Revision of the methods used for monitoring the phenology of trees that are important for the diet of the western chimpanzee (*Pan troglodytes verus*) in the Boé Sector of Guinea-Bissau.

Esmee Mooi
August 14th, 2017
Almere, the Netherlands

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Front page image: Overview of an agricultural field along the Fulacundéum River near the Boé village of Dinguirai, photo provided by M.J. Breider

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Sincerely,
Esmee Mooi,
Almere, 2017.

Abstract

The critically endangered western chimpanzee (*Pan troglodytes verus*) once occurred in 12 West African countries. However, increasing anthropogenic factors have caused a dramatic decline in the species' habitat and population. This dramatic decline raises fears that the species may become extinct in the coming decades unless measures are taken to safeguard its survival. One of such measures is the prioritization of the western chimpanzee's habitat. Knowledge of the species' food sources and their availability may further help this prioritization. Therefore, the future aim is to close the knowledge gap on phenology patterns of chimpanzee fodder trees. The present aim of this study is to find a method that is suitable to monitor the phenology of chimpanzee fodder trees in the Boé Sector of Guinea-Bissau. This sector is believed to be home to at least 710 chimpanzees in a savannah-forest mosaic habitat. In total, ten commonly used phenology monitoring methods were found, compared and rated. The first selection process assessed whether these methods were suitable for the aim of the study and environment of the Boé Sector. Six of the ten commonly used methods were found to be applicable in the Boé Sector.

These six methods were then compared and rated on three different subjects: 1) subject objective (which describes objective, aim and research question), 2) subject research design (which describes research set up, *e.g.* number of trees per species) and 3) subject observation procedure (which describes how the observation of trees is conducted). The comparison of these methods found that a combination of three methods is the most suitable for use in the Boé Sector.

This combination of methods consists of: 1) an objective that is based on that of the PanAf method, 2) a research design based on that of the Monthly fruit index method and 3) an observation procedure that is based on the procedure of the Nature's Notebook method with the Monthly fruit index incorporated. In other words, the selected method is 1) aimed at chimpanzee research, 2) compatible with the Boé habitat and 3) observation of leaves, flowers, and fruits are recorded by estimating an amount or percentage in comparison to crown cover, from which the fruit availability can be calculated per tree species per month. Using this selected method, a long-term phenology of trees study can be set-up. This long-term study can provide information necessary to reach the future aim.

Résumé

Le chimpanzé verus (Pan troglodytes verus), en danger critique d'extinction, s'était trouvé autrefois dans 12 pays d'Afrique de l'Ouest. Cependant, l'augmentation des facteurs anthropiques a causé une baisse spectaculaire de l'habitat et de la population de l'espèce. Ce déclin dramatique cause de la peur que les espèces peuvent disparaître dans les décennies à venir, à moins que des mesures sont prises pour préserver leur survie. Une de ces mesures est conserver l´habitat de chimpanzés. Connaissance des sources de nourriture du chimpanzé et leur disponibilité peuvent également contribuer à cette préservation. C'est pourquoi, le but futur est combler les lacunes de connaissance phénologique des arbres importants d'alimentation des chimpanzés. Le but actuel de cette étude est de trouver une méthode appropriée pour surveiller la phénologie des arbres d'alimentation des chimpanzés dans le secteur de Boé de la Guinée-Bissau. Ce secteur héberge au moins 710 chimpanzés dans un habitat de mosaïque de savane et forêt. En total dix méthodes de surveillance de phénologie, couramment utilisées, sont été trouvées, comparées et évaluées. La première procédure de sélection a évalué si les méthodes étaient applicables pour le but de cette étude et l'environnement de Boé. Six de ces méthodes sont applicables dans le Boé. Ensuite, ces six méthodes étaient comparées et évaluées sur trois sujets différents: 1) sujet objectif (qui décrit les objectifs, le but et la question de recherche), 2) sujet conception de la recherche (qui décrit le plan de la recherche, par exemple le nombre d'arbres par espèce) et 3) sujet procédure d'observation (qui décrit comment l'observation des arbres est menée). La comparaison des méthodes a été constaté qu'une combinaison de trois méthodes est la plus appropriée pour être utilisée dans le secteur de Boé. Cette combinaison de méthodes consiste en : 1) un objectif basé sur celui de la méthode 'PanAf', 2) une conception de recherche basée sur celle de la méthode 'Monthly Fruit Index' et 3) une procédure d'observation basée sur la procédure de la méthode 'Nature's Notebook' inclusivement la méthode 'Montly fruit index'. En d'autres termes, la méthode sélectionnée est : 1) vise à mener des recherches sur les chimpanzés, 2) compatible avec l'habitat de Boé et 3) L'observation des feuilles, des fleurs et des fruits est enregistrée en estimant d'une quantité ou un pourcentage par rapport à la couverture de la couronne dont une disponibilité de fruits peut être calculée par arbre par mois. Cette étude à long terme peut fournir des informations nécessaires pour atteindre le but futur.

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Glossary

Diameter at breast height (DBH)	Standard height at which the diameter of the trunk or bole of a standing tree is measured. DBH is assumed to reflect the tree's ability to produce fruit, as mature trees grow more fruit (Browak & Thompson, 2000). The height at which DBH is measured is defined differently in different countries (*e.g.* 1.3 meters continental Europe, the UK, and Canada; 1.4 meters in the US, Australia, New Zealand, Burma, India, Malaysia, and South Africa). In this report, DBH stands for the standard measurement of 1.3 meters, unless otherwise noted.
Flagship species	A species that is the center of the attention for conservation of an area and that is used to secure a conservation program (*e.g.* by stimulating people's interest and sympathy) (Simberloff, 1998).
Interobserver variability	Variation in data that can be assigned to the data being recorded by two or more observers, even though both use the same method and examine the same subject.
Phenology	The study of recurrent biological events and of how these are influenced by seasonal and inter-annual variations in seasonality of biotic and abiotic factors in the habitat (*e.g.* bird migration or plant flowering) (Sakai, 2001; Tierney et al., 2013).
Phenophase	Short for 'phenological phase', which is an observable stage or phase in the seasonal recurrent cycle of a plant or animal. Phenophases can be defined by a start and an end, often lasting for a few days to a few weeks (*e.g.* the period during which newly emerging leaves are visible or the period during which open flowers are present on a plant) (Carvalho, Vicente, & Marques, 2015).
RGB-colour model	Color model in which red, green and blue are added together in different compositions to reproduce a broad array of colors. This model is used in phenology of vegetation's to measure the ''greenness'' of vegetation by use of the greenness index. (Ide, 2010; Sonnentag et al., 2012)

1. Introduction

The critically endangered western chimpanzee (*Pan troglodytes verus*) (Humle et al., 2016) is known to have once occurred in 12 countries in West Africa (Lee, Thornback, & Bennett, 1988; Akom, 2015). However, the effects of increasing anthropogenic factors such as deforestation and habitat fragmentation have caused a dramatic decline in the western chimpanzee's habitat and population (Carvalho, Marcques, & Vicente, 2013). It is estimated that 80% of the original forest cover was lost by the early 2000's, mainly due to deforestation by slash and burn-agriculture (Kormos et al., 2003; Humle et al., 2016). As a result of this habitat loss, western chimpanzee populations have experienced a dramatic decline of more than 80% in the last 70 years (Humle et al., 2016). Currently, the western chimpanzee is patchily distributed over nine or ten countries, from south-east Senegal to the Dahomey gap (a 200 km wide area characterized by forest-savannah mosaic habitat separating the West African rainforests from those of Central Africa; Salzmann & Hoelzmann, 2005) with an estimated population of 18,000-65,000 individuals (Akom, 2015; Humle et al., 2016; Demenou, Pineiro, & Hardy, 2016). The current alarming decline in western chimpanzee numbers raises fears that the species might become extinct in the coming decades unless appropriate measures are taken to safeguard their survival (Kormos et al., 2003; Torres et al., 2010; Humle et al., 2016). One of such measures is the prioritization of areas of the western chimpanzee's habitat. Such prioritization may benefit from knowledge of the species' food sources and their availability in these areas (Furuichi, Hashimoto, & Tashiro, 2001; Watts et al., 2012; Carvalho et al., 2015). Therefore, knowledge of the western chimpanzee's food abundance and availability is believed to be necessary (Hashimoto et al., 2003; Bessa, Sousa, & Hockings, 2015; Breider 2017a).

Chimpanzees generally have a broad and flexible omnivorous diet (Bessa et al., 2015) comprised of many plant parts (leaves, flowers, fruits and piths) (Watts et al., 2012) and animal foods (*e.g.* insects and small mammals) (Gomes & Boesch, 2008). Their primary food source is believed to be ripe fruit from trees (Wrangham, Conklin-Brittain, & Hunt, 1998; Watts et al., 2012). As other primates with broad diets (*e.g.* baboon; *Papio ssp.*) (Kunz & Linsenmair, 2009), their diet varies across habitats. The food availability in their habitats is highly seasonal and usually includes one or two periods of fruit scarcity (Furuichi et al., 2001; Takenoshita, Ando, Iwata, & Yamagiwa, 2008). These patterns of food availability often affect chimpanzee behavior and distribution (*e.g.* group size, foraging range) (Hashimoto et al., 2003; Takenoshita et al., 2008). Therefore, understanding the temporal food availability for chimpanzees is crucial to understanding chimpanzee behavior and distribution (Bessa et al., 2015). Such information can assist conservationists in establishing conservation strategies that safeguard the future survival of chimpanzees (Watts et al., 2012; Carvalho et al., 2015). This information can also help understand how chimpanzees can be protected in areas with increasing habitat degradation (Tweheyo & Babweteera, 2007), for instance by prioritizing areas with year-round food availability for chimpanzees. Food availability patterns can be assessed by studying tree phenology (Carvalho et al., 2015; Bessa et al., 2015), which is the study of the seasonally recurrent activities of plants and animals such as the timing of plant flowering or bird migration (Tierney et al., 2013).

The term 'phenology' stands for the adaptation of organisms to the seasonality of biotic and abiotic factors (*e.g.* deviations in flowering of plants caused by temperature) (Sakai, 2001; Tierney et al., 2013), which is central to understanding ecological interactions (Denny et al., 2014). Tree communities adapt to this seasonality with flowering, fruiting, and leaf-flushing events (Sakai, 2001; Anderson, Nordheim, Moermond, Gone, & Boesch, 2005), in which the majority of tree communities share a general seasonally recurrent phenology pattern (Singh & Kushwaha, 2005). However, deviations from these recurrent patterns are commonly observed (*e.g.* deviations in flower initiation) (Tierney et al., 2013). In response to these deviations, trees may vary the initiation, intensity or duration of a seasonal recurrent activity (seasonal recurrent activities will hereafter be referred to as 'phenophases') (Singh & Kushwaha, 2005; Broich et al., 2015). Such a deviation in one phenophase may consequently affect other phenophases (Singh & Kushwaha, 2006). For instance, the delayed initiation of flowering can disrupt the timing of fruiting (Silva & Pires, 2014). Consequently, this disruption may cause a low fruit abundance as the delayed flowering can overlap the optimal fruiting period (Günter et al., 2008). Generally, the intensity of a phenophase (*e.g.* the abundance of fruit) is expected to vary rather than the duration or initiation of a phenophase (Anderson et al., 2005). Factors influencing plant phenology are abiotic factors such as temperature, rainfall, and humidity, (Anderson et al., 2005; Haugaasen & Peres, 2005; Walker, Beurs de, Wynne, & Gao, 2012), as well as biotic factors such as intraspecific and interspecific competition for various resources (*e.g.* interactions with other organisms such as herbivores, pollinators, and seed dispersers) (Schaik, Terborgh, & Wright, 1993; Sakai, 2001; Chapman, Wrangham, Chapman, Kennard, & Zanne, 1999; Richardson et al., 2013). Chimpanzees – as seed dispersers – indirectly influence the phenology of their feeding trees (Wrangham et al., 1998; Carvalho et al., 2015), while they can also be influenced by deviations in phenology (*e.g.* alterations in competitive behavior with small or great food availability) (Isabirye-Basuta, 1988; Newton-Fisher, Reynolds, & Plumtre, 2000; Takenoshita et al., 2008). Therefore, understanding the phenology of trees that provide important chimpanzee food sources may be beneficial to future chimpanzee conservation.

Studies of the phenology of trees that are important to chimpanzees (hereafter 'chimpanzee fodder trees') are scarce. However, some studies of the subject have been performed. Most of these past studies were performed in tropical habitats (*e.g.* Tweheyo & Babweteera, 2007; Watts et al., 2012; Carvalho et al., 2015), while few were performed in savannah-forest mosaic habitats. One of these few studies in savannah-forest mosaic was a census of fallen fruit by Takenoshita et al. (2008). This census gathered knowledge of fluctuations in food availability for great ape populations, including chimpanzee. This study found large annual fluctuations in fruiting patterns and found that areas with a constant abundance of fruit may support higher great ape densities. As phenology is not only highly seasonal but also varies largely across habitats (Furuichi et al., 2001; Takenoshita, Ando, Iwata, & Yamagiwa, 2008). Studies performed in one area are therefore not necessarily representative for another area. Even though studies of the chimpanzee in a savannah-forest mosaic are scarce, these studies may play a crucial role in chimpanzee conservation as the harshness of savannah-forest mosaic habitats may increase the pressure on chimpanzee populations (Pruetz, Marchant, Arno, & McGrew, 2002; Tweh et al., 2014; Kormos et al., 2015). Therefore, studies of chimpanzees in a savannah-forest mosaic may be crucial to the conservation of the critically endangered western chimpanzee, as this subspecies is most abundant in savannah-forest mosaic habitats (Kormos et al., 2003; Humle et al., 2008; Humle, et al., 2016).

The western chimpanzee is currently present in nine West-African countries (Torres et al., 2010), although the species is already considered rare or close to extinction in four of these countries (Kormos et al., 2003; Akom, 2015). In Guinea-Bissau, the western chimpanzee was previously considered extinct (Lee, thornbeck, & Bennet, 1988; Humle et al., 2008; Hocking & Sousa, 2012; Sá et al., 2013). Later studies disregarded this status and report. However, there is still inconsistency about the conservation status and population size of the western chimpanzee in Guinea-Bissau (Gippoliti & Dell'Omo, 2003; Brugiere, Badijnca, Silva, & Serra, 2009; Torres et al., 2010). The total western chimpanzee population of Guinea-Bissau was estimated to range between 600 to 1000 individuals (Kormos et al., 2003). However, the combined population estimates of the Cantanhez National Park and the Boé Sector together already exceed this estimate (approximately 400 in Cantanhez and 710 in the Boé Sector) (Serra, Silva, & Lopes, 2007; Hockings & Sousa, 2013). As the western chimpanzee is used as '' flagship" species in the Boé Sector, the protection of the species is in the interest of conservation throughout Guinea-Bissau. Especially considering the recent creation of the Boé National park, where little to no information is available about the chimpanzee's present in the park. To aid the protection of these chimpanzee's information about its habitat and food source is necessary (Sousa & Frazão-Moreira, 2010).

In the past, an attempt was made to gather knowledge of the food availability of the western chimpanzees in the Boé Sector. A study by Van der Meer (2014) examined the phenology of trees eaten by the western chimpanzee. However, a recent study by Breider (2017a) reported the collected data to be partially unfit for analysis as interobserver variability was high. Since the data was collected by multiple individuals, chances of interobserver-variability in the collected phenology data are high. Therefore, a more suitable method to study the phenology of trees important for the chimpanzee's diet in the Boé Sector is necessary, to facilitate a better conservation of the Boé chimpanzees and their habitat.

1.1 Problem statement

Ideally, there is a significant amount of knowledge of chimpanzee fodder tree phenology available to be used by conservationists in planning chimpanzee protection. Deriving this knowledge from long-term studies of tree phenology have been especially valuable, as it helps to understand the possible deviation from the recurrent patterns. Such information can aid in understanding how critically endangered western chimpanzee populations can be protected in areas with increasing threats from habitat degradation, as it can help ascertain effective protection and regeneration of important fodder trees. Currently, however, there is little to no data available on the phenology of chimpanzee fodder trees in the savannah-forest mosaic habitats where the western chimpanzee mostly occurs (see appendix IV Keywords used to search in scientific databases for keywords and sources used in search of previous studies in comparable habitats). In the Boé Sector of Guinea-Bissau – one such savannah-forest mosaic habitat area – an attempt was made to study tree phenology. However, the lack of a suitable method to gather long-term data on tree phenology is believed to have limited the amount of information currently available in this area. As phenology is highly seasonal and varies largely across habitats, information presented by previous studies of tree phenology from outside the Boé Sector are also no representatives of the Boé environment and are therefore of limited use to conservationists working in the Boé Sector. Therefore, there is a need for a suitable method to study the phenology of chimpanzee fodder trees in the Boé to facilitate a better conservation of the Boé chimpanzees and their habitat.

1.2 Objective

The future aim of this study is to close the knowledge gap that currently exists on phenology patterns of western chimpanzee fodder trees. Therefore, the present aim of this study is to find a suitable method to study the phenology of chimpanzee fodder trees in the Boé Sector. As fruit is the one most important food source for the chimpanzee, it crucial that this method collects detailed data on fruiting phenology. However, as the western chimpanzee has a broad diet that also includes leaves and flowers, the selected method should not solely collect fruit phenology data.

The above-described aim is fulfilled by the following objectives: 1) search for commonly used phenology monitoring methods; 2) compare and analyze the objective, research design, and observation procedure of these methods; 3) select the most suitable method (or combination of method) that best fits the Boé Sector; 4) describe how the selected method can be applied in the Boé Sector; and 5) describe how the selected method should be maintained in the future in the Boé Sector. These objectives will answer the following research question:

- What is the most suitable method (derived from existing methods) to monitor the phenology of trees that are important for the diet of the western chimpanzee (*Pan troglodytes verus)* in the Boé Sector of Guinea Bissau?

To answer this research question the following sub-questions were answered:

- What are commonly used methods to monitor phenology?
- Are these methods suitable to fulfill the aim of this of this study?
- What are the objectives of the methods?
- What are the research designs of the methods?
- What are the observations procedures of the methods?
- How can this method be applied in the Boé Sector?
- How should this method be maintained (be kept in a good condition over the course of years) in the future?

1.3 Hypothesis

It is hypothesized that the to-be-selected method is compatible with the habitat of the Boé Sector. As the Boé is a rough and isolated area, long transects with great distances in-between are time-consuming and labor-intensive. Therefore, a balance had to be found between transect length on the one hand, and the time and the labor that it will take to carry out the phenology observations on the other. Secondly, as the selected method is meant to monitor the phenology for a multiple-year study period, multiple researchers will have to carry out the monitoring of trees. Therefore, it is important that the selected method has a low interobserver variability and is easily reproducible. Thirdly, the method must be easily understandable for local guides that are supposed to independently perform the monitoring of phenology. Lastly, the method should be broadly applicable to tree species with different physiology (*e.g.* oil palm tree *Elaeis guineensis* and fig species *Ficus ssp.*).

2. Methodology

In this study, a literature review was performed to find a suitable method to monitor the phenology of chimpanzee fodder trees in the Boé Sector of Guinea-Bissau. Information on different methods that are commonly used to monitor phenology of trees was gathered, analyzed and compared. This comparison of methods – of which the methods will be described in this chapter – will eventually lead to a detailed description of the method and how it can be applied and maintained in the Boé Sector.

2.1 Study site

The Boé Sector is located in the southeast of Guinea-Bissau (Figure 1) (Gippoliti & Dell'Omo, 2003) and is one of the least developed regions of this already underdeveloped country (O'Regan & Thompson, 2013). As a result of this underdevelopment, the Boé currently is an isolated area with an important biodiversity and a low human population (Breider, Goedmakers, Wit, Niezing, & Sila, 2016). The sector covers 3,289 km² (wit & Reintjes, 1989), of which the recently created Boé National Park covers 1,054 km² and the 499.22 km² TcheTche Wildlife Corridor connects the BNP with the Dulombi National park (Figure 1) (IBAP,2014; Breider,2017). The Boé Sector's climate is characterized by a dry season from November to May and a wet season from June to October. The average annual rainfall ranges between 1,600mm and 2,100mm and the average temperature is 28°C (with maximum values of 42°C in April and a minimum of 8°C in January) (Wit & Reintjes, 1989; Ferreira et al., 2014; Steenis, 2017). The Boé habitat can be characterized as a savannah- forest mosaic This mosaic habitat is partially the result of the laterite cap covering large parts of the sector. This laterite cap prevents trees from growing in places where this cap is close to the surface. However, in places where a layer of soil covers the laterite cap (*e.g.* along the rivers or on hillsides) trees can root and forests have developed (Wit & Reintjes, 1989; Serra, Silva, & Lopes, 2007). Most of these forests have been converted into slash and burn agricultural fields (Oosterlynck, 2014). Despite this slash and burn agriculture, small patches of sacred forests have remained intact throughout the Boé (Breider, 2017c). These sacred forests have been protected by the superstition that gods or spirits of the forest live in these forests and that disturbing them can have serious consequences (B. Camara, Boé resident, personal communication, December 8, 2015). These sacred forests and the forests along rivers or hills are an important habitat for most animal species living in the Boé Sector (IBAP, 2014), including the critically endangered western chimpanzee (Brugiere et al., 2009; Humle et al., 2016; Breider, 2017a).

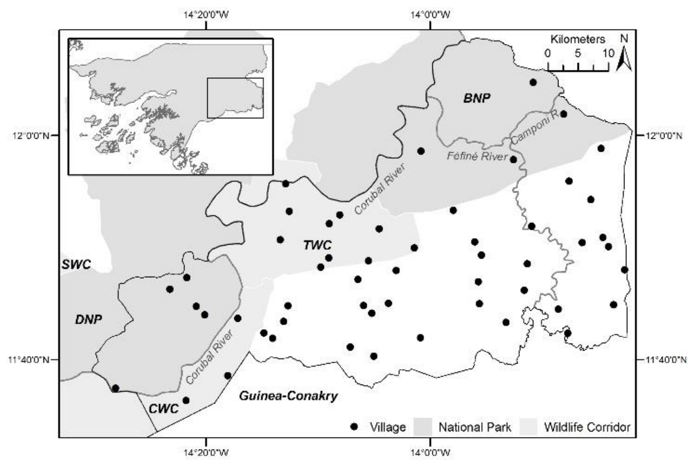

Figure 1: Map of the Boé displaying village locations and the areas of the Boé National Park (BNP) Dulombi National Park (DNP) and TcheTche Wildlife Corridor (TWC) (Breider, 2017b)

2.2 Previous studies in the Boé Sector

In preparation for this study, two previous studies of the phenology of trees in the Boé Sector have been consulted to gather information on the currently available knowledge of phenology in the Boé. These previous studies were: 1) ''An inventory of the vegetation structure and food availability for the western chimpanzee (*Pan troglodytes verus*)'' by van der Meer (2014), a phenology study of trees eaten by the western chimpanzee; and 2) ''The fruiting cycle of trees eaten by the western chimpanzee (*Pan troglodytes verus*) in the Boé Sector of Guinea-Bissau.'' by Breider (2017a), also a phenology study of trees eaten by the western chimpanzee that also reflected on the used methodology and found that the recently collected data was partially unfit for further analysis and that the current method was unfit for the collection of long-term data. The conclusions and recommendation of these studies were considered in creating the new method.

2.3 Database of sources

In this study a literature review has been performed, different sources on methods that are commonly used to monitor phenology of trees were gathered. These sources were obtained from scientific publication databases such as Google scholar, Wiley library and Green-I Catalogue. In the search for these sources, the focus lay on commonly used methods that monitor tree phenology. The keywords that were used to find the sources are given in Appendix IV Keywords used to search in scientific databases.

2.4 Analysis of methods

All sources from the established database of sources were read and organized per method used in the sources. If less than three sources were found per method, the method was considered not commonly used and was therefore discarded. As a result, ten methods were found to be commonly used for monitoring phenology (see 2.5 Commonly used methods for monitoring phenology).

2.5 Commonly used methods for monitoring phenology

A large database of sources for the ten selected methods was established in which a lot of information is available on these methods. The sources of a method either use the same method or differ slightly. This variation is usually caused when the method is modified to suit the environment its study site. In the following paragraphs (paragraph 2.5.1 to 2.5.10) a summary of each method is given, followed by a list of the sources that describe the method. Five of the selected methods focus mainly on the phenology of fruit, which is chosen because a detailed observation procedure for fruit is believed to be important as chimpanzees have a high percentage of fruit in their diet (Potts et al., 2011).

2.5.1 Pan African Programme method

The Pan African Programme (hereafter 'PanAf') is the method that is currently used to monitor the chimpanzee fodder tree phenology in the Boé Sector. This method samples reproductively mature (adult) trees, defined as individuals with a diameter at breast height (DBH; 1.4 m) larger than 10 cm (1.4 m from the ground). The observation procedure estimates the percentage of fruits, leaves and flowers in comparison to the crown cover, giving it a score from 0 to 4 (0= 0% crown cover, 1 = 1 to 25 %, 2 = 26 to 50%, 3= 51 to 75% and 4 = 76% to 100%). As forests, usually have closed canopies, it is often difficult to have a good view of the whole tree crown. Therefore, an estimation of the entire crown cover is done by selecting three branches of a tree crown that have at least a two-meter-long section visible. It is essential to select a branch that is known to carry either, flowers, fruits or leaves. In most case, these are the tips of young branches. Along these branches, the proportion of leaves, flowers, and fruits are estimated. In addition to these estimations, the amount of fruits on the ground are noted, classified as either 0 = none, 1 = little, 2 = some, or 3 = many. Sources that describe the Pan African Programme method are given in Table 1.

Table 1: Sources for Pan African Programme method

[1] Meer, Van der, I., (2014) Inventory of the vegetation structure and food availability for the western chimpanzee *(Pan troglodytes verus)* in the Boé region, Guinea-Bissau. Chimbo.
[2] Haugaasen, T., (2005) Tree phenology in adjacent Amazonian flooded and unflooded forests. Biotropica 37(4):620-630.
[3] Breider, M.J., (2017) The fruiting cycle of trees eaten by a western chimpanzee *(Pan troglodytes verus)* in the Boé Sector of Guinea- Bissau. Chimbo.
[4] Arendjelovic, M., Boesch, C., Campell, G., Hohmann, G., Junker, J., Kouakou, C. Y., . . . Head, J. (n.d.). Pan african programme, the cultured chimpanzee, guidelines for research and data collection. Pan african programme, Max Planck Insistute.
[5] kristensen, K. A., Kaplin, B. A., Sun, C., Munyallgoga, V., Mvukiyumwami, J., Kajondo, K. K., & Moermond, T. C. (1996). Tree phenology in a tropical montane forest in Rwanda. Biotropica, 28(4), 668-681. doi:10.2307/2389053.

2.5.2 Fruit trails method

The Fruit trails method monitors fruit abundance and the number of fruiting trees along so-called fruit trails: 1 m wide trails along an established transect walk. When walking a fruit trail, fallen fruit is counted and identified to species. Fruit clusters are used to count the amount of fruit. Such clusters are specified as an aggregation of fruit that has fallen from one tree. Data from larger contiguous fruit clusters that come from several trees of the same species are divided by the number of fruiting trees. The fruit in each cluster is counted and its state (ripe/unripe) is recorded. Sources that describe the Fruit trails method are given in Table 2.

Table 2: Sources for Fruit trails method

[1] Furuichi, T., Hashimoto, C., Tashiro, Y., (2001) Fruit availability and habitat use by chimpanzees in the kalinu, Uganda: an examination of fallback foods. International journal of primatology, 22(6):929-945.
[2] Takenoshita, Y., Ando, C., Iwata, Y., & Yamagiwa, J. (2008). Fruit phenology of the great ape habitat in the Moukalaba-doudou national park, gabon. African study monographs, 39, 23-39. doi: http://doi.org/10.14989/66240
[3] White, F.J. (1998) Seasonality and socioecology: The importance of variation in fruit abundance to bonobo sociality. International journal of primatology. 19(6):1998.
[4] Hashimoto, C., Suzuki, S., Takenoshita, Y., Yamagiwa, J., Basabose, A. K., & Furuichi, T. (2003). How fruit abundance affects the chimpanzee party size: a comparison between four study sites. Primates, 44(2), 77-81. doi:10.1007/s10329-002-0026-4.

2.5.3 Fruit count method

The Fruit count method monitors fruit abundance by counting the amount of fruit instead of estimating this amount in percentages (as used by most other phenology monitoring methods). First, the DBH (1.2 m) is used as an indicator of the maturity of trees. Then, the amount of fruit in the tree is counted. To visually count the amount of fruit in a tree, the tree is divided into counting units 1 m^3 each of which five that are representative for the tree are randomly selected and the amount of fruit in them is counted (hereafter 'sampled counting units'). The average number of fruits in the sampled counting units (F_{avg}) is calculated as

$$F_{avg}=\frac{s_1+s_2+s_3+s_4+s_5}{5}$$

were s_1 is the amount of fruit in sampled counting unit 1, s_2 the number of fruit in sampled counting unit 2, and so forth. Then, the total number of counting units in the tree (T_S) is calculated as

$$T_S = n_{Sa} \times T_a$$

Were n_{Sa} is the estimated number of counting units in one arm of the trees and T_a is the estimated total number of arms in the tree. Lastly, the total number of fruit in the tree (T_f) is calculated as

$$T_f = F_{avg} \times T_s$$

To decrease interobserver variability, training trials where observers made estimates of fruit abundance on a trial tree and afterward discuss the found measurements. Sources that describe the Fruit count method are given in Table 3.

Table 3: Sources for Fruit count method

[1] Tweheyo, M., Lye, K.A., (2003) Phenology of figs in Budongo forest Uganda and its importance for the chimpanzee diet. African journal of ecology, 41:306-316. [2] Tweheyo, M., & Babweteera, F. (2007). Production, seasonality and management of chimpanzee food trees in Budongo forest, Uganda. African journal of ecology, 45(4), 535-544. doi:10.1111/j.1365-2028.2007.00765.x. [3] Chapman, C.A., Chapman, L.J., Wrangham, R., Hunt, K., Gebo, D., Gardner, L. (1992) Estimators of fruit abundance of tropical trees. Biotropica 24(4): 527-531.

2.5.4 Nature's Notebook method

This method is similar to the PanAf method (see 2.5.1 Pan African Programme method). It also estimates the percentage in comparison to crown cover of leaves, flowers, and fruits. However, the Nature's Notebook also uses visual counts. In estimating percentages, this method distinguishes five different percentage categories: less than 5%, 5 – 24%, 25-49%, 50-74%, 75-95% and more than 95%. In visual counts, this method distinguishes 6 different categories: less than 3, 3 to 10, 11 to 100, 101 to 1,000, 1,001 to 10,000 and more than 10,000). First, this method notes whether a certain phenophase is present or absent. If present, the intensity of a phenophase is noted using the categories above. Sources that describe the Nature's Notebook method are given in Table 4.

Table 4: Sources for Nature's Notebook method

[1] Tierney, G., Mitchell, B., Miller-Rushing, A., Katz, J, Denny, E., Brauer, C., . . . Dieffenbach, F., (2013) Phenology monitoring protocol, Northeast temperate network. Natural resource report NETN/NRR – 681. [2] Denny, E. G., Gerst, K. L., Miller-rushing, A. J., Tierney, G. L., Crimmins, T. M., Enquist, C. A., . . . Weltzin, J. F. (2014). Standardized phenology monitoring methods to track plant and animal activity for science and resource management application. International journal of biometeorlogy, 58(4), 591-601. [3] Elmendorf, S.C., Jones, K.D., Cook, B.I., Diez, J.M., Enquist, C.A.F., Hufft, R.A., Jones, M.O., Mazer, S.J., Miller-Rushing, A.J., Moore, D.J.P., Schwartz, M.D., Weltzin, J.F. (2016) The plant phenology monitoring design for the national ecological observatory network. Ecosphere. 7(4):e01303. Doi: 10.1002/ecs2.1303

2.5.5 Monthly fruit index

The Monthly fruit index method uses line-transect surveys to estimate the density of woody species and assess the fruit availability in different vegetation types. The presence of fruits was recorded twice per month, and monthly data is then calculated by averaging the two records. The density and basal area $[(1/2DBH)^2 \times \pi]$ of each species were calculated. A monthly fruit availability index (F_m) is then calculated as

$$F_m = \sum P_{km} \times B_k$$

were P_{km} is the proportion of trees or shrubs of species k in month m and B_k is the sum of the basal areas of all trees of species k per hectare. This method uses the basal area as this measure was used as a good estimation of canopy volume. Sources that describe the Monthly fruit index method are given in Table 5.

Table 5: Sources for Monthly fruit index method

[1] Basabose, A.K., Yamagiwa, J. (2002) Factors affecting nesting site choice in chimpanzees at Tshibati, Kahuzi-Biega National Park: influence of sympatric gorillas. International journal of primatology 23(2):263-283.
[2] Yamagiwa, J., Basabose, A., & Kaleme, K. (2008). Phenology of fruit consumed by a sympatric population of gorillas and chimpanzees in Kahuzi-Biega National park, Democartic replublic of Congo. Human evolution, 39, 3-22. doi:http://doi.org/10.14989/66241.
[3] Basabose, A. K. (2002). Diet composition of chimpanzee inhabiting the Montane Forst of Kahuzi Democratic Replublic of Congo. American. Journal of primatology, 58(1), 1-21. doi: 10.1002/ajp.10049.

2.5.6 BBCH code method

The BBCH code method classifies the plant growth phases of multiple species according to a standardized system. This method is an internationally recognized standard in the agricultural sector, but it has also been used to study phenology in nature (Koch et al., 2007; Schwartz, Beaubien, Crimmins & Weltzin, 2013). This method is broadly applicable for different plant species (Koch et al., 2007) and is therefore applicable for use in agriculture as well as in nature. The BBCH code method measures specific phenophases on a scale from 0 to 9, in which 0 is germination and 9 is dormancy. A second number that corresponds to the respective growth stage of the phenophases, 0 is the beginning of the principal growth stage and 9 is the end of the stage. (*e.g.* BBCH60 beginning of flowering, BBCH69 end of flowering). Sources that describe the BBCH code method are given in Table 6.

Table 6: Sources for BBCH code method

[1] Koch, E., Bruns, E., Chmielewski, F.M., Defila, C., Lipa, W., Menzel, A., (2007) Guidelines for plant phenological observation. World Climate Data and Monitoring Programme.
[2] Bruns, E., Chmielewski, F.M, VanVliet, J.H. (2003) The global phenological monitoring concept. Tasks for vegetation science 39:93-104.
[3] Zhang, H.N., Sun, W.S., Sun, G.M., Liu, S.H. Li, Y.H., Wu, Q.S., Wei, Y.Z. (2016) Phenological growth stages of pineapple (Ananas comosus) according to tot the end extended biologische bundesantalt, Bundessortemant and Chemische industrie scale. Annals of applied biology. ISSN 0003-4746.
[4] Meler, U., Bleiholder, H., Buhr, L., Feller, C., Hack, H., Heβ, M., Lancashire, P.D., Schnock, U., Stauβ, R., Boom van den, T., Weber, E., Zwerger, P. (2009) The BBCH system coding the phenological growth stages of plants history and publications. Journal Für Kulturpflanzen, 61(2): 41-52.
[5] Hess, M., Barralist, G., Bleiholder, H., Buhr, L., Eggers, T.H., Hack, H., Stauss, R.(1997) Use of the extended BBCH scale – general for the description of the growth stages of mono and dicotyledonous weed species. Weed research, 37:433-441.

2.5.7 MODIS and Landsat methods

MODIS (Moderate Resolution Imaging Spectroradiometer) and Landsat are programs that use satellite images of vegetation for phenology monitoring. These satellite images are analyzed using logistic functions that calculate the vegetation index. The minima and maxima of the vegetation index display minimum and maximum 'greenness' at certain time series, which can be identified as the transition from one phenophase to another. Sources that describe the MODIS and Landsat method are given in Table 7.

Table 7: Sources for Modis and Landsat method

[1] Fisher, J.I., Mustard, J.F. (2007) Cross-scalar satellite phenology from ground, Landsat, and MODIS data. Remote Sensing of environment 109: 261-273.
[2] Walker, J.J., Beurs de, K.M., Wynne, R.H., (2014) Dryland phenology across an elevation gradient in Arizona, USA, investigated with fused MODIS and Landsat data. Remote sensing of environment 144:85-97.
[3] Zhang, X., Friedl, A.F, Schaaf, C.B., Strahler, .H., Hodges, J.C.F., Gao, F., Reed, B.C., Huete, A. (2003) Monitoring vegetation phenology using MODIS. Remote Sensing of Environment 84: 471-475.

2.5.8 Digital time-lapse method

The digital time-lapse method uses time-lapse camera's that take multiple pictures of vegetation per day. These pictures are then used to determine the phenology of vegetation. Usually, the camera has a broad overview of a forest, and the pictures are taken from afar. Determination of (intensity of) phenophases is done by visually inspecting the pictures. Intensity of phenophases is determined by the 'greenness' index using the RGB color model (color model in which red, green and blue light are added together in various ways to reproduce a broad array of colors), which is calculated by computer programs and equations. Sources that describe the Digital time-lapse method are given in Table 8.

Table 8: Sources for Digital time-lapse method

[1] Ahrends, H.E., Etzold, S., Kutsch, W.L., Stoeckli, R., Bruegger, R., Jeanneret, F., Wanner, H., Buchmann, N., Eugster, W., (2009) Tree phenology and carbon dioxide fluxes: use of digital photography for process-based interpretation at the ecosystem scale. Climate research, 39:261-274.
[2] Bater, C.W., Coops, N., Wulder, M.A., Hilker, T., Nielsen, S.E., McDermid, G., Stenhouse, G.B., (2011) Using digital time-lapse cameras to monitor species-specific overstorey phenology in support of wildlife habitat assessment. Environ monitor asses 180:1-13.
[3] Ecosystem Thematic Centre (2015) Phenocamera: automated phenology monitoring. Wingate, L., Cremonese, E., Migliavacca, M., Brown, T., D'Odorico, P., Peichl, M., Gielen, B., Hortnagl., L. Retrieved from: European-webcam-network.net.
[4] Ide, R., Oguma, H. (2010) Use of digital cameras for phenological observations. Ecological informatics 5:339-347.
[5] Keenan, T.F., Darby, B., Sonnentag, O., Friedl, M.A., Hufkens, K., Keefe, J.O., Klosterman, S., Munger, J.W., Toomey, M., Richardson, A.D. (2014) Tracking forest phenology and season physiology using digital repeat photography: a critical assessment. Ecological Applications, 24(6):1478-1489.
[6] Nagai, S., Yoshitake, S., Inoue, T., Suzuki, R., Muraoka, H., Masajara, K.N., Saitoh, T.M. (2014) Year-to-year blooming phenology observation using time-lapse digital camera images. Journal of agricultural meteorology 70(3): 163-170.
[7] Zhao, J., Zhang, Y., Tan, Z., Song, Q., Liang, N., Yu, L., Zhao, J. (2012) Using digital cameras for comparative phenological monitoring in an evergreen broad-leaved forest and a seasonal rain forest. Ecological informatics 10:65-72
[8] Sonnentag, O., Hufkens, L., Teshera-Sterne, C., Young, A.M., Friedl, M., Braswell, B.H., Milliman, T., O'Keefe, J., Richardson, A.D. (2012) Digital repeat photography for phenological research in forest ecosystems. Agricultural and forest meteorology 152:159-177.
[9] Crimmins, M.A., Crimmins, T.M. (2008) Monitoring plant phenology using digital repeat photography. Environmental management, 41(6):949-958E

2.5.9 Fruit traps method

The Fruit traps method uses a square frame of 0.08 m^2 with a plastic bag suspended from its top – raised 0.4 m off the ground – to collect fruit falling from trees. These traps are set at 20 m intervals, 1 m from transects trails. Fruit, seeds, and leaves are collected and analyzed weekly. The total weight of fruit is determined after which the fruits are dried and weighed again. Sources that describe the Fruit traps method are given in Table 9.

Table 9: Sources for Fruit trap method

[1] Chapman, C.A., Wrangham, R. (1994) Indices of habitat-wide fruit abundance in tropical forests. Biotropica, 26(2):160-171. [2] Malenky, R.K., Wrangham, R., Chapman, C.A., Vineberg, E.O. (1993) Measuring chimpanzee food abundance. Tropics 2(4):231-244. [3] Stevenson, P.R., Quinones, M.J., Ahumada, J.A. (1998) Annual variation in fruiting pattern using two different methods in a Lowland tropical forest, Tinigua National Park, Colombia. Biotropica 30(1): 129-134. [4] Terborgh, J. (1983) Five New world primates. Princeton University Press, Princeton, New Jersey.

2.5.10 Food availability index method

The Food availability index method (FAI) records the presence and abundance of fruit as a percentage of the crown cover during transect walks. This data is then combined with data on either the basal area or the diameter at breast height (DBH) in a formula. The formulas used in the sources on this method varied per source. Despite this variation, all sources used the same parameters in their formula. As a result of this variation, a definitive formula cannot be given. Sources that describe the FAI method are given in Table 10.

Table 10: Sources for Food availability method

[1] Bessa, J., Sousa, C., Hockings, K. (2015) Feeding ecology of chimpanzees (pan troglodytes versus) inhabiting a forest-mangrove-savanna- agriculture matrix at caiquene-cadique, Cantanhez National Park, Guinea-Bissau. American Journal of Primatology, 77:651-665. [2] Potts, K.B., Chapman, C.A., Lwanga, J.S. (2009) Floristic heterogeneity between forested sites in Kibale National Park, Uganda: insights into the fine-scale determinants of density in a large-bodies frugivorous primate. Journal of animal ecology, 78:1269-1277. [3] Carvalho, J.S., Vicente, L., Marques, T.A. (2015) Chimpanzee (*Pan troglodytes verus)* diet composition and food availability in a human - modified landscape at Lagoas, de Cufada Natural Park, Guinea-Bissau. International journal primatology, 36(4):802-822.

2.6 Selection and comparison of methods

A first selection process was used to assess whether the ten commonly used methods were suitable for use in the Boé Sector and fit with the hypothesized method, commonly used methods that do not fit with the hypothesized method or environment of the Boé Sector are eliminated from further comparison. After this first selection process, a comparison of the remaining methods was performed to determine which (combination) of these methods is most suitable to monitor tree phenology in the Boé. The remaining methods were compared on three different subjects: objective, research design, and observation procedure. To specify each subject, sub-questions that can be answered per method were formed. Answers to these sub-questions were then compared to an 'ideal method' (2.7 Rating the methods) that was set-up to best fit the possibilities in the Boé Sector and the aim of this study. In some methods, some sub-questions have remained unanswered, despite the use of multiple sources. This inability to answer one (or multiple) of the sub-questions does not necessarily make the method unsuitable, as the information from other sub-questions may include enough information to assess the suitability of the method. Therefore, an unanswered question is not rated positively or negatively (further information on rating in 2.7 Rating the methods).

2.6.1 Subject objective

The subject objective describes the aim, research question, and objectives of the method. Sub-questions established with this subject have been listed in Table 11.

Table 11: Sub-questions for the subject objective

Sub-questions for the subject objective
• What was the aim of the study? • What was the research question of the study? • What were the objectives of the study?

2.6.2 Subject Research design

The subject research design describes the design of the method and informs on study set-up. The focus of this subject lies, for instance, on the habitat type in which the study was performed or the size of the used samples. This subject will mainly give information on the suitability of the method for use in the Boé Sector. Sub-questions established with this subject have been listed in in Table 12.

Table 12: Sub-questions for the subject research design

Sub-questions for the subject research design
• Where was the study performed? • In what type of habitat was the study performed? • What was the sample size? • How many trees were monitored in total? • How many tree species were monitored? • How many trees of each species were selected? • Why are those species measured? • Are there criteria for selecting individual trees? • What was the frequency of monitoring the trees? • What was the study period?

2.6.3 Subject observation procedure

The subject observation procedure describes how the monitoring of trees was conducted. The focus of this subject lies, for instance, on the method by which data is recorded, on which phenophases were measured and on the time per observation. The observation procedure was the most important subject in developing a suitable method for the Boé Sector, as the monitoring of the trees will be performed using this observation procedure. Sub-questions established with this subject have been listed in Table 13.

Table 13: Sub-questions for the subject observation procedure.

Sub-questions for the subject observation procedure.
• How are the observed data recorded? • Which materials are needed for the observations? • How expensive are the required materials? • How much time does the measurement cost? • How many people are needed to perform fieldwork? • What are the required skills? • What phenophases are measured? • Is the method broadly applicable to tree species with different physiology? • What is the scoring system for the observation of the phenophases? • Is the method reproducible?

2.7 Rating the methods

The selected methods have been rated using an ''ideal method'' (Table 14). This method a combination of all the ideal answers to the sub-questions of the three subjects (see 2.6.1 to 2.6.3). This rating gives an impression on the suitability of the remaining methods for use in the Boé Sector. The ideal method is based on recommendations and conclusions made in the previous studies by van der Meer (2014) and Breider (2017a), personal communication with A. Goedmakers, G. Niezing and M. Breider and analysis of scientific sources.

The rating of methods consists of two steps. First, each source will independently be rated on its similarity with the ideal method (2.7.1 Rating of sources). The rating of sources will then be combined per sub-question per method to rate the method (2.7.2 Rating of sub-questions). This will result in a rating of similarity with the ideal method per selected method.

2.7.1 Rating of sources

Selected methods were rated using a measure of similarity to an ideal method (Table 14) that was set-up to best fit the possibilities in the Boé Sector and hypothesized method. This rating rated the similarity of sub-question answers of a method to sub-question answers of the ideal method. Similarity to the ideal method was assessed by using a rating system that specifies six categories: '++', '+', '+/-', '-' ', '--', 'NA' (answer not available). In this rating, '++' is given when the answer to the sub-question identical to the ideal method and '--' when the answer differs from the ideal method. To rate the commonly used methods consistently, a rating table with rating criteria to sub-question answers was established (see appendix I Criteria for rating the sources). This table describes possible answers to the sub-questions and provides the appropriate rating depending on the similarity to the ideal method. In Appendix III Rating of the sources, a detailed description of how the sources are rated given.

2.7.2 Rating of Sub-questions

To quantify the rating of the sub-questions, a rating for each sub-question was calculated as

$$Sub\ question\ rating = \frac{(Sum\ of\ \ +) - (Sum\ of\ \ -)}{sources -\ NA}$$

were the *Sum* of *+* is the total number of '+' given for each subject (+ = 1, ++ = 2 and +/- = 0) and *Sum of –* is the total number of '-' given for each subject (- = 1, -- = 2 and +/- = 0). As the *Sum of -* is subtracted from the *Sum of +*, '-' is given a positive value instead of a negative. As the selected methods, all had a varying number of sources, the sub-question rating has been divided by the number of sources. The number of 'NA' answers is subtracted from the number of sources, as unanswered questions are neither '+' or '-' and are therefore not included in the rating.

Table 14: Ideal answers to the sub-questions of the three subjects

Sub-questions for the subject objective	Ideal Answer
What was the aim of the study?	Monitoring the phenology of chimpanzee fodder trees for multiple years (Meer, 2014; Breider, 2017a).
What was the research question of the study?	What is the phenology of chimpanzee fodder trees in the Boé Sector? (Meer, 2014; Breider, 2017a)
What were the objectives of the study?	1. Monitoring phenology for multiple years, 2. Low interobserver variability, 3. Suitable for the habitat of the Boé Sector, 4. Easily understandable method. (Meer, 2014; Breider, 2017a)
Sub-questions for the subject research design	
Where was the study performed?	In the Boé Sector of Guinea-Bissau (Meer, 2014; Breider, 2017a).
In what type of habitat was the study performed?	A savannah-forest mosaic (Meer, 2014; Breider, 2017a).
What was the sample size?	Ideally, the current phenology transects in the Boé Sector can be used by the future method. Currently, there are three transects of approximately 7 km each in the Boé (Breider, 2017a). It is possible to include one more transect, but no more than four as this may cause the study to be too labor-intensive to be performed within a 1 week period (as the Boé Sector is highly seasonable and differences in phenophases may be large when intervals between samples are too large).
How many trees were monitored in total?	Approximately 200 trees (current amount selected in the Boé) (Breider, 2017a) However, as there is an option to add another transect, about 60 more trees can be added.
How many tree species were monitored?	Approximately 25 species (Breider,2017a).
How many trees of each species were selected?	A minimum of fifteen trees ideally spread over different locations and habitats (Morellato et al., 2010).
Why are those species measured?	Because they are known to be eaten by chimpanzees (Meer, 2014; Breider, 2017a).
Are there criteria for selecting individual trees?	Tree DBH (diameter at breast height) at 1.3 m from the ground should be at least 10 cm (Brokaw & Thompson, 2000; Chapman et al., 1992; Arendjelovic et al., n.d.) and the species must be eaten by the western chimpanzee.
What was the frequency of monitoring the trees?	Fortnightly (Morellato et al., 2009).
What was the study period?	Multiple years, with a minimum of three years (Breider, 2017a; A. Goedmakers, personal communication).

Sub-questions for the subject observation procedure.	
How are the observed data recorded?	The data are recorded by walking transects and individual trees are observed to identify the presence and intensity of phenophases (Morellato et al., 2009; Meer, 2014; Breider, 2017a).
Which materials are needed for the observations?	As the data is recorded by walking transect no heavy equipment should be necessary. A binocular could be necessary to look for phenophase (for example flowers) in trees with high canopies.
How is expensive are the required material?	The materials needed for the observation should not be expensive (A. Goedmakers, personal communication, October 13, 2015).
How much time does the measurement cost?	The observations of one transect must be possible to complete in one day. Approximately 5 km is cycled to reach the transects (± 45 min). In addition to that, 7 km long transects must be walked (± 3 hours). Along the transect, approximately 65 trees are monitored. The measurement should therefore ideally take approximately one minute (totaling to one hour and five minutes). In total, monitoring time for phenology will total up to 5.5 hours without breaks (1.5 hours cycling, three hours walking, one-hour observing) (A. Goedmakers, personal communication, October 13, 2015).
How many people are needed to perform fieldwork?	Ideally, the field work should be able to be performed by a local guide, so by one person. (A. Goedmakers, personal communication, 04 July 2017) In addition, the method does not need knowledge on how to operate a GPS.
What are the required skills?	Ideally, the local guide can help or should even be able to monitor the phenology of trees. Therefore, the method must be easily understandable (A. Goedmakers, Personal communication, December 1, 2015).
What phenophases are measured?	The measured phenophases should include leaves, flowers, and fruits. Ideally, the following phenophases are recorded to add more detail: breaking leaf buds, leaves, colored leaves, falling leaves, flower buds, ripe fruits, recent fruit or seed drop (Tierney, 2013).
Is the method broadly applicable to tree species with different physiology?	Ideally, the method should be broadly applicable to physiological different trees (M. Breider, A. Goedmakers, G. Niezing P. Wit, personal communication, December 1, 2015).
What is the scoring system for the observation of the phenophases?	Not only the presence but also intensity (or abundance) of the phenophases should be recorded (Breider, 2017a, Morellato et al., 2009).
Is the method reproducible?	The cited methods must be reproducible (Breider, 2017a, A. Goedmakers, personal communication, October 13, 2015, G. Niezing, personal communication, November 12, 2015).

3. Results

A database of sources that describe ten commonly used methods for monitoring the phenology of trees was established (as described in paragraph 2.3 Database of sources and 2.4 Analysis of methods). First, a selection process was performed to discard methods that were either unsuitable for use in the Boé or did not fit with the hypothesized method. The remaining methods were then compared on three subjects (objective, research design, and observation procedure) and rated on their similarity with an ideal method (as described in 2.7 Rating of the methods).

3.1 Does the method fit the Boé environment and the aim of this study?

This selection process has assessed whether the methods are suitable for the environment in the Boé Sector and the hypothesizes method. The suitability of each method and whether the method is eliminated from further analysis is listed in Table 15.

3.2 Eliminated methods

Four of the ten commonly used methods were eliminated (Table 15 and Appendix II eliminated methods). The remaining six methods have been compared on three different subjects: objective, research design, and observation procedure.

3.3 Comparison of methods

The remaining six methods were rated on the three subjects (objective, research design, and observation procedure resp.) in comparison to the ideal method (described in 2.7 Rating of the methods). The results of this rating are given in paragraphs 3.3.1 to 3.3.3. Per subject, the sub-questions (introduced in 2.6 Selection and comparison of methods) were ranked on their importance to the aim of the current study in the Boé. This ranking has helped to select the most suitable method (Appendix II Rating of the sources and Table 16, 18 and 20 resp. per subject).

Table 15 Suitability of methods for the Boé environment and the aim of this study. In this table, the first column shows the method, the second column the motives for whether the method was included in or excluded from further analysis, and the last column whether the method is eliminated or not.

Method	Suitability for the environment and aim of the study in the Boé Sector.	Eliminated (Yes/No)
PanAf	The aim of the PanAf method is to identify the annual cycle and productivity of chimpanzees feeding species at the study site (Arandjelovic et al., n.d.; Meer, 2014; Breider, 2017a). This aim matches the aim of the current Boé study.	No
Fruit trail	The aim of the Fruit trail method varies per source, but it is mostly used to examine seasonal changes in fruit phenology (White, 1998; Takenoshita et al., 2008), this aim matches the aim of the current Boé study.	No
Fruit count	The aim of the Fruit count method varies per source, but the overall aim is to examine the seasonal variation of fruit (Tweheyo & Lye, 2003; Tweheyo & Babweteera, 2007). This aim matches the aim of the current Boé study.	No
Nature´s Notebook	The aim of the Nature's notebook method varies per source. The overall the aim is to examine annual changes in phenology (of plants and animals) (Tierney et al., 2013; Denny et al., 2014; Elmendorf et al., 2016). This aim is no exact match with the aim of the current Boé study, as the current study only monitor tree phenology. However, as the method also monitors tree and fruit phenology, the method is suitable for use in the Boé Sector.	No
Monthly fruit index	The aim of the Monthly fruit index method is to examine the monthly fluctuations in the abundance of fruit for gorillas and chimpanzees. This method only monitors fruit (presence/absence) and has a low interobserver variability (Basabose & Yamagiwa, 2002; Yamagiwa et al., 2008). This aim matches the aim of the current Boé study.	No
BBCH code	The aim of the BBCH code varies per source. Despite its originates from agriculture, it can also be used to monitor tree phenology in ecology. The aim of this method in ecology is to examine the annual fluctuation in phenological trends (Bruns et al., 2003; Koch et al., 2007). This aim matches the aim of the current Boé study.	No
Digital time-lapse method	The aim of the Digital time-lapse method is to monitor the phenology of vegetation. (Crimmins & Crimmins, 2008; Bater et al., 2011). As the costs to set up the camera's are between 55,000 and 82,000 euro's, this is an expensive method (Sonentag et al., 2012). Also, as the pictures are taken from afar, it can be difficult to determine the intensity of phenophases (Keenan et al., 2014; Nagai et al., 2014). This method uses complicated algorithms and researchers and students must be trained to work with these algorithms. To local guides, these algorithms will most definitely be too complicated to understand (Ide & Oguma, 2010; Zhao et al., 2012). This method is therefore believed to be unsuitable for use in the Boé.	Yes
MODIS and Landsat	The MODIS and Landsat methods use satellite images to monitor tree phenology. As these pictures are taken by a satellite, it is difficult to determine the intensity of phenophases (Zhang et al., 2003; Fisher & Mustard; 2007; Walker, Beurs de, Wynne, 2014). This method uses complicated algorithms and researchers and students must be trained to work with these algorithms. To local guides, these algorithms will most definitely be too complicated to understand (Zhang et al., 2003; Fisher & Mustard, 2007; Walker et al., 2014). This method is therefore believed to be unsuitable for use in the Boé.	Yes
Fruit traps	The Fruit traps method collects fruit using a trap set under every individual tree (Terborgh, 1983; Malenky, Wrangham, Champman, & Vineberg, 1993; Furuichi, Hashimoto, & Tashiro, 2001). Even though the materials for the fruit traps are not expensive, the method will be time and labor intensive (White, 1998). This method is therefore believed to be unsuitable for use in the Boé.	Yes
Food availability index (FAI)	The FAI method calculates the fruit availability per month using a formula. There were a lot of sources that describe this formula. However, the formula varied largely across different sources, because of this uncertainty this method is believed to be unsuitable for use in the Boé. As the Monthly fruit index method is similar to the FAI method, the monthly fruit index is used instead of the FAI (Basabose, 2002; Yamagiwa, Basabose, Kaleme, 2008; Potts & Lwanga, 2009; Watts et al., 2012; Bessa et al., 2015; Carvalho et al., 2015).	Yes

3.3.1 Subject objective

The sub-question rating of the subject objective is given in Table 16. Of the six methods, the PanAf method scored best on the total sub-question rating and the fruit trail method scored worst. The PanAf method also scored best on the first (and most important) sub-question, on which the Fruit trails method, Nature's Notebook and Monthly fruit index scored the worst. The answers to the sub-questions of the subject objective for the best scoring method (PanAf method) are listed in Table 17.

Table 16: Sub-question rating of the subject objective. Calculation of ratings is described in paragraph 2.7.3 Rating of the methods. The best ratings are highlighted green and the worst in red. The last row shows the total sub-question rating (sum of all ratings per method). Sub-question in the left column are (ranked from most to least important): 1) What were the objectives of the study?; 2) What was the aim of the study?; 3) What was the research question of the study?

Objective						
	Methods					
Sub-questions	PanAf	Fruit trail	Fruit count	Nature's Notebook	Monthly fruit index	BBCH code
1	2,0	0,0	1,5	0,0	0,0	0,2
2	0,6	-1,3	1,5	1,0	-0,3	0,4
3	1,0	0,0	0,0	0,0	0,0	0,0
Total	3,6	-1,3	3,0	1,0	-0,3	0,6

Table 17: Answers to the sub-questions given for the best scores for the subject objective.

Sub-question 1:	What were the objectives of the study?
To gain knowledge of the food availability of the western chimpanzee.	
Sub-question 2:	What was the aim of the study?
To gain knowledge of the food availability of the western chimpanzee. To monitor the phenology of chimpanzee fodder trees for a one-year period.	
Sub-question 3:	What was the research question of the study?
What is the phenology of trees that are eaten by the western chimpanzee in the Boé Sector of Guinea-Bissau? (the phenology of the trees has been monitored for one year)	

3.3.2 Subject research design

The sub-question rating of the subject research design is given in Table 18. Of the six methods, the Monthly fruit index method scored best on the total sub-question rating and the BBCH code scored worst. The Monthly fruit index scored best on the first three (most important) sub-questions, on which the BBCH code scored worst. Of these first three sub-questions, the first is the most important. On this first sub-question, the BBCH code scored best and the Fruit trails method scored worst. In other words, the monthly fruit index has the best ranking rating for the subject research design for the total sub-question rating and the three most important questions, and the BBCH code method has the best rating for the first (most important) sub-question. The answers that were given to the sub-questions of the research design for the BBCH code method and Monthly fruit index are given in Table 19 (see Appendix II Rating the sources).

Table 18: Sub-question rating of the subject research design. Calculation of ratings is described in paragraph 2.7.3 Rating of the methods. The best ratings are highlighted green and the worst in red. The last row shows the total sub-question rating (sum of all ratings per method). Sub-question in the left column are (ranked from most to least important): 1) What was the study period?; 2) What was the frequency of monitoring the trees?; 3) How many trees of each species were selected?; 4) Why are those species measured?; 5) Are there criteria for selecting trees?; 6) In what type of habitat was the study performed?; 7) Where was the study performed?; 8) How many tree species were monitored?; 9) How many trees were monitored in total?; 10) What was the sample size?

Research design						
	Methods					
Sub-questions	PanAf	Fruit trail	Fruit count	Nature's Notebook	Monthly fruit index	BBCH code
1	1,2	0,8	1,5	2,0	1,7	2,0
2	1,0	2,0	2,0	0,0	2,0	-1,0
3	-0,6	0,0	-0,7	1,5	1,0	0,0
4	1,4	0,0	1,3	-0,5	2,0	-1,0
5	1,6	0,0	0,7	0,0	2,0	-1,0
6	1,2	0,5	0,3	-1,0	1,0	-2,0
7	1,6	1,0	1,0	-1,0	1,0	-1,0
8	0,8	-1,0	0,3	1,0	0,0	0,5
9	0,6	-1,0	-0,7	0,3	-1,0	-1,0
10	0,3	0,5	1,0	0,0	1,0	0,0
Most important (1,2,3)	1,6	2,8	2,8	3,5	4,7	1,0
Normal (4,5,6,7)	5,8	1,5	3,3	-2,5	6,0	-5,0
Least important (8,9,10)	1,7	-1,5	0,7	1,3	0,0	-0,5
Total	9,1	2,8	6,8	2,3	10,7	-4,5

Table 19: Answers to the sub-questions of the subject research design. The method in-between brackets are the best ranking for either the first question, the most important questions or the best total sub-question rating.

Sub-question 1:	What was the study period?
More than one year (BBCH code method)	
Sub-question 2:	What was the frequency for monitoring the trees?
Fortnightly (Monthly fruit index)	
Sub-question 3:	How many trees of each species were selected?
A minimum of 10 trees. (Monthly fruit index)	
Sub-question 4:	Why are those species monitored?
Because they are known to be eaten by a chimpanzee in the area. (Monthly fruit index)	
Sub-question 5:	Are there criteria for selecting trees?
Yes, the tree DBH at 1.3 m from the ground should be at least 10 cm (Monthly fruit index).	
Sub-question 6:	In what type of habitat was the study performed?
A dry habitat with similar conditions (dry and wet season) as a savannah-forest mosaic, such as a dry forest, savannah, woodland, etc. (Monthly fruit index)	
Sub-question 7:	Where was the study performed?
In similar circumstances as Guinea-Bissau (poor country, in a remote area). (Monthly fruit index)	
Sub-question 8:	How many species were monitored?
More than 40 tree species. (Monthly fruit index)	
Sub-question 9:	How many trees were monitored in total?
More than 500 individual trees. (Monthly fruit index)	
Sub-question 10:	What was the sample size?
Less than 5 km. (Monthly fruit index)	

3.3.3 Subject observation procedure

The sub-question rating of the subject observation procedure is given in Table 20. Of the six methods, Nature's Notebook scored best on the total sub-question rating and the fruit trail method scored worst. The PanAf method and Nature's Notebook method scored best on the first four (most important) sub-questions, on which the Monthly fruit index scored worst. Of these first four sub-questions, the first is the most important. On this first sub-question, the Monthly fruit index scored best and the BBCH code scored worst. As this method does not measure phenology as intensively as the other methods (it only measures presence/absence of fruit), the monthly fruit index will not be recommended to be used on its own. However, because of its score on the first (most important) question, a method in which the Monthly fruit index is incorporated can be suitable to be used in the Boé Sector. In other words, the combination of Nature's Notebook and PanAf would be the most suitable method, which is believed to be possible as Nature's Notebook method and the PanAf method are quite similar (see 2.3 selected methods). The answers that were given to the sub-questions of the observation procedure for the three best scoring methods are given in Table 21.

Table 20: Sub-question rating of the subject observation procedure. Calculation of ratings is described in paragraph 2.7.3 Rating of the methods. The best ratings are highlighted green and the worst in red. The last row shows the total sub-question rating (sum of all ratings per method). Sub-question in the left column are (ranked from most to least important): 1) Is the method reproducible?; 2) How are the observed data recorded?; 3) What is the scoring system for the observation of the phenophases?; 4) How many people are needed to perform fieldwork?; 5) What phenophases are measured?; 6) How much time does the measurement cost?; 7) What are the required skills?; 8) Is the method broadly applicable to tree species with different physiology?; 9) How expensive are the required materials?; 10) Which materials are needed for the observations?

Observation procedure						
	Methods					
Questions	PanAf	Fruit trail	Fruit count	Nature's Notebook	Monthly fruit index	BBCH code
1	0	0	0	0	1	-1
2	2	-1	1	2	-1	2
3	2	-1	2	2	-2	2
4	-1	2	-1	-1	1	-1
5	0,8	-2	0	2	-2	2
6	2	0.8	1	2	2	2
7	0	0	0	-1	1	-1
8	1	-1	0	2	-1	1
9	2	2	2	2	2	2
10	2	2	2	2	2	2
Most important (1,2,3,4)	3	0	2	3	-1	2
Normal (5,6,7)	2.8	-1.3	1	3	1	3
Least important (8,9,10)	5	3	4	6	3	5
Total	10.8	1.8	7	12	3	10

Table 21: Answers to the sub-questions given for subject observation procedure. The method in-between brackets is the best ranking for either the first question, the most important questions or the best total sub-question rating. As the Monthly fruit index method can be incorporated in other methods, a second-best method is also noted when this method scored best.

Sub-question 1:	Is the method reproducible?
The method is easily reproducible and has a low interobserver variability (Monthly fruit index) The scoring system is easily reproducible but has a high interobserver variability. (Nature's Notebook and PanAf)	
Sub-question 2:	How is the observed data recorded?
The data recorded by identifying multiple specific phenophases. The phenophases are detailed (*e.g.* not only fruit is monitored but also whether they are ripe or unripe). In addition, the intensity of the phenophases is recorded. (Nature's Notebook and PanAf)	
Sub-question 3:	What is the scoring system for the observation of the phenophases?
Not only the presence of the phenophases but also the intensity of all phenophases is recorded. (Nature's Notebook and PanAf)	
Sub-question 4:	How many people are needed to perform the field work?
Local guides should be able to perform the field work, preferably with knowledge on how to operate a GPS, otherwise, the guide must remember a large number of trees and transects. (monthly fruit index) The fieldwork is not suitable to be performed by a local guide and has to be performed by a student or researcher. Since they are not allowed to perform the field work by themselves (because of the risks in the field such as accidents, dangerous animals etc.). Therefore, the field work is ideally performed by two persons, including one local guide and one student or researcher. (Nature's Notebook and PanAf)	
Sub-question 5:	What phenophases are monitored?
The phenophases that are monitored are detailed and similar to the following phenophases: breaking leaf buds, leaves, colored leaves, fallen leaves, flower buds, open flowers, fruits, ripe fruits, recent fruit or seed drop. (Nature's Notebook)	
Sub-question 6:	How much time does the monitoring cost?
The monitoring of an individual tree takes approximately one minute. (Monthly fruit index and PanAf)	
Sub-question 7:	What are the required skills?
Little skill is required to perform the field work. (Monthly fruit index) Some training is required to learn how to record the data. For students and research, this should be easy. However, for local guides, this method may be too complicated for a local guide to understand. (PanAf)	
Sub-question 8:	Is the method broadly applicable to trees species with different physiology?
The method is broadly applicable to all tree species. (Nature's Notebook)	
Sub-question 9:	How expensive are the required materials?
The materials needed for the observation should not be expensive. Ideally, it costs no more than pen, paper, and labor. (Nature's Notebook, Monthly fruit index, and PanAf)	
Sub-question 10:	Which materials are needed for the observations?
Ideally, the data can be recorded using only pen and paper. (Nature's Notebook, Monthly fruit index, and PanAf)	

4. Discussion

This study performed a literature review to find a suitable method to study the phenology of chimpanzee fodder trees in the Boé Sector of Guinea-Bissau. In this sector, a new method is necessary to close the current knowledge gap about phenology patterns of the western chimpanzee fodder trees. This information will help to facilitate a better conservation of the western chimpanzee and its habitat. It was hypothesized that the selected method is compatible with the habitat of the Boé Sector, has a low interobserver variability, is easily understandable and is broadly applicable to tree species with different physiology. Ten commonly used methods were found and compared to find out whether they were suitable for the environment and the hypothesized method. The remaining methods were then compared on three subjects: Objective, research design and observation procedure (using the rating system given in 2.8 Rating the method).

Ten commonly used methods were found in scientific databases. Of these ten methods, six were found to be suitable for use in the Boé Sector and match with the hypothesized method. study. Two of the four eliminated methods (the Time-lapse camera and MODIS and Landsat methods) were discarded as they monitored the phenology of vegetation instead of individual trees (Zhang et al., 2003; Nagai et al., 2014; Walker et al., 2014; Keenan et al., 2015). The monitoring of vegetation is not suitable to monitor the intensity of fruit (Cleland et al., 2007) and therefore, is not suitable for the aim of the study in the Boé Sector. A third method (the Fruit traps method) was commonly used in the past. However, no recent sources that use this method were found (Most recent source found: Stevenson, 1998). Also, the construction, maintenance, and monitoring of fruit traps are labor intensive and time-consuming, leading to small sampling sizes and a limitation to only a small proportion of the chimpanzee's habitat (Chapman & Wrangham, 1994; White, 1998). The last method to be eliminated (FAI method) uses an equation to calculate the food availability index each month. However, the equations given in the sources differ greatly between sources (Potts, watts, & Wrangham, 2011; Bessa et al., 2015; Carvalho et al., 2015). As this method, can also be replaced by another commonly used method that calculates a fruit index (the Monthly fruit index method) (Basabose & Yamagiwa, 2002; Yamagiwa et al., 2008; Elmendorf et al., 2016), the FAI method was discarded.

It is not claimed that all commonly used phenology monitoring methods have been found in this study. To minimize the chance that a method is missed, a large list of keywords was used to search for methods in multiple scientific databases (see Appendix IV Keywords used to search in scientific databases). It may, however, still be possible that not all commonly used methods have been found or that a not-so-commonly used method is more suitable for the study in the Boé Sector.

Also, as seen in 2.3 Selected methods and 3.1 Does the method fit the Boé environment and the aim of this study? the first six of the ten commonly used methods are not eliminated and the last four methods were eliminated. This was no coincidence, as this paragraph was previously divided into two sub paragraphs: First the selected methods and then the eliminated methods. When this subdivision into paragraphs was canceled the previous order of methods remained, resulted in one paragraph in which the first six methods were selected and the last four were eliminated.

The first of the three comparison subjects, the objective, found that the PanAf method scored best on this subject. This method had the best rating on the first (most important) sub-question (what were the objectives of the study?) and on the total sub-question rating. This result is expected to have been caused by the specific aim of this method, as it is aimed at chimpanzee research (Arandjelovic, n.d.). In addition to that, the method scored best because the sources for the method describe the research question, while the sources of other methods did not include a research question. Also, the aim of the proposed phenology study in the Boé Sector is similar to the PanAf method. The proposed Boé study aims to monitor the phenology of chimpanzee fodder trees for multiple years and gain knowledge of the food availability of the western chimpanzee over the different seasons, whereas the PanAf method aims to gain knowledge of the food availability for the western chimpanzee by monitoring the phenology of chimpanzee fodder trees for one year (Arandjelovic, n.d.). Even though the PanAf method originally only monitors phenology for a one-year research period, it can also be for multiple-year research periods. For these reasons, the PanAf method is chosen as the best fitting method for this subject.

The second of the three comparison subjects, the research design, found that the BBCH code method and Monthly fruit index scored best on this subject. The BBCH code method had the best rating for the first (most important) sub-questions (what was the study period?), whilst the monthly fruit index scored best at the sub-question rating for the three most important questions and the total sub-question rating. The BBCH code method scored best on the first sub-question as it monitors phenology during a multiple-year research period (Bruns et al., 2003; Koch et al., 2007; Zhang et al., 2016), which corresponds to the ideal multiple-year research period for the future Boé study. However, it scored low on other sub-questions as the method originates from agriculture (Hess et al., 1997; Bruns et al., 2003; Meler et al., 2009; Zhang et al., 2016), which does not correspond with the habitat or ideal criteria for selecting trees and species. The monthly fruit index can also be used for multiple year-researchch periods (Basabose, 2002; Yamagiwa et al., 2008). However, as the length of the study varied between sources (Basabose & Yamagiwa et al., 2002; Yamagiwa et al., 2008), its score for the first sub-question was lower than the BBCH code method. In addition, the research design of the monthly fruit index is similar to the selection process that was previously used to select trees in the Boé Sector (see subparagraph 2.6.2 Subject research design), which is an advantage as the currently selected trees can be used for the selected method. Lastly, as the monthly fruit index monitors the phenology of trees fortnightly, it collects detailed phenology data (Basebose, 2002; Basabose & Yamagiwa, 2002; Yamagiwa et al., 2008). For these reasons, the monthly fruit index is chosen as the best fitting method for this subject, and the BBCH code method will be discarded.
Despite being the best fitting method for the subject research design, the Monthly fruit index is not similar to the ideal research design. Most of the ratings for the research design vary largely in this method. For instance, the fruit trail method has the best sub-question rating for two sub-questions, but it also has the lowest rating for three other sub-questions. However, the research design of the method can also be altered to fit the ideal method. For instance, the number of trees for the monthly fruit index does not correspond with the ideal method, but the number of trees selected can be altered to match the ideal method.

The third and last of the three comparison subjects, the observation procedure, found that Nature's Notebook and Monthly fruit index scored best on this subject. The Monthly fruit index had the best rating for the first (most important) question (Is the method reproducible?). The PanAf and Nature's Notebook had the best sub-question rating for the four most important questions and Nature's Notebook also had the best total sub-question rating. The high rating of the Monthly fruit index for the first sub-question is expected to have been caused by the low interobserver variability of this method (Yamagiwa et al., 2008), as this method only monitors the presence and absence of fruit while the measurements of the other methods are more detailed. The other two methods (the PanAf method and Nature´s Notebook) show similarities in their method of data collection (Arandjelovich, n.d.; Haugaasen, 2005'; Tierney et al., 2013; Denny et al., 2014; Elmendorf et al., 2016). These similarities have led to an identical sub-question rating for the first four (most important) sub-questions. However, the PanAf is less broadly applicable than Nature's Notebook, because observation procedure for the phenophases is better described for Nature's Notebook (Tierney et al., 2013). In addition, the Nature's Notebook has an extended protocol on how to use the method, as the method is used by professionals and volunteers in the National Phenology Network of the USA (Tierney et al., 2013; Denny et al., 2014; Fucillo, Crimmins, de Rivera, & Elder, 2015; Elmendorf et al., 2016). This extended protocol can help to apply the method to the Boé Sector. As this protocol also includes methods for observations of the phenology of animals, this method can be extended to also include animals when it is proven to be suitable for use in the Boé Sector. The protocol of the PanAf method is less detailed than Nature's Notebook protocol: Nature's Notebook protocol (Tierney, 2013) has 272 pages (included appendixes) of which 17 are specifically for monitoring phenology of plants (excluded appendixes), while the PanAf protocol (Arandjelovic, n.d.) has 94 pages (included appendices) of which 2 are specifically for monitoring phenology of plants (excluded appendices). Therefore, the PanAf method will be discarded and Nature's Notebook with the Monthly fruit index incorporated is believed to be the most suitable method to be used in the Boé Sector. Despite scoring best on the first (most important) sub-question, the sub-question rating of the Monthly fruit index for the other sub-questions is low. This was caused by the aim of this method, as this method only monitors the phenology of fruit (Basabose, 2002) whilst the other methods also monitor phenology of other parts (leaves, flowers, etc). This does not mean that the method is not suitable for use in the Boé, but rather that – if selected – this method should be incorporated in another method to gather more in-depth knowledge on fruit availability.

Combining two methods may seem extensive and labor-intensive, as different forms of data for both methods have to be gathered. However, in combining the observation procedure of Nature's notebook with the Monthly fruit index, the data necessary for the calculation of the monthly fruit index can be easily obtained from Nature's Notebook. Therefore, only one form of data needs to be collected which consequently can be used to calculate the second type of data in data management software (*e.g.* by use of a preset formula in Microsoft Excel software). Adding the Monthly fruit index to Nature's Notebook method is believed to be beneficial; to future chimpanzee studies in the Boé because, the Monthly is often used to study chimpanzee behavior in relation to food availability (Basabose, 2002; Basabose 2005; Head, Boesch, Makaga, & Robbings, 2011). The study of Basabose (2005), for instance, compares the fluctuations in the Monthly fruit index to chimpanzee ranging patterns. Therefore, a combination of these two methods is believed to be achievable and not as labor-intensive as it may seem.

Based on the above, the most suitable method is based on the objective of the PanAf method the research design of the Monthly fruit index and the observation procedure of Nature's Notebook in combination with the Monthly fruit index. Such a combination of methods is possible because the different subjects are classified to be independent of each other, and can, therefore, be combined in different compositions to form a new method. This has resulted in a proposed method with the objective to study chimpanzee fodder tree phenology as the PanAf method (Arandjenovic, n.d.); that is designed to fit the Boé environment based on the Monthly fruit index; and collects phenology data using the observation procedure of the Nature's notebook, which can easily be extended to also gather data on fruit presence based on the Monthly fruit index method. This observation procedure is broadly applicable to different trees species (Tierney et al., 2013; Elmendorf et al., 2016), applicable in different environments (Elmendorf et al., 2016), has an extended protocol (Tierney, 2013) and can be used to study chimpanzee behavior in relation to food availability (Basabose, 2002; Basabose, 2005; Head, Boesch, Makaga, & Robbings, 2011). Even though this combination of methods does not meet all the criteria of the ideal method, it does come closest to the ideal method.

As this combination of methods does not meet all the criteria of the ideal method, not all the requirements of the hypothesis were met. As seen in 3.4 Observation procedure, all the common methods used for monitoring phenology had interobserver variability, whilst the ideal method does not. Therefore, the selected method will have some interobserver variability and precautions must be taken to prevent a high interobserver variability. A possibility is to give training on how to monitor the phenology to lower the interobserver variability (Chapman et al., 1992; Denny et al., 2014). This would also give an opportunity to local guides to get familiar with the method. Another criteria of the ideal method that was not entirely met was that the method should be used independently by local guides without the help of international students or researchers. As guides are believed to encounter difficulties with understanding monitoring protocols and most guides are unable to read or write, none of the methods were believed to be suitable to be used independently by guides (see 3.4 observation procedure). However, as the guides are familiar with the trees in the Boé Sector and their phenophases, they can help the observer with identifying these phenophases. This is also useful for trees with different physiology for which the monitoring might be more challenging as phenophases may be difficult to distinguish.

5. Conclusion and recommendations

This study aimed to answer the following research question: What is the most suitable method (derived from existing methods) to monitor the phenology of trees that are important for the diet of the western chimpanzee (*Pan troglodytes verus*) in the Boé Sector of Guinea-Bissau? Answering this question is necessary to find a method that can be used to close the current knowledge gap on the phenology of western chimpanzee fodder trees. Ten commonly used methods for monitoring the phenology of trees were found. Of the ten commonly used methods found, six were applicable in the Boé Sector. These six remaining methods were then rated on three different subjects: objectives, research design, and observation procedure. Further analysis found that a combination of three of these methods was most suitable for use in the Boé Sector. This combination of methods consists of an objective based on that of the PanAf, a research design based on that of the Monthly fruit index and an observation procedure based on the Nature's Notebook with the Monthly fruit index incorporated.

A combination of methods as described above was found to come close to the criteria of an ideal method that was composed to fit the hypothesis of this study. This hypothesis was that the selected method is compatible with the habitat of the Boé Sector, is applicable to be used for multiple years, has a low interobserver variability, can be performed by local guides and is broadly applicable to different tree species. The selected combination of methods monitors the phenology of chimpanzee fodder trees for multiple years and is broadly applicable to different species. The selected method does have interobserver variability. However, this can be decreased by using an extended protocol and training the observers on how to use the method. This selected method may still be too complicated for guides to be performed by themselves. However, as the guides are familiar with the plants of the Boé Sector, they can help the student or researcher with recording data. In addition to the similarities of the selected method with the hypothesis, the research design also fits with the currently used selection process for trees in the Boé. Therefore, the trees that are currently selected in the Boé Sector can be used by the selected method. Lastly, the selected method can be performed by using an only a pen, paper, and a GPS, which is an advantage as there are few materials available in the Boé Sector.

With the selected method, an improved phenology monitoring network can be set up in the Boé Sector. This monitoring network can provide information that can help understanding the food availability of chimpanzees. This information can help to reach the future aim of this study, which is close the knowledge gap on the phenology patterns of the western chimpanzee fodder trees in the Boé Sector. Information on food availability patterns can help understand chimpanzee behavior and distribution and can assist conservationists in establishing conservation strategies that safeguard the future survival of chimpanzees. This information can also help to understand how chimpanzees can be protected in areas with increasing habitat degradation, for instance by prioritizing areas with year-round food availability.

As the method selected in this study was selected to fit the aim and environment of the Boé Sector, this method may not be as suitable to be used in other areas. Therefore, when consulting this report in search of a method to study the phenology of chimpanzee fodder trees, one should keep in mind that characteristics and criteria may differ between areas. However, the general information in this report may be beneficial to other studies of the subject as well. Also, the method used to find a suitable method for the Boé Sector can also be adapted to find a method that is suitable for use in other areas, for instance by creating a different ideal method.

5.1 Recommendations

It is recommended to apply the selected method in the Boé Sector, as this method is believed to fit the Boé environment and the aim of the study in the Boé Sector. When applying this method in the Boé Sector, precautions must be taken to keep interobserver variability as low as possible. Such precautions are, for instance, training the method beforehand and to write an extended protocol to lower the interobserver variability. Besides lowering the interobserver variability, such a protocol can also be beneficial to the set-up and maintenance of the study. For instance, a protocol can provide the staff with an established goal when setting up the study and can be consulted when uncertainties are encountered during the execution of the selected method. Therefore, it is also recommended to write an extended protocol. Applying these recommendations to the future study will greatly benefit the data recording of the monitoring network that is to be set up in the Boé Sector

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6. The selected method

This chapter will summarize the most important properties of the selected method. The description of the method in paragraph 2.3 Selected methods will be combined with the information from the results. This summary is divided in three paragraphs, one for each of the subjects that were used to select the method. (2.6 selection and comparison of methods).

6.1 Subject objective

The subject objective is based on the PanAf method and 2.7 Rating the methods (Kristensen et al., 1996; Haugaasen, 2005; Meer, 2014; Breider, 2017a, Arendjehovic et al., n.d.).

The aim of the study is to monitor the phenology of chimpanzee fodder trees. The objective of the study is to gain knowledge of the food availability of the western chimpanzee for a period of more than one year. The research question of the study is:
What is the phenology of trees that are eaten by the western chimpanzee in the Boé Sector of Guinea-Bissau?

6.2 Subject research design

The research design is based on the Monthly fruit index and 2.7 Rating the methods (Basabose, 2002; Basabose & Yamagiwa, 2002; Yamagiwa et al., 2008).

The study will be performed for multiple years in the Boé Sector of Guinea-Bissau. In the Boé Sector, the main habitat is a savannah-forest mosaic. Approximately 25 species that are known to be eaten by a chimpanzee of the Boé Sector will be selected for the monitoring of the phenology. A minimum of 15 induvial trees for each species will be selected, each individual should be healthy, undamaged and free of pests and disease. Each of these individual trees will have a DBH of at least 10 cm at 1.3 m from the ground and are divided over three or four transects with a maximum length of 7 km. The monitoring of phenology will be monitored fortnightly.

6.3 Subject observation procedure

The observation design is based on the Monthly fruit index and Nature's Notebook and 2.7 Rating the methods (Basabose, 2002; Basabose & Yamagiwa, 2002; Bruns; Yamagiwa et al., 2008; Tierney et al., 2013, Denny et al., 2014; Elmendorf et al., 2016).

The fieldwork for monitoring the phenology requires one student or researcher, who is accompanied by a local guide. The materials that are needed to perform the field work are a pen, paper, and a GPS. The monitoring of an individual tree takes approximately one minute. During this monitoring, the presence, absence, and intensity of the phenophases are monitored. The local guide can help identify these phenophases but is probably unable to perform the fieldwork by himself. The phenophases that are going to be monitored are: breaking leaf buds, leaves, colored leaves, falling leaves, flower buds, ripe fruits, recent fruit and seed drop. After the identification of the included species, a list of the phenophases that describes how the phenophases are recognized should be made to make the method broadly applicable to all species including the physiologically different species. This list should also describe whether a percentage estimate or visual counts must be recorded for each phenophase. During the monitoring of the individual trees, presence or absence of phenophases is recorded. Only when a phenophase is present, the intensity is given. The intensity of a phenophase is given as a percentage or visual estimate in comparison to crown cover. There are five different categories for percentages (less than 5%, 5-24%, 25-49%, 50-74%, 75-95% and more than 95%) and visual estimates (less than 3, 3 to 10, 11 to 100, 101 to 1,000, 1,001 to 10,000 and more than 10,000).

From this observation, the Monthly fruit index (F_m) can be calculated. The presence of fruits has been recorded twice in a month (as described above), which is then used to calculate the Monthly fruit index (F_m) by taking the average of the records in one month. The Monthly fruit index (F_m) is then calculated as

$$F_m = \sum P_{km} \times B_k$$

Were P_{km} denotes the proportion of a number of trees or shrubs in fruit for species k in month m, and B_k denotes the total basal area per hectare for species k. The Basal area of each species is calculated as

$$\frac{1}{2} DBH^2 \times \pi = Basal\ area$$

Were DBH is measured at 1.3 m from the ground and has a minimum of 10 cm.

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Appendixes

Appendix I Criteria for rating the sources.

Sub-questions	Rating				
Rating	++	+	+/-	-	--
Sub-questions for the subject objective					
What was the aim of the study?	Monitoring the phenology of chimpanzee fodder trees for multiple years.	Monitoring the phenology for multiple years but not specifically for chimpanzees Or Monitoring the phenology of chimpanzee fodder trees for one year.	Monitoring the phenology of only one phenophase, but has been performed for multiple years. Or Monitoring the phenology of all phenophases for only one year.	Monitoring the phenology of one phenophase for only one year.	Monitoring the phenology less than one year.
What was the research question of the study?	What is the phenology of trees that are eaten by the western chimpanzee in the Boé Sector of Guinea-Bissau? (The phenology of the trees has been observed for multiple years)	What is the phenology of trees that are eaten by the Chimpanzee? (not specifically in the Boé Sector or western chimpanzee) Or What is the phenology of trees? (not specifically chimpanzee) (the phenology of trees has been observed for multiple years.)	What is the phenology of trees eaten by chimpanzees? Or What is the phenology of trees? (not specifically chimpanzee) (The phenology of trees has been observed for one year)	what is the phenology of vegetation? (not specifically trees) (The phenology trees have been observed for multiple years)	What is the phenology of vegetation? (not specifically trees) (the phenology has been observed for one year) Or What is the phenology of agricultural plantations?
What were the objectives of the study?	1. To gain knowledge of the food availability of the western chimpanzee 2. To detect long-term and interannual variability in the timing or intensity of phenophases	1. To describe the phenological patterns of tree species in a savannah-forest mosaic.	1. Explore relationships between phenological observations and climate variable (*e.g.* temperature) 2. To describe the phenological patterns of habitat like a savannah-forest mosaic.	3. To describe the phenological pattern of fruits.	4. To observe the beginning and end of the growing season (presence-absence leaves)

Sub-questions for the subject research design					
Where was the study performed?	In the Boé Sector of Guinea-Bissau.	In similar circumstances (poor country, in a remote area) as Guinea-Bissau.	In a similar country but not remotely located.	In a country that is not like Guinea-Bissau, and is not remotely located.	In a country that is not like Guinea-Bissau and it is performed close to or in a city (city park)
In what type of habitat was the study performed?	A savannah-Forest mosaic.	The habitat has similar conditions (habitats with dry and wet season) as a savannah-forest mosaic, such as a dry forest, savannah, woodland, etc.	The habitat is slightly similar to a savannah-forest mosaic, such as tropical rainforest, desert etc. (habitat with a dry and wet season)	The habitat is not similar to savannah-forest mosaic but it is still a natural habitat (habitat with winter and summer, depending on temperature and not so much rainfall), such as deciduous forest, tundra, coniferous forest.	The habitat is not similar to savannah-forest mosaic such, as agriculture
What was the sample size?	Three transects of approximately 7 km (currently the sample size in the Boé Sector). However, one more transect could be added. A total of approximately 21 to 28 km (15 to 30 km in total) km transects.	Transects are used to monitor the phenology of the trees. The transects are between 5 to 15 km or between 30 and 40 km.	Transect walks are less than 5 or more than 40 km in length.	Transects are used to monitor the phenology, however, the method does not state the length of the transects.	Transects are not used to monitor the phenology of trees.
How many trees were monitored in total?	200 - 300 trees (currently the amount selected in the Boé Sector)	Between 100 and 200 or 300 and 400 trees are monitored.	Between 50 and 100 trees or 400 and 500 trees are monitored.	Less than 50 or more than 500 trees are monitored.	Other vegetation then trees are monitored.
How many tree species were monitored?	Approximately 25 species. Between 20 and 30 species are monitored.	Between 10-20 species or 30-40 species are monitored.	Less than 10 or more than 40 species are monitored.	Species are not specifically selected beforehand but are recorded for every tree.	The species selected for the method are not mentioned, only the phenology of the vegetation (*e.g.* leaf presence-absence) is recorded.
How many trees of each species were selected?	A minimum of fifteen individuals is monitored.	Between 10 to 15 individuals of each species are selected.	Between 5 to 10 or 15 to 20 individuals of each species are selected.	Less than 5 or more than 20 individuals of each species are selected.	The method is not individual specific, only the phenology of the vegetation (*e.g.* leaf presence-absence) is recorded.
Why are those species measured?	They are chosen because they are known to be eaten by chimpanzees in the area.	The species are chosen from a list of tree species which are known to be eaten by the chimpanzees. (no research has been performed in the area, they have used information	The species are not chosen because they are eaten by chimpanzees, however, the method is specifically for monitoring the phenology of trees and is, therefore,	The method is not specifically for monitoring trees but is might be applicable for the use of monitoring phenology of trees.	The method is used to monitor agricultural vegetation.

		from research in other areas to select their trees.)	applicable to be used for trees that are eaten by chimpanzees.		
Are there criteria for selecting individual trees?	Yes, the tree DBH (diameter at breast height) at 1.3 m from the ground should be at least 10 cm. Or other criteria then is beneficial to select fruit producing adult trees.	Yes, the DBH is used to select trees but the values are different. Other criteria in the method are not specifically beneficial for the selection of fruit producing adult trees.	Yes, but the DBH is not used. However, other criteria are used to select the individual trees.	No, specific criteria are stated in the method. However, a description of how they selected the trees is given.	No criteria or description is given for selecting the individual trees.
What was the frequency of monitoring the trees?	Fortnightly, twice every two weeks.	Once a month	Once every week.	Every day.	Less than once a month.
What was the study period?	More than one year. (multiple years)	One year	Less than a year, but is applicable to be used for multiple years.	Less than a year and is not applicable to be used for multiple years.	Only applicable for one season.
Sub-questions for the subject observation procedure.					
How is the observed data recorded?	The data recorded by identifying multiple specific phenophases. The phenophases are detailed (*e.g.* not only fruit is monitored but also if they are ripe or not ripe). In addition, the intensity of the phenophases is recorded.	The data recorded by identifying multiple specific phenophases. The phenophases are detailed (*e.g.* not only fruit is monitored but also if they are ripe or not ripe). However, the intensity of the phenophases is not recorded.	The data is recorded by identifying multiple specific phenophases. The phenophases are not detailed only the presence or absence is recorded Or The phenophases are not detailed (*e.g.* only the presence of leaves is monitored not if they leaf buds, colored, dead etc.)	The data of only one phenophase is recorded.	Phenophases are not used to monitor the phenology of trees (e.g agriculture).
What are the materials needed for the observations?	Ideally, the data can be recorded using only a pen and paper.	The data is recorded by using materials that are easily obtained and transportable.	The data is recorded by using more materials that are transportable but not easily obtained.	The data is recorded by using difficult transported materials but are easily obtained	The data is recorded by using materials that are difficult to transport and obtain.
How expensive is required material?	The materials needed for the observation should not be expensive. Ideally, it just costs pen and paper. To write down the observations of the phenophases.	The materials are not expensive. In total less than 100 Euro's	The materials a little expensive. In total, less than 500 euro.	The materials are expensive between 500 and 1000 euro.	The materials are expensive more than 1000 euro.
How much time does the	The measurement of an individual tree takes approximately a minute or	The measurement of individual trees takes less than 5 minutes.	The measurement of individual trees takes more than 5 minutes.	The measurement of individual trees in the field takes more than 10 minutes.	the date in the field is not recorded by measuring individual trees.

measurement cost?	data can be collected in the field and specific phenophases can be identified after the field work (*e.g.* the use of photos).				
How many people are needed to perform fieldwork?	Ideally, the field work should be able to be performed by a local guide, so by one person. (A. Goedmakers, personal communication, 04 July 2017) In addition, the method does not need knowledge on how to operate a GPS.	The fieldwork should be able to be performed by a local guide, preferably with knowledge on how to operate a GPS, otherwise, he must remember a large number of trees and transects.	The fieldwork should be able to be performed by a local guide and must have knowledge on how to operate a GPS because it is necessary for collecting data.	The fieldwork is not suitable to be performed by a local guide and has to be performed by a student or researcher. Since they are not allowed to perform the field work by themselves (because of the risks in the field, for instance, accidents, dangerous animals etc.). Therefore, the field work ideally is performed by two persons, including one local guide and one student or researcher. (M.J. Breider, A. Goedmakers, G. Niezing P. Wit, personal communication, December 1, 2015)	The fieldwork should be performed by two persons.
What are the required skills?	Little skill is required to perform the field work. A local guide should be able to perform the field work.	Basic skills are required. However, a local guide should be able to record the data after learning how to record the data.	Some training is required to learn how to record the data, for students and research this should be easy. However, for local guides, this method might be too complicated for a local guide to understand.	Training is required for students and researchers to perform the field work.	The methods required specific skills (*e.g.* understanding complicated computer programs.) and student should be trained in using them.
What phenophases are measured?	The measured phenophases are detailed and are similar to the following phenophases: breaking leaf buds, leaves, colored leaves, fallen leaves, flower buds, open flowers, fruits, ripe fruits, recent fruit or seed drop,	The measured phenophases are detailed for some phenophases. (*e.g.* breaking leaf buds, leaves, colored leaves, fallen leaves) and less detailed for other phenophases (*e.g.* fruit).	The measured phenophases are leaves, flowers, fruits.	One of the following phenophases is not recorded in the method: leaves, flowers fruits.	Only one phenophases is recorded in the method.
Is the method broadly applicable to tree species with different physiology?	The method is broadly applicable to all tree species.	The method is broadly applicable to tree species, however, trees with different physiology are a bit more difficult to observe.	The method is broadly applicable to most species; some species might be difficult to monitor.	The method is not broadly applicable to all tree species. Only certain species are applicable to the method.	The method is only applicable to one tree species.

What is the scoring system for the observation of the phenophases?	Not only the presence of the phenophase but also the intensity of all the phenophases are recorded.	The presence and absence of detailed phenophases are given but the intensity of fruit is monitored.	The presence and absence of all the detailed phenophases are monitored.	the presence and absence of the leaves, flowers, and fruit are monitored.	The presence and absence of only one phenophase are monitored.
Is the method reproducible?	The scoring system should be easily reproducible and have no interobserver variability.	The scoring system is easily reproducible and has a low interobserver variability	The scoring system is easily reproducible but has a high interobserver variability. Or The scoring system is difficult to reproduce but has a no interobserver variability.	The scoring system is difficult to reproduce but has low interobserver variability.	The scoring system is difficult to reproduce and has a high interobserver variability.

Appendix II Selection on the suitability of the methods to the aim of the study in the Boé Sector.

1. PanAf Programme

The PanAf method scores different phenophases of the trees phenology (fruit leaves and flowers) and uses these phases to estimate the percentage of fruit, leaves, and flowers in comparison to the tree crown cover. This percentage is an estimate that is given a score from 0 to 4 (0 = not present, 1= 1 to 24%, 2 = 25 to 49 %, 3= 50 to 74% and 4=75 to 100%) (Arandjelovic et al., n.d.; Breider, 2017a; Haugaasen, 2015; Kristensen et al., 1996; Meer, 2014). The aim of the PanAf was to identify the annual cycle and productivity of chimpanzee fodder trees at the site (Breider, 2017a; Meer, 2014). This aim corresponds wth the aim of the study in the Boé Sector. Even though the PanAf recommends to study the phenology for only one year period, the method is, applicable for multiple year studies (Kristensen et al., 1996). For these reasons, this method will be included in further analysis because the aim fits with the of the study that is going to be performed in the Boé Sector.

2. Fruit trail

The fruit trail method monitors the fruit abundance and the number of fruiting trees along 1 m wide transects trails (Furuichi et al., 2001; Takenoshita et al., 2008; White, 2008; Hashimoto et al., 2003). The aim of the fruit trail method differs between sources. Mostly it is used to examine seasonal changes in fruit phenology (Takenoshita et al., 2008; White,1998). The method is applicable to be used for multiple years (Takenoshita et al., 2008). This aim fits with the aim of the study that is going to be performed in the Boé Sector. There is, however, a bias in this study, as frugivorous animals could have been eating the fruit before it fell to the ground or when it lay on the ground. Therefore, the number of fruit that is counted may be less than the tree produced. However, this method will not be eliminated because the aim fits with the aim of the study that is going to be performed in the Boé Sector.

3. Fruit count method

The Fruit count method counts the number of fruit. This differs from the other methods, which estimates the amount of fruit in percentages (Tweheyo & Lye, 2003; Tweheyo & Babweteera, 2007; Chapman et al., 1992). The fruit count method uses visual counts instead of estimating the intensity. However, the interobserver variability is not necessarily lower. As only a fraction of the tree is counted (only a few branches) and then multiplicated to fit the entire crown, these multiplications can cause a high interobserver variability. This is because a small difference quickly becomes a huge difference after a multiplication. The aim of the fruit count method differs between sources, but the overall aim is to examine the seasonal variation of fruit (Tweheyo & Lye, 2003; Tweheyo & Babweteera, 2007). Even though the method specifically monitors the number of fruit usually the leaf phenology is also monitored (Tweheyo & Lye, 2003; Tweheyo & Babweteera, 2007) and therefore fits with the aim of the study that is going to be performed in the Boé Sector. In addition, the method is applicable to be used for multiple years (Tweheyo & Babweteera, 2007). For these reasons, this method will not be eliminated because the aim fits with the aim of the study that is going to be performed in the Boé Sector.

4. Nature's Notebook

Nature's Notebook method uses the percentage of fruits and visual counts to estimate the intensity of phenophases. The aim of the method differs between sources, though the overall aim is to examine annual changes in phenology (plants and animals). The aim does not exactly fit with the aim in the Boé Sector as the aim is to monitor the phenology of trees and animals are not included, but as the method does include trees and is broadly applicable for multiple species the method is suitable to be used in the Boé Sector. For these reasons, the method will not be eliminated because the method is applicable to be used in the Boé (Tierney et al., 2013; Denny et al., 2014; Elmendorf et al., 2016.

5. Monthly fruit index

The Monthly fruit index method is estimated by using the number of fruiting trees in a month and the basal area per hectare for each the species (Basabose & Yamagiwa, 2002; Yamagiwa et al., 2008; Elmendorf et al., 2016) The aim of the study is to examine the monthly fluctuations in the abundance of fruit for gorilla's and chimpanzees (Yamagiwa et al., 2008, Basabose, 2002). However, this method only monitors fruit phenology and has a low interobserver variability as it only uses the presence and absence of fruits (Basabose & Yamagiwa, 2002; Yamagiwa et al., 2008; Elmendorf et al., 2016). In addition to that, the aim fits with the aim of the study in the Boé Sector. For these reasons, the method will not be eliminated because the method is applicable to be used in the Boé Sector.

6. BBCH Code

The BBCH code method uses a coding system for phenophases and their intensity, both coding systems in which 0 defines the beginning or germination and 9 depict the end of a growing stage or being dormancy (Koch et al., 2007; Bruns et al., 2003; Zhang et al., 2016; Meler et al., 2009; Hess et al., 1997). The aim of the method varies between sources. As the method originates from agriculture most sources monitor the phenology of crops. the method is also used for assessing phenology in nature (Attibayeba et al., 2010). The aim of the method for phenology in nature is to examine the annual fluctuation in phenological trends (Bruns et al., 2003; Koch et al., 2007), therefore, the aim fits with the aim of the study in the Boé Sector. For these reasons, this method will not be eliminated as the method fits with the aim of the Boé Sector.

7. Digital time-lapse method

The digital time-lapse method uses time-lapse cameras to gather data on the phenology of vegetation. As this method uses pictures to gather the phenology, it minimizes the interobserver variability (Crimmins & Crimmins, 2008; Bater et al., 2011). However, the costs to purchase all the time-lapse cameras would be too expensive. A time lapse camera costs approximately 275 euro's and as the phenology program ideally has about 200-300 trees the costs would be between 55,000 and 82,500 euro's (Sonnentag, et al., 2012). On top of that, cameras are set up in high places (*e.g.* specially build platforms or towers or on a hill looking over a gallery forest) (Ahrends et al., 2009) and photos were taken from afar (Ahrends et al., 2009; Ide & Oguma, 2010; Bater et al., 2011; Sonnentag, et al., 2012; Zhao, et al., 2012). As a result, the method would be suitable to monitor the vegetation of forests (*e.g.* when the trees have leaves or flowers) (Keenan et al., 2014; Nagai, et al., 2014). However, it may be difficult to determine the intensity of phenophases (especially fruit) because photos are taken from afar. However, monitoring the intensity of the fruit phenophase is one of the most important factors for the phenology of chimpanzee fodder trees (see 1.3 Hypothesis). In addition to that, some sources use complicated algorithms to determine the phenology of the vegetation and researchers must be trained to work with the algorithms. This will also result in local field workers not being able to contribute to the work because it is complicated for them to understand. For these reasons, this method will be eliminated.

8. MODIS, and Landsat

The MODIS and Landsat method use satellite images to monitor the phenology of vegetation (Zhang et al., 2003; Fisher & Mustard, 2007; Walker, Beurs de, & Wynne, 2014). As a result, this method would be suitable to monitor the vegetation of forests (*e.g.* when the trees have leaves or flowers), but it is difficult to determine the intensity of phenophases in detail. In addition, MODIS and Landsat use complicated programs and algorithms to determine the phenology (Zhang et al., 2003; Fisher & Mustard, 2007; Walker et al., 2014). This will make it difficult if multiple researchers monitor the trees, as researchers must be trained in working with the programs and algorithms. This will also result in local field workers to not being able to contribute because it is too complicated for them to understand. For this reasons the method has been eliminated.

9. Fruit traps

The fruit traps method is similar to the fruit trail method, see 2.5.2 and 2.5.9. Both methods use fallen fruits to estimate the availability of fruit (Chapman, Wrangham, & Chapman, 1994; Furuichi, Hashimoto, & Tashiro, 2001). However, the method with fruit traps uses plastic traps to collect fruit that has fallen from trees (Malenky, Wrangham, Chapman, & Vineberg, 1993). To collect the fruit, a trap should be set up under every individual tree in the monitoring program (Terborgh, 1983). Even though, the materials for the fruits traps are not expensive it would take a lot of time and labor, and would not be practical. Also, as White (1998) stated in his research '' Fruit trails are used rather than fruit traps, as fruit traps have proven to be less effective for large areas.'' Also, not all fruit falls to the ground, as the fruit is eaten by a large variety of animals in the trees. Lastly, sources that describe this method were scarce and mostly outdated (Terborgh, 1983; Malenky et al., 1993; Chapman et al., 1994; Stevenson et al., 1998). For these reasons, this method has been eliminated.

10. Food availability index (FAI)

The food availability index (FAI) is similar to the method Monthly fruit index method, both methods use an equation to calculate an index of fruit, see 2.5.5 and 2.5.10. There were a lot of sources using equations to calculate an index of fruit abundance (Basabose, 2002; Basabose & Yamagiwa, 2002;Yamagiwa, Basabose, & Kaleme, 2008; Potta & Lwanga, 2009; Watts et al., 2012; Bessa et al., 2015; Carvalho et al., 2015). However, the formula for FAI and monthly fruit index were the two most common ones, but the formula for FAI varied largely across different sources (Bessa et al., 2015; Carvalho et al., 2015; Potts, Watts, & Wrangham, 2011). For these reasons, the FAI method will be eliminated, and instead, the monthly fruit index will be used for further comparison and analysis.

Appendix III Rating of the sources.

1. Subject objective

The objective will describe the aim, research question and objectives of the method. A rating has been given to them by comparing them to the ideal method, see 2.7 Rating the methods. In Table 1 the ratings are given for the method and for each source. At the end of this chapter, a table with all the ratings for the sources has been given, see Table 2.

Table 1: The rating for the method for each source of the subject objective, in the first column the name of the method has been given, the second column describes what the criteria are in the sources and the last two columns give the source and the rating of the source. The criteria for the rating has been given in Appendix I Criteria for rating the methods.

Sub- question 1: what were the objectives of the study?		Source	Rating
PanAf	Method 1, has the same rating for all five source. This is a ++ rating of ++, this is because the aim of the method is to gain knowledge of the food availability of the chimpanzee.	1	++
		2	++
		3	++
		4	++
		5	++
Fruit trail	Method 2, the Fruit trail method, monitors the phenology on only one phenophase (fruit) for multiple years.	1	+/-
		2	+/-
		3	+/-
		4	+/-
Fruit count	Method 3, has three sources, two of these have a ++ rating, this is because the objective is to gain knowledge of the food availability of chimpanzees. Even though the method is explicit to monitor fruit, the method also monitors the leaf phenology. The third source with an NA (Not Available) compares three methods for estimating fruit numbers and thus, does not correspond with the objectives for using the method for monitoring.	1	++
		2	++
		3	NA
Nature's Notebook	Method 4, has four sources all of them have the same rating of +/-, this is because all three sources have approximately the same objective. This is to explore the relationship between phenological observations and climate variables (*e.g.* temperature).	1	+/-
		2	+/-
		3	+/-
Monthly fruit index	Method 5, the Monthly fruit index, monitors the phenology on only one phenophase (fruit) for multiple years.	1	+/-
		2	+/-
		3	+/-
BBCH code	Method 6, has five sources, the objective for the BBCH code varies a lot. The first source describes different objectives where the method could be used for, one of them is to gain knowledge of the food availability for	1	++
		2	+/-

	animal species this corresponds with a ++ rating. The second source has an as objective to explore relationships between phenological observations and climate variables, thus gaining a +/- rating. The third source describes the phenology of only the pineapple *(Ananas comosus)* for the use in agriculture, as this objective is not included in the criteria (see Appendix I criteria for rating the methods) and thus NA has been given to the source. The fourth source describes the history and the method itself, therefore the objectives of the study do not correspond with objectives for using the method for monitoring and the rating NA has been given. The last source uses the method to monitor weeds and since this was not in a savannah forest and not only the presence or absence of a phenophase been monitored a rating of – has been given.	3	NA
		4	NA
		5	-

Sub- question 2: what was the aim of the study?		Source	Rating
PanAf	Method1 has five sources, three of the five methods monitor the phenology of chimpanzee fodder trees for one year. Which corresponds with a + rating. The first source monitored the phenology for less than a year and thus gained a score of --. This study was performed by a student who was limited with her time in the study area and therefore performed a study of less than a year. The last source monitors the phenology of chimpanzee fodder trees for multiple years and thus has gained a ++ rating.	1	--
		2	+
		3	+
		4	+
		5	++
Fruit trail.	Method2 has four sources, two of the four have a rating of --, this is because the phenology is monitored for less than a year. The second source monitored the phenology of one phenophase (fruit) for multiple years, thus gaining a +/- rating. The third method monitors the phenology of one phenophase for one year, thus gaining a – rating.	1	--
		2	+/-
		3	-
		4	--
Fruit count	Method 3, the objective varies a lot between sources. The first source monitored the phenology of all phenophases for a year, which corresponds with a + rating. The second source monitors the phenology of chimpanzee fodder trees for multiple years which corresponds to a ++ rating. The third and last method has been given the rating NA since the method compares three methods to monitor the number of fruit and this is not like any of the aims given in the criteria.	1	+
		2	++
		3	NA
Nature's Notebook	Method 4, has three sources, all sources have the same + rating, this is because the aim of the source is the same. All three sources monitor the phenology for multiple years but not specifically for the chimpanzee, which corresponds with a + rating.	1	+
		2	+
		3	+
Monthly fruit index	Method 5, has three sources, two of the tree has a rating of +/-, this is because of they the phenology of one phenophase (fruit) for multiple years. The first source monitored the phenology on one phenophase (fruit) for one year which corresponds with a – rating	1	-
		2	+/-
		3	+/-
BBCH code	Method 6, has an objective that varies a lot between the sources. The first and the second source have a rating of +, this is because they monitor the phenology for multiple years, but not specifically for chimpanzees. The third	1	+
		2	+
		3	+/-

	source monitors the phenology of pineapples for one year. As the source does measure all the phenophase for one year the rating of +/- has been given. The last two sources have been given an NA rating, one source describes the history of the BBCH code and how it should be used. The other method describes how the BBCH code can be applied for research on weeds. Both these aims are not like any of the aims given in the criteria	4	NA
		5	NA

Table 2: An overview of all the ratings for the sources of the subject objective.

Question	PanAf					Fruit trail				Fruit count			Nature's Notebook			Monthly fruit index			BBCH code				
	1	2	3	4	5	1	2	3	4	1	2	3	1	2	3	1	2	3	1	2	3	4	5
1	++	++	++	++	++	+/-	+/-	+/-	+/-	++	++	NA	+/-	+/-	+/-	+/-	+/-	+/-	++	+/-	NA	NA	-
2	--	+	+	+	++	--	+/-	-	--	+	++	NA	+	+	+	-	+/-	+/-	+	+	+/-	NA	NA
3	NA	NA	+	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

2. Subject research design

The research design will describe the design of the method and will inform about the suitability of the method for the habitat in the Boé Sector. A rating has been given to them by comparing them to the ideal method, see 2.7 Rating the methods. In Table 3 the ratings are given for the method and for each source. At the end of this chapter, a table with all the ratings for the sources has been given, see Table 4.

Table 3: The rating for the method for each source, in the first column the name of the method has been given, the second column describes what the criteria are in the sources and the last two columns give the source and the rating of the source. The criteria for the rating has been given in Appendix I Criteria for rating the methods.

Sub- question 1: what was the study period?		Source	Rating
PanAf	The first source is a study performed by a student who was limited with her time in the area and performed field work for three months. The second and fifth source monitor the phenology for multiple years. Source number three and four have a study period of one year which corresponds to a + rating.	1	+/-
		2	++
		3	+
		4	+
		5	++
Fruit trails	The first and fourth source had a study period of less than a year but the method is applicable to be used for multiple years. The second source monitors the phenology for multiple years and the third source monitors the phenology of one year.	1	+/-
		2	++
		3	+
		4	+/-
Fruit count method	The first source monitors the phenology for one year and the second for multiple years, which corresponds with a rating of + and ++. The third and last method has been given the rating Na because it the method compares to monitor the number of fruit and has no study period.	1	+
		2	++
		3	NA
Nature's Notebook	All the sources monitor the phenology for multiple years which corresponds to a ++ rating.	1	++
		2	++
		3	++
Monthly fruit index	Only the first source monitors the phenology for one year. The other two sources monitor the phenology for multiple years.	1	+
		2	++
		3	++
BBCH code	All the sources except two NA rating monitor the phenology for multiple years. The first source with the NA rating explains the BBCH coding system and its history, thus a study is not given in the source. The other source with the NA rating describes how the BBCH code can be used to monitor the phenology of weeds, it only explains how it BBCH code is applicable for weeds not how long the phenology should be monitored.	1	++
		2	++
		3	++
		4	NA
		5	NA

Sub- question 2: what was the frequency of monitoring the trees?		Source	Rating
PanAf	Method 1, PanAF, has an overall rating of +, this is because the method monitors the phenology once a month. All the sources monitor the phenology once a month.	1	+
		2	+
		3	+
		4	+
		5	+
Fruit trails	Method 2, Fruit trails, has an overall rating of ++, this is because the method monitors the phenology fortnightly (once every two weeks). All the sources monitor the phenology fortnightly.	1	++
		2	++
		3	++
		4	++
Fruit count	All the sources except the third method monitor the phenology fortnightly, the third method has been given the rating Na because it the method compares to monitor the number of fruit and has no study frequency.	1	++
		2	++
		3	NA
Nature´s Notebook	Method 4, Nature´s Notebook, has an overall rating of +/-, this is because the method monitors the phenology once every week. All the sources monitor the phenology once every week.	1	+/-
		2	+/-
		3	+/-
Monthly fruit index	Method 5, Monthly fruit index, has an overall rating of ++, this is because the method monitors the phenology fortnightly. All the sources monitor the phenology fortnightly	1	++
		2	++
		3	++
BBCH code	Method 6, BBCH code, has an overall rating of NA, this is because most sources do not state the frequency in which they monitor the phenology. Only the first source stated the frequency for monitoring the phenology, in this source the frequency for monitoring the phenology was every day.	1	-
		2	NA
		3	NA
		4	NA
		5	NA

Sub- question 3: How many trees of each species were selected?		Source	Rating
PanAf	Four of the five sources monitor less than 5 individuals for each species, which corresponds to a – rating. Only the fourth source monitors at least 10 individuals and therefore has a + rating.	1	-
		2	-
		3	-
		4	+
		5	-
Fruit trails		1	NA

	The method monitors all the trees along a transect which drop fruit, therefore trees are not selected before hand and a number could not be described.	2	NA
		3	NA
		4	NA
Fruit count	The first and the second source monitor less than 5 individuals for each species, which corresponds to an – rating. The third source monitors between 7 to 12 individuals for each species, which corresponds to a +/- rating.	1	-
		2	-
		3	+/-
Nature´s Notebook	The first source monitors at least 9 individuals for each species, which corresponds with a + rating. The second source does not state the number of individual's species for each species. The third and last source monitors ideally monitors between 10 to 20 individual's trees which correspond with a ++ rating.	1	+
		2	NA
		3	++
Monthly fruit index	Two of the three sources monitor at least 10 individuals for each species, the other source does not state the number of individual trees for each species.	1	NA
		2	+
		3	+
BBCH code	Only of the sources state the number of individuals for each species which is between 5 and 10 individuals which correspond with a +/- rating.	1	NA
		2	NA
		3	+/-
		4	NA
		5	NA

Sub- question 4: Why are those species monitored?		Source	Rating
PanAF	Three of the five sources are monitored because they are known to be eaten by chimpanzees. Only the second and the fifth source have a different reason for monitoring those species of trees. The second source did not select trees because they are known to be eaten by chimpanzees, the method does monitor the phenology of trees. The fifth source monitors trees that are part of a frugivore-seed dispersal study, they are no specifically eaten by chimpanzees but are eaten by other species and therefore a + rating has been given.	1	++
		2	+/-
		3	++
		4	++
		5	+
Fruit trails	All the sources, monitor the phenology of trees but not specifically for the chimpanzee.	1	+/-
		2	+/-
		3	+/-
		4	+/-
Fruit count	Two of the three sources monitor trees that are known to be eaten by chimpanzees in the area. Only the third source but since trees are monitored it is applicable to be used for the use of trees that are eaten by chimpanzees.	1	++
		2	++
		3	+/-
Nature's Notebook	The first source does not specifically monitor the phenology of trees but it might be applicable to be used to monitor the phenology of trees. The second source does not state why these species are selected and therefore,	1	-
		2	NA

	the rating of NA has been given. The third source does monitor the phenology but not specifically trees that are known to be eaten by chimpanzees.	3	+/-
Monthly fruit index	All three sources monitor trees that are known to be eaten by chimpanzees in the area.	1	++
		2	++
		3	++
BBCH code	The first and fourth source does not state why they monitor these species. The second source does monitor the phenology of trees but not specifically because they are known to be eaten by chimpanzees. The third source monitors the phenology of agriculture. The fifth and last source monitors the phenology but not specifically trees but it might be applicable to be used to monitor the phenology of trees that are known to be eaten by chimpanzees.	1	NA
		2	+/-
		3	--
		4	NA
		5	-

Sub- question 5: Are there criteria for selecting the individual trees?		Source	Rating
PanAf	Method 1, PanAf, has an overall rating of ++, this is because the criteria used for selecting trees is the DBH at 1.3 m from the ground, which should be more than 10 cm. The first, second and fourth source use the DBH at 1.3 m from the ground as criteria for selecting trees, which corresponds to a ++ rating. The second and fifth source, do also use the DBH to select trees but they use different values as described above, which corresponds with a + rating.	1	++
		2	+
		3	++
		4	++
		5	+
Fruit trails	All the sources monitor trees from which fruit has fallen, therefore only trees which produce and drop fruit are monitored in this method.	1	+/-
		2	+/-
		3	+/-
		4	+/-
Fruit count	The second source uses the DBH at 1.3 m from the ground as criteria for selecting a tree. The first source does also use the DBH but with other values. The third source compares three methods to calculate the number of fruit and they selected trees which were suitable for their aim of the comparison.	1	+
		2	++
		3	-
Nature's Notebook	The first source selects trees based on their site (convenient, undisturbed, representative, uniform, species presence) and individual trees (healthy, undamaged and free of pests and diseases), the plants should also not be closer than 6 m to a road or building. The second source does not state the criteria for selecting the trees. The third source selects trees based on their site (representative, species, disturbance).	1	+/-
		2	NA
		3	+/-

	All sources use the DBH at 1.3 m from the ground, which corresponds to a ++ rating.	1	++

		Source	Rating
Monthly fruit index		2	++
		3	++
BBCH code	The first source selects trees based on their species (easily recognized, well known) and distribution. The second source selects the trees based on their species (easily, recognized, economically important), phenological stages, distribution, and propagation. The third and the fifth source do not have criteria for selecting the trees. The fourth source does not state if there are criteria to select the trees.	1	+/-
		2	+/-
		3	--
		4	NA
		5	--

Sub- question 6: In what type of habitat was the study performed?		Source	Rating
PanAf	Three of the five sources performed the study in a savannah forest mosaic, which corresponds to a ++ rating. The other two sources performed the study in a slightly similar habitat to Savannah forest mosaic (Floodplain forest, forest with steep slopes), both are habitat with a dry and a wet season, which corresponds with a +/- rating.	1	++
		2	+/-
		3	++
		4	++
		5	+/-
Fruit trails	Three of the four sources performed the study in a moist evergreen forest, which corresponds to a +/- rating. The second source performed the study in a savannah forest mosaic, which corresponds to a ++ rating.	1	+/-
		2	++
		3	+/-
		4	+/-
Fruit count	Method 3, Fruit count method, has an overall rating of rating of +/-, this is because the habitat in which they study was performed in a habitat slightly like a savannah forest mosaic. All sources performed the study in a tropical rain forest, the only source performed the study in a combination of tropical rain forest, savannah, and woodland.	1	+
		2	+/-
		3	+/-
Nature's Notebook	The first source performed the study in a northern hardwood forest and the second source performed the study in a fresh water and marine plant habitat, both corresponds with a – rating. The third source does not state the study habitat.	1	-
		2	-
		3	NA
Monthly fruit index	Two of the three sources performed the study in a montane forest in Congo, the other source performed the study in a bamboo forest in Congo. All of the these correspond with a + rating.	1	+
		2	+
		3	+
BBCH code	All sources performed the study in agriculture.	1	NA
		2	--
		3	--
		4	--
		5	--

Sub- question 7: Where was the study performed?		Source	Rating
PanAf	Three of the five sources perform the study in the Boé Sector of Guinea-Bissau, which corresponds to a ++ rating. The the other two sources performed the study in an area with similar circumstances as the Boé Sector (Central amazion forest, montane forest, Rwanda), which corresponds with a + rating.	1	++
		2	+
		3	++
		4	++
		5	+
Fruit trails	All the sources performed the study in an area with similar circumstances as the Boé Sector in Guinea-Bissau. The first source performed the study forest reserve in Uganda, the second in a National Park in Gabon, the third in a forest in Congo and the last source in four different sites in a forest in Congo.	1	+
		2	+
		3	+
		4	+
Fruit count	All the sources performed the study in a forest reserve in Uganda.	1	+
		2	+
		3	+
Nature's Notebook	All three studies are performed in the USA. All source performed the study in a country that is not like Guinea-Bissau and is not remotely located.	1	-
		2	-
		3	-
Monthly fruit index	All the sources performed the study in a National Park in Congo.	1	+
		2	+
		3	+
BBCH code	Method 6, BBCH code, has an overall rating of NA, this is because most of the sources do not state a place where the study has been performed. The sources one, two and fours describe the method and how it can be applied to certain plants but does not state a certain area where the study has been or will be performed. The third source performed that study in an agricultural area in China and the fifth sources in an agricultural area in Germany.	1	NA
		2	NA
		3	-
		4	NA
		5	-

Sub- question 8: How many tree species were monitored?		Source	Rating
PanAf	The first source monitors 25 species, the second source monitors 126 species, the third source monitors 24 species, the fourth source monitors 15 to 20 species and the fifth and last source monitors 49 species.	1	++
		2	-
		3	++
		4	+
		5	+/-
Fruit trails		1	NA

	The method monitors all the fallen fruit from trees, thus the tree species are not selected beforehand. Usually, they calculate how much fruit is available each month and do not state exactly which species have been monitored. Only the second source stated the number of species which was 117 species.	2 3 4	- NA NA
Fruit count	The first source monitors 15 species, the second source 40 species and the third and last source 4 species.	1 2 3	+ + -
Nature's Notebook	The first source monitors 15 species, the second does not state how many species are monitored and the third and last source monitors 20 species of which three are ''dominant'' species which are monitored following the method. The other 17 species are addition species which have a more limited sampling than the dominant species. In total 20 species, have been monitored which would correspond with a ++ rating, but 17 of those species only addition species and have a limited sampling compared to the dominant species a rating of + has bee given to the source.	1 2 3	+ NA +
Monthly fruit index	The first source does not state the number of species, the second and third source both monitor 49 species.	1 2 3	NA +/- +/-
BBCH code	Method 6, BBCH code, has an overall rating of NA, this is because most sources do not state the number of species monitored. Only the second and third source state the number of species monitored, for the second source this is one and the third monitors 14 species.	1 2 3 4 5	NA + +/- NA NA

Sub- question 9: How many trees were monitored in total?		Source	Rating
PanAf	The first source monitors 221 individual trees, the second source monitors 1200 individual trees, the third source monitors 179 individual trees, the fourth source monitors between 150 and 200 individual trees, the fifth and last source monitors 568 individual trees. Even though the number of trees varies, an overall rating of ++ has been given because the method is applicable to 200-300 individual trees and this rating is also the most abundant.	1 2 3 4 5	++ - + ++ -
Fruit trails	Method 2, Fruit trail method, has an overall rating of NA, this is because the method does not state the total number of individual trees. Only the fourth source states the number of individual trees which is 1758. The other sources do not state the number of individual trees.	1 2 3 4	NA NA NA -
Fruit count	Method 3, Fruit count method, has an overall rating of -, this is because the total number of individual trees is less than 50 or more than 500 trees.	1 2	+/- -

		Source	Rating
	The first source monitors a total of 84 trees, the second source monitors a total 575 trees and the third and last source a total of 41 trees.	3	-
Nature's Notebook	Method 4, Nature's Notebook, has an overall rating of +, this is because the total number of individual trees is between 50 and 100 trees or 400 and 500 trees. The first source monitors 135 trees in one park, but the source does mention they have multiple monitoring networks. However, they only give the number of trees in one park, but since there are multiple areas where they monitor the number of total trees is higher than 135. Thus, a rating of +/++ has been given to the source. The second source does not state the number of individual trees. The third and last method monitors 4230/4700 individual trees. Even though the number of individual trees varies, the rating of + has been given because the method is applicable to be used between 100 and 200 or 300 and 400 trees are monitored.	1 2 3	+/++ NA -
Monthly fruit index	Method 5, Monthly fruit index, has an overall rating of -, this is because they monitor between less than 50 or more than 500 trees. The first source monitors 1758 individual trees and the second and third source monitors 2033 and 280 trees.	1 2 3	- - -
BBCH code	Method 6, BBCH code, has an overall rating of NA, this is because most sources do not state the total number of individual trees. Only the third source states the total number of individual trees which is 6.	1 2 3 4 5	NA NA - NA NA

Sub- question 10: What was the sample size?		Source	Rating
PanAf	The first source has a sample size of 7 transects of 8 km which totals to 56 km, the second source does not state the sample size, the third source has a sample size of 3 transects of 7 km which totals to 21 km, the fourth source does not state the sample size, the last and fifth source uses transects but does not state the length of the transect.	1 2 3 4 5	+/- NA ++ NA -
Fruit trails	The first source has a sample size of 10 transects of 5 km and one transect of 1.5 km, the second source has a sample size of 9 transects of 4 km and one transect of 6.699 km totaling to 38.699 km, the third source has a sample size of 3 transects of 6 km which totals to 18 km, the fourth and last source has a sample size of 10 transect of 5 km and 37 km totaling to 87 km. Since the method is applicable for a transect between 5 to 15 or 30 to 40 km, the method got a + rating.	1 2 3 4	+/- + + +/-
Fruit count	Only one source the second stated the sample size which is 8 transects of 2 km totaling to 16 km.	1 2 3	NA + NA

Nature's Notebook	None of the sources stated the sample size of the study.	1	NA
		2	NA
		3	NA
Monthly fruit index	All three sources have a sample size of 1 transect of 5 km.	1	+
		2	+
		3	+
BBCH code	None of the sources stated the sample size of the study.	1	NA
		2	NA
		3	NA
		4	NA
		5	NA

Table 4: An overview of all the ratings for the sources of the subject research design.

	PanAf					Fruit trail				Fruit count			Nature's Notebook			Monthly fruit index			BBCH code				
Question	1	2	3	4	5	1	2	3	4	1	2	3	1	2	3	1	2	3	1	2	3	4	5
1	+/-	++	+	+	++	+/-	++	+	+/-	+	++	NA	++	++	++	+	++	++	++	++	++	NA	NA
2	+	+	+	+	+	++	++	++	++	++	++	NA	+/-	+/-	+/-	++	++	++	-	NA	NA	NA	NA
3	-	-	-	+	-	NA	NA	NA	NA	-	-	+/-	+	NA	++	NA	+	+	NA	NA	+/-	NA	NA
4	++	+/-	++	++	+	+/-	+/-	+/-	+/-	++	++	+/-	-	NA	+/-	++	++	++	NA	+/-	--	NA	-
5	++	+	++	++	+	+/-	+/-	+/-	+/-	+	++	-	+/-	NA	+/-	++	++	++	+/-	+/-	--	NA	--
6	++	+/-	++	++	+/-	+/-	++	+/-	+/-	+	+/-	+/-	-	-	NA	+	+	+	NA	--	--	--	--
7	++	+	++	++	+	+	+	+	+	+	+	+	-	-	-	+	+	+	NA	NA	-	NA	-
8	++	-	++	+	+/-	NA	-	NA	NA	+	+	-	+	NA	+	NA	+/-	+/-	NA	+	+/-	NA	NA
9	++	-	+	++	-	NA	NA	NA	-	+/-	-	-	+/++	NA	-	-	-	-	NA	NA	-	NA	NA
10	+/-	NA	++	NA	-	+/-	+	+	+/-	NA	+	NA	NA	NA	NA	+	+	+	NA	NA	NA	NA	NA

3. Subject observation procedure

The subject observation procedure will describe how the observation for monitoring trees was conducted, this describes how data for monitoring should be recorded. A rating has been given to them by comparing them to the ideal method, see 2.7 Rating the methods. In Table 5 the ratings are given for the method and for each source. At the end of this chapter, a table with all the ratings for the sources has been given, see Table 6.

Table 5: The rating for the method for each source, in the first column the name of the method has been given, the second column describes what the criteria are in the sources and the last two columns give the source and the rating of the source. The criteria for the rating has been given in Appendix I Criteria for rating the methods.

Sub- question 1: How reproducible is the method?		Source	Rating
PanAf	All the sources have the same rating, which is understandable as all sources have been selected to have the same observation procedure. The rating of +/- has been given because the method is easily reproducible but has a high interobserver variability.	1	+/-
		2	+/-
		3	+/-
		4	+/-
		5	+/-
Fruit trails	All the sources have the same rating, which is understandable as all sources have been selected to have the same observation procedure. The rating of +/- has been given because the method is easily reproducible. The interobserver variability Is low with species with large fruits but is much higher for small fruits and the rating of +/- has been given.	1	+/-
		2	+/-
		3	+/-
		4	+/-
Fruit count	All the sources have the same rating, which is understandable as all sources have been selected to have the same observation procedure. The rating of +/- has been given because the method is easily reproducible but has a high interobserver variability.	1	+/-
		2	+/-
		3	+/-
Nature's Notebook	All the sources have the same rating, which is understandable as all sources have been selected to have the same observation procedure. The rating of +/- has been given because the method is easily reproducible but has a high interobserver variability.	1	+/-
		2	+/-
		3	+/-
Monthly fruit index	All the sources have the same rating, which is understandable as all sources have been selected to have the same observation procedure. The rating of + has been given because the method is easily reproducible and has a low interobserver variability.	1	+
		2	+
		3	+
BBCH code	All the sources have the same rating, which is understandable as all sources have been selected to have the same observation procedure. The method got a +/- - rating instead of +/- because the PanAf and Nature's Notebook use percentages to estimate the crown cover. The PanAf and Nature's Notebook use five categories (0 = 0%, 1 = 0 – 25%, 2 = 26 – 50 %, 3 = 51 – 75 %, 4 = 76 – 100%) the BBCH code uses 10 categories (, 0 defines the beginning and 9	1	+/--
		2	+/--
		3	+/--
		4	+/--
		5	+/--

	depicts the end of the principal growth stage), for this reason the interobserver variability is higher for the BBCH code but does still correspond with +/- rating, but since the interobserver variability is higher the rating of +/-- has been given to show the difference in the variability.

Sub- question 2: How is the observed data recorded?		Source	Rating
PanAf	All the sources have the same rating, which is understandable as all sources have been selected to have the same observation procedure.	1	++
		2	++
		3	++
		4	++
		5	++
Fruit trails	All the sources have the same rating, which is understandable as all sources have been selected to have the same observation procedure.	1	-
		2	-
		3	-
		4	-
Fruit count	Two of the three sources, recorded the data by identifying specific phenophases are detailed. Only source three has a rating of – this is because the data that is recorded of only one phenophase. Even though the method is specific for monitoring the phenology of fruit, but the first and the second source also monitor the phenology of leaves.	1	++
		2	++
		3	-
Nature's Notebook	All the sources have the same rating, which is understandable as all sources have been selected to have the same observation procedure.	1	++
		2	++
		3	++
Monthly fruit index	All the sources have the same rating, which is understandable as all sources have been selected to have the same observation procedure.	1	-
		2	-
		3	-
BBCH code	All the sources have the same rating, which is understandable as all sources have been selected to have the same observation procedure.	1	++
		2	++
		3	++
		4	++
		5	++

Sub- question 3: What is the scoring system for the observation of the phenophases?		Source	Rating
PanAf	All the sources have the same rating, which is understandable as all sources have been selected to have the same observation procedure.	1	++
		2	++
		3	++

		4	++
		5	++
Fruit trails	All the sources have the same rating, which is understandable as all sources have been selected to have the same observation procedure.	1	-
		2	-
		3	-
		4	-
Fruit count	All the sources have the same rating, which is understandable as all sources have been selected to have the same observation procedure.	1	++
		2	++
		3	++
Nature's Notebook	All the sources except the third source have a rating of ++. The third source does not exactly state the scoring system but does mention that they use the observation procedure of Nature's Notebook method, which is then described in detail in the other two sources.	1	++
		2	++
		3	NA
Monthly fruit index	All the sources have the same rating, which is understandable as all sources have been selected to have the same observation procedure.	1	--
		2	--
		3	--
BBCH code	All the sources have the same rating, which is understandable as all sources have been selected to have the same observation procedure.	1	++
		2	++
		3	++
		4	++
		5	++

Sub- question 4: How many people are needed to perform the field work?		Source	Rating
PanAf	The fieldwork is not suitable to be performed by a local guide and must be performed by a student or researcher. Since they are not allowed to perform the fieldwork by themselves the field work is performed by two people. One student or researcher and one local guide.	1	-
		2	-
		3	-
		4	-
		5	-
Fruit trail	The fieldwork can be performed by a local guide, so by one person.	1	++
		2	++
		3	++
		4	++
Fruit count		1	-

	The fieldwork is not suitable to be performed by a local guide and must be performed by a student or researcher. Since they are not allowed to perform the fieldwork by themselves the field work is performed by two people. One student or researcher and one local guide.	2	-
		3	-
Nature´s Notebook	The fieldwork is not suitable to be performed by a local guide and must be performed by a student or researcher. Since they are not allowed to perform the fieldwork by themselves the field work is performed by two people. One student or researcher and one local guide.	1	-
		2	-
		3	-
Monthly fruit index code	All the sources have a method for which the phenology can be monitored by one researcher	1	+
		2	+
		3	+
BBCH code	The fieldwork is not suitable to be performed by a local guide and must be performed by a student or researcher. Since they are not allowed to perform the fieldwork by themselves the field work is performed by two people. One student or researcher and one local guide.	1	-
		2	-
		3	-
		4	-
		5	-

Sub- question 5: What phenophases are measured?		Source	Rating
PanAf	All the sources except the fifth monitor some phenophases detailed and other photophases less detailed. The fifth source is the only source that has a +/- rating, this is because the measured phenophases are leaves, flowers, and fruits.	1	+
		2	+
		3	+
		4	+
		5	+/-
Fruit trail	All the sources have the same rating, which is understandable as all sources have been selected to have the same observation procedure.	1	--
		2	--
		3	--
		4	--
Fruit count	All the sources except the third source monitor some phenophases detailed and other phenophases less detailed. Only the third source does not have a + rating, this is because this source only records one phenophase.	1	+
		2	+
		3	--
Nature's Notebook	All the sources have the same rating, this is because they monitored approximately the following phenophases: breaking leaf buds, leaves, colored leaves, fallen leaves, flower buds, open flowers, fruits, ripe fruits, recent fruit or seed drop.	1	++
		2	++
		3	++
Monthly fruit index		1	--
		2	--

	All the sources have the same rating, which is understandable as all sources have been selected to have the same observation procedure.	3	--
BBCH code	All the sources have the same rating, which is understandable as all sources have been selected to have the same observation procedure.	1	++
		2	++
		3	++
		4	++
		5	++

Sub- question 6: How much time does the measurement cost?		Source	Rating
PanAf	All the sources have the same rating, which is understandable as all sources have been selected to have the same observation procedure.	1	++
		2	++
		3	++
		4	++
		5	++
Fruit trail	All the sources except the second source have a method for which the monitoring of the individual trees takes less than 5 minutes. Only the second source has an +/- rating, this is because the measurement of individual trees takes more than 5 minutes. The monitoring of the second source is longer than the other sources because the source removes all the fruit to avoid recording those fruits to avoid recording those fruits in the next session.	1	+
		2	+/-
		3	+
		4	+
Fruit count	For all sources, the monitoring of the individual trees takes less than 5 minutes.	1	+
		2	+
		3	+
Nature´s Notebook	All sources except the third source have a method for which the monitoring of the individual trees takes less than 5 minutes. On the third does not state the observation procedure and thus also does not state the time the monitoring takes.	1	++
		2	++
		3	NA
Monthly fruit index	For all sources, the monitoring of the individual trees takes approximately a minute and specific phenophases can be identified after the fieldwork.	1	++
		2	++
		3	++
BBCH code	For all sources, the monitoring of the individual trees takes approximately a minute and specific phenophases can be identified after the fieldwork.	1	++
		2	++
		3	++
		4	++
		5	++

Sub- question 7: What are the required skills?		Source	Rating
PanAf	Some training is required to learn how to record the data, for students and researchers this should be easily understandable. However, for local guides, this method might be too complicated for a local guide to understanding.	1	+/-
		2	+/-
		3	+/-
		4	+/-
		5	+/-
Fruit trail	Some training is required to learn how to record the data, for students and researchers this should be easily understandable. However, for local guides, this method might be too complicated for a local guide to understanding.	1	+/-
		2	+/-
		3	+/-
		4	+/-
Fruit count	Some training is required to learn how to record the data, for students and researchers this should be easily understandable. However, for local guides, this method might be too complicated for a local guide to understanding.	1	+/-
		2	+/-
		3	+/-
Nature´s Notebook	Training is required for students and researchers on how to perform the field work.	1	-
		2	-
		3	-
Monthly fruit index	Basic skills are required. However, a local guide should be able to record the data after learning how to record the data.	1	+
		2	+
		3	+
BBCH code	Training is required for students and researchers on how to perform the field work.	1	-
		2	-
		3	-
		4	-
		5	-

Sub- question 8: Is the method broadly applicable to tree species with different physiology?		Source	Rating
PanAf	All the sources are broadly applicable to tree species. However, trees with a different physiology are a bit more difficult to observe.	1	+
		2	+
		3	+
		4	+
		5	+
Fruit trail	All the sources are not broadly applicable to all tree species; only certain species are applicable to the method.	1	-
		2	-

		Source	Rating
		3	-
		4	-
Fruit count	All the sources are broadly applicable to most species, although some species might be difficult. .	1	+/-
		2	+/-
		3	+/-
Nature´s Notebook	All the sources are broadly applicable to all tree species.	1	++
		2	++
		3	++
Monthly fruit index	All the sources are not broadly applicable to all tree species; only certain species are applicable to the method.	1	-
		2	-
		3	-
BBCH code	All the sources are broadly applicable to tree species. However, trees with a different physiology are a bit more difficult to observe. to observe.	1	+
		2	+
		3	+
		4	+
		5	+

Sub- question 9: How expensive is the required materials?		Source	Rating
PanAf	None of the sources use expensive materials, only pen and paper are necessary to write down the observations of the phenophases.	1	++
		2	++
		3	++
		4	++
		5	++
Fruit trail	None of the sources use expensive materials, only pen and paper are necessary to write down the observations of the phenophases.	1	++
		2	++
		3	++
		4	++
Fruit count	None of the sources use expensive materials, only pen and paper are necessary to write down the observations of the phenophases.	1	++
		2	++
		3	++
Nature´s Notebook	None of the sources use expensive materials, only pen and paper are necessary to write down the observations of the phenophases.	1	++
		2	++
		3	++

Monthly fruit index	None of the sources use expensive materials, only pen and paper are necessary to write down the observations of the phenophases.	1	++
		2	++
		3	++
BBCH code	None of the sources use expensive materials, only pen and paper are necessary to write down the observations of the phenophases.	1	++
		2	++
		3	++
		4	++
		5	++

Sub- question 10: What are the materials needed for the observations?		Source	Rating
PanAf	For all the sources, only pen and paper are necessary to monitor the phenology.	1	++
		2	++
		3	++
		4	++
		5	++
Fruit trail	For all the sources, only pen and paper are necessary to monitor the phenology.	1	++
		2	++
		3	++
		4	++
Fruit count	For all the sources, only pen and paper are necessary to monitor the phenology.	1	++
		2	++
		3	++
Nature´s Notebook	For all the sources, only pen and paper are necessary to monitor the phenology.	1	++
		2	++
		3	++
Monthly fruit index	For all the sources, only pen and paper are necessary to monitor the phenology.	1	++
		2	++
		3	++
BBCH code	For all the sources, only pen and paper are necessary to monitor the phenology.	1	++
		2	++
		3	++
		4	++
		5	++

Table 6: An overview of all the ratings for the sources of the subject observation procedure.

	PanAf					Fruit trail				Fruit count			Nature's Notebook			Monthly fruit index			BBCH code				
Question	1	2	3	4	5	1	2	3	4	1	2	3	1	2	3	1	2	3	1	2	3	4	5
1	+/-	+/-	+/-	+/-	+/-	+/-	+/-	+/-	+/-	+/-	+/-	+/-	+/-	+/-	+/-	+	+	+	+/--	+/--	+/--	+/--	+/--
2	++	++	++	++	++	-	-	-	-	++	++	-	++	++	++	-	-	-	++	++	++	++	++
3	++	++	++	++	++	-	-	-	-	++	++	++	++	++	NA	--	--	--	++	++	++	++	++
4	-	-	-	-	-	++	++	++	++	-	-	-	-	-	-	+	+	+	-	-	-	-	-
5	+	+	+	+	+/-	--	--	--	--	+	+	--	++	++	++	--	--	--	++	++	++	++	++
6	++	++	++	++	++	+	+/-	+	+	+	+	+	++	++	NA	++	++	++	++	++	++	++	++
7	+/-	+/-	+/-	+/-	+/-	+/-	+/-	+/-	+/-	+/-	+/-	+/-	-	-	-	+	+	+	-	-	-	-	-
8	+	+	+	+	+	-	-	-	-	+/-	+/-	+/-	++	++	++	-	-	-	+	+	+	+	+
9	++	++	++	++	++	++	++	++	++	++	++	++	++	++	++	++	++	++	++	++	++	++	++
10	++	++	++	++	++	++	++	++	++	++	++	++	++	++	++	++	++	++	++	++	++	++	++

Appendix IV Keywords used to search in scientific databases

Table 1 Key words used to search in scientific databases.

Guinea-Bissau Biodiversity	Chimpanzee diet	African rainforest
Pan troglodytes diet	Chimpanzee food availability	Pan troglodytes food availability
Chimpanzee phenology	Chimpanzee phenology Savannah habitat	Savannah fruit phenology
Phenology Savannah	Savannah chimpanzee feeding ecology	Savannah chimpanzee
Fruit abundance	Phenology monitoring	Camera phenology
Phenology protocol	Phenology of tropical trees	Phenology of forest
Feeding ecology Guinea-Bissau	Chimpanzee Guinea-Bissau	Tree phenology
Plant phenology	Phenology seasonality	Fruit phenology
Land surface phenology	Food availability index (FAI)	Fallen fruit
Fruit count	Ripe fruit score (RFS)	Global phenology monitoring
Fruit clusters	Tree seasonality	Digital time lapse phenology
Phenocamers	Digital repeat photography phenology	Phenology of trees
Estimator of fruit abundance	BBCH phenology	Modis
Landsat	Phenology	

Table 2:(scientific) databases used.

Wiley library	Google scholar	Elsevier	ScienceDirect
Website of Chimbo	Wageningen University	Google	Ecosia
Springer	Green-I catalogue	Biotropica	