerio del Ambiente	The Peruvian Ministry of the Environment
ODK	n.a.	Open Data Kit
OEFA	Organismo de Evaluación y Fiscalización Ambiental	Environmental Assessment and Enforcement Agency
OSINFOR	Organismo de Supervisión de los Recursos Forestales y de Fauna Silvestre	Agency for the Supervision of Forest Resources and Wildlife
PNCB-MCC	Programa Nacional de Conservación de Bosques para la mitigacion del cambio climático (administered by MINAM)	National Programme for the Conservation of Forests to Mitigate Climate Change
SERFOR	Servicio Nacional Forestal y de Fauna Silvestre (reporting to MIDAGRI)	National Forest and Wildlife Service
SERNANP	Servicio Nacional de Áreas Naturales Protegidas por el Estado (reporting to MINAM)	National Service for Protected Areas of Peru
SIFT	n.a.	Social Impact Feedback Tool
SMART	n.a.	Spatial Monitoring and Reporting Tool
TDC	Transferencias Directas Condicionadas	Conditional Direct Transfers

a) Abbreviations that do not exist in Spanish are marked with 'n.a.' for not applicable; b) The authors are responsible for the translation of Spanish acronyms into English.

1 Introduction

1.1 Digital transformation in low-tech environments

Digital transformation has been associated with economic growth and reducing inequality, and has therefore been a priority in rural and agricultural development.
Digital transformation is seen as a global priority as it is generally associated with positive effects on economic growth (Bahrini and Qaffas, 2019; Myovella et al., 2020). The use of digital technologies is also regarded as a contributing factor to realise the UN's Sustainable Development Goals (SDGs), particularly for reducing inequality (ITU, 2023), both between individuals and between regions. In particular digital transformation in the agricultural sector and rural areas is seen as a priority for global policy makers (Trendov et al., 2019; World Bank, 2017 and 2019) as the economies of many countries are largely dependent on the agricultural sector, both in terms of GDP (World Bank, 2023a) and employment (World Bank, 2023b). As a result, digitalisation is very high on the political agenda in many countries (Haefner & Sternberg, 2020). For instance, the African Union developed a *Digital Transformation Strategy for Africa 2020-2030* (African Union, 2020).

Research on the (co-)development, uptake and use of digital technologies is often focused on high-income countries where digital technologies are widely available, also referred to as *high-tech* environments.
The term *low-tech* environments is often used in contrast to high-tech environments, where more advanced technologies and complex systems are common. Rural, remote, and some areas in low middle-income countries (LMICs) can generally be labelled as lower-tech environments; access to advanced technology or infrastructure is often constrained (Ceccarelli et al., 2022; Porciello et al., 2021). Introducing new digital technologies in low-tech environments can have different effects on the dynamics between stakeholders, and the distribution of costs and benefits among stakeholders.

1.2 Deforestation in the Peruvian Amazon

The low-tech environment in this case study is the Amazon region in south-east Peru, where deforestation is rampant.
In Peru, 60% of the land cover are tropical forests; 72 million ha in 2020 (FAO 2020). This makes it the fourth largest country in terms of global tropical forest, and second in Amazon rainforest, after Brazil (Mostiga et al., 2024b). However, deforestation is a significant problem; between 2000-2020, Peru lost 3.4 million ha of forest, and national deforestation rates accelerated (Mostiga et al., 2024a). The drivers of deforestation are diverse and include: agricultural expansion, timber extraction, mining, infrastructure development, climate change, and socio-economic factors (Cruz et al., 2023). Deforestation is an important global issue as it affects biodiversity, carbon and water cycles (in Mostiga et al., 2024a) as well as the livelihoods of local communities through agroforestry opportunities and ecosystem services (Montoya-Zumaeta and Naime, 2022).

One mechanism to prevent and mitigate deforestation is the Reducing Emissions from Deforestation And Forest Degradation (REDD+), to protect forests as part of the Paris Agreement.
REDD+ is a results-based payment mechanism and intends to reduce carbon emissions from deforestation and degradation, conserve and enhance forest carbon stocks and promote sustainable management of forests (FAO et al., 2021), in developing countries. REDD+ can contribute to a country's climate mitigation commitments under the Paris agreement: under Peru's revised NDCs (2020), the country committed to reducing carbon emissions by 40% by 2030 (UNDP, 2023). Examples of initiatives that form part of REDD+ include afforestation, reforestation and restoration, land titling, community monitoring and zero deforestation agriculture (Montoya-Zumeta and Naime, 2022). However, monitoring, comparison and understanding the drivers and interrelations of forest loss are difficult because of a lack of historical data (forest inventories), different forest loss classifications and different methods used (Mostiga et al., 2024a).

National Forest Monitoring Systems can potentially be enhanced by the implementation of community-based monitoring and digital tools.
Under REDD+, reduced emissions are encouraged by payments if results are transparent and consistent, which requires a Monitoring, Reporting and Verification (MRV) system. Moreover, countries that implement REDD+ are required to develop a National Forest Monitoring System (NFMS), most often based on satellite data, and intended to provide information on the status of forest cover in conservation areas (Kowler and Larson, 2016). In Peru, there is much focus on community-based monitoring, as an important part of its NFMS, and complementary to the satellite-based monitoring (Pratihast et al., 2013; Kowler, 2020). With this approach, community monitors patrol communal forest and receive satellite-based alerts of forest cover changes (Slough et al., 2021; Capello et al., 2022). There is a general trend that digital tools are increasingly used in community-based environmental monitoring processes (Johnson et al., 2021).

1.3 Problem Statement & Research Objectives

Community-based forest monitoring has been implemented by numerous communities across Peru. The use of digital tools for this purpose has been increasing, yet social impacts are often overlooked.
Traditionally, community-based forest monitoring in the Peruvian Amazone is done with low-tech methods, e.g. forest patrols, ocular inspection, with paper forms to be filled out, and the same papers to be sent over long distances to centralised offices. This is a labour-intensive process, with a slow transfer of information back and forth, which is prone to human error at different levels. In recent years, several government agencies and NGOs involved in forest conservation have started to use digital technologies in this process, such as smartphone apps and drones. Assessment of the social impact is available for the forest conservation programme (e.g., Kalman et al., 2024), but not for the digital innovation aspect of this program.

The objective is to understand the social impact on stakeholders of a high-tech solution for community-based forest monitoring in the Peruvian Amazon, and to develop an analytical tool to analyse these impacts.
Better understanding of social impacts and opportunities can contribute to responsible introduction of high-tech solutions, together with stakeholders. We aim to contribute to the development of technology that is equitable and durable, by including and strengthening social feedback to improve its design. The specific goal is to explore the potential impacts, costs and benefits of using a forest monitoring app, as well as the related challenges and opportunities, together with community monitors and other stakeholders.

As such, the research question addressed in this project is as follows:

What are the social impacts of a high-tech solution (smartphone app) on the stakeholders of community-based forest monitoring, in the low-tech environment of the Peruvian Amazon?

1.4 Report Outline

To assess social impacts of high-tech in low-tech environments, several analytical frameworks from literature served as guidance; these frameworks are briefly introduced in Chapter 2. They also provided the foundation of a social impact assessment tool that has been developed as part of this project; this tool and related assessment methodology are introduced in Chapter 3. Subsequently, the specific case of digital community-based forest monitoring in the Peruvian Amazon will be outlined in more detail in Chapter 4. Eventually, the results of preliminary tests of the tool, during visits to the Peruvian Amazon, are presented in Chapter 5, followed by a discussion and conclusion in Chapter 6.

2 Analytical Frameworks

To assess the social impacts resulting from digital innovation in this case study, we made use of existing analytical frameworks from literature for guidance. These frameworks are briefly outlined in this chapter.

2.1 Social-Cyber-Physical System

Digital transformation can be seen as systemic change which encompasses digital (data), physical (material aspects and the environment) and social domains (people).

The process of digital transformation affects the way people, things and institutions coordinate themselves in order to perform their activities (Cowie et al., 2020; Klerkx and Rose, 2020; Nambisan et al., 2019). These three domains each consist of a variety of entities (see Table 2.1). Adopting a systems approach, it is furthermore important to understand the relations within and between these domains as the interactions between entities and domains can lead to outcomes and adaptation to the Social-Cyber-Physical System (SCPS, see Figure 2.1) that they form together (Rijswijk et al., 2021).

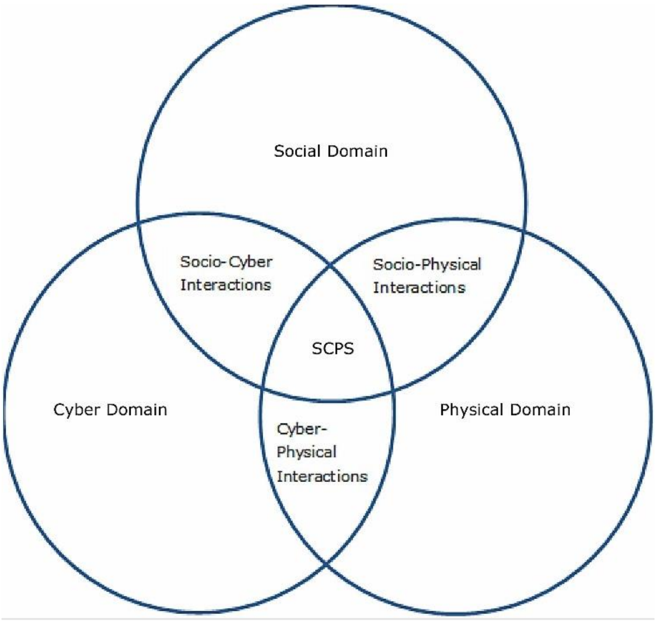

Figure 2.1 *Schematic overview of the SCPS*
Source: Rijswijk et al. (2021).

Table 2.1 *Entities en interactions related to the SCPS domains*

Domain	Entities	Interactions
Social	Social actors, groups and communities, and institutions	Relations between entities in the social domain are regulated by *social rules*, such as routines, social norms, ethical norms, informal behaviour, policy, laws
Cyber	Cyber entities are composed of a) digital reproductions of the physical sphere created by digitisation processes, e.g. from a paper-based map to a digital model of a farm which can be used by a drone, as well as b) original digital constructs, such as software, big data, cloud computing, Internet of Things, etc.	The relations between entities in the cyber domain are regulated by *cyber-rules*. For example, communication between devices is regulated by specific protocols (such as WiFi, Bluetooth, 5G); another example is the data format (PDF, DOC, …), a specific arrangement of data so that they can be stored, exchanged, and correctly interpreted. Digital technologies can communicate with other technologies, digital entities interact with other digital entities, performing operations and making choices potentially independently of humans, while initially being designed by humans.
Physical	These entities can be natural or artificial, according to the degree of manipulation they have undergone as a result of human activities. This includes living organisms and natural resources (plants, animals, etc.) and physical things to support living and working in the (natural) environment (e.g. analogue technology, infrastructure, finances)	Relations between entities in the physical domain are regulated by *natural rules* and by *technical rules*. For example, wild animals select in the environment the entities – plants or animals – that suit their nutrition, avoiding harmful entities. Water cycles are regulated by natural processes, such as evaporation and precipitation, but also by technical processes, such as water extraction from wells or circulation into pipes.

Source: Rijswijk et al. (2021).

2.2 RRI and ELSA Frameworks

To mitigate unforeseen consequences, it is key to approach the development and implementation of digital technologies in a responsible manner.

Introducing digital technologies may address or solve a specific problem, however, it may also have undesirable, unseen and unknown impacts that only become clear once these technologies are implemented (Klerkx and Rose, 2020; Pansera et al., 2019; Scholz et al., 2018). The negative social impact often occurs in a form of social inequality and various digital divides. The social impact of digital technologies and the digital transformation process is affected by multiple factors, including: access to digital technologies; people's attitudes and perceptions towards technologies; the design of the technology; and complexity of the broader system in which it is embedded (McCampbell et al., 2021; Rijswijk et al., 2021). Thus, a digital transformation process is not inherently 'good' as it impacts on many aspects (e.g. economic, environmental, social, technological, institutional) and the relations between them.

To support a (more) responsible innovation process, approaches such as Responsible Research and Innovation (RRI) and Ethical, Legal and Social Aspects (ELSA) have been developed.

Both ELSA and RRI consider fundamental aspects as participation, involvement and inclusion of a wide variety of stakeholders. Moreover, both approaches aim to better align technology developments and scientific research with societal needs and values through public participation. At the same time, both concepts may be incomplete to fulfil intended goals (responsible and sustainable research and innovation), but they can be complementary (Ryan and Blok, 2023) and in practice are often used interchangeably. To meet the challenges of both approaches and to apply them in a low-tech environment, it is thus key to make use of both approaches in order to mitigate unwanted social impacts as much as possible. Ryan and Blok (2023) therefore indicated a set of features in which ELSA and RRI align; these are summarised in Table 2.2 below.

Table 2.2 *Alignment features of the RRI and ELSA frameworks*

ELSA-RRI Alignment Features
1. Ethics and anticipation: Identify and evaluate potential societal impacts and purposes of scientific and technological research, their uncertainties and possible outcomes, and those responsible for dealing with these issues.
2. Inclusion and interactivity: Include diverse perspectives from stakeholders that may be affected by a particular course of actions, and attempt to arrive at amenable solutions for these stakeholders.
3. Participation and Interdisciplinarity: Embed ELSA-RRI researchers in scientific programmes and at early stages of scientific and technological R&I. Ensure participation of natural and social scientists and also industry partners. Bridge the boundaries between different research communities throughout the entire process of scientific and technological R&I.
4. Responsiveness: Implement suitable action, which should entail involvement/liaising with relevant stakeholders (e.g. policymakers, industry, research community, and societal actors).
5. Solutionism and negotiation: Focus on the economic, ethical, legal, and societal impacts of R&I and reflection on how society will be affected by different potential outcomes, through a balance of targeted solutions and open negotiation and compromise.

Source: Ryan and Blok (2023).

3 Methodology

The methodology of this study comprises the development of the SIFT framework and the implementation of SIFT to the use case. In this chapter we explain the development of the Social Impact Feedback Tool (SIFT) first, and how it was tested during the field visits in Peru (3.1). Next, in Section 3.2, we highlight the methods for data collection and analysis.

3.1 Social Impact Feedback Tool (SIFT)

We built a consistent Social Impact Feedback Tool (SIFT), based on a combination of deduction (RRI/ELSA principles) and induction (case-specific social impact elements).

For a systematic assessment of social impact of the digital innovation, we developed a Social Impact Feedback tool. The philosophy behind the SIFT framework is that it can be used for an external assessment of social impact by researchers, but also for a self-assessment by the stakeholders themselves. The SIFT framework aims to serve as a starting point for dialogue between different stakeholders involved. The iterative development of the SIFT framework followed four steps, combining inductive and deductive methods:

1. Based on conceptual literature, we identified the five core dimensions of the RRI/ELSA framework;
2. To feed our tool design with specific elements about digital innovation in a low-tech environment, we extracted relevant dimensions of social impact[3] from the use case in Peru. We used available documentation about the use case (government reports, academic articles), and we had an initial round of interviews with the Peruvian Ministry of Environment and community forest monitors in the four communities (first field visit, December 2023);
3. We then built a more complete version of the tool, deducing 14 evaluation questions from the five RRI/ELSA criteria and putting all the dimensions into a coherent framework;
4. Finally, we tested the SIFT framework during a second field visit (June 2024), with a broad set of actors and stakeholders involved in forest and deforestation monitoring.

The SIFT framework consists of 5+1 dimensions, and 14 sub-dimensions

The SIFT framework is built around the five RRI/ELSA dimension presented earlier in Table 2.2. A sixth dimension, preceding the other five, is a factual review of the digital tool and its process of implementation. These 5+1 dimensions were further detailed into 14 sub-dimensions. For each sub-dimension, a discussion question was formulated. The summary of the SIFT framework is presented in Table 3.1 and the detailed SIFT framework, including the questions, can be found in Appendix 3 – SIFT framework.

[3] The five initial elements that emerged from the use case in the first round were: the functioning of the forest monitoring process, benefits and beneficiaries, participation of communities, inclusion of individuals within the communities, and collaboration between institutional stakeholders.

Table 3.1 *Summary of the SIFT framework*

ELSA/RRI dimension	Sub-dimension
1. The innovation and its implementation	1. Digital tool quality & implementation process
2. Ethics & anticipation	2. Benefits
	3. Beneficiaries
	4. Ex-ante responsibilisation[4]
3. Inclusion & interactivity	5. In-/exclusion
	6. Participation of key stakeholders for social impact
	7. Collaboration between stakeholders
4. Responsiveness	8. Feedback (including process protocol with feedback loops)
	9. Ex-post responsibilisation[5]
5. Solutionism & negotiation	10. Performance of the governance model
	11. Lastingness
	12. Scaling
6. Participation & Interdisciplinarity	13. Interdisciplinary collaboration between researchers
	14. Consideration of social aspects in the overall technology innovation process

The dimensions of the SIFT framework are briefly explained here:

1. *The innovation and its implementation*
   First, we explore the quality of the digital tool and how it was implemented, as perceived by users. This includes the functionalities as well as the process of its deployment, user training and after-sales support.
2. *Ethics & Anticipation*
   We explore how the potential social impacts of the digital innovation are anticipated, and who can be affected by them in a positive or negative manner. This starts with the expected benefits of the digital innovation, and the question for whom these benefits are important. Unexpected social impacts, opposed interests and possible negative effects are also treated. And we look at who is responsible for addressing or resolving potential negative effects (ex-ante responsibilisation').
3. *Inclusion & interactivity*
   This dimension investigates who is included in the digital innovation, and whether certain actors run the risk of being excluded. We also explore the level and quality of participation of key stakeholders in the digital innovation, in terms of being informed or consulted, or co-designing the innovation or co-deciding about it. This dimension also includes a question about the level of interaction and collaboration between different stakeholders concerning the digital tool.
4. *Responsiveness*
   Responsiveness is explored by asking about the feedback cycle concerning the digital innovation: how have users and other stakeholders been given the opportunity to provide feedback and has that feedback led to modifications in the digital tool? Also, in case of unexpected side effects, have the responsible actors intervened to address these side effects?
5. *Solutionism & Negotiation*
   We assess how the governance structure around the digital innovation has proven effective in dealing with possible disputes or opposed interests and explore how the lasting use of the digital tool is secured, and to what extent the digital tool can be replicated at a substantially larger scale.
6. *Participation & Interdisciplinarity*
   In the RRI/ELSA framework, participation refers to the integration of a social lens into the technological research and development. It combines interdisciplinary collaboration between researchers (ELSA angle) and the participation of social experts in innovation processes of digital technologies (RRI angle). In the context of our Peru case, we asked questions about the internal WUR collaboration between Wageningen Environmental Research (development of the digital tool) and Wageningen Social & Economic Research (social impact research), and about the collaboration within the Peruvian ministry (MINAM) between the digital innovation team and the social development team.

[4] Responsibilisation is about setting standards for responsible behaviour, related to the possible positive and negative consequences of a certain intervention (in this case, a digital innovation). Ex-ante responsibilisation allows for the minimisation of risks, on the basis of current knowledge, *before* an intervention is undertaken (Rijswijk et al., 2021).

[5] Ex-post responsibilisation is the duty of actors to respond to undesired or unintended consequences of new (digital) technologies (Rijswijk et al., 2021).

SIFT interview guides contain both a Likert scale and a free response format to answers the 14 evaluative questions.
Each of the 14 sub-dimensions is translated into an open evaluative question, which can be scored on a Likert scale (see first Appendix 2 – Interview Guides). The Likert scale ranges from 'very weak' (1) to 'very strong' (5). The evaluative questions ask for the interviewees' perceptions about how well a certain aspect of the digital innovation is handled. These scores are easy to answer as well as inherently very subjective, as they depend on factors such as a person's role in the project, their organisational affiliation, their personal scoring style, their mood of the day, the atmosphere of the interview, the rapport with the interviewer. Also, asking for scores challenges the interviewee to reflect and to speak out, and to step away from providing polite and desired answers. Complementary to the scores are the answers given by the interviewees using a free response format. This provides a lot of qualitative data for the research. By going systematically through the 14 evaluative questions, and by showing interest in explanations about 'why and how', respondents are prompted to give comprehensive and detailed answers about different dimensions of social impact and different ways to look at them, leading to deeper and more nuanced insights.

3.2 Process Protocol

In general, the SIFT framework process is envisaged as a feedback cycle to investigate social impact, within the wider Plan-Do-Learn cycle[6] of a certain digital innovation.
The process protocol of the SIFT framework itself consists of three basic steps: data collection on social impact, analysis and reporting, and the providing debriefing to discuss feedback with the stakeholders. This feedback enables the actors to improve the digital innovation project (the app in Peru), and possibly also the wider project in which the digitalisation is embedded (the deforestation monitoring and forest conservation program of PNCB).

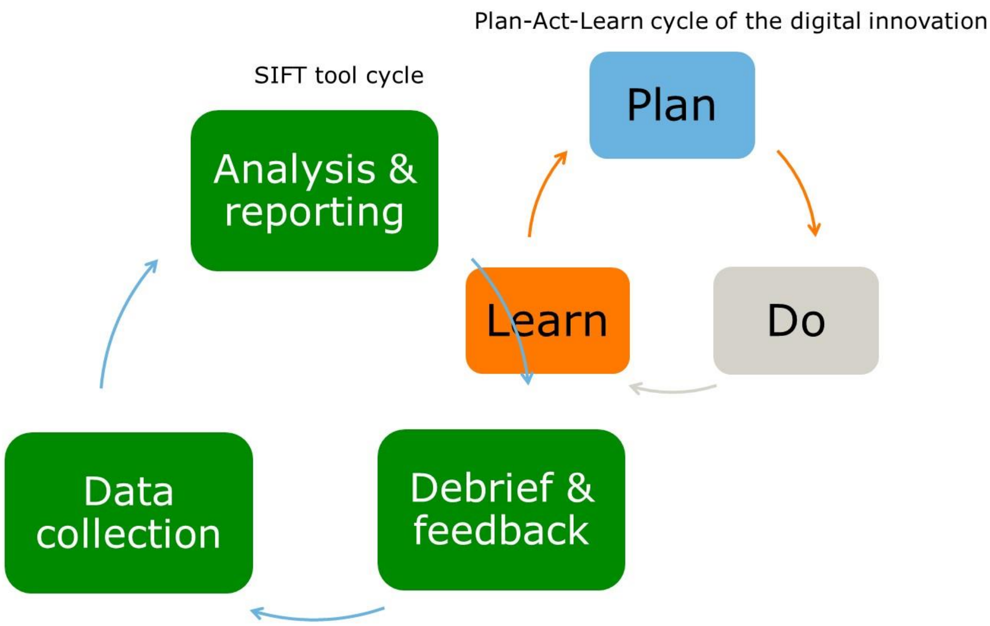

Figure 3.1 *SIFT framework cycle, connected to the Plan – Do– Learn cycle of the digital innovation*

[6] Based on Deming's Plan-Do-Study-Act (PDSA) cycle, alternatively named the Plan-Do-Check-Act (PDCA) cycle, which is used in different variants of quality and improvement management (Moes, 2020). For our purpose, we summarised the Study/Check and Act phases into one learning step whereby the actors collect and analyse data and deliberate about re-adjustments to the intervention.

In the Peru context, the implementation of the SIFT framework is part and parcel of the 'learn' step around the smartphone app, within the wider context of PNCB's forest conservation activities.
In the Peru case, the SIFT framework was implemented for a specific digital innovation: the introduction of a smartphone app for PNCB's community-based forest monitoring, which was tested in four communities in the Madre de Dios department in Peru.

For the development and first application of the SIFT framework, we used a combination of document review, stakeholder mapping, interviews and focus group discussions.
Following the three steps in the SIFT framework development cycle, the following methods were applied:

1. Data collection (per step):[7]

Step 1 (RRI/ELSA framework)
- *Document review*: conceptual literature about RRI and ELSA for digital innovation.

Step 2 (inventory of use case elements to feed the SIFT framework)
- *Document review*: this included a review of reports of the PNCB programme, as well as scientific and newspaper articles about the community-based forest monitoring, the REDD+ incentive system and the context of deforestation in the Madre de Dios department.
- *Stakeholder mapping*: a first round of stakeholder mapping was done within the research team, based on the knowledge of the Peruvian researcher. This was the basis for the selection of interviewees.
- *Semi-structured interviews (Dec 2023):* 11 interviews with PNCB (2) and members of three communities (9) – 1 village chief, 3 forest monitoring administrators and 5 members of forest monitoring committees.
- *Focus group discussion (FGD) with involved communities (December 2023)*: forest monitoring committees from three communities participated in the FGDs (see Section 4.2).

Step 3 (testing the SIFT framework, by implementing it in the use case)
- *Semi-structured interviews with institutional stakeholders*: a total of 10 persons interviews from institutional stakeholders (both governmental and non-governmental) were interviewed, including PNCB at HQ (3) and regional level (1), the forestry service of the regional government of Madre de Dios (2), a federation of indigenous communities (1), several NGOs (2) and a co-administration entity of a Protected Area (3) (see Appendix 1 – Lists of interviewees). In the interviews, all 14 evaluative questions of the SIFT framework were asked, including the Likert scoring and the free response format.
- *Focus group discussions (FGDs) with involved communities*: forest monitoring committees in three of the four communities participated in the FGDs (13 participants in 3 FGDs), combined with interviews with the administrators (3) of the conditional payment schemes in which the communities participated (see Section 4.2). In the FGDs, a selection of the SIFT questions was treated, because FGDs lasting 1.5-2 hours only allow for a limited number of topics to be treated. The topics were selected because of their particular relevance at community level.
- *Stakeholder mapping*: A second round of stakeholder mapping was done as result of the interviews, leading to a more complete picture of different types of stakeholders in forest conservation, also outside the PNCB program. See Appendix 4 – Stakeholder Mapping for a visualisation of stakeholders.

2. Analysis and reporting (after step 3):
- The results of the four data sources were manually sorted and allocated to the 14 topics. This base material was analysed and transformed into chapter texts for each of the 5+1 dimensions of the SIFT framework (see Chapter 5).

3. Debriefing and feedback (still envisaged):
- It is still envisaged to distribute a short and accessible summary factsheet of the findings to the stakeholders (in Spanish). Whenever new visits are scheduled to the four communities, these findings can be discussed and the stakeholders can be invited to formulate their recommendations for improvement, to PNCB, to WUR and to the communities.

[7] The four steps are listed at the beginning of Section 4.1.

4 Use Case Description

In this chapter, the specific context of (digital) community-based forest monitoring in the Peruvian Amazon is described, according to the three domains of the Social-Cyber-Physical System (Sections 4.1 - 4.3). The focus in this project is on assessing social impacts that are the result of using a smartphone app for forest monitoring activities. Because forest monitoring using a digital tool builds upon a paper-based system of community-based forest monitoring, understanding the manual process is pivotal for identifying the social impacts. Therefore, some dynamics of the paper-based system are also described throughout Sections 4.1 - 4.3. In Section 4.4, the entities and interactions in each domain are summarised.

4.1 Physical domain: Deforestation in Madre de Dios

One of the main drivers of deforestation in Madre de Dios is illegal gold mining, which leads to severe risks for local communities.

Madre de Dios is considered one of the most biodiverse places in the world, and 12% of the Peruvian Amazon is located in this region (WWF, n.d.). In 2010, Madre de Dios had a tree cover that extended over 98% of its land area. However, there has been a steady increase in deforestation rates in the region (Bennett et al., 2023). Between 2002 and 2023, 278 kha of (humid) primary forest was lost, a decrease in the total area of humid primary forest in Madre de Dios of 3.5% (Global Forest Watch, n.d.). Throughout the Amazon, the intensity but also the drivers of deforestation vary. For example, in Ucayali the production of illegal crops mainly drives deforestation and in San Martin it is related to expansion of agriculture. In Madre de Dios, the main problem is mining, and about 97% of the gold is extracted illegally (Chirif, 2019). Mining creates substantial environmental and health issues, as water and air are polluted by mercury (Radwin, 2024). Despite these negative impacts, increasing numbers of people have moved to Madre de Dios since the 2000s due to the construction of the Interoceanic Highway and for gold mining (Jensen et al., 2018). In many cases, local communities, who experience the detrimental effects, are also involved in mining themselves. The trade-off between forest conservation and economic activities frequently leads to violent conflicts.

Due to land sub-division and overlapping concessions, multiple actors have a stake in forest management, making it more complex to effectively address deforestation issues.

Madre de Dios has the most protected natural areas in Peru (Bennett et al., 2023), covering about 45% of the land area of the region. There are 3 national parks, 1 national reserve, 2 communal reserves and about 25 private conservation areas for research and tourism (gob.pe, n.d.). Furthermore, there is a territorial reserve that protects indigenous and uncontacted peoples. Most areas fall under the responsibility of SERNANP (part of MINAM), though, the Ministry of Culture administers territorial reserve, and the communal reserve is co-managed by SERNANP and indigenous organisation ECA Amarakaeri. Concessions for conservation often overlap with concessions for, e.g., brazil nut production, logging, or mining (Garrish et al., 2014), exacerbating opposing interests in the natural resources. Only recently, a start was made of creating a cadaster of land allocations (madrededios.com, 2020). These land sub-divisions also imply a change in responsibilities of local communities. Although communities have been controlling their borders to identify invaders for generations, monitoring and accounting for land use is a relatively new task. The severity of the deforestation problem has been recognised by the government (Paskay, 2022), and actions taken to stop illegal mining are taken from time to time (Catanoso, 2019). Nevertheless, opposing interests are at play (Peru Support Group, 2022), and adequately addressing deforestation remains a challenge.

4.2 Social domain: Community-based Forest Monitoring & PNCB

The Peruvian Ministry of Environment (MINAM) committed to reduce deforestation and established the National Forest Conservation Program for Climate Change Mitigation (PNCB-MCC) in 2010.

The overall goal of PNCB-MCC is to conserve 54 million ha of tropical forests (Amazonian, dry and Andean) in the country by 2030, as a contribution to climate change mitigation and sustainable development. It aims to do so via three pathways: first, by identifying and mapping areas for forest conservation; second, by promoting the development of sustainable forest-based production systems to provide income for local communities; and, lastly, by strengthening the capacities of regional and local governments, as well as local communities, for forest conservation (MINAM, 2023). Regarding the latter pathway, PNCB's target has been to conserve 10m ha of forest under agreements, to the benefit of 1,000 local communities. Under the Conditional Direct Transfers (TDC) mechanism, communities received economic incentives per hectare of monitored forest, if all agreed targets and efforts are fulfilled. Communities that have satisfactorily fulfilled a 5-year TDC contract can obtain an 18-month FIP-BID contract (Forest Investment Program of the Inter-American Development Bank), which is positioned as a successor programme of TDC, but limited to economic activities only. Insights from the forest monitoring data are made publicly available through the web-based GeoBosques platform (dashboard).

Under TDC agreements, as part of PNCB, it is estimated that the loss of 27% of native community forest was avoided (MINAM, 2023).

Between 2011 and 2020, 2.934.713 ha of forest has been brought under TDC conservation contracts. As part of forest conservation activities, forest monitoring (vigilance) committees are formed, who are responsible for patrolling the forest, verifying deforestation alerts, and reporting back to PNCB. Agreements about deforestation reduction targets, the area under conservation as well as expenditure of incentives on different activities are outlined in a Incentive Management Plan (PGI). Incentives are allocated to five different categories: forest monitoring activities, community organisation, economic activities, subsistence activities, and cultural activities. The PGI is co-developed by PNCB and the community, and one person (that is affiliated with the community) is appointed as *gestor*, to manage the budget. As of 2020, 274 local communities had been involved in the PNCB conservation efforts (MINAM, 2023).

There is a variety of actors active in forest monitoring and addressing deforestation in the Madre de Dios.

International agencies and donors, non-governmental- and civil society organisations are actively involved in forest conservation. Civil society organisation include indigenous organisations, such as AIDESEP and its affiliated regional federations (FENAMAD in Madre de Dios), as well the co-administrations for protected areas (ANECAP). Indigenous organisations play a central role in alignment and communication between local communities and the government, since their presence is considered more permanent, and because of their familiarity with the local context of communities. In addition to the monitors that collect and share data with PNCB, there are also other groups of forest monitors. Some include monitors that report to Global Forest Watch (also called *vigilantes*), and monitors that report to FENAMAD (*veedores*). The regional government of Madre de Dios has also recognised and appointed forest monitors, on personal title (*custodios*), and in the protected national areas, dedicated park rangers (*guardaparques*) are assigned. Individuals from communities may be part of multiple groups of monitors. However, different reporting methods (including apps), incentives and targets may apply, creating sometimes interdependencies and overlapping responsibilities. In many cases, communities are governed by a board (*Junta Directiva*) that is formed by about three community members. However, board members usually rotate every two years, which can lead to a lack of consistency in management plans and priorities, and therefore the allocation of resources. As such, activities of forest monitoring committees are also impacted by prioritisation of forest protection by the board. An inexhaustive map of stakeholders in forest conservation and monitoring in Madre de Dios, and the relations between them, can be found in Appendix 4 – Stakeholder Mapping.

4.3 Cyber domain: High-tech in a Low-tech Environment

The initially paper-based system for forest monitoring by local communities is time consuming and prone to data losses.

MINAM detects changes in forest cover using satellite images and generates alerts if deforestation is suspected. These alerts, which include a map and geo-coordinates, are printed on paper and send to the regional office of MINAM (*area zonal*). Subsequently, this regional office shares the alerts as well as verification forms with individual communities. Community forest monitors are requested to verify the alerts and collect and provide relevant data in the paper template. They have to report back to the regional PNCB office within 60 days after receiving the alert. Sending paper forms to and from MINAM's HQ in Lima, the regional offices and the local communities can also take several weeks, sometimes even months, and is therefore time consuming. Besides, communities face practical struggles such as forms that get lost or rained on in the forest. Also, only one forest monitor at a time can annotate relevant information. As such, this delays potential actions to counter deforestation where needed.

Wageningen Environmental Research developed a smartphone app to facilitate community-based forest monitoring activities and increase data accuracy.

For collecting data, including photographs and information about drivers of deforestation, a smartphone app was developed. The Open Data Kit (ODK) was used as a platform, which allows users to customise digital forms for data collection according to their needs. As such, ODK forms have been designed to collect deforestation verification information. Forest monitors can fill out the forms offline and data is uploaded to a server once the app is connected to the internet, which is a major benefit in low-tech environments where connectivity and internet coverage are generally very limited. The aim of the app is to increase efficiency of data collection and data exchange, to improve the accuracy with GPS data and limit human error in data collection.

The app has been implemented and tested by Wageningen Environmental Research in four communities in the Madre de Dios region, in collaboration with PNCB.

In 2022, a pilot has started in Madre de Dios region, including the following communities: Tres Islas, Infierno, Puerto Arturo, and Boca Pariamanu. Although all three communities are relatively easy to reach from Puerto Maldonado, the regional capital, the availability of internet connection is generally very limited. Owning and operating smartphones, including apps, had not been common practice within all communities. Members of the monitoring committees have received training on the use of the smartphone app and a limited number of smartphones was provided to each community. The first session was organised in July 2022 in Puerto Maldonado, which included theoretical explanation as well as in-field practice. Between mid-2022 and mid-2024, forest monitors provided verification data via two channels. During patrols, data has been collected both on paper forms and with the digital smartphone app. Data collected via paper forms are shared directly with PNCB, whereas app-data were sent to the ODK server managed by Wageningen Environmental Research. Although access to this server was granted to PNCB, the possibility of accessing the data has not been utilised.

4.4 SCPS Summary

The three SCP domains interact with each other. Both the communities, the government and other stakeholders have an interest in the forest, either in exploiting it or in reducing deforestation (socio-physical interaction). The entities and interactions in each of the SCPS domains, as described in the preceding sections, are summarised in Table 4.1.

Table 4.1 *Outline of the Social-Cyber-Physical domains of this case study*

Domain	**Entities**	**Interactions**
Social	• Groups of forest monitors from local communities • Community boards (Juntas Directivas) • Representatives of MINAM-PNCB on national and regional level • Indigenous organisations • NGOs & development organisations • The local government (*gerencia regional*) • Other community members.	The co-existence of multiple social governance systems, and the interactions between national- and regional level management frequently creates complexity in the interactions between different stakeholders. Interactions are further complicated by fragmented decision-making power and limited information sharing.
Cyber	• Customised smartphone ODK app + ODK server • Satellite-based deforestation alerts • Smartphones • GPS devices • Internet availability.	Satellite images are used for deforestation alerts, GPS devices and information collection via apps, which is stored on a server. Availability of internet affects data uploads and the overall system is dependent on sharing of data between devices.
Physical	• Forest canopies • Mining activities • Tree logging • Community borders and zonification • (In)accessibility of community territory • Physical security risks.	Different forest activities, such as mining and logging, conflict with forest protection goals. Gaps in the forest canopy created by these activities or by natural causes can generate deforestation alerts, if detected on satellite images. Security risks and the accessibility of territories affect monitoring activities.

5 Results

In this chapter, the research findings are described, based on the SIFT implementation during the second field visit (June 2024). The results are structured according to the (sub-)dimensions of the SIFT framework, as outlined in Chapter 3.

5.1 Ethics & anticipation

5.1.1 Benefits & Disadvantages

There is consensus among interviewees about the positive contribution that smartphone apps and other novel technologies, such as drones have for efficient forest monitoring.
Among the main benefits, it is perceived that the use of apps facilitates the organisation, structuring, and storage of information. This also allows the information to be shared more easily and timely. Or, as one interviewee pointed out: 'Information arrives faster. [This is useful], especially in the months where there are more alerts.'

By using technologies such as apps it is possible to establish certain mechanisms for better monitoring and improve the reliability of the data.
Data collected via digital devices does not need to be transcribed, is generally easier to structure and prevents human error, for example by GPS coordinates and automatic indication of the observation date. In that sense, the collected data is traceable and allows for timely data sharing between stakeholders. It was also pointed out by forest monitors that the use of the smartphone app is faster than filling out a paper form and is easier to use. A government representative also remarked that '[forest monitors] are able to collect information more easily because using paper in the field is problematic. It is also helpful to be able to collect images'.

However, there are some disadvantages and risks that have been highlighted on the community level.
The use of technology requires a certain logistical infrastructure that can facilitate its operation in the field. The gap between rural and urban areas in terms of internet connectivity and energy supply remains large and represents a significant disadvantage for local communities. The communities that have been part of the trial of the smartphone app are all located relatively close to the city of Puerto Maldonado, where basic communications infrastructure is generally available. However, internet availability in the communities has been variable, in part due to coverage in the area, but also because at least two communities decided to cancel their internet subscription considering that the costs exceeded the benefits. Moreover, several people from each community are nowadays based in Puerto Maldonado, which increases information sharing between the town and rural areas. It is assumed that for communities that are located at a greater distance from the town, available infrastructure is much more scarce or non-existent.

Likewise, the management of digital tools requires skills, time and resources to be successful, as working with digital tools is not a common task for many (intended) users.
Developing capabilities and digital skills requires an operational and logistical process that costs time and effort. These trainings are generally provided by the institutions that promote forest monitoring initiatives. In the words of some interviewees: 'It is a challenge to understand the application.' A government representative remarked: 'Transferring technology and technology ownership increases (operational) costs, in terms of labour hours, because trainings are essential.'

Important issues are the safety of people collecting the deforestation data and the security of the collected data itself.
There are security risks related to data collection (both paper-based and digital), especially because the loss of forests can be associated with illegal activities. According to a government representative: 'One may

encounter delicate situations and illegal activities. The invaders also realise that they are becoming more visible and that there is more capacity to identify them.'

One forest monitor expressed concerns about potential encounters with invaders: 'If miners or invaders see us with the drone or smartphone, they may think we are reporting them or filing complaints.' In turn, this may increase the risk of personal attacks on forest monitors. Additionally, there are concerns that digital information could be leaked or fall into the wrong hands, for example, with the theft of a smartphone. Thus, an indigenous leader mentioned: 'When an observation is collected by the team, sometimes it's recorded who took that data point. And if that information, which is sensitive, falls into the wrong hands, it could be a problem.'

5.1.2 Beneficiaries

There is a need for all actors involved in forest monitoring to be able to use digital tools and/or interpret the collected data.
There must be capabilities at all stages of the forest monitoring system to access, understand and manage the data. It is of no use to strengthen digitalisation in forest monitoring at the initial stages, or in the first line of monitoring (by forest monitors), if the later links (e.g., law enforcement institutions and PNCB) are unwilling or unable to use the information collected. Vice versa the same argument holds, or as a government representative pointed out: 'Apps can help a lot [in addressing deforestation], if users know how to use them well. Thus, an entire communication chain is needed to create this impact.' However, the forest monitors can currently not access the data they collected once it is submitted. Feedback on the quality and content of submitted forms is also not provided. Forest monitors may benefit from better forest conservation, yet they are not able to benefit from the collected data in the current system.

There are indications that the benefits of using digital technology for forest monitoring are currently not equally distributed among involved stakeholders, which mainly results from differences in data access.
Not all stakeholders have the same level of access to information. For example, the government has access to all collected forest monitoring data, whereas indigenous organisations are dependent on collaboration and data (e.g., alerts) sharing by others. 'The [question] is how prepared we all are to be able to achieve this information interoperability.' It was acknowledged that data owners are also more likely to benefit from the use of it, for example more immediate actions or sanctions by authorities against illegal activities. In terms of ownership, government officers mentioned: 'The ones who collect and the ones who request the data should both be able to decide about who has access to the data and who has not, and in what detail. It should be regulated in the future; [it would be good] to have some guidelines.'

5.1.3 Ex-ante responsibilisation

It has been recognised that ex-ante responsibilisation is not always considered, for instance regarding data processing and ensuring equal access to the smartphone app.
It is important to recognise that the introduction of digital technologies can open a series of consequences, desired and unintended. When issues regarding the use of the smartphone app materialised, PNCB and/or Wageningen Environmental Research have sometimes been able to amend the course and take corrective measures. In others stances, innovative suggestions have been proposed by the end users of the smartphone app from the community members. These suggestions have to do with acquiring financing to develop capabilities, continuous learning, support and feedback about data collection. In the words of some interviewees: 'The negative impacts have not been considered and resolved from the beginning. But in practice you notice it, and you can overcome it to a certain extent. Examples of negative consequences are that not everyone has equal access to technology.' One forest monitor mentioned that it would be beneficial if projects allocate budget to trainings, as learning how to work with an app takes time, but that budget is unfortunately not always available for such activities.

5.2 Inclusion & Interactivity

5.2.1 In-/Exclusion

Involving community members in forest monitoring provides recognition for their contribution and interest in forest conservation, however, the level of inclusion of individuals differs between and within communities.
Actively including community members encourages their commitment to forest monitoring activities in the long run. However, not everyone has the same possibilities and capabilities to understand and manage technological devices and applications used for forest monitoring. In fact, most interviewees indicated substantial differences according to gender, age, language skills and other sociocultural factors. For example, some mentioned that: 'There is a digital gap between men and women, and between youth and elder people'; 'It's a generational issue. For older people it is a little more difficult to get into technology'; 'As a comparison, a 60-year-old park ranger vs a 25-year-old park ranger. The younger one has been involved in the digital world since he was born, there is obviously a digital gap.'

Instead of trying to resolve these differences among community members, they can also be beneficial for improving forest monitoring activities.
The importance of knowledge of the community territory for forest monitoring has been recognised, both by community members and government officers. This includes knowing where community boundaries are located, and which parts of the territory are swamps and therefore inaccessible. Generally, this information resides with the elderly within the community. In the words of a forest monitor: 'The community has been able to balance ease of technology use by youth, and the knowledge of the territory that the elders have.' Likewise, the importance of women's roles within the surveillance system has also been highlighted, although they are not always in the front line of forest monitoring. A government representative pointed out: 'Women are less involved in patrolling, but there is potential to get them more involved in surveillance; women often stay in the village where there is (internet) connectivity, so they can use smartphones more often to communicate.' Thus, the group in charge of forest monitoring could also be perceived as a dynamic entity, which can take advantage of its variability and different strengths.

5.2.2 Participation of key stakeholders

Several strategies have been used to close the existing digital knowledge gaps, and to promote the participation of different stakeholders.
Since women and elderly are often less involved in the use of digital technology, there have been initiatives to get women more involved in the use of digital technology, for example by using apps for the sales of artisanal crafts. Likewise, there have been sessions (in at least one community) where young people shared digital knowledge and supported the elderly in using digital technology. These learning initiatives are generally strongly appreciated by community members.

During the process of introducing the (wider) PNCB forest monitoring mechanism, end users from the local context could have been involved more.
The structure of the PNCB forest monitoring system, and the introduction of digital technologies used in the process, has been implemented in a top-down manner. This implies little participation of local and regional stakeholders, such as communities and indigenous organisations, in the design of forms and tools. In words of an indigenous leader: 'There should be participation of indigenous organisations, and all the actors involved in forest conservation. There is no co-creation process, it is imposed.' A government representative, on the other hand, stated that the extent of involvement of communities in co-design of the process is very variable, and that it depends a lot on the level of organisation within the communities.

5.2.3 Collaboration between stakeholders

There are several mechanisms to align and coordinate the collaboration between different stakeholders in forest management in Madre de Dios.
Indigenous organisations are important actors in facilitating collaboration on the regional level, particularly between communities and other organisations. Many times, this collaboration occurs through formal and

informal communication channels. A few times per year the regional government of Madre de Dios hosts a roundtable, the Regional Forestry and Wildlife Control and Surveillance Board. This is a space where multiple parties, such as SERFOR, SERNANP, OSINFOR, FENAMAD and the police, come together to discuss forest management plans and issues. However, not all stakeholders are included, PNCB being one of them.

The use of (multiple) digital tools could facilitate the collaboration between stakeholders, though it may also create a situation where multiple similar initiatives run in parallel.
Collected forest monitoring data could serve multiple purposes simultaneously. In the words of a government representative: 'The use of apps can help the collaboration between different organisations because oftentimes multiple entities are working on the reduction of deforestation at the same time. If multiple organisations are involved in the same community, it would be easier to share information. But at this point that is difficult because everything is focused on data collection.' On the contrary, the variety of digital technologies could lead to a situation of initiatives operating in parallel. Although there are multiple apps in development and used by sometimes different groups within a community, coordination efforts sometimes do not work out well. At community level, this has led to complexities and the existence of different structures for community forest surveillance, where adequate collaboration channels do not always exist. For example, in one community there have been two groups of forest monitors, working with different apps and reporting to different authorities.

In some cases, collaboration between stakeholders has been indicated as insufficient to address issues identified based on forest monitoring data.
This may occur in some cases due to the low familiarity with digital technology that makes it difficult to understand the data, and therefore, to take action. In this way, it was pointed out that: 'A digital culture is required throughout the [forest conservation] chain.' Several actors need to be involved in order to address problems identified based on forest monitoring data, like the police, OSINFOR, OEFA, prosecutor's office, and/or others. It is important that collected data can be interpreted and that conclusions are made based on the collected data (for the system to work). 'What is missing, is a faster response from the government actors. There needs to be a chain of action; from data collection to reporting, to concrete actions or sanctions.'

5.3 Responsiveness

5.3.1 Feedback

For the development and design of the smartphone app for data collection, multiple feedback iterations between stakeholders provided improvements for data collection.
Prior to using the smartphone app, there had been a co-design process, involving the regional office of MINAM (*area zonal*) and some communities, with the goal to make the data collection forms less complex. The information collected, as part of the TDC, had no standardised format in the beginning. As such, it was also complicated to process the data. WUR was tasked to improve the digital data collection form, making it available in the smartphone app. PNCB indicated that the suggestions they provided are generally incorporated well by the WUR team. ODK has also be installed on the Bosques server, to improve transparency and information sharing between WUR and PNCB, and was also used by JICA (for another bilateral project). Over time, the data form has been consolidated and standardised, but problems were reported regarding the use of the server.

There seems to be a trade-off between the extent of user-feedback included and the response rate in the development of apps for forest monitoring processes.
Apart from the ODK smartphone app, there have been other apps for forest monitoring that have been promoted by PNCB and other organisations, which differ substantially in the level of user-feedback incorporated. Examples of other apps are: SMART, Locus Map, ForestWatcher and MAPEO. For the development of the SMART app, feedback from SERNANP has been considered, though indigenous organisations had not been included in the process. For MAPEO, on the contrary, there has been a more profound co-design process in place. Awana digital, which developed MAPEO, collaborated with indigenous organisations and different groups of forest monitors (*vigilantes* and *guardaparques*). This way, they actively asked for elements of the app

that are required or desired, to better align with the needs of the users in the communities. However, requested modifications to the apps are also processed at a different speed. For SMART, there is a dedicated team of developers that can make adjustments quickly, when needed. For MAPEO there are limited resources available, such as budget and time, which slows down the development process.

5.3.2 Ex-post responsibilisation

PNCB indicated that the speed and responsibility of solving issues encountered by users in the communities varies case-by-case.

The forest monitoring with the use of smartphone apps comes with various issues, both issues experienced by the app users as well as related to the functioning of the system. Based on interviews and informal conversations, it was understood that user issues include lost smartphones, not knowing how to reinstall the app and unclarity regarding what information to provide in which field of the form. Some of these issues are addressed by the PNCB directly whereas other issues are resolved by local organisations. The familiarity and continuity of collaboration between communities and other organisations affects the efficiency of problem solving. Issues are mostly addressed on an ad hoc basis, depending on the type and severity of the experienced issue. It has to be noted that this holds for the use of apps in general and is not specifically related to the ODK smartphone app.

A differentiation has been created between different groups of forest monitors, which complicates the functioning of the overall monitoring system.

FENAMAD has been appointing forest monitors (*veedores*), which are nominated by the individual communities, and pays them a monthly fee, while other types of forest monitoring are on a voluntary basis or provide an in-kind compensation. This disparity leads to a divide between monitors, with many of them preferring to become a *veedor* because of the obtained incentives. This unintended consequence may lead to a shortage of other types of monitors and therefore may create a problem on an institutional level. It remains unclear which institution is responsible for addressing this issue. How this translates into effects on forest monitoring and reduction of deforestation is beyond the scope of this study.

5.4 Solutionism & Negotiation

5.4.1 Performance of governance model

Identified drivers of deforestation and any issues encountered in the implementation of (digital) forest monitoring, which require involvement of the state, are mainly addressed on an ad hoc basis.

As in any process, difficulties have been encountered in the implementation and continuation of community-based forest monitoring, as well as related to the introduction of the smartphone app. Thus far, there are no standard protocols or procedure in place for problem solving within the PNCB mechanism. Depending on the urgency and context, PNCB subsequently chooses an appropriate approach, on a case-by case basis. Overall, the criticism from forest monitors is that they have the impression that although they are providing information about the drivers of deforestation, which pose a risk to their activities (e.g., mining, drug trafficking), there is insufficient action on behalf of the state to address these drivers of deforestation.

The solution to encountered problems can oftentimes not be provided by a single authority, but requires parties with different responsibilities, which creates alignment problems.

As one respondent stated: 'It is one thing to generate information about deforestation [and report to PNCB]. But deforestation can only be reduced if that information is used effectively, and action is taken.' This may require involvement of e.g., SERNANP, SERFOR and/or the police. The need for multiple stakeholders complicates decision making. Another respondent mentioned the need for spaces/dialogue, 'to highlight the problems of forests, so that much more complex decisions can be made.' The division of responsibilities among multiple organisations and state actors also causes that not all recommendations from users can be taken into account. For example, users of the smartphone app suggested to include a functionality so that they can report pollution issues. However, problems related to pollution in Peru fall under the authority of OEFA[8] rather than under the control of MINAM directly.

Limited communication within communities about monitoring requirements and incentives can hinder the functioning of the (digital) forest monitoring system.

Within communities, there have been opposing opinions about the implementation of monitoring programs, although they often decide about participation in general assemblies. In one community, several members did not understand why the agreement with PNCB was accepted, as they worried that logging would no longer be allowed, while it provided their source of income. Forest land allocation plans (*zonificación forestal*) are discussed during general community meetings and helped to communicate which activities were permitted in what areas of the community. Another sensitive point was that not all community members benefit directly from incentives provided by programs such as TDC or FIP-BID. Eventually, agreement was reached after additional clarification, according to forest monitors and *gestor* of the community. It was explained that although someone may not receive personal incentives, their relatives may do so. E.g. parents that receive support for agriculture, or a cousin that receives support as a student. In other communities, the community boards have not been sufficiently aware of the tasks of monitoring committees, creating a lack of support for their activities and possibly opposing priorities.

Between the state and the communities, it is essential to consider the continuity of communication and room for dialogue, to generate adequate understanding.

After participating successfully in the TDC, communities can continue in the FIP-BID programme. For one community, this new programme started three months ago, yet they did not receive any information and therefore feel deceived. In the same community, someone exclaimed that 'we are being managed!' This referred to the fact that often programme implementers decide about the type of incentives and how they are allocated. In this case there have been 22 beneficiaries for cocoa, plantain and poultry, but the community members would have preferred support for other crops. The lack of a main contact person, that represents the community and is recognised by the program management, increases this communication issue.

5.4.2 Lastingness

Inconsistent resource allocation by community boards poses a risk for continuous forest monitoring activities, and dependencies in information supply affect the users' autonomy to use the smartphone app.

The relatively frequent changes of community board members (every two years) come at an expense. Every board has different plans and priorities, and information transfer between boards is often limited. The time and resources available to monitoring committees is directly impacted by the priorities of the board. Poor communication between the forest monitoring committees and the board regularly creates issues (such as missed workshop opportunities). Moreover, the effectiveness of forest monitoring is dependent on the sharing of deforestation alerts, provided by PNCB. In one community it was remarked that 'we will face difficulties in the future because we won't know where the alert is located,' referring to the 5-year timespan of the TDC programme. It is unclear if the sharing of alerts will be continued in the longer term.

Lastingness of digital apps and monitoring systems also depends on the extent to which the system and the apps align with users' intrinsic needs or motivation.

In communities, there has been an ancestral practice of patrolling to protect their territory. Patrolling and reporting land use change and deforestation, in collaboration with the government, is a rather new activity that community members will not necessarily continue without receiving incentives. This may indicate that motivation for deforestation monitoring is more extrinsic. Moreover, youth generally have limited knowledge of their community territory, including the terrain and boundaries. In the past, when there were invaders, community members negotiated with them, allowing them to exploit the land, but they had to take care of the forest in return. This custom has not been passed down to younger generations, who consider the land their own, without conditions. As such there is no or limited negotiation with settlers, increasing the risk of conflicts. Forest conservation, in contrast to territory protection, is also relatively new and incentivised by conservation programmes, making continuation less certain.

[8] OEFA, or Environmental Assessment and Control Agency for its acronym in Spanish, is a specialised technical agency that is in charge of keeping oversight and ensuring an balance between private economic investment and environmental protection. OEFA is affiliated to the Ministry of the Environment.

Multiple respondents indicated that the lasting technology use by communities is connected to the monetary incentives received.
In the current situation, it is expected that 'if financial support goes away, the entire system collapses', as pointed out by a government representative. PNCB therefore attempts to link forest monitoring activities to incentives that support the cultivation of specific crops, as an income-generating source. However, the incentives and target crops do not always match the activities and priorities within specific communities. If there are few economic resources in a community, the interest in monitoring is lower because they prioritise obtaining money for food and fuel. The cost-benefit trade-off of forest monitoring is important. If the value of the standing forest is higher, e.g., for tourism, than logging trees, priorities may shift.

PNCB acknowledged the importance of lastingness, or sustained use of the smartphone app over time, and has therefore recently set up a new team to improve this likelihood.
PNCB indicated that one of the lessons learnt from the trial with the smartphone app of Wageningen Environmental Research is the importance of creating the capacity for PNCB to manage the processes themselves, autonomously. In the beginning, the ODK smartphone app was linked to the server of WUR, thereby limiting access to the collected data by PNCB. Similarly, they had been dependent on external parties for storing relevant data of ForestWatcher and GLAD. To address this, a connection has been made between ODK and the Bosques platform. At the same time, insights shared by WUR also helped to tune the data collection forms to the situation in the field.

It has also been recognised that there is a need for institutional capacity to safeguard the continuity of the forest monitoring.
The communities that are transferring from the TDC to FIP-BID programme have experienced a drop in information and incentives received. This void creates a lack of trust in PNCB, possibly affecting the level of collaboration in and success of subsequent monitoring programmes. As a consequence, the number of forest monitors has been decreasing over time. There needs to be an organised 'chain of action' that facilitates the flow of information and incentives between actors. Now, projects are often temporary, thereby impacting the lastingness of the monitoring systems set up. In this 'chain', it is considered important that indigenous organisations play a key role, since their presence is considered more permanent than that of for example PNCB.

Monitoring agreements bring both direct and indirect benefits to communities.
For the forest monitors, these agreements provide direct incentives to undertake monitoring activities. Without budget for monitoring, the number of patrols decreases substantially. One respondent remarked that monetary incentives are not only needed to cover expenses such as fuel, but also to create a sense of accountability. In some communities, the existence of agreements also serves as a deterrent factor that keeps invaders at bay, to some extent, because they know the government is involved and their presence won't go unnoticed. In these communities there are fears that, when the current agreement ends, invaders will seize their opportunity and start extracting resources from the forest.

On a digital system level, the lastingness of the smartphone app is linked to the availability and costs of data.
For example, LANDSAT images that are used to generate alerts are freely available. Even so, software such as ODK are for free. If costs related to satellite images and/or software would increase, this would also affect the feasibility of the system, given limited ministerial budgets etc. On the other hand it is also noted that to be able to provide training, purchase equipment and invest in application design, it is important that budget is allocated to these tasks, in order to maintain and improve the system over time.

5.4.3 Scaling

It is expected that in Peru there is a relatively high readiness to adopt new digital technologies, compared to some other countries, but there are several barriers.
There is a need for tools that can prove that there have been changes to the environment, to make a case. This contributes to the ability to report and denounce undesired activities. Nevertheless, the scaling potential of digital tools is sometimes limited by individuals in management positions who are reluctant to change to newer, digital systems. Besides, the diversity in digital tools available for forest monitoring also complicate the scaling of a single tool to areas where other tools are already incorporated in activities.

Although the different apps were first piloted with a limited number of users, the capacity to scale up a single app depends on prior introductions of other apps in the region.
The ODK smartphone app has been piloted, with only a limited number of users involved (see also Section 4.3). Similarly, the use of the SMART app began as a pilot in the Tambopata and Manu areas. Later, it was scaled to all natural protected areas, for which previous experience proved useful according to a government representative. In the Madre de Dios region, however, there is limited capacity to scale the use of digital apps further, according to a respondent from a civil society organisation. The two protected areas and reserve occupy two-thirds of the total territory, and apps have already been used there. The same interviewee mentioned that in other regions in Peru, such as in Ucayali, there is a larger potential to scale the use of digital technologies for forest monitoring. There are more communities living in this region (that have not yet been introduced to digital apps), which offers an opportunity for scaling.

Gaps in (digital) literacy and internet coverage are other factors that impeded the scaling of smartphone apps, in general.
Limited availability of internet access and digital skills, which are required to operate apps, pose a risk for scaling digital apps. The language used in the app is sometimes also a limiting factor. Some apps (partly) use English as the main language. Even when available in Spanish, this may still be a barrier for illiterate people or people with limited knowledge of the Spanish language. A third factor that may hamper the scaling of digital technology in a practical way is the limited accessibility of some areas via road or other networks. Sometimes indigenous organisations connect and facilitate in-person sessions with members of multiple (remote) communities. As such, monitoring topics can be addressed in somewhat more centralised and collective way.

5.5 Participation & interdisciplinarity

5.5.1 Interdisciplinary research collaboration

From a research perspective, it is relevant to assess how different (technical and social) disciplines have been combined in the implementation and development of the smartphone app.
The goal of the project was to understand the social impact on stakeholders of a smartphone app for community-based forest monitoring, which is intended to replace an initially paper-based forest monitoring process. Generally it has been a positive experience to work on community-based forest monitoring with different disciplinary WUR teams. Wageningen Environmental Research indicated that the social impact assessment served as an 'extra pair of eyes' to verify the (anticipated positive) impact of the technology. 'We may feel, think or assume that impacts are positive, but that may not be the case.' Wageningen Social & Economic Research appreciated that they were included in an existing network, and were able to work with valuable partners and stakeholders. Both research teams agreed that the visits to the communities, that work with the digital app in the Amazon, were milestones. These moments were important to interact with the technology users; to make them feel heard and build trust. Moreover, the visits were key for creating a shared understanding of the local context, among researchers. The interpersonal connections that were formed, helped to overcome obstacles in the course of the project.

The WUR researchers reflected together on several social dimensions (from SIFT) in relation to project activities:

Collaboration

The digital data collection form (in ODK) has been co-designed together with PNCB.
Over time, both WUR and PNCB gained insights in gaps in the data collection requirements and format. User-input has also contributed to this process. During the past year, detected deforestation has been verified with photographs in 75 instances, by monitoring committees. This marks a success and proves that vigilance committees are capable of deforestation verification with the smartphone app, and there is a likelihood of other committees using such apps in the future.

It proved challenging to start a social analysis while the smartphone app was already being used and being further developed.
Since the social analysis builds upon smartphone app development activities, it is important to have sufficient understanding of this development process, which started well before the social analysis. Spending more time on information exchange between the WUR teams could have lessened this issue. However, the interviews that were held in December, by researchers from both teams, greatly helped to increase mutual understanding of project activities and progress.

Feedback

There have been formal feedback loops between Wageningen Environmental Research and PNCB regarding the app development, and informal feedback received from communities has also been included.
Collecting feedback from the technology users in the communities was done in an informal way by Wageningen Environmental Research, mainly during the in-person visits to Madre de Dios. No formal feedback form or other feedback collection method was used, though recommendations for app improvements were inferred from conversations. Some interviewees expressed that more frequent moments, preferably in a group setting, to exchange feedback would have been appreciated. The switch to ODK Central[9] made it easier to subsequently provide the users with requested changes to the application. As such this made the feedback loop faster. Feedback exchange with PNCB, on the other hand, followed a more formal process. PNCB communicated their requests and requirements, and WUR indicated the technical feasibility and/or limitations regarding the local context.

The importance of social dynamics and learning aspects is increasingly being acknowledged by PNCB.
Until recently there was limited attention for the social dimensions of technology introductions in local communities by PNCB. However, a new team has been established that specifically takes social impacts into consideration, and has started to align with the technology development teams. As a result, there has been coordination about the development of, e.g., early warnings, business plans and the use of videos for trainings. To ensure that the technology is operable and useful, understanding of the local context, is essential, according to PNCB representatives. Both the government and communities indicated that visits to communities where the digital apps are being used are important to generate this understanding. By PNCB, it was remarked that visits of the WUR team to Madre de Dios also contributed to this.

Anticipation

For both WUR teams, it has been challenging to understand developments in the other workstream, as activities were carried out in parallel.
At the beginning it was difficult to anticipate the results of the project, and of the smartphone app development. It was not evident that it would be possible to build a functional version of the ODK smartphone app. Besides, Wageningen Environmental Research was not yet familiar with social evaluations. At the same time, some operational arrangements can also affect social impacts. For example, agreements about data collection and related payments influence perceived benefits and motivation of technology users. It has been beneficial that both teams considered the same scope. In retrospect, it would have been beneficial to have insight in the usage of different forest monitoring apps by different (groups of) stakeholders earlier on in the development process.

5.5.2 Consideration of social aspects

Beyond the scope of this project it is also relevant to consider the level to which social and ethical aspects have been included in the development of digital tools for forest monitoring.
Now that PNCB has started the development of an own app for forest monitoring, this has become particularly of interest. There is general agreement among respondents that the integration of technical aspects on the one hand, and socio-cultural and ethical aspects on the other hand, can be improved in case of the PNCB programmes. At PNCB the integration of different expertise and perspectives is in early development stages.

9 The switch to ODK Central allowed that changes to the application form are automatically updated in the app on the phones of users. As such they don’t have to manually re-install or update the app.

Socio-economic contextual information was needed in the development process of the smartphone app.
Understanding the context was essential for making this smartphone app more useful: 'Else, you are simply going to have a very nice tool that probably won't be very useful in practice.' According to some interviewees, technical engineers in general often lack awareness of how information will be used (in the field) and by whom. If a digital tool is clear and easy to use, and if the purpose is clear, they become more useful at the user-level.

6 Discussion & Conclusions

6.1 Discussion of research findings

There is the general perception among stakeholders that the use of smartphone app is beneficial for forest monitoring in this use case. It can contribute positively by facilitating data collection, data structuring and storage, thereby increasing the potential opportunities for data sharing (interoperability) as well. As compared to the paper-based system, the ODK smartphone app brings the benefits that images can be collected, that the data collected are more standardised by allowing only specified data entries, and that the risk of human error is lowered. For example, information such as dates and GPS coordinates can be provided automatically. Moreover, in the forest, using an app enables multiple monitors to collect data faster, simultaneously, and data losses due to lost papers or rain damage are eliminated.

Digital data collection and sharing may also bring (potential) disadvantages, such as additional risks and factors limiting the potential benefit of an app for forest monitoring. Since deforestation in Madre de Dios is often linked to illegal activities, collecting data about such developments can be sensitive. With digital apps and data, the traceability of information increases, for example personal information about who collected the data. This may increase personal safety risks for forest monitors. Among the most important limiting factors are the lack of internet connectivity in local communities, causing delays in uploading the data, and the resources required to train forest monitors on the proper use of the technology. There is also unclarity about the authority and willingness within the government agencies to use community-based data for sanctioning and enforcing actions to curb deforestation.

Currently, there are asymmetries regarding access to data and the ability to interpret collected information. In turn, this affects who are the beneficiaries of forest monitoring, including the use of the app. The Peruvian government has access to a large database of satellite and forest monitoring data (from paper-based data collection). However, forest monitors generally only provide data, without being able to access submitted data at a later moment. Indigenous organisations are often dependent on (alerts and monitoring) data shared with them. The introduction of the smartphone app has so far not altered these dynamics. More alignment and data sharing between different stakeholders can improve the more equal distribution of benefits among stakeholders.

Thus far, there have been hardly any efforts to foresee potential negative or unintended consequences prior to the introduction of apps. Nevertheless, some building blocks for ex-ante responsibilisation regarding forest management and conservation seem to be present. For example the collaboration between the regional government of Madre de Dios, FENAMAD, SERNANP, and others. Ex-ante responsibilisation with respect to the digitalisation of forest monitoring did not yet take place. The government recognised however that more regulation of data access and ownership will be needed.

The inclusion of community members in forest monitoring initiatives gives them some form or recognition for their role and their interests in forest conservation. However, the inclusion of individuals in forest monitoring committees is tied to a number of socio-demographic factors, particularly gender and age. Women are underrepresented in monitoring committees, mostly because the forest patrols are considered physically demanding and therefore considered more suitable for men. This may partly be reflective of traditional gender roles that play a role in the communities. It is expected that the use of digital technologies for monitoring will increase the number of youth participating in committees, since elderly people often lack the required digital skills. In some communities there are initiatives to promote mutual learning, about technology (youth) and the territory (elderly), to create a group of committee members of varying ages.

A limitation in this technology development project is that indigenous organisations have not actively participated in the development of the ODK smartphone app, and forest monitors could only provide feedback on few occasions. More feedback moments would have been appreciated by communities, on top of the formal and informal feedback loops between WUR, PNCB and the communities. Stakeholders also agreed that feedback from the government towards users, for example insights from and evaluations on submitted data forms, has been minimal. There is thus potential to better close the feedback loop and improve co-creation between technology developers and implementers on the one hand, and users on the other hand.

In general, there is limited attention for managing unintended consequences and/or ex-post responsibilisation during the introduction of apps for forest monitoring. Although issues and suggestions highlighted by forest monitors are considered by the government, this usually happens on a case-by-case basis. Likewise, any issues that are encountered in the implementation of the smartphone app are primarily addressed on an ad-hoc basis. There are no problem-solving governance protocols or procedures in place, neither for solving ODK-related problems nor for community-based forest monitoring in general. One recommendation, based on the interviews and group discussions, would be to create (more) opportunities for more consistent dialogues between government and involved communities, to enhance understanding and improve problem-solving. In the wider monitoring system, the shared responsibility for forest management and conservation creates complexity, as it often requires multiple authorities to provide solutions for identified issues like mining, pollution or invasions by settlers.

Understanding of the use context, and adjusting digital tools accordingly, is essential for sustained use over time, or lastingness. Users are generally positive about the value of the smartphone app, and indicate that the app has been relatively easy to use. Nevertheless, patrolling community forests for land use changes, as requested by the government, has been a relatively new activity. It has been indicated that forest monitors feel accountable for forest data collection, partly because they receive incentives, though they are also aware that they rely to a large extent on the information that is shared with them by the government. If alerts are no longer provided, which seems to be the case after the 5-year TDC contract, it significantly complicates forest patrols. The information supply dependency (e.g., alerts and feedback on submitted forms) does limit the sense of ownership regarding the app. Lastly, the lastingness of apps for monitoring is also linked to the costs of internet data and devices required. For example, if apps only run on the newest smartphones, this lowers the probability of lasting use.

Social and technological developments continuously influence each other, as do developments in the physical surroundings (as described by the SCPS framework). These interrelations make it more complex to anticipate next steps in the technology development process. Nevertheless, combining perspectives from different research disciplines has had added value in this study. Regarding the development of forest monitoring apps, there has been an exchange of views on different levels: between PNCB and communities; between PNCB and WUR; and between WUR and a (limited) number of communities. Generally, in the context of community-based forest monitoring with apps in the Peruvian Amazon, it has increasingly been acknowledged that social impacts consideration is essential. Yet, the integration of such insights in technology development and scaling at PNCB is in early stages.

6.2 Conclusion

In this study, the following main research question has been addressed:

What are the social impacts[10] of a high-tech solution (smartphone app) on the stakeholders of community-based forest monitoring, in the low-tech environment of the Peruvian Amazon?

In the current community-based monitoring system of PNCB, forest monitors rely on satellite data (deforestation alerts) provided by the government, whereas feedback on submitted forms is rarely provided. This interaction has not changed with the introduction of a forest monitoring app. This information asymmetry and resulting dependency may affect the sense of ownership over the technology by forest monitors to some extent.

[10] To address the main research question, the analysis has mainly been focused on the social impacts on forest monitors from local communities. The reason for this is that although PNCB has been involved in the design of the ODK app, it did not actively use or implement the (data of the) app. Similarly, other identified stakeholders, such as indigenous organisations, have not actively been included in the technology development process.

Based on the research findings, we can conclude that the use of the smartphone app for forest monitoring purposes has generally been perceived as beneficial by stakeholders, from a functional point of view. Although (standardised) procedures for solving problems encountered during the use of the app are lacking, this is not perceived as a problem. The app was perceived to work faster than paper-based forest monitoring activities and administration. At the same time, it may increase risks for forest monitors when personal data falls into the wrong hands (data confidentiality), particularly in relation to illegal mining activities. With increased use of digital technologies (apps and drones), the composition of forest monitoring committees has been subject to change because youth generally have more digital skills than elderly community members, whereas the elderly have better knowledge of the forest territory.

Although community forest monitors are eager to be involved in the use and development of the app, they are also aware that continued institutional support for using the app is uncertain. For the lasting use of the app, continued institutional and financial support is needed, to sustain the communities' forest monitoring activities. The importance of available training has furthermore been highlighted, to ensure that monitors possess the required digital skills, and make the forest monitoring activities more inclusive.

One of the promises of using this smartphone app for forest monitoring is that it facilitates the data sharing and therefore collaboration between different stakeholders. There is so far no systematic data sharing (to the knowledge of the researchers) between different actors, other than between forest monitors and the authorities requesting the data, e.g., PNCB. Apart from the ODK app, multiple other forest monitoring apps have been developed and implemented in parallel. Increased data exchange between these initiatives could prevent double-work and increase overall insight in the state of the forests. The potential of data interoperability through apps still exists, but has so far not really been exploited.

Overall, the importance of interdisciplinary perspectives during the development of apps for forest monitoring has increasingly been acknowledged, by stakeholders. It has been recognised that better aligning the app to the capabilities and needs of the users improves the lasting use. Ultimately, the potential of data interoperability by using apps for forest data collection still remains, but has thus far not been exploited.

6.3 Evaluation of the SIFT framework

In this project, we developed a Social Impact Feedback Tool for digital innovations, and we tested the tool in one specific project: the deployment of a smartphone app for community-based forest monitoring, in partnership with the PNCB program in Peru. From this first implementation of the SIFT framework, we draw the following lessons learnt:

a. The SIFT framework, based on 5 RRI/ELSA dimensions, and operationalised into 14 evaluative questions, proved to be a valuable and effective tool to assess the social impact of a digital innovation.
b. The SIFT framework is not a mechanic questionnaire, but rather a tool for judicious use. The Likert scores can be used as an entry point for discussion, and to distinguish positive and negative elements, but they should not be read literally. Also, the SIFT framework intends to capture differentiated stakeholder perceptions as well as rich factual information, rather than trying to arrive at uniform answers to the evaluation questions.
c. Prior to the application of the SIFT framework, an initial mapping is required of the project context. Such a mapping does not need to be very complicated, but requires some document review and key informant interviews. The SCPS framework (social-cyber-physical system) is a practical instrument to structure such a mapping. Also, the stakeholder mapping proved to be a powerful tool, both as an initial background mapping and as a more in-depth result of the SIFT exercise.
d. For the Peru project, we customised the 14 evaluation questions to the specifics of the PNCB project. This will again be necessary when the SIFT framework is used in another project. In this sense, SIFT is a generic framework that requires customisation to each specific project.
e. A semi-formal office environment is required to complete the SIFT interview in all its 14 dimensions. Such an interview takes about 1.5 hours, if efficiently managed. In an FGD setting, and in a more informal environment (e.g., rural communities), a selection of the 14 topics needs to made, or a longer workshop is needed to cover all 14 dimensions.

f. The SIFT framework can also be applied to discuss social impact between social experts and digital and technology experts, both in academia and in implementing agencies.
g. The SIFT framework was tested as an assessment tool in the hands of external researchers. It has the potential and ambition to grow into a tool to be used by the stakeholders themselves. But that will require a separate process of dissemination of the tool, for example in language, in format and in digital tooling.
h. From the first experience, our impression is that the SIFT framework is sufficiently robust to be applied to very different types of digital innovations, in different kinds of projects and a variety of contexts. This impression evidently needs to be tested and verified, by applying SIFT to a variety of digital innovation projects.

Future potential of the SIFT framework

The SIFT framework can be further developed into a tool for stakeholders, and can also be applied in other digital innovation projects.

The WUR project (KB38) that enabled the development of the SIFT framework and its testing in Peru came to an end in December 2024. In case follow-up funding would become available, the SIFT framework can be further developed in a variety of manners:

- the SIFT analysis can be repeated after some time (one or more years), with the same four communities, to assess improvements made to the digital tool and its application; this can be initiated by any actor in or around the PNCB system
- the SIFT analysis can be deployed at a national scale, in connection to the new digital app developed by PNCB; this can be initiated by PNCB or by any actor in or around its programme
- WUR can further develop the SIFT framework, for example as an app-based tool, to be used by the stakeholders themselves (PNCB, communities and others). Such an app-based tool can also be used for other digital innovation projects.

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Appendix 1 Lists of interviewees

Table A1.1 *Interviewees during first visit to Peru in December 2023*

Organisation	Function	No. of People	Place, date
PNCB-MINAM (HQ)	GeoBosques platform	1	Lima, Dec 15
PNCB-MINAM (regional)	Head of zonal office, Madre de Dios	1	Pto Maldonado, 29 Nov
Puerto Arturo community	Chair of the vigilance committee	1	Pto Maldonado, Dec 8
	Administrator PGI	1	Pto Maldonado, Dec 4
	Vigilance committee members	2	Pto Maldonado, Dec 5
Tres Islas community	Administrator PGI	1	Tres Islas, Dec 7
	Chief of the community	1	Tres Islas, Dec 7
	Vigilance committee members	2	Pto Maldonado, Dec 8 & Dec 5
	Forest monitor for FENAMAD	1	Tres Islas, Dec 7
Boca Pariamanu community	Chief of the community & Administrator PGI	1	Boca Pariamanu, 6 Dec

Table A1.2 *Interviewees during second visit to Peru in June 2024*

Organisation	Function	No. of People	Place, date
PNCB-MINAM (HQ)	Head of the sub-unit Monitoring of the State of Conservation of Ecosystems in Forests	1	Lima, 18 June
	GeoBosques platform	1	Lima, 18 June
	FIP/IDB Project, Component II Supervisor - PIP04	1	Online, 11 July
PNCB-MINAM (region)	Head of zonal office, Madre de Dios	1	Pto Maldonado, 19 June
Puerto Arturo community	Administrator PGI & Chair of the vigilance committee	2	Pto Maldonado, 19 June Pto Arturo, 21 June
	Vigilance committee & Junta Directiva	3 + 3	Pto Arturo, 21 June
Tres Islas community	Administrator PGI	1	Pto Maldonado, 19 June Tres Islas, 22 June
	Vigilance committee	4	Tres Islas, 22 June
Infierno community	Administrator PGI and currently counselor of the Province of Tambopata	1	Online, 20 June
	Vigilance committee	4	Infierno, 21 June
Regional Forestry and Wildlife Management (Regional Government of Madre de Dios)	Regional manager and chairperson of the Regional Forestry and Wildlife Control and Surveillance roundtable	1	Pto Maldonado, 20 June
	Head of Informatisation office	1	Pto Maldonado, 20 June
ECA Amarakaéri	President Monitoring and surveillance vocal Technical team	3	Pto Maldonado, 20 June
FENAMAD	Project specialist	1	Pto Maldonado, 18 June
ACCA (NGO)	Drone Program Coordinator	1	Pto Maldonado, 19 June
Not for Sale (NGO)	Peru program officer	1	Lima, 17 June

Appendix 2 Interview Guides

The general interview guide shown below was used during the June 2024 mission, that is, the testing of the comprehensive SIFT framework. All fourteen topics were treated in the bilateral interviews with government officials and NGOs. For the focus group discussions at community level, a selection of the questions was made, because the group dynamics takes more time for each question.

PREGUNTAS CLAVES

Lugar/fecha : __________________________

Nombre : __________________________

Function : __________________________

Organisation : __________________________

			1 = muy débil, 5 muy fuerte **na = no aplica** **ns = no sabe**						
KQ	**Nº.**	**Pregunta**	**na**	**ns**	**1**	**2**	**3**	**4**	**5**
1A	1	Basado en su experiencia, cómo aprecia el **funcionamiento** de aplicaciones para el monitoreo de bosques? (como ODK u otras[11])							
2A	2	Si compara el uso de la aplicación con el proceso manual de levantamiento de información, cómo aprecia los **beneficios** de la(s) aplicación(es)?							
2A	2b	Y cómo aprecia el **impacto** de usar aplicaciones en la reducción de la deforestación? *(cumplimento de la ley, sanciones contra actividades ilegales)*							
2B	3	Hay varios actores involucrados en esta digitalización de la colección de información. Se benefician de manera **igualitaria** tanto las comunidades como el programa?							
2C	4	A veces la introducción de una aplicación digital puede conllevar ciertas **consecuencias (sociales) negativas** – no-intencionadas. En el caso de estas aplicaciones, tales consecuencias han sido tomadas en cuenta desde el inicio? *(riesgos? ejemplos?, dónde discutirlo? quien toma decisiones? cómo tomadas en cuenta?)*							
3A	5	Como aprecia el nivel de **inclusión** de diferentes actores en el desarrollo y uso de estas aplicaciones? *(hay tipos de actores que no son fácilmente incluidos?)*							
3B	6	Cómo aprecia el nivel y la calidad de **participación** de las comunidades y comuneros en el desarrollo y uso de la aplicación ODK?							
3C	7	En qué medida el uso de esas aplicaciones ha facilitado la **colaboración** entre diferentes actores involucrados en el monitoreo de la deforestación?							
4A	8	En qué medida sus **inquietudes y sugerencias** sobre la aplicación han sido tomadas en cuenta? *(cómo expresadas, que tipo de espacios, periodicidad, cómo tomadas en cuenta?)*							
4B	9	Cuando se han dado **impactos inesperados** de la aplicación, en qué medida esos impactos inesperados han sido oportunamente resueltos? *(qué tipo de impactos inesperados, cómo resueltos, podría haberse anticipado?)*							
5A	10	Cuando se han presentado **diferencias de opinión** sobre estas aplicaciones, qué tan satisfecho está usted con la forma de resolver tales diferencias? *(ej derechos sobre los datos, app comercial o ODK, dónde administrar los datos, …)*							
5B	11	En qué medida se está asegurando el **uso permanente** y duradero de este tipo de aplicaciones? *(app PNCB, contribución ODK, mejoras, interoperabilidad, ..)*							
5C	12	En qué medida existen condiciones para la utilización de estas aplicaciones a **mayor escala**? *(técnicas, condiciones en las comunidades forestales, gobernanza, colaboración/ interoperabilidad)*							
6A	13	WUR internal (incl Alonso) Para desarrollar nuevas herramientas digitales, se requieren expertos técnicos pero también se tocan muchos aspectos sociales y organizacionales, no? Cómo aprecia la integración de **expertos sociales y organizacionales** en el desarrollo de este tipo de herramientas?							
6B	14	Para desarrollar nuevas herramientas digitales, se requieren expertos técnicos pero también se tocan muchos aspectos sociales y organizacionales, no? Cómo aprecia la integración (en la práctica) de **aspectos sociales y éticos** en el desarrollo de estas aplicaciones?							

[11] Other apps circulating in the Madre de Dios region are e.g. LocusMap (Rainforest); Collectaur/Forestlink; SMART.

Preguntas al final de la entrevista:

- Hay temas que no discutimos pero que son importantes?
- Cuál es su opinión sobre este cuestionario y su utilidad?
- Tiene usted preguntas para nosotros?

Appendix 3 SIFT framework

Table A3.1 *Detailed SIFT framework*

ELSA/RRI dimension	Sub-dimension	Key Question	Key Elements
1. The innovation and implementation	Digital tool quality & implementation process	Key question 1A: Based on your experience, how would you rate the functioning of the digital tool?	user-friendliness; information availability; learning opportunities; performance of the technology; data management
2. Ethics & anticipation	Benefits	Key question 2A: How would you rate the benefits of the digital tool compared to working without the digital tool?	assumptions and assumed (socio-economic) benefits; materialised outcomes; negative impacts; unexpected impacts; trade-offs
	Beneficiaries	Key question 2B: Does everyone benefit fairly/equally?	changes in distribution of benefits; opposed interests, data control and privacy
	Ex-ante responsibilisation	Key question 2C: Have foreseeable (negative/unintended) consequences sufficiently been addressed from the beginning?	ex-ante governance mechanisms to resolve issues; mitigation of negative impacts; negotiation of opposed interests
3. Inclusion & interactivity	In-/exclusion	Key question 3A: How would you rate the level of inclusion of stakeholders?	in-/exclusion of actors from digitalisation and/or the core process; changes in social in/exclusion of actors; drivers and barriers to participation
	Participation of key stakeholders for social impact	Key question 3B: How would you rate the participation of key stakeholders (from social impact perspective)?	selection or targeting of stakeholders; level of participation; motivation and willingness; available skills and resources; changes in actors' roles and activities
	Collaboration between stakeholders	Key question 3C: To what extent has the digitalisation of [main activity] enhanced collaboration between stakeholders?	changes in collaboration among and between stakeholders; new stakeholders involved
4. Responsiveness	Feedback (incl. process protocol with feedback loops)	Key question 4A: To what extent have your concerns and suggestions about the digital tool been considered?	existing feedback mechanisms; response to feedback; involvement of technology users; co-creation
	Ex-post responsibilisation	Key question 4B: To what extent have unexpected or unforeseeable impacts been sufficiently dealt with?	unexpected or unforeseen impacts; handling thereof
5. Solutionism & negotiation	Performance of the governance model	Key question 5A: In case there have been disputes about the digital tool, how satisfied are you with the way these disputes have been resolved?	conflicts or disputes about digitalisation; governance mechanisms to resolve issues; negotiation among stakeholders; satisfaction with handling of conflict
	Lastingness	Key question 5B: To what extent is the lasting use of the digital tool secured?	technology ownership, legitimacy, conditions and barriers for lasting technology use
	Scaling	Key question 5C: To what extent are there enabling conditions to deploy the use of the digital tool at a substantially larger scale?	conditions and barriers for scaling of technology; business models
6. Participation & Interdisciplinarity	Interdisciplinary collaboration between researchers	Key question 6A: When looking at interdisciplinary collaboration, how would you rate the way social impact has been included in the development of the digital tool?	interdisciplinary interaction among researchers
	Consideration of social aspects in the overall technology innovation process	Key question 6B: How would you rate the way social and ethical topics have been included in the development of the digital tool?	role of ELSA and RRI principles in technology development processes

Appendix 4 Stakeholder Mapping

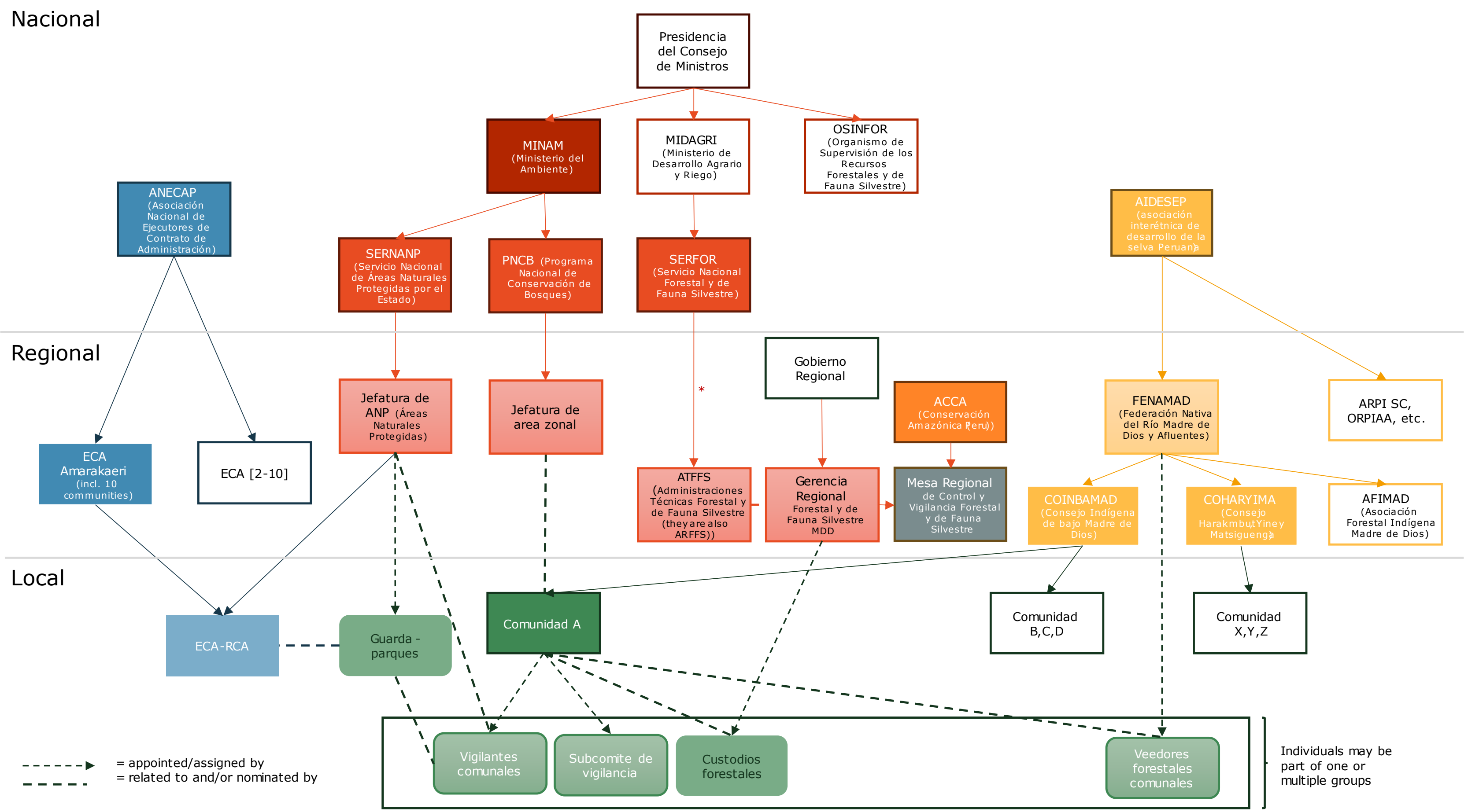

Figure A4.1 *Digital forest monitoring stakeholders on local, regional and national level*
** = La estructura de la autoridad forestal (ATFFS o Gerencia Regional) depende de la región*

Wageningen Social & Economic Research
P.O. Box 88
6700 AB Wageningen
The Netherlands
T +31 (0)317 48 48 88
E info.wser@wur.nl
wur.eu/social-and-economic-research

REPORT 2025-003

The mission of Wageningen University & Research is “To explore the potential of nature to improve the quality of life”. Under the banner Wageningen University & Research, Wageningen University and the specialised research institutes of the Wageningen Research Foundation have joined forces in contributing to finding solutions to important questions in the domain of healthy food and living environment. With its roughly 30 branches, 7,700 employees (7,000 fte), 2,500 PhD and EngD candidates, 13,100 students and over 150,000 participants to WUR’s Life Long Learning, Wageningen University & Research is one of the leading organisations in its domain. The unique Wageningen approach lies in its integrated approach to issues and the collaboration between different disciplines.

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Wageningen Social & Economic Research
P.O. Box 88
6700 AB Wageningen
The Netherlands
T +31 (0) 317 48 48 88
E info.wser@wur.nl
wur.eu/social-and-economic-research

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