

# Analytical review of methods and tools for assessing crop damage caused by elephants: implications of new information technologies

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**Photo 1.**  
Collecting location data with the KoboCollect application and a smartphone.  
Photos C. N'safou Mbani.

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## RÉSUMÉ

### Examen analytique des méthodes et outils d'évaluation des dommages causés aux cultures par les éléphants : implications des nouvelles technologies de l'information

La dévastation des cultures par les éléphants attise de plus en plus la colère des producteurs dans le conflit homme-éléphant. Cependant, les dégâts sur les cultures imputés aux éléphants par les agriculteurs semblent démesurés. Malgré l'observation de dégâts sur les espaces culturels, impactant la vie des populations locales, les évaluations des dégâts restent un sujet de controverse. La multitude de méthodes d'évaluations utilisées par les informateurs induit une difficulté à comparer les résultats issus de différentes zones et une difficulté à harmoniser et/ou transposer les stratégies de gestion. Il est donc judicieux de s'intéresser aux méthodes d'évaluation, de connaître leurs contraintes, avantages et leurs points de connexion. C'est l'objet de cette étude qui propose une synthèse bibliographique du sujet, basée sur une recherche documentaire, une analyse et synthèse des articles et documents. Il en ressort deux types d'évaluation de dégâts : une évaluation quantitative et une évaluation qualitative. Chaque type d'évaluation requiert des méthodes d'évaluations différentes, pouvant être associées pour des résultats plus précis. Une évaluation qualitative peut être effectuée par des entretiens, des questionnaires, des recherches documentaires, etc., et une évaluation quantitative par une visite totale du site, une visite des points chauds et froids du conflit, ou une visite d'un échantillon aléatoire du site. Les évaluations peuvent être jumelées car l'évaluation qualitative est subjective. Plusieurs informateurs y ont recours pour sa simplicité de réalisation et pour l'idée de l'état des dévastations des cultures et des contraintes sociologiques fournies. L'évaluation quantitative requiert des ressources mais fournit des résultats du terrain. Toutefois, le couplage des types d'évaluation améliore la précision, la fiabilité des résultats et la compréhension du conflit. Cette synthèse bibliographique révèle aussi des outils d'évaluation des dégâts portés aujourd'hui vers les nouvelles technologies d'information et de communication qui rendent le travail plus facile et précis.

**Mots-clés :** évaluation des dommages, méthodes d'évaluation, outils d'évaluation, outils traditionnels, outils numériques, conflit homme-éléphant, gestion participative.

## ABSTRACT

### Analytical review of methods and tools for assessing crop damage caused by elephants: implications of new information technologies

The devastation of crops by elephants is increasingly fuelling the anger of farmers in the human-elephant conflict. However, the crop damage attributed to elephants by farmers appears disproportionate. Despite the fact that observed crop damage has an impact on the lives of local populations, the assessment of damage remains a controversial issue. The multitude of evaluation methods used by informants makes it difficult to compare results from different areas and to harmonise and/or transpose management strategies. It is therefore wise to take an interest in evaluation methods, to know their constraints, their advantages, and their connection points. This is the purpose of this study, which offers a bibliographic synthesis of the subject based on documentary research and a synthetic analysis of articles and documents. Two types of damage assessment emerge: quantitative and qualitative. Each type of assessment requires different assessment methods, which can be combined to obtain more accurate results. A qualitative assessment can be carried out through interviews, questionnaires, bibliographic research/review, etc., and a quantitative assessment through a total site visit, a visit to conflict hot and cold spots, or a visit to a random sample of the site. Ratings can be combined because qualitative rating is subjective. Many informants use it because it is easy to carry out and gives an idea of the state of devastation of cultures and sociological constraints. Quantitative assessment requires resources but provides results on the ground. However, combining different types of assessment improves the accuracy, reliability of results, and understanding of the conflict. This bibliographic synthesis also reveals that damage assessment tools are today moving towards new information and communication technologies, because these make the work easier and more practical while improving precision.

**Keywords:** damage assessment, assessment methods, assessment tool, traditional tools, digital tools, human elephant conflict, participatory management.

## RESUMEN

### Revisión analítica de los métodos y herramientas para evaluar los daños causados por los elefantes en los cultivos: implicaciones de las nuevas tecnologías de la información

La devastación de los cultivos por los elefantes alimenta cada vez más la ira de los agricultores en el conflicto entre humanos y elefantes. Sin embargo, los daños a los cultivos atribuidos a los elefantes por los agricultores parecen desproporcionados. Aunque se han observado daños en los cultivos que afectan a la vida de las poblaciones locales, la evaluación de los daños sigue siendo una cuestión controvertida. La multitud de métodos de evaluación utilizados por los informadores dificulta la comparación de los resultados de las distintas zonas y la armonización y/o transposición de las estrategias de gestión. Por eso tiene sentido examinar los métodos de evaluación, conocer sus limitaciones, ventajas y puntos de conexión. Este es el objetivo del presente estudio, que propone una síntesis bibliográfica del tema, basada en una búsqueda documental, un análisis y síntesis de artículos y documentos. Surgen dos tipos de evaluación de daños: cuantitativa y cualitativa. Cada requiere métodos de evaluación diferentes, que pueden combinarse para obtener mejores resultados. Una evaluación cualitativa puede llevarse a cabo entrevistas, cuestionarios e investigación documental y una evaluación cuantitativa con una visita total del lugar, visita a los puntos calientes del conflicto o visita a una muestra aleatoria del lugar. Las evaluaciones pueden combinarse porque la evaluación cualitativa es subjetiva. Muchos informadores la utilizan porque es fácil de realizar y proporciona una idea del estado de devastación de los cultivos y de las limitaciones sociológicas. La evaluación cuantitativa requiere recursos, pero proporciona resultados sobre el terreno. La combinación de diferentes evaluaciones mejora la precisión, la fiabilidad de los resultados y la comprensión del conflicto. Esta revisión bibliográfica también revela que las herramientas de evaluación de daños están evolucionando hacia las nuevas tecnologías de la información y la comunicación, que facilitan el trabajo y mejoran la precisión de los resultados.

**Palabras clave:** evaluación de daños, métodos de evaluación, herramienta de evaluación, herramientas tradicionales; herramientas digitales, conflicto entre el hombre y el elefante, gestión participativa.

## Introduction

Human-elephant conflicts (HEC) resulting from crop damage caused by elephants are the most common form of conflict on all continents and in all elephant-bearing countries. It is recognised as the most prevalent form of human-wildlife conflict worldwide (Mishra et al. 2003; Atta et al. 2016; Manral et al. 2016; Liu et al. 2017). The subsistence crops of local populations, namely food and/or cash crops, are ravaged and destroyed by elephants (Fairet 2012; Kalyanasundaram et al. 2014; Ngama 2018). Elephants are crop raiders who forage on farms to meet their dietary needs because crops are nutritionally richer than wild plants (Sitati et al. 2003; Graham et al. 2010; Sitienei et al. 2014; Liu et al. 2016; Ngama 2018).

Crops are most often attacked at harvest time, prompting farmers to retaliate in the event of crop losses (Chen et al. 2006; Graham et al. 2010; Webber et al. 2011; Gubbi 2012; Atta et al. 2016). In India and Asia, for example, damage caused by elephants can be observed on more than 30 species cultivated by the population (Kalyanasundaram et al. 2014). However, the banana tree (*Musa paradisia*), the bethel palm (*Areca catechu*), and the coconut (*Cocos nucifera*) are the crops most plundered by elephants (Jayson and Christopher 2008; Suresh and Jayson 2016). Crop losses in countries with high elephant densities are high. Household income from agriculture declined by 35.1% in Baringo District, Kenya, in 2014 (Amwata and Mganga 2014). In the Democratic Republic of Congo (DRC), for example, elephants generally destroy cassava, which represents 65% of the most traded products, before consuming bananas; and the estimated annual economic losses per farmer were approximately 77% of the average gross domestic product (GDP) per capita (Inogwabini et al. 2013). In Gabon, crop damage is very significant in all conflict zones. Indeed, Walker (2011) notes that annual crop damage can be estimated at an average of 45% of total crops, and recorded damage on 75% of the total surface area of the fields studied in the Mont de Cristal Park area; this even though forests represent 97% of the landscape around villages. The presence of wild fruit trees in the plots, such as *Pseudospondias microcarpa*, *Chrysophyllum africanum*, *Irvingia gabonensis*, and *Tetrapleura tetraptera*, as well as the presence of certain plants, the first of which is the banana tree, in the plantations increases the occurrence of crop damage by elephants. These losses are particularly important for residents of areas whose diet and economy rely on these products (Mishra et al. 2003; Manral et al. 2016). Indeed, the relative impact of damage on household income varies considerably depending on economic dependence on agriculture and livestock. Thus, for households with subsistence savings, even small losses can have disastrous consequences (Oli 1994; Rao et al. 2002). Faced with these situations, distraught farmers often turn to administrations in search of solutions (ANPN 2016). The latter refers to the assessment methods and tools available to assess, quantify, and objectify the extent of the damage, as well as the responses and solutions to be provided (ANPN 2016).

The scale of damage caused by elephants to HEC crops often contrasts with the laments and discontent of farmers (Hoare 2007; Nsonsi 2018). Indeed, only a few farms are seriously affected, while many others are often little affected by elephant attacks (Nsonsi 2018). Small-scale damage is more common than large-scale damage (Nsonsi 2018). The damage is therefore often extrapolated or poorly assessed by farmers. Furthermore, elephants are part of a wide range of crop pests that includes several species such as primates, suids, rodents, birds, and insects (Hoare 2007, Fairet 2012). It is therefore often not easy to distinguish responsibilities for damage caused to crops among all the species concerned (Fairet 2012). The number of complaints about elephant damages seems disproportionate to its actual contribution to agricultural problems (Hoare 2007). Independent damage assessment using different methods and with different results presented in different ways makes it difficult to compare damage (Hoare 2007; Nsonsi 2018), although these methods are used according to the time and resources available to the assessor and the objectives of the assessor. Hoare (2007) decried the lack of a standardised system for assessing elephant crop damage, which prevents valid comparisons of the extent of damage and intensities of HEC both within and between different biogeographical regions of the world. Therefore, for greater clarity on all these issues, it is necessary to look at the crop damage assessment methods and tools used and/or available. Indeed, as much as an overview of management strategies and origins of HEC are proposed in journal articles (Shaffer et al. 2019; Nsonsi 2018), this is absent for crop damage assessment in HEC management (Hoare 1999; 2007).

The aim of this paper is therefore to review some of the knowledge on the assessment of crop damage by elephants, focusing on: i) the types and methods of damage assessment; ii) the tools used in the assessment and/or that can be used today; and iii) the implication of the latter in HEC management. It builds on the methods and tools currently in use and presents those that should be considered.

## Methodology

For this work, we carried out a bibliographic research/review in the databases provided by the search engines Google, Google Scholar, Academia, Web Science, Elsevier, and Human-Wildlife Conflict and Coexistence. The initial key sentences were “human-elephant conflict”, “elephant crop damage assessment” and “data collection tools”. These initial researches/review resulted in more than 150 articles, theses, master’s theses, and documents containing the keywords. We selected 60 sources in English or French, consisting of academic research and reports that address the subject, produced by conservation practitioners and organisations. The analysis aims to provide trends and identify existing research on how human-wildlife conflicts are assessed on the ground, particularly conflicts between elephants and herders.

This review focuses specifically on methods and tools for assessing crop damage caused by wild herbivores. We examined the documents found and classified them according to the themes they addressed in their content, namely the method of evaluation between them and the evaluation tools between them. Even if research has particularly focused on elephant-human conflicts: the involvement of technological communication tools in the reporting of these destructions has been developed. The scope includes disputes or confrontations involving individuals or communities over time, ranging from isolated to multi-stage incidents.

## Results

### Methods for assessing incidents of crop damage caused by elephants

There are two types of assessment of crop damage caused by elephants: qualitative assessment and quantitative assessment of crop damage. Several methods can be used to arrive at these types of evaluations and depend on them. However, the choice of method of assessing crop damage varies from one person to another (population, conservationist, and researcher) depending on time, resources, and objectives relating to the crop damage evaluation (Hoare 2001). Damage assessment methods depend on the type of assessment required.

Quantitative evaluation provides objective and unbiased numerical information through human emotion. They are easy to analyse and compare with figures from other areas. Examples of quantitative data are spatial measurements such as the area of a field, the location of damage (HEC maps on Geographic Information System, GIS), the number of droppings, etc. (Hoare 2007; Parker et al. 2007).

A qualitative assessment of crop damage caused by elephants helps to understand the direct and indirect problems of the incidents. It offers a wide range of issues to address in relation to incidents (physical damage, risk perception, and strong emotions) (Hoare 2007; Parker et al. 2007).

#### Qualitative evaluation method

There are many methods for obtaining a qualitative damage assessment. These include meetings, interviews, questionnaires, observations, and documentary research:

- Meetings (formal or informal) can be organised to gather information and can be as simple as a conversation in the street.
- Interviews, on the other hand, help to understand people's feelings and points of view. They can also be used to explore the history of the problem and gather basic information.
- Questionnaires are used at times when we want to ensure that standardized information is collected.
- Finally, observations can be based on own observations and perceptions of a place, while documentary research is limited to searching for documents that already describe the conflict in the area studied (Gubbi 2012).

Interviews and questionnaires are also called surveys of conflict stakeholders (producers, authorities, environmental defenders, etc.). Surveys are carried out to obtain information on damage caused to plantations by residents of an area (Hoare 2007; Tekem Tessa and Tiawoun 2008; Nath et al. 2009; Kalyanasundaram et al. 2014; Lingaraju and Venkataramana 2016). Questionnaires are directed or directional surveys, while interviews can be semi-directional or open-ended surveys. In these methods, no evaluation or data collection consider real-time field data (Kouao et al. 2018).

Recording damage using these methods is often a "passive" task for the investigator. Thus, when correctly applied, the results logically lead to a descriptive summary called the "raid frequency index" or RFI (Hoare 2007). These frequency indices integrate both spatial and temporal dimensions (Hoare 2007). The results show the periods of intrusions, the crops most attacked, and the quantities destroyed according to the respondent's own assessment. This method is entirely appropriate for sociological and anthropological approaches to conflicts (Hoare 2007), and requires little time and few resources to implement.

#### Quantitative evaluation method

A quantitative assessment of crop damage caused by elephants requires a face-to-face assessment of devastated fields or areas. There are three types of assessment methods: sampling the terrain or area, visiting the entire area, and finally visiting conflict hot or cold spots (places known to everyone due to the presence or absence of the problem) (Hoare 2007; Parker et al. 2007):

- Visiting conflict hot or cold spots is a field assessment method carried out directly in previously known areas. This method requires certainty as to the existence of areas where damage is present or absent (distribution and location) and the frequency of damage (duration/repeatability of damage). It was popularized by the International Union for Conservation of Nature (IUCN), when it identified the need to standardize data collection on HEC (Kouao et al. 2018; Mishra et al. 2015). In practice, assessing the damage with this model requires good judgement and the use of maps (locating the location of the incident and interpreting the map) and a global positioning system (GPS) (Hoare 2007; Parker et al. 2007).
- The evaluation method by field sampling consists of evaluating in the field a percentage of plants present in randomly chosen sampling units representative of the plantation (if we take into account the stratification of the area, the effects borders...). These sampling units are observation grids of variable dimensions, well defined depending on the author and the study (Naughton-Treves, 1998; Inogwabini et al. 2013; Atta et al. 2016; Kouao et al. 2018). Observations on the probable presence of crop damage caused by elephants are made in these sampling units. The random nature of data collection means that data will not be collected solely or necessarily at the scene of incidents. Likewise, the total area of fields and the areas destroyed are estimated within the sampling units by considering the regular geometric shapes they occupy (squares, rectangles, triangles, etc.). This model is used by several authors,

including Ouattara et al. (2010), who collected their data in the field in two plots of 2,000 m x 500 m, unlike Atta et al. (2016) who used plots of 50 m x 50 m in a plantation, in which plants damaged by elephants (uprooted, broken, organs consumed, etc.) were counted to later extrapolate them to the entire impacted field.

- Visiting the entire area consists, as its name suggests, of searching the entire area for places where there is damage.

### Qualitative and quantitative assessment methods

Qualitative assessment can be combined with quantitative assessment. This is the most recommended form of crop damage assessment. This evaluation must begin with the qualitative evaluation and end with the quantitative evaluation, because the second phase allows us to confirm or refute the information obtained during the first phase (Hoare 2007; Inogwabini et al. 2013; Mishra et al. 2015; Atta et al. 2016; Suresh and Jayson 2016; Kouao et al. 2018). Indeed, the observation of damage on the ground during the second phase is in one way or another derived from information previously collected from stakeholders. This evaluation makes it possible to obtain precise results in terms of perception and reality, but nevertheless requires relatively acceptable conditions in terms of costs, deadlines, and logistics for its feasibility (Mavah et al. 2006; Nyemgah Wo-Ndong 2009; Sidaway 2010; Sirima et al. 2020; Kobon et al. 2022).

### Analysis and comparability of assessment types and methods

Table I presents the authors' list of bibliographic references dealing with the assessment of crop damage in human-elephant conflicts. We note that out of the 64 documents and articles, we found the types and methods of evaluation in 27. Among these 27 documents and articles (42.2%), 22 documents (81.5%) combined the two methods of evaluation of damage (qualitative and quantitative). This combined assessment makes it possible to obtain quantitative data which are real and objective figures, not biased by human emotions and which reflect the situation on the ground (Parker et al 2007). However, surveys reflect the views and feelings of the respondents. 11.1% of the authors out of the 27 made a purely qualitative evaluation. The remaining 7.4% of authors presented the methods to be used. Surveys coupled with visits to conflict hotspots are the most used methods in the panel of 27 authors, i.e. 29.7%, followed by surveys coupled with random sampling (22.2%). However, we see in this table I that the different evaluation methods can be associated with each other, for example, random sampling of conflict hot or cold spots (Ouattara et al. 2010; Sidaway 2010; Boukoulou et al. 2012; Hema et al. 2018).

Table II presents the advantages and disadvantages of the different evaluation methods. Damage assessment based solely on surveys, documentary research, and meetings with

**Table I.**  
Study on damage assessment.

N°	Study using one or more types of assessment	Objective	Quantitative evaluation methods	Qualitative evaluation methods	Number of studies	%
	Total documents in list of bibliographic				27 on 64	42.2
	Total of documents combining qualitative and quantitative assessment on the 27 documents				22 on 27	81.5
1	Qualitative assessment	Assess the damage caused by elephants	-	Documentary research	2/27	7.4
2	Qualitative assessment	Analysis of human-elephant conflict	-	Survey	1/27	3.7
	Total qualitative evaluation studies				3/27	11.1
3	Qualitative and quantitative assessment	Assess the damage caused by elephants	Randomly placed collection grids	Survey	6/27	22.2
4	Qualitative and quantitative assessment	Assessing the damage caused by elephants	Farmers visit fields declared conflict hotspots	Survey	8/27	29.6
5	Qualitative and quantitative assessment	Compare surveys with damage in the field	Randomly placed collection grids	Documentary research and meeting	2/27	7.4
6	Qualitative and quantitative assessment	Assess the damage caused by elephants	Surveying the entire area	Survey	2/27	7.4
7	Qualitative and quantitative assessment	Assess the damage caused by elephants	Farmers visit fields declared conflict hotspots	Documentary research and meeting	1/27	3.7
8	Qualitative and quantitative assessment	Analysis of crop damage	Randomly placed collection grids in areas identified as hot and cold spots by local people	Survey	2/27	7.4
9	Qualitative and quantitative assessment	Inventory of human-elephant conflicts	Visit to random fields declared conflict hotspots by producers	Survey	1/27	3.7
	Total qualitative and quantitative evaluation studies				22/27	81.5
10	Descriptions of all types and methods of evaluation				2/64	3.1

**Table II.**  
Advantages and disadvantages of the valuation type, method and model.

Type/method/model of assessment	Advantage	Disadvantage
Qualitative evaluation	<ul style="list-style-type: none"> <li>• Provides direct assessments (areas devastated, space and time, etc.).</li> <li>• Helps to understand the indirect problems of the conflict (impact, fears, etc.).</li> <li>• Easy to carry out, as there is no need to go out into the field.</li> <li>• Low resource requirements (financial, human, material and time) compared with quantitative assessments.</li> </ul>	<ul style="list-style-type: none"> <li>• A team of trained monitoring agents is required.</li> <li>• A good understanding of the objectives to be achieved and the methods and techniques to be used to assess the damage.</li> <li>• Good ability to gather, translate and interpret information.</li> <li>• Lack of precision can be overcome by quantitative assessments.</li> </ul>
Quantitative assessment	<ul style="list-style-type: none"> <li>• Easy to analyse because it provides figures and is easier to compare with other areas.</li> <li>• Accuracy of information.</li> <li>• Helps to understand the direct problems of the damage (area devastated, number of elephants involved, space-time assessment, etc.).</li> </ul>	<ul style="list-style-type: none"> <li>• A team of trained monitoring agents is required.</li> <li>• Information must be comparable with other areas.</li> <li>• Maximum amount of data describing the conflict, but sometimes not used.</li> <li>• Does not take into account indirect problems such as fear...</li> <li>• Need for resources (financial, human and material) to carry out assessments in the field.</li> <li>• Significant investment of time.</li> </ul>
Evaluation methods by sampling the area	<ul style="list-style-type: none"> <li>• Assessment of the conflict in the area is more accurate than in the hot or cold spots in that it gives an overview of the situation of elephant attacks at plantation and area level.</li> </ul>	<ul style="list-style-type: none"> <li>• If the knowledge of the environment, the grid and the sample are not consistent (strata, etc.), and if information such as the edge effect is forgotten, the assessment could be biased.</li> <li>• Good judgement and use of maps (locating the location of the incident and interpreting the map), and GPS.</li> <li>• Need for resources (financial, human and material) to carry out field assessments.</li> <li>• Technical knowledge required to carry it out.</li> </ul>
Method for assessing hot and cold spots in the area	<ul style="list-style-type: none"> <li>• Conflict assessment in known areas.</li> <li>• The simplest method for quantitative assessment.</li> </ul>	<ul style="list-style-type: none"> <li>• Good judgement and use of maps (location of incident and interpretation of map) and GPS.</li> <li>• Possibility of missing data in areas that have not been prospected and therefore of screwing up the data.</li> </ul>
Method for surveying the entire area	<ul style="list-style-type: none"> <li>• Conflict assessment in the area is complete.</li> </ul>	<ul style="list-style-type: none"> <li>• Depends on time, surface area and resources.</li> <li>• Need for resources (financial, human and material) to carry out field assessments.</li> </ul>

the population will only produce results that can easily be described as descriptive and subjective (Hoare 2007). However, these methods are justified in assessment studies, as they provide insight into the damage situation at local and global levels, while remaining easier to use and implement, even under conditions of limited time and resources.

The quantitative assessment itself makes it possible to understand the damage on the ground (Nsonsi 2018). However, the application of a visit to the entire site (Mavah et al. 2006), a random or even stratified sample (Naughton-Treves, 1998), and visits to the hot and cold spots of the conflict areas depends on time, resources, and objectives (Graham et al. 2010). On the other hand, an information bias could appear in the visit to hot and cold spots (table II). Indeed, in these two cases, if several parameters are not taken into account, such as the edge effect, stratification, etc., information could go unnoticed, thus producing questionable results.

The information collected during the second phase (in the field) and/or during the first phase (from stakeholders) is of several types. The general, devastated areas of fields (Hoare 2007; Parker et al. 2007) provide information on the extent of the damage. The quality of the crops before and after the damage, as well as their stage of development, give an idea of the seriousness of the disaster. This is usually done by categorizing plants (good, average, poor plant quality, young plants, intermediate growth, mature plants, etc.). The information already described can then be used to estimate the losses incurred. Observation of the consumption or pillaging of crops, the trampling of crops, the location of devastated fields, destroyed and/or non-destroyed crops, the impacted area, the frequency of damage and/or incursions, periods of damage, and the type of culture destroyed provides information on the origin or reason for the conflict.

Damage assessment is carried out using various tools. For each type of evaluation, different tools can be used and/or combined, depending on the methods chosen. These tools can be traditional or digital.

### Damage assessment tools

The damage assessment must be carried out using the right tools. For each type of evaluation, different tools can be used separately or combined depending on the methods chosen, making it possible to create circuits for collecting, processing, and analysing data and, therefore, assessment of the damage.

Nowadays, data collection and evaluation tools are classified into two types: traditional tools and digital tools. By digital tools, we mean technological or digital tools that operate by leveraging computer data. Digital tools can be devices such as smartphones, tablets or laptops. Digital tools also include software and online platforms called specific digital tools. However, here we are referring to classic tools and everything that has nothing to do with digital, such as paper, notebooks and pens, tape measurers.

In this document, we will present all the data collection tools that exist in the environmental field, specifying those already used in the assessment of damages for the management of HCE and those not yet used in the assessment of damages for the management of HEC, as well as their advantages and disadvantages.

### Classic and digital qualitative and quantitative assessment tools

Classical and/or digital tools for qualitative and/or quantitative assessment of crop damage are used in the different damage assessment methods for data collection, processing and analysis.

For qualitative and quantitative assessment, the classic tools are pens, pencils, sheets of paper, a notebook or notebook to collect information; strings, a tape measure, or the number of steps to determine surfaces; and a compass for orientation.

For qualitative and quantitative assessment, digital tools used in the environmental field include electronic notebooks, GPS devices to record areas and locations, and cameras to capture images. Smartphones and tablets are also digital tools that combine several other tools (cameras, notebooks, location recording).



**Photos 2.**

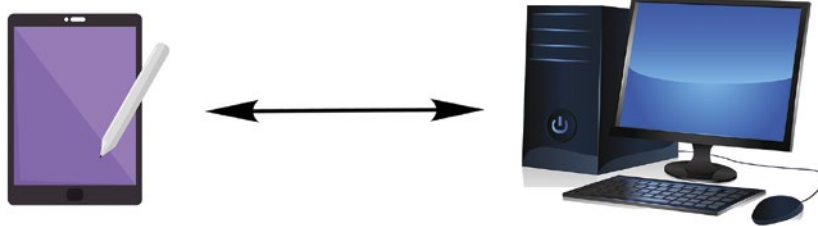
Damage to banana trees destroyed by elephants (A and B).  
 Photos C. N'safou Mbani.

The data collected is generally processed and analysed using digital tools (software) embedded in computers. These can be of all kinds. Mapping software or tools (ArcGIS, QGIS, etc.) make it possible to process, visualize, manage, create, and analyse geographic data in terms of position, location, and surface area. Electronic spreadsheet software or tools (Microsoft Excel) for quick and accurate calculations. Software or statistical analysis tools (R, STATISTICA, etc.) are used to analyse the data. Digital data processing and analysis tools are cited in studies assessing damage by elephants because they are used in 100% of studies.

### Specific digital tools

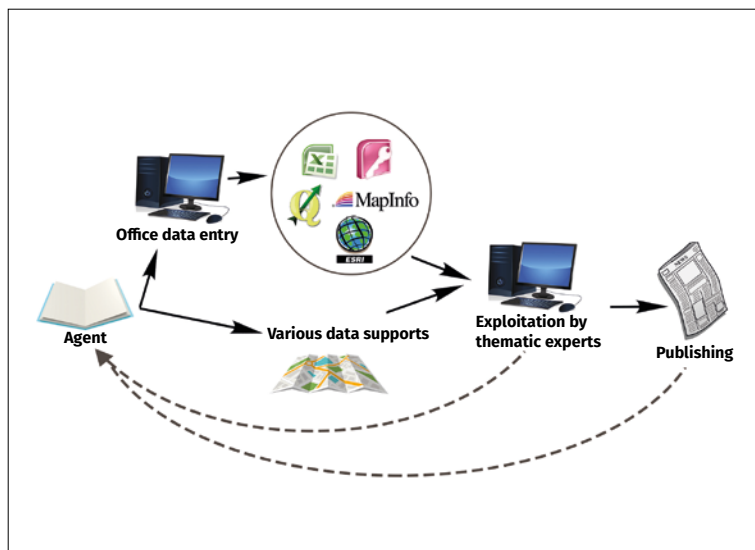
Several specific software and applications that could be described as connected digital tools have been developed and exist today. Their particularity is that they alone allow data to be collected, processed, and analysed. These are specific digital tools allowing simple and rapid evaluation, often called decision support tools. They must be connected or embedded in specific and specially adapted devices (androids, Personal Digital Assistants, etc.) to enable the collection of all necessary information. With this type of digital tool, data such as sounds, photos, videos, recording of points or traces (lines and areas) of GPS coordinates, geolocation, observation notes, areas, etc., can be collected directly (Stevenson et al. 2003). Data is easy to process because it can be extracted from devices and sent and stored directly in “master software or tools” via Universal Serial Bus port (USB), or the Internet.

As a result, data is present in computers without the need to manipulate it (figure 1). These tools can also be used for analyses and cartographic processing thanks to their extensions and connections. These connected digital tools are developed and used to reduce the data evaluation circuit (collection, processing, and analysis of data) and limit errors in transcription, transfer, and analysis of information (Bossaert et al. 2015). None of the various studies on the assessment of crop damage caused by elephants yet mentions such specific tools, even if tests of such tools have been carried out in certain countries such as Gabon (ANPN 2016) and Southern Africa (Le Bel et al. 2015). However, in the management of the HEC, which includes reporting attacks and monitoring pachyderms in conflict zones, connected digital tools have already been tested and cited. In other areas, connected digital tools have been created and exist, such as Ornidroid in ornithology; CarNat as a forest key in floristry; Anymals + plants for identification keys for fauna and flora; SMART in wildlife management; ODK collects for general surveys; Cybertracker for wildlife inventory, etc. (Liebenberg et al. 1998, 1999; OSU OREME 2012ab; Bossaert et al. 2015; Renggli et al. 2018; Olajide 2019).



**Figure 1.**

Data collection with a digital tool. Source: Bossaert et al., 2015.



**Figure 2.**

Normal data collection circuit when using conventional tools. Source: Bossaert et al., 2015.



**Figure 3.**

Data collection circuit with a digital tool. Source: Bossaert et al., 2015.



The addition and development of specific digital tools make it possible to divide the evaluation circuit into two types: the classic evaluation circuit, and the evaluation circuit using connected digital tools.

#### Classic evaluation circuit

The classic or conventional evaluation circuit involves the use of classic and digital tools for the collection, processing, and analysis of data (figure 2). This circuit consists of collecting data in the field using traditional or digital tools, transcribing them, or transferring them to a computer to process and analyse them using other digital tools (statistical analysis, establishment maps, etc.) (Bossaert et al. 2015). This is the circuit that we find in all (100%) studies on crop damage caused by elephants in HEC.

#### Evaluation circuit using connected digital tools.

The journey using connected digital tools or software makes it possible to collect all the necessary information using the tool embedded on suitable devices (phone, tablet, etc.) (OSU OREME 2012ab; Bossaert et al. 2015; Blanárová 2017). The software can be downloaded to a device, which allows multiple devices to have access to it (figure 3), i.e. multiple collectors transferring data to the same computing server. Installing digital tools in devices requires a minimum of configuration, the presence of two modules (a data server module and a client module installed on mobile devices), as well as the ability for the device to access the computing server either by web or by satellite (Bossaert et al. 2015). Although this assessment circuit has been introduced in several wildlife management studies, it has not yet been cited in studies assessing the damage caused by elephants to crops.



**Photos 3.**

Elephant identification index: (A) Elephant droppings; (B) Cassava plant destroyed by consumption.  
Photos C. N'safou Mbani.

### Analysis, advantages and disadvantages of digital tools

Assessment tools are increasingly moving towards digital tools compared to traditional tools, even if they have not yet been introduced in damage assessment for HEC management for specific digital tools or connected. However, the development of completely connected digital tools is popularised and encouraged, and even tested (Chhem 2016). However, as with other evaluation tools and circuits, there are advantages and disadvantages (Stevenson et al. 2003) (table III). Traditional tools (sheets of paper, surfaces, etc.) require a less expensive purchase than the use of digital tools in general (camera, phone, GPS, etc.). However, data may be altered during transcription. If the data collected with connected digital tools will be preserved and faithfully transcribed, the collection of data requires certain conditions, such as the energy in the tools. Also, suppose the use of connected digital tools offers the possibility of carrying out the entire evaluation circuit (collection, transfer, processing and analysis of data) in less time than a traditional

evaluation, by removing the step transcription and avoiding the loss of information. In that case, this still requires a minimum of equipment and training adapted to the handling of these tools.

Collecting or evaluating data with connected digital tools offers the possibility of participatory data collection, centralizing data with numerous collectors, given that the tool can be embedded in several devices. Since there are now a multitude of connected digital tools that allow or attempt to meet field needs in several areas (Chhem 2016), there is also the freedom to download these applications for greater competitiveness and objectivity (OSU OREME 2012a; Bossaert et al. 2015). One of the biggest disadvantages of connected digital tools is that they can encounter several difficulties when using them. We can observe the deterioration of the devices, the impossibility of using them in the event of a low battery, the obligation to adapt between the networks of tools used, and the need for adequate training in their use.

**Table III.**

Advantages and disadvantages of assessment tools and circuits.

Assessment tools and circuits	Advantage	Disadvantage
Data collection using traditional tools (paper, decimeters, number of steps, etc.)	<ul style="list-style-type: none"> <li>• Ease of direct collection of data not considered but observed during the study.</li> <li>• Low cost of traditional tools compared to digital tools.</li> </ul>	<ul style="list-style-type: none"> <li>• Risk of data loss during storage and transfer of information for analysis, altering the final results.</li> <li>• In the case of multiple agents at the various stages of data collection, transcription and analysis, there must be confidence in the data.</li> <li>• Longer procedure than with digital tools.</li> </ul>
Data collection using digital tools (GPS, cameras, etc.)	<ul style="list-style-type: none"> <li>• Data stored in the tool.</li> <li>• Data collected quickly and easily with the right tools.</li> </ul>	<ul style="list-style-type: none"> <li>• Risk of losing the tool and therefore the data if it has to be transcribed from data collection to analysis.</li> <li>• Energy required to operate tools.</li> <li>• Weather conditions that may prevent the tool from working properly.</li> <li>• Cost of acquiring the tools is higher than that of conventional tools.</li> <li>• Knowledge of how to use them is required.</li> </ul>
Conventional damage assessment circuit (use of several tools)	<ul style="list-style-type: none"> <li>• Control and management of information at every stage of the circuit.</li> </ul>	<ul style="list-style-type: none"> <li>• Risk of losing the tool and/or the data when transferring data from collection to analysis if the tools are different from one another.</li> <li>• Lengthy data collection circuit for data entry, processing and analysis.</li> </ul>
Digital damage assessment circuit (use of tools or software in plug-in devices: e.g. SMART, etc.)	<ul style="list-style-type: none"> <li>• No need to transcribe information.</li> <li>• Short data collection, processing and analysis circuits.</li> <li>• Possibility of collecting several pieces of information using the same tool embedded in the appropriate device.</li> <li>• Central database hosted on a computer and secured personally.</li> <li>• Possibility of having several collection devices.</li> </ul>	<ul style="list-style-type: none"> <li>• Need for equipment that can accommodate tools.</li> <li>• Need to recharge equipment.</li> <li>• The cost and performance of the equipment to be used must be taken into account in their choice.</li> </ul>
Digital damage assessment circuit (use of tools or software in internet-connected devices: e.g. Kobotoolbox, etc.)	<ul style="list-style-type: none"> <li>• No need to transcribe information.</li> <li>• Short data collection, processing and analysis circuit.</li> <li>• Possibility of collecting several pieces of information using the same on-board tool in the appropriate device.</li> <li>• Central database hosted and backed up on the Internet.</li> <li>• Possibility of having several collection devices.</li> </ul>	<ul style="list-style-type: none"> <li>• Difficulty in transferring information in the event of an Internet blackout.</li> <li>• Central database hosted on the Internet and risk of piracy.</li> <li>• Requirement to have devices that can receive the tools.</li> <li>• Need to recharge equipment.</li> <li>• The cost and performance of the equipment to be used must be taken into account in their choice.</li> </ul>

Thus, even if they are not yet developed in the field of damage assessment in the management of HEC, their introduction and/or development would also make it possible to benefit from the advantages offered by these tools, in addition to become basic decision-making tools in the long term.

### **Introduction of connected digital damage assessment tools for HEC management**

#### **The first steps of connected digital tools in HEC management**

The use of connected digital tools in the management of HEC is of great importance today. They have already been used in several projects with good results. Five references in our review present studies using connected digital tools in the management of HEC. Two of them feature digital tools connected to elephant tracking devices (cell phones) with positioning systems through which smart collars attached to the elephants relayed location information over the cell phone network in Laikipia County (Kenya) and Sri Lanka (Graham et al. 2009). These tools were used to reduce HEC if the position of elephants in space and time could be determined. The other three studies focus on the presence of mobile phones in rural conflict contexts (Gamage and Wijesundara 2014), which allow the use of Global System for Mobile communications. Likewise, they show improved communication during an early warning of conflict between humans and elephants with authorities to coordinate responses to incidents (Sitati et al. 2005; Le Bel et al. 2014). Indeed, communication by mobile phone has helped to bridge possible communication gaps between different groups in conflict (communities, private landowners and local authorities) by creating an effective local network for inclusive social learning. This has gone a long way towards building trust, which is vitally important not only for the uptake of information and communication, but also for addressing wider conservation issues (Pretty 2002; Morawczynski and Miscione 2008; Boyle 2010; Graham et al. 2011; Lewis et al. 2016). This has led to an increase in the use of mobile phones and other means of information and communication technology (ICT) in protected areas and rural environments in developing countries (Le Bel et al. 2014, 2015; Lewis et al. 2016). Their use in rural areas has already shown great potential in HEC management.

The use of connected digital tools to assess elephant damage on plantations can be added to the services that phones can provide in HEC management. Indeed, limiting the use of mobile phones to improve communication between HEC stakeholders highlights certain difficulties, such as network coverage in forest areas (Gamage and Wijesundara 2014; Lewis et al. 2016). The use of more accessible satellite monitoring (Annasiwaththa et al. 2012) therefore facilitates the use of digital tools in the assessment of damage caused by elephants, as they are used in other aspects of conflicts between man and wildlife.

Two studies were carried out on this subject using a connected digital tool, KoBoCollect for testing (ANPN 2016; Le Bel et al. 2015). The latter tested the damage assessment with this tool in two areas, one in South Africa and the other in Gabon. In doing so, they demonstrate the ability of a fun-

damentally open and universally accessible tool for assessment in different fields to be used in the field of elephant crop damage assessment. Indeed, even if specific tools exist for each field (entomology, health, wildlife management, etc.), there is not yet a tool specific to this field of wildlife damage assessment and management of human-elephant conflict (HEC)/human-wildlife conflict (HWC). This is why creating specific tools or using tools from other areas of this HEC area is just as feasible if the results are the same in terms of cost, effectiveness, etc.

#### **Examples of digital tools used and that can be used to assess the damage caused by elephants**

Several connected digital tools exist. Some of them are gradually being introduced into the assessment of damage caused by elephants and into the management of HECs. Others, used elsewhere, seem suitable for use in the HEC/HWC field due to their usefulness and adaptability. Here we will present one of the main ones in each field: the SMART/Cyber tracker and the KoBoToolbox.

#### **SMART platform and his tools**

The Spatial Monitoring and Reporting Tool (SMART) is a platform that was designed to “improve anti-poaching efforts and overall law enforcement effectiveness in conservation areas and established management areas” (OSU OREME 2012ab; SMART 2017). SMART is a panel of software tools that allows the collection, storage, communication, and evaluation of data and results of the fight against poaching in protected areas. In several sites using the SMART, its effectiveness has already been demonstrated (SMART 2017). The use of SMART platform and the establishment of a database make it possible to obtain key information in the field when the collection sheets are well-developed (OSU OREME 2012ab). For example, it provides information such as GPS points and makes it possible to design maps of study areas, observations to be noted, filmed and selected from several previously encoded. Another of its advantages is the data security it provides; since the tool is secure on a computer and does not have a direct link to the web, which can create a hackable environment. Its partnership with Cyber Tracker means that many situations are already encoded or illustrated in the tool, such as the presence of animal evidence, damage to crops, human activities, etc. Observations during the assessment of damage that relate to devastated areas, GPS points of the location, and crop conditions before and after the damage, in addition to images, can be collected with the SMART platform. It is therefore a tool that can be used to assess damage on the ground. However, the SMART platform still remains difficult to use for certain tasks, such as taking area measurements, unlike GPS or the classic method with the tape measure. This is why it is necessary to accompany these digital tools with other conventional tools to overcome these limitations in the field of damage assessment. However, being a constantly evolving tool for good competition with other tools, its designers add extensions year after year, allowing it to perform more tasks. Therefore, its improvement for damage assessment is still possible.

### KoBoToolbox

The KoBoToolbox is a data collection, management, and visualization platform used globally for research and social good. It was developed by the Harvard Humanitarian Initiative, an organisation hosted at Harvard University and distributed and supported by the United Nations Office for the Coordination of Humanitarian Affairs (UNOCHA). It is appreciated for its comprehensiveness, ranging from questionnaire design, device data collection, and related tool suites, such as KoBoCollect and ODK collect, data storage and analysis of the results. It allows everyone (researchers, NGOs, etc.) to have access to its interface to store large quantities of data. If it were not for the ethical character of UNOCHA, the presence of the interface on the Web could create doubts about the fact that it could be hacked. With the KoBoToolbox many tasks are possible, such as area and population surveys, audio photos, and GPS points. Assessing damage with this tool is easy because it includes all the necessary tasks for a good evaluation, whether for the producer survey or the field evaluation. Unlike SMART, which is still only used for anti-poaching purposes, KoBoCollect has already been tested in South Africa to collect data (Le Bel et al. 2015).

### Perspectives for damage assessment in HEC management

The evaluation circuit using connected digital tools seems to be established in science in general. It should therefore continue to be introduced in the evaluation of damage caused to crops by elephants for the management of HEC, like the KoBoCollect which is currently being tested. Indeed, as it eliminates and facilitates several tedious steps in the damage assessment process (ease of data collection, elimination of the transcription step, etc.), it is now appreciated by its peers. Likewise, with advantages such as allowing multiple and participatory use by different people, and centralised data accessible to all, the field of crops, damage assessment, and HEC management could be improved. For example, all parties involved in the conflict could have access to these tools. Anyone could collect data and assess damage freely and in real-time using the tool. Given the increased trust that a well-organised and regulated participatory activity can generate, this type of tool would therefore make it possible to establish a relationship of trust between the actors in the conflict and to improve the management of HEC.

On the other hand, the use of the evaluation circuit with connected digital tools requires much more careful work in developing the data collection sheet by each person so as not to forget anything in the field because, with a sheet of paper and a pen, the investigator can quickly note a point that he forgot to enter in his data collection form. This is more difficult to do with a digital form if it is not correctly configured. Similarly, using connected digital tools such as KoBoCollect to assess crop damage from elephants means that the cost/effort factor and the ability to understand and use the tools must be taken into account. Even if the results of using these tools are accurate, the cost of obtaining them (phones adapted to the tools, etc.) and the effort required to use and understand them must be accessible to everyone (Mayer et al. 2008).

## Conclusion

Elephant damage assessment involves two main types of assessment: qualitative and quantitative. The evaluation methods used for both types are multiple and can be combined. We have a qualitative assessment through interviews, questionnaires, etc., with parties involved in conflicts and using desk research to obtain information. And we have a quantitative assessment through a total site visit, a visit to conflict hot and cold spots, or a visit to a random sample of the site to get real data on the ground. In order to confirm or refute the assessments made, it is possible to compare the results by combining both types of evaluation and the different methods within each type.

The digital space currently being developed offers advantages thanks to the design of connected digital tools already widely used in several areas of environment and wildlife management (SMART for anti-poaching efforts). These are digital tools (hardware and software) that allow data to be collected, transcribed and analysed quickly and securely. In the field of assessing crop damage caused by elephants, connected digital tools such as KoBoCollect are also offered, encouraged and tested because they make the work easier.

But also, thanks to the development of participatory actions among several people that this type of tool offers, their use would open the doors to improving the management of human-elephant conflicts (HEC). All stakeholders could be more involved in the damage assessment and a climate of trust could be created between the authorities and the producers.

It is important to know whether the digital tools and mobile devices necessary for their use are accessible in terms of cost and feasibility, and whether they can be understood by all stakeholders (producers, NGOs, government) in order to achieve the best results and get the most out of their use.

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