

Article

## Complexity of Forest Management: Exploring Perceptions of Dutch Forest Managers

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**Abstract:** Challenges of contemporary forest management are frequently referred to as complex. This article empirically studies complexity in forest management decision-making. In contrast to what is often assumed in the literature, this article starts by assuming that complexity does not just consist of an external descriptive element, but also depends on how decision-makers perceive the system at hand. This “perceived complexity” determines decision-making. We used a straightforward interpretation of perceived complexity using two criteria: the number of factors considered and the uncertainty perceived about these factors. The results show that Dutch forest managers generally consider forest management decision-making to be complicated (many factors to consider) rather than complex (many uncertain factors to consider). Differences in sources of complexity confirm the individual character of perceived complexity. The factors perceived to be most relevant for decision-making (the forest itself, the organization’s objective, the cost of management, public opinion, national policies and laws, and new scientific insights and ideas) are generally seen as rather certain, although “complexity reduction” may play a role that can adversely affect the quality of decision-making. Additional use of more open-ended,

forward-looking methods, such as qualitative foresight tools, might enable addressing uncertainty and complexity, and thereby enhance decision-making in forest management to prepare for increasing complexity in the future.

**Keywords:** complicatedness; decision-making; forestry; the Netherlands; uncertainty

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## 1. Introduction

Climate change, stakeholders' value and interest disputes, turbulent timber markets, environmental shocks—these are only a few of the factors that a forest manager has to deal with in day-to-day management. It is therefore not surprising that, in the past few decades, the literature has classified forest management decision-making as complex (e.g., [1]). Mollinga [2] (p. 2), for example, states that contemporary resource management is “a complex phenomenon” that “poses complex problems,” which “few will want to disagree with.” Kohm and Franklin [3] (p. 1) wrote that 21st-century forestry can be defined by “understanding and managing complexity.” Allen and Gould [4] and Ludwig [5] even describe forest management as a typical example of a “wicked problem,” *i.e.*, a problem that is “complex, tricky and thorny” [6] (p. 505) and open ended, preventing separation into a series of less complex and more easily manageable components [7,8]. Current trends also suggest that this “wickedness” will increase over time [9].

The fact that forest management decision-making is of a complex nature is not unique. In many sectors, decision-making is perceived as a complex process: a process influenced by many different factors. Billou *et al.* [10] even call complexity one of the “salient hallmarks of the 21st century.” What makes complexity challenging, especially for forest managers, are the often long-term horizons (related to the production cycles in forests) that they have to take into account. The human capacity for analysis and decision-making is notoriously limited to a certain number of items of information, and grasping the “whole complexity” is simply impossible [11] (p. 8), especially when dealing with such far-off horizons [12]. Nevertheless, the rational paradigm—assuming knowledge of all factors involved in a decision (including the outcomes of all possible decisions) and deduction of the best option by detailed analyses, even in complex situations—is still dominant in forest sciences and forest management. The underlying assumption in this paradigm is that complexity consists solely of an intrinsic property of a system, which exists externally and independently from us [13]. Complexity, in this view, “can be discovered, measured and possibly modelled, manipulated, maintained or predicted” [14] (p. 31). Some authors indicate that decisions based on the rational paradigm can be unsuccessful [15], as inappropriate simplifications are made [16].

The focus of this paper is therefore on another element of complexity: the interaction of a system with other systems or observers that have individual perceptions. In this way it is not possible to regard complexity as simply one property of a system taken in isolation [13,14]. These two elements are a hybrid, as joint properties of a system, and are not necessarily the same [17]. Even if a system can be defined as complex (based on a multiplicity and diversity of factors, interactions, and issues involved), observers can perceive it as not complex, when they do not find the factors and issues of relevance [18–21]. As Casti [22] (p. 149) explained, complexity is as much in the eye of the beholder

as it is in the system itself. Moreover, it is this (inter) subjective perception of a system that forms the basis of one's decision-making [23,24]. As the famous Thomas theorem states, "If men define situations as real, they are real in their consequences" [25] (p. 572). The research of Pregernig [26] illustrates this. He found that the willingness of forest professionals and forest owners to adopt management activities in the field of forest ecosystem restoration depended, to a large extent, on their individual perception of a problem. Joubert and Davidson's research [27] also described how different forestry practices are based on different perceptions of the same situation.

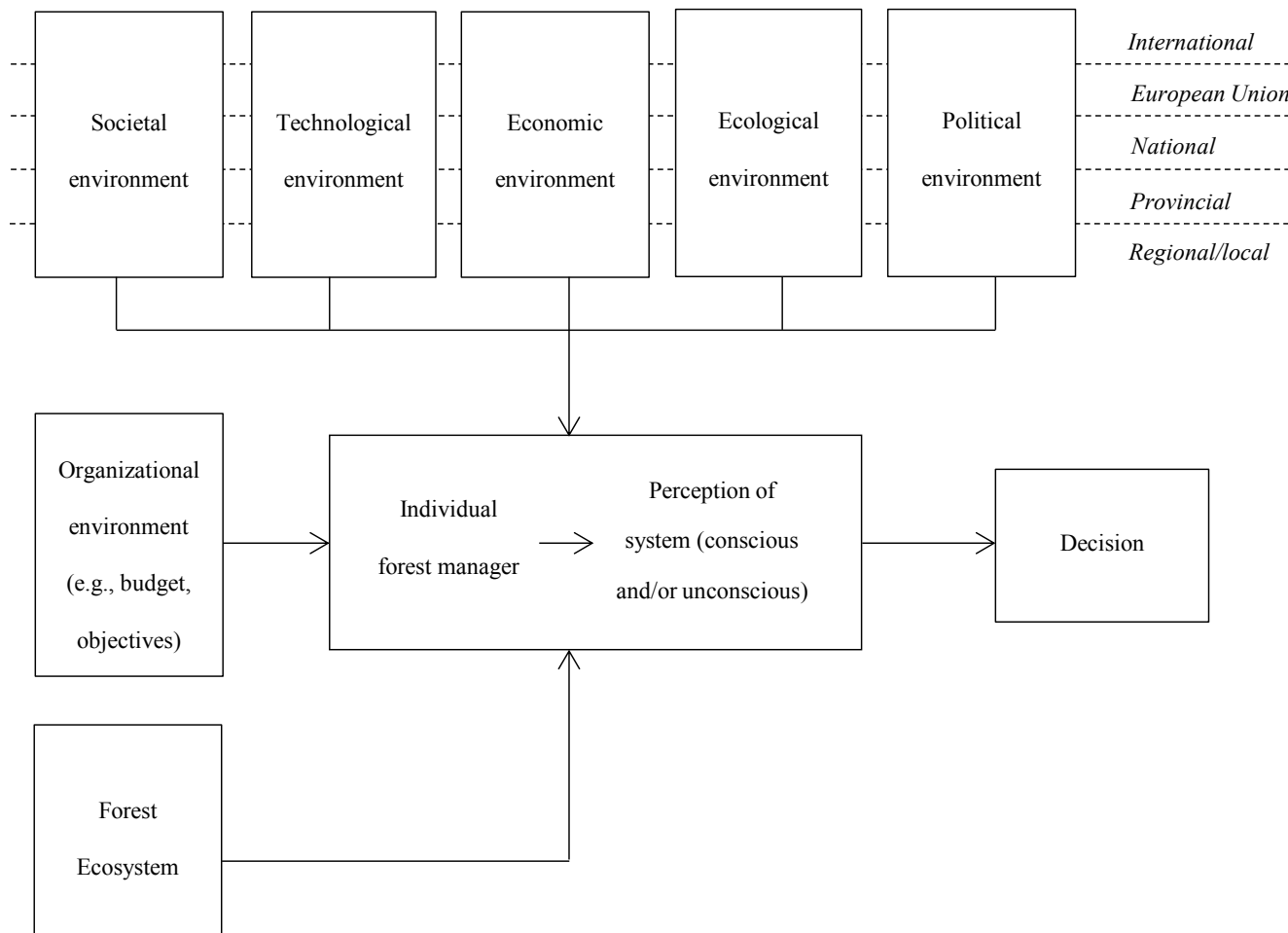
By understanding how a forest manager perceives complexity, more insight is gained into the decisions made in forest management. This is not only of interest for understanding decisions made individually; it will also provide insight for multi-stakeholder processes. The view of "perceived complexity" also implies that a shared understanding of a complex system, and how to come to decisions regarding it, does not necessarily initially exist in decision-making processes [28]. Considering that the involvement of different stakeholders is a major feature of current sustainable forest management, and as a consequence results in the presence of different perceptions, it is essential to gain more understanding of these individual views as they need to be taken into account in stakeholder processes.

So far, in the forestry literature, there has been only limited attention paid to research on perceptions of complexity. Therefore, the aim of this article is to bridge this gap and explore the decision-making situations of forest managers for the complexity perceived. To do this, the following section first provides the theoretical frame describing complexity and decision-making. Next, the research methodology and the results are explained. The final section presents the study's main conclusions and its limitations, and discusses the implications of this study's results.

## 2. Theoretical Background

Though there is a general consensus in the literature that contemporary forest management is a complex issue, the question of what complexity is, is not that clear [29]. As Ruitenbeek and Cartier [30] (p. 10) stated, "complexity itself is a complex topic" and "little agreement yet exists on a precise definition of complexity." Rosen [31] concurs that the views on complexity are as varied as the concept itself. It is because of these many different definitions that Schindwein and Ison [14] decided not to define complexity, but first of all to group the different definitions into two categories: descriptive and perceived. Descriptive complexity, on the one hand, sees complexity predominantly as an "intrinsic property of a certain kind of system, or as occurring in a certain kind of natural and social phenomena" [14] (p. 28). Perceived complexity, on the other hand, relates to a type of complexity in which reality is something constructed and experienced by the observer [14]. Other terms that are used in the literature to describe these two categories of complexity are objective and subjective complexity (e.g., [17]), system and observer complexity (e.g., [32]), and computational and cognitive complexity (e.g., [33]). Often, the two categories were seen as related to two different epistemologies which excluded one another. More recently, however, it has been argued that complexity is not "either ... or ...," but "both ... and ..." [14]. Both types of complexity exist and are closely linked. A system has properties that make it more or less complex in itself and these properties exist independently of the decision-maker in that situation. The observer perceives this system and tries to make sense of it.

As explained by Weick *et al.* [34] (p. 409), this perception (“sensemaking”) turns complexity into a “situation that is comprehended [...] and that serves as a springboard to action” (see Figure 1 for an overview of the relations between the different concepts). To what extent an observer perceives a system as complex is an individual matter as it depends on his experience with the kind of situation, his memory, his knowledge, his emotions, the time available to make the decision, and so forth [17]. Two people, therefore, can perceive a situation completely differently and, based on this, come to different decisions. As we are interested in this direct source of decision-making, we focus solely on perceived complexity.



**Figure 1.** Theoretical framework of external factors possibly influencing decision-making in forest management (only the direct links between the factors and decision-maker are drawn; interrelations between factors are excluded from the research; the sizes of the shapes in the figure are not drawn to scale and thus bear no meaning).

However, while now the focus of the research may be clear, it has to be explored in more detail as the concept of perceived complexity itself also has different connotations [35] and no singular definition exists. In general, perceived complexity seems to refer to the difficulty a person has understanding a system. This is, however, a very broad definition, raising more questions than it can possibly answer, e.g., is a complicated system also a complex one? In order to have a clearer starting point for the research, the conceptualization of (perceived) complexity is based on the interpretation of

Ruitenbeek and Cartier [30]. They combined the dimensions of quantity and uncertainty in their approach to complexity and thus distinguished between simple (few factors, readily understood and predictable), complicated (many factors, but once understood predictable), and complex (many factors, not predictable) systems. An overview of these three types of system is shown in Figure 2. We added a fourth type of system, called chancy, to represent the fourth system that logically follows from the two dimensions used by Ruitenbeek and Cartier [30]. We use this term following several authors (e.g., [36,37]) who use it to describe a system with few elements that are not predictable.

<b>Uncertainty</b>	<i>High</i>	CHANCY	COMPLEX
	<i>Low</i>	SIMPLE	COMPLICATED
		<i>Low</i>	<i>High</i>
		<b>Number of factors</b>	

**Figure 2.** Types of systems distinguished, based on the dimensions of number of factors involved and level of uncertainty (based on and adapted from [30]).

Ruitenbeek and Cartier [30] acknowledge that the interpretation of something being understandable and predictable is also a relative concept: it is different for different people. In other words, complexity can be considered as relating to the number of factors and the uncertainty about these factors as experienced by the forest manager in his decision-making. This definition gives a clear remit for this research to explore the perceived complexity as a basis for forest managers' decision-making using only two criteria, *i.e.*, the quantity of factors considered and the uncertainty perceived about these factors.

When (a) the quantity of factors considered by the forest managers in their decision-making and (b) the uncertainty they perceive about these factors are determined, the extent to which a forest manager perceives his day-to-day decision-making to be complex or not, can be understood. However, not only are the number of factors and the perceived uncertainty relevant, but those factors that are the source of the perceived complexity also need to be identified. Two forest managers can both experience a situation as complex, but the factors that are perceived as the source of the complexity can be different for both. This in turn can lead to different decisions in the same situation.

From previous research, it can be concluded that different types of factors can have a wide range of effects on forest management decision-making (e.g., [38,39]). These factors can be both internal to the forest manager and external to him [40]. Internal (or personal) factors relate to the characteristics of the forest manager himself [38]. Several studies have shown that factors like age, socioeconomic status, gender, type of ownership, and cognitive abilities influence decision-making (e.g., [38,41,42]). External factors relate to the environment of the forest manager, or, as Duncan [43] (p. 314) explained it, encompass “the totality of physical and social factors that are taken directly into consideration in the decision-making behavior of individuals.” This research is particularly interested in how forest

managers perceive their external decision-making situation, and, consequently, the nature and size of the dataset did not allow for analysis of the internal factors.

The external factors influencing forest management are distinguished in three different categories:

- the ecosystem—characteristics of the forest that can influence decision-making, e.g., size, location, and age of the forest;
- the organization—the organizational frame that is of importance for individual decision-making, e.g., the set of management objectives, and rules and regulations within the organization;
- the external environment—factors surrounding the manager, the organization, and the ecosystem.

The last category is sometimes divided into five subcategories, summarized by the acronym STEEP: *i.e.*, social (e.g., public support for nature), technological (e.g., available harvesting techniques), economic (e.g., timber prices), environmental (e.g., climate change), and political (e.g., forest laws), and has a spatial scale (varying from the local to the international level) [44].

Figure 1 gives an overview of these external factors, including their spatial scale, and their relation to forest management decision-making. This framework was the basis for the data collection from the forest managers regarding:

- the number of factors relevant to their decision-making;
- the number of factors perceived to be uncertain;
- which factors specifically are relevant to their decision-making; and
- which factors specifically are perceived as uncertain.

Based on these data, more detailed conclusions on the extent and type of complexity perceived by forest managers can be drawn.

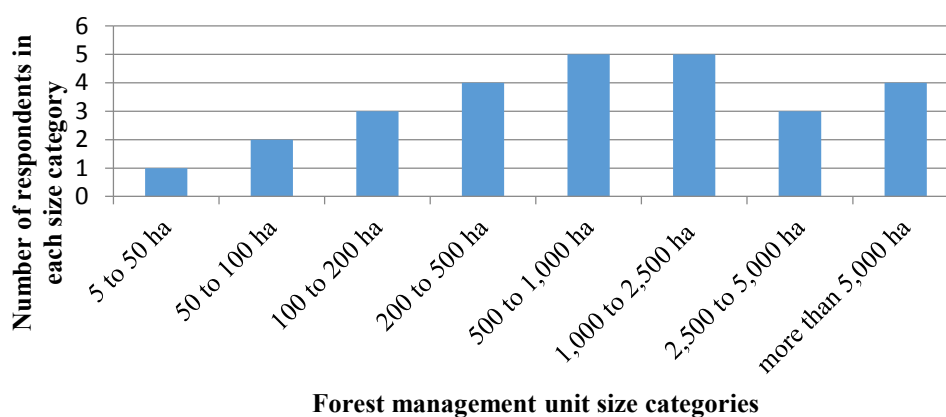
### 3. Materials and Methods

The empirical data used in this research were collected in the frame of the European Union (EU) project INTEGRAL (Future Oriented Integrated Management of European Landscapes). This is a collaboration project of universities and research institutes that aims to develop solutions for better forest and landscape management in Europe [45]. For this research project, a survey was carried out in 20 different case study areas throughout Europe to map the most important factors influencing forest management. This paper draws on (part of) the data gathered for the Dutch case study.

Semi-structured, face-to-face interviews were carried out. In total, 30 Dutch forest managers were approached for an interview, 28 of whom agreed to participate. In the end, 27 forest managers participated. An overview of the characteristics of the sample of forest managers is given in Table 1 and Figure 3.

**Table 1.** Characteristics of the sample of forest managers ( $N = 27$ ).

Sample Characteristic	Value(s) in This Sample
Ownership Situation	14 Private (52%) and 13 Public (48%)
Gender	27 male (100%), 0 female (0%)
Educational background	23 forest/nature (85%), 4 other (15%)
Educational level	6 university (22%), 12 higher professional (45%), and 9 lower professional (33%)
Experience as manager (in years)	
Mean	22.69
Minimum	6
Maximum	37
SD	10.81

**Figure 3.** Distribution of the sample of forest managers based on the size of forest management unit they manage ( $N = 27$ ).

An important point to note is that we acknowledge that the sample is not a random sample taken from a well-framed population. The respondents together manage about 53,200 ha of forest, which is about 15% of the total Dutch forested area [46], and therefore the results are descriptive for this specific sample only. In order to cover important characteristics of Dutch forest management within the sample, the managers were selected intentionally, following the approach of Hoogstra and Burger [47], based on the following two categories:

(a) Ownership category

In the Netherlands, forests are either publicly (*i.e.*, by the state, administrative units of the public administration, or institutions or corporations owned by the public administration) or privately owned (*i.e.*, by individuals, families, communities, private co-operatives, corporations and other business entities, private religious and educational institutions, pension or investment funds, NGOs, nature conservation associations, and other private institutions). At present, about 50% of Dutch forests are publicly owned [46]. The sample of respondents in this paper reflects this distribution (see Table 1, row 1).

(b) Forest property size

The forest areas publicly and privately owned differ enormously with regard to their size, varying from 0.5 ha up to 90,000 ha (the latter subdivided in different management units) [46]. Little is known,

however, about the large number of small-scale forest owners (smaller than 5 ha) who are not officially registered. As these small-scale forest owners are difficult to reach, this category of forest property size is not included in the research. The size of the management units managed by the respondents range from the smallest to the largest category (see Figure 3), thereby including a range of management unit sizes.

The semi-structured interviews included, among others, the following set of questions:

- general questions about the respondent and the management unit;
- questions related to the factors influencing day-to-day forest management decisions;
- a ranking exercise, in which the respondents were handed a list of factors, categorized according to the categories as distinguished in the theoretical framework (see Figure 1), and asked to select five factors that influence their decision-making the most and to rank these from most influential to least influential, and
- questions related to the uncertainty about factors perceived by the respondent.

All interviews were conducted by the same researcher, visiting the respondents at either their homes or offices. All interviews were recorded and transcribed. The transcription was sent to the respondent and checked for irregularities.

## 4. Results

In the theoretical framework complexity is defined as relating to (a) the number of factors (quantity) and (b) the uncertainty about these factors as perceived by a forest manager in his decision-making. Section 4.1 first describes the results of both elements separately and then discusses the elements combined to classify the complexity perceived by forest managers, using Figure 2. Subsequently, Section 4.2 discusses in more detail the source of the complexity—the combination of perceived relevance and uncertainty of specific factors in relation to the respondents' decision-making.

### 4.1. Perceived Complexity

#### 4.1.1. Number of Factors

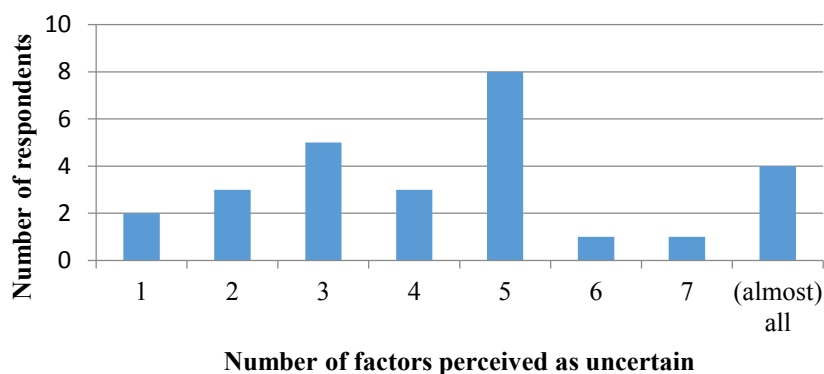
Most of the respondents found it difficult to determine how many of the external factors influence their decision-making. This is mostly an unconscious process. As one of the respondents (manager of a private forest estate, 1200 ha forest) stated, "I am thinking about it during this interview and this exercise, but it is not something I do in my day-to-day work." Most of the respondents, faced with the list of factors, indicated that, in one way or another, they take most of the factors in the list into account when making a decision: "It is sort of a mix when you make a decision" (manager of a nature conservation organization, 1250 ha forest) and "Everything is part of our forest management" (manager of a municipal forest, 1200 ha forest). One respondent (manager of the National Forest Service, 2500 ha forest) saw the broadness of the factors involved as a strength of a forest manager: "Specialization is good in an organization, but you need to have people who have the overview [...], I am able to connect the different things." Another respondent (manager of a private forest estate, 170 ha



forest) said that “Everything plays a role somehow, and that is exactly the fun part of it, you weigh all the different things and find a solution.”

#### 4.1.2. Uncertainty Perceived by Forest Managers

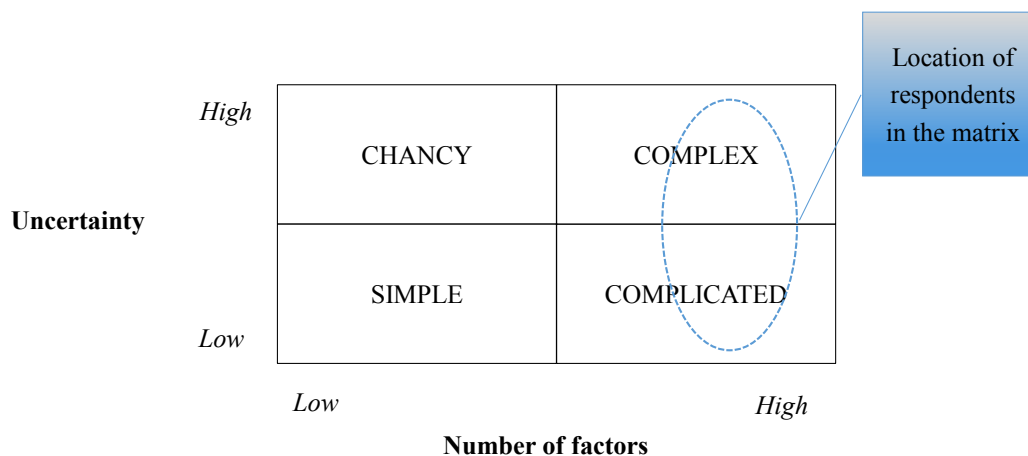
When asked which of the factors the respondents perceive as uncertain, four respondents indicated that they perceive all factors to be uncertain. One of these four added “except the ecology” (manager of a nature conservation organization, 1250 ha forest) and another stated “except the objectives of the organization” (manager of a nature conservation organization, 3500 ha forest). The number of factors perceived by the other 23 respondents as uncertain varied from one to seven per person (see Figure 4).



**Figure 4.** Number of factors perceived as uncertain by the respondents ( $N = 27$ ).

#### 4.1.3. Classifying Perceived Complexity

The answers of the respondents on the number of factors relevant for decision-making and the uncertainty perceived were combined in order to determine the perceived complexity of respondents (see Figure 5). All respondents indicated that they deal with a vast range of factors in their decision-making, which places them on the right-hand side of Figure 5. However, the perceived uncertainty about these factors differed within the group of respondents: from almost non-existent to almost ever-present uncertainty.



**Figure 5.** Classification of the respondents’ perceived complexity of their decision-making situation based on interview results.

For the extremes in responses (almost non-existent and almost ever-present uncertainty), the classification is clear: on the right hand side in the lower quadrant (complicated system) and in the upper quadrant (complex system), respectively, of Figure 5. As it is difficult (if not impossible) to determine exactly where the numerical boundary between a complicated and a complex system lies—every quantitative boundary would be an arbitrary one—we prefer not to classify the perceptions of the other respondents as either complicated or complex. Instead we thus far conclude that forest managers' perception of their decision-making situation ranges between complicated and complex systems.

## 4.2. Source of Complexity

### 4.2.1. Factors Considered to Be Relevant

The respondents were asked to name the five most relevant factors for their decision-making and rank them. In total, 21 different factors were mentioned by the respondents. Table 2 lists each factor mentioned, the category of the theoretical framework it is part of, the number of times it was mentioned (independent of the ranking), and the weighted average ranking (based on the total ranking score (summation of rankings given, with a score of 1 if a factor was ranked as number one, a score of 2 if it was ranked second, *etc.*) and the number of times it was mentioned).

**Table 2.** List of factors the respondents indicated as most relevant to their decision-making ( $N = 23$ ).

Factor	Category of Theoretical Framework	Number of Times Mentioned	Weighted Average Ranking
The forest itself	Object	21	1.9
Objectives of the owner/organization	Organization	19	2.2
Cost of management	Economic	14	3.6
Public opinion	Societal	11	3.7
National policy and laws	Political	9	4.1
New scientific insights and ideas	Societal	9	4.3
Timber market/timber prices	Economic	8	4.0
Available budget	Organization	7	4.2
Subsidies/incentives	Economic	7	4.4
Provincial/regional policy and laws	Political	7	4.4
Income from non-timber products	Economic	6	4.5
EU policy and laws	Political	5	4.4
Insects, pests, and diseases	Ecological	4	4.8
Availability of time	Organization	3	5
Certification standards and criteria	Economic	2	5
Availability of labor	Economic	1	5
Available technologies	Technological	1	5
Weather conditions (e.g., frost, drought)	Ecological	1	5
International debates	Societal	1	5
Climate change	Ecological	1	5
Results of monitoring	Ecological	1	5

EU: the European Union.

As can be seen in Table 2, the top five of most mentioned factors consists of:

- the forest itself (mentioned 21 times, average ranking 1.9);
- objectives of the owner/organization (mentioned 19 times, average ranking 2.2);
- cost of management (mentioned 14 times, average ranking 3.6);
- public opinion (mentioned 11 times, average ranking 3.7), and
- national policy and laws (average ranking 4.1) and new scientific insights and ideas (average ranking 4.3) on a joint fifth place (both mentioned 11 times).

Of this top five, the first two stood out in the analysis. Not only were they mentioned more often than the other factors, they were also considered as the most relevant. When asked for the most relevant factors to their forest management, several respondents mentioned that it all centers around the object of decision-making (“the forest itself”), “the forest is number one” (manager of a nature conservation organization, 1000 ha forest). One respondent (manager of a private forest estate, 390 ha forest), however, stated that he would like to see that his decision-making *was* about the forest, but “this is only the case when you are completely detached from the external world and you can do whatever you want, which is just not the case and also possibly not the best for the forest.” Another respondent (manager of the National Forest Service, 7000 ha forest), said: “Honestly, we allow ourselves to be influenced relatively strongly by the external environment: by the public, by the demand for certain products, by the market. [...] And by the politicians.”

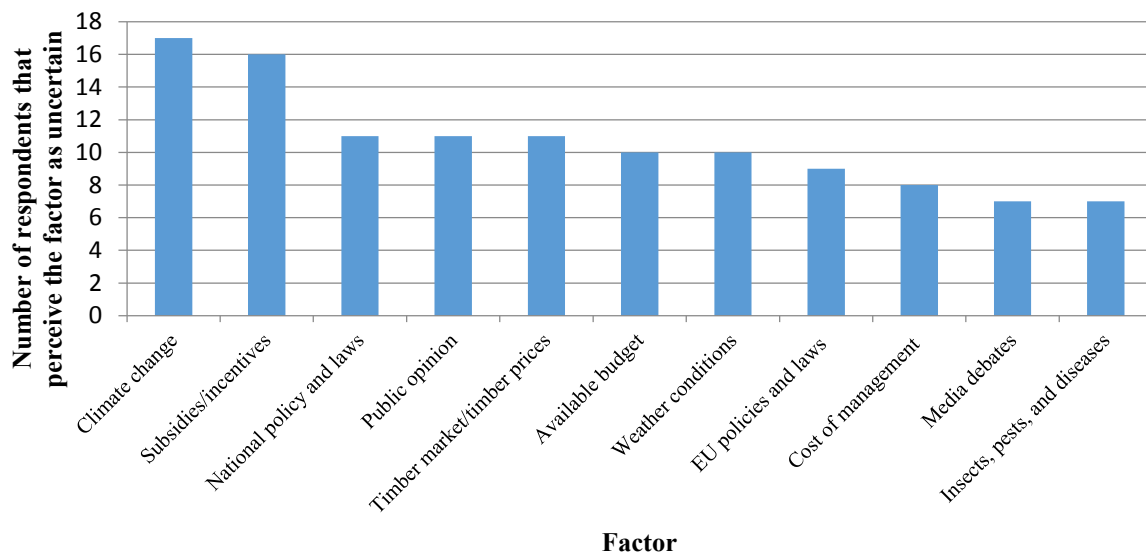
Respondents who mentioned the “objective of the owner/organization” experience this factor in different ways: restrictive, e.g., “they are imposed on me and I have to follow them” (manager of a municipal forest, 280 ha forest); a reason to stay with the organization or not—“If I wouldn’t agree with them, I would leave” (manager of the National Forest Service, 7500 ha forest); but this same respondent also sees this factor in a more flexible sense: “The objectives are a general framework that flesh out ‘on the forest floor’. That translation is my responsibility: I keep the objectives in the back of my mind when I am in the field.” Or, as a manager of a private forest estate (400 ha forest) said: “There is flexibility, given the varying conditions at different times, but decisions should never violate the main objectives.”

#### 4.2.2. Factors Considered to Be Uncertain

An overview of the specific factors perceived as uncertain can be found in Figure 6. Though many different factors are considered to be uncertain, two factors feature, *i.e.*,

- climate change, and
- subsidies/incentives,

which are mentioned by more than half of the respondents. Regarding “climate change,” the classification of this factor as particularly uncertain is not that surprising considering the ongoing discussion in the forest and nature management sector on the possible, but not yet known, effects of it. The recent extraordinary budget cuts of the Dutch government in, among other things, subsidies for forest and nature management, which came as a surprise to the sector, might be an explanation for the relatively high level of perceived uncertainty about “subsidies/incentives.”



**Figure 6.** Factors perceived as uncertain by the respondents (only those factors are listed that were mentioned by more than five respondents) ( $N = 27$ ).

#### 4.2.3. Combining Relevance and Uncertainty

To gain more understanding about the connection between the relevance of different factors for decision-making and the uncertainty about these factors, the perceived relevance of factors for decision-making was linked with the uncertainty perceived about these factors. This, what we called the “complexity score,” indicates the number of times a respondent indicated a factor as being relevant and at the same time uncertain, normalized between the values 0 and 1 (see Table 3), e.g., “national policy and laws” was mentioned as relevant as well as uncertain by four respondents; the complexity score therefore is  $4/23 = 0.17$ . Table 3 lists the factors mentioned in the ranking exercise, the category of the theoretical framework it is part of, the number of times it was mentioned in the ranking exercise, the number of times it was mentioned as uncertain, and its complexity score.

Table 3 first of all shows that several factors considered to be the most relevant are not considered to be uncertain at all. This is most prominently seen in the factor “the forest itself,” which was considered to be very relevant by most of the respondents (mentioned 21 times), but none of these respondents at the same time saw this factor as uncertain (therefore a complexity score of 0). The same applies to several factors that were perceived as very uncertain but were not considered the most relevant. “Climate change” forms an excellent example: this factor was perceived to be uncertain by many of the respondents (mentioned 12 times), but only one at the same time mentioned it as relevant. A possible explanation could be that forest managers (can) take only those factors into account of which they are most certain. As one of the respondents (manager of the National Forest Service, about 2700 ha forest) stated: “You cannot take these kinds of factors into consideration as they are uncertain.” This might be “the only way to make sense” [12] (p. 84) of the complexity they are faced with.

**Table 3.** Factors the respondents indicated in the ranking exercise ( $N = 23$ ). The category of the theoretical framework each factor is part of, the number of times it was listed as top 5, the number of times it was mentioned as uncertain, and its complexity score are given.

Factor	Category of Theoretical Framework	Relevance	Uncertainty	Complexity Score
National policy and laws	Political	9	7	0.17
Timber market/timber prices	Economic	8	7	0.17
Available budget	Organization	7	6	0.17
Objectives of the owner/organization	Organization	19	4	0.13
Cost of management	Economic	14	4	0.13
Public opinion	Societal	11	7	0.13
Subsidies/incentives	Economic	7	12	0.09
EU policy and laws	Political	5	5	0.04
Climate change	Ecological	1	12	0.04
The forest itself	Object	21	1	0
New scientific insights and ideas	Societal	9	0	0
Provincial/regional policy and laws	Political	7	1	0
Income from non-timber products	Economic	6	2	0
Insects, pests, and diseases	Ecological	3	3	0
Availability of time	Organization	2	1	0
Certification standards and criteria	Economic	2	0	0
Availability of labor	Economic	1	1	0
Available technologies	Technological	1	2	0
Weather conditions (e.g., frost, drought)	Ecological	1	6	0
International debates	Societal	1	2	0
Results of monitoring	Ecological	1	0	0

Overall, Table 3 also shows that the complexity scores of the factors are not very high. The maximum score of a factor is 0.17, but the majority of factors have a score of 0 (while in theory the maximum score could be 1, when all respondents mentioned a factor as relevant as well as uncertain). This means that the respondents perceive the majority of factors as either relevant or uncertain, but as both at the same time only in a small number of cases. We can therefore conclude that Dutch forest managers generally consider forest management decision-making as being “complicated” (many factors to consider) rather than “complex” (many uncertain factors to consider). The factors they perceive to be most relevant for decision-making (like the forest itself, the organization’s objective, and the cost of management) are generally not seen as very uncertain. However, there is not much agreement among the respondents on the main sources of complicatedness. The sources shared by some of the respondents are quite diverse: policy (rules, regulations, taxes), financial (budget) and economics (timber market), the organization (goals, objectives), and society (public opinion).

## 5. Discussion and Conclusions

The challenges of forest management are frequently described as being increasingly complex, and forest managers are expected to cope with that complexity. However, the extent of the complexity and the underlying sources of complexity as perceived by the forest managers have not been studied so far. The objective of this paper was, therefore, to shed light upon the question of how forest managers perceive their, in theory, highly complex environment. To do this, we used a rather straightforward interpretation and measurement of what perceived complexity is. Structuring our measurement of complexity in this manner gave a basis for analysis, and our results clearly show that forest management decision-making is not a simple task. While from a descriptive complexity perspective the decision-making environment of forest managers can be seen as complex, many forest managers perceive their decision-making environment rather as complicated.

The more detailed analysis of the relation between the two elements of our complexity concept (quantity of factors and level of uncertainty) revealed more differences than similarities in sources of complicatedness as perceived by the respondents. This again confirms the individual character of perceived complexity and, moreover, the relevance of internal factors of the forest manager on decision-making (although the latter were not empirically assessed in this study). It, however, also shows the importance of gaining insight into the sources of complexity: not only to understand individual decision-making in forest management as a result of a certain perception, but also to achieve effective multi-stakeholder processes. Failing to address the simultaneous presence of different perceptions may result in ambiguity, e.g., what is problematic and what is not, what the boundaries of the problem are, what really is at stake, who should be involved or not, and what the right decision is [48]. We therefore recommend that, in the problem-structuring phase of a decision-making process, different perceptions of complexity are acknowledged in an attempt to come to a shared understanding of the subject and, in that way, improve decision-making in forest management [49,50]. As Brugnach *et al.* [48] stated, coping with this diversity means recognizing the different views at play.

The findings of our research point towards complicatedness in forest management decision-making, rather than complexity. Forest managers might, consciously or unconsciously, reduce complexity by excluding those factors that they are uncertain of from their decision-making (such as “climate change”). Simplification is very functional in the sense that it “reduces [...] uncertainty, makes decisions easier, and allows easy, logical explanations of those decisions. It “captivates the mind” [15] (p. 17). This is in sharp contrast to a situation of complexity, which confuses and leads to decisions based on, e.g., experiences and intuition, which in turn are very difficult to explain to other people involved. It is human nature to try to avoid confusion and to make seemingly logical, rational decisions, even though it can be questioned whether decisions made using this approach are optimal. On the other hand, the “inevitable consequence of complexity” is that “there is no right answer to a complex problem, so every decision will be wrong in some way” [51] (p. 27). Stepping out of the comfort zone of simplification and acknowledging and embracing complexity, however, increases the capacity to expect and adapt to unpredicted outcomes and surprises [52], which is essential in forest management [53–56].

This way of thinking is much easier said than done, especially in a sector where the rational paradigm is still alive and kicking. However, as this study shows, perceived complexity differs from

person to person, and since (i) the involvement of different stakeholders is a major feature of current sustainable forest management; (ii) complexity or complicatedness is an intrinsic part of forest management; and (iii) it is said that complexity will only increase in future [9], it is evident that this multitude of perceptions can no longer be denied or ignored in decision-making processes and in the tools and communication pathways used. Additional use of more flexible, open-ended, forward-looking methods, such as the Multi-criteria Approval method, Stochastic Multi-criteria Acceptability Analysis (SMAA), Delphi method, or qualitative foresight tools, in which uncertainty, complexity, and different perceptions are incorporated, might enable us to address these issues [56–62]. These might enable forest managers to include uncertain factors in their decision-making and grasp complexity, rather than to exclude factors and thereby reduce the situation to complicatedness. Qualitative scenarios, for instance, when developed in a participatory manner, allow for inclusion of and discussion about a multitude of factors, perceptions, stakes and values, both in time and space. In this manner, decision-making in forest management would be enhanced so as to prepare for increasing complexity in the future [9].

In conclusion, this research has empirically shown the complicated, if not complex nature of forest management. This study has shown that investigating the individual perceptions of complexity is an interesting line of further empirical research. Future research should focus on the importance of how actors cope with complexity, how different perceptions of complexity affect a multi-stakeholder decision-making process, and how to deal with different perceptions in such processes. Insight into these topics will aid either arriving at a shared understanding of a system that is the subject of a decision or, at least, increased awareness of a multitude of perceptions involved to “learn our way towards purposeful action that is situation improving” [14].

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### **Author Contributions**

Jilske O. de Bruin and Marjanke A. Hoogstra-Klein designed the study. Jilske O. de Bruin collected and analyzed the data and wrote the paper. Marjanke A. Hoogstra-Klein, Frits M.J. Mohren, and Bas J.M. Arts contributed to writing the paper.

### **Conflicts of Interest**

The authors declare no conflict of interest.

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