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Multi-stakeholder analysis of fire risk reduction in a densely populated area in the Netherlands: a case-study in the Veluwe area

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Abstract

Reducing the climate change-induced risk of uncontrollable fires in landscapes under nature management, with severe impacts on landscape and society, is particularly urgent in densely-populated and fragmented areas. Reducing fire risk in such areas requires active involvement of a wide diversity of stakeholders. This research letter investigates stakeholders' needs with regard to fire risk reduction in the Veluwe area in the Netherlands. This densely populated landscape is a popular tourist attraction, and it is one of the most fire-prone landscapes of the Netherlands, with abundant fuels and human ignition sources. We draw upon seven in-depth qualitative interviews with key stakeholders in the Veluwe area, which we situate in a wider review of existing literature. Our analysis demonstrates that the rising incidence of uncontrollable fires poses four types of new challenges to these stakeholders in the Veluwe area. First, stakeholders express the need to reshape existing policy tools and develop novel ones that create synergies between existing policy-priorities (e.g. biodiversity conservation) and fire risk reduction. Second, stakeholders argue for a critical rethinking of the value of landscapes in society, and the diverse roles that fire may play in landscape management research and practice. Third, developing such policy tools requires new modalities and platforms for multi-stakeholder and multi-level collaboration, which are currently lacking because the current and expected future risk of uncontrollable fire is unprecedented. And fourth, the development of effective policy tools requires new knowledge that is interdisciplinary, sensitive towards the local social and ecological characteristics of the area, and which approaches current fire risk challenges and their possible solutions dynamically. While our stakeholder analysis is specific to the Veluwe area in the Netherlands, our findings are also likely to be relevant to other fire-prone nature areas in fragmented landscapes, particularly in Northwestern Europe.

1. Introduction

The risk of uncontrollable fires occurring in landscapes under nature management is increasing in the context of anthropogenic climate change [1], with devastating consequences, including loss of livelihoods and human health [1, 2], biodiversity loss [3, 4] and loss of cultural heritage [5]. European landscapes are often densely populated and highly fragmented, and many European countries have developed their own set of landscape and fire management strategies [6]. In these densely populated

areas under nature management, reducing fire risks is both urgent—as the consequences are particularly severe [7] and challenging, as the work cuts across diverse domains and involves many diverse stakeholders but the number of stakeholders involved is large and diverse who each relate differently to the landscape [8].

The Veluwe area in the Netherlands is an example of a densely populated landscape under nature management. Historically, the risk of uncontrollable fires in this region has been low [9]. With climate change and the more frequent occurrence of extreme droughts, the Veluwe is becoming more vulnerable to fire [10–15]. Several fires have occurred across the Netherlands in recent years, including the 200 ha Meinweg fire in 2018 [16] and the 710 ha Peel fire in 2020 [17] fires which are among the largest ever recorded in the Netherlands. Reducing the risk that such fires occur presents policy-makers with the challenge of evaluating measures' trade-offs between fire risk reduction and a wide variety of other landscape management priorities (e.g. biodiversity conservation, water management, etc) [18]. Furthermore, these measures cut across the responsibilities and priorities of a diversity of stakeholders, including land owners, land users, local and national government authorities, water authorities and fire brigades [8, 19]. The issue of fire risk reduction has gained traction among stakeholders in and around the Veluwe, and stakeholders are in search of an effective and integrated approach. This research letter thus asks: what do stakeholders in the Veluwe area need in order to reduce the risk of uncontrollable fires? And what are the implications thereof for future research on fire risk reduction strategies?

As understanding and addressing elevated fire occurrence in fragmented landscapes in Northwestern Europe cuts across disciplinary boundaries, this study is part of an interdisciplinary project in which we integrate insights and methods from various fields including climate science, environmental sciences, cultural geography, public policy and governance, and science and technology studies. As a result, this letter presents findings that are relevant to the wide variety of academics concerned with the relationship between climate change, fire risk reduction, landscape management and policy, and wider human-landscape interactions.

2. Methods and approach

2.1. Methodology

We conducted seven in-depth semi-structured qualitative interviews with key stakeholders of the Veluwe area (table 1). When relevant, we complement interview statements with insights from grey and scientific literature on fire risk reduction measures and their potential trade-offs with different landscape management priorities.

2.1.1. Interviewee selection

Through our interviewee selection, we aimed to maximise diversity with regard to organisations' responsibilities in the Veluwe area, including bodies of government (the Ministry of Agriculture, Nature and Food Quality, Gelderland Provincial Government and the Water Board 'Valley and Veluwe'), public institutes responsible for public safety (the Safety Regions 'North & East Gelderland' and 'Gelderland Central' and the National Institute for Public Safety), and land managers and owners (State Forest Management). From each organisation, we selected interviewees working on fire risk reduction in landscapes under nature management at a strategic level—e.g. policy advisors, managers, project leaders etc.

2.1.2. Interview process and questions

Semi-structured interviews are considered an effective method to explore an interviewee's thoughts about a particular topic—in this case, stakeholders' needs with regard to fire risk management [20]. During a semi-structured interview, a researcher asks informants open-ended questions, based on an predetermined interview guide: a set of questions that were to be answered during each interview (included in supplementary S.3) [20]. During the interview, we asked relevant follow-up questions to ensure sufficient depth of understanding of stakeholders' points of view with regard to each of the interview guide's questions. Each interview was conducted by at least two authors, and lasted between 60 and 90 min.

2.2. Data analysis

The interviews were transcribed and analysed on the basis of open coding, followed by axial coding [21]. Open coding allowed for identification of all relevant themes, axial coding for the identification of interrelationships between the themes. The codebook that emerged from the first round of coding is displayed in figure 1. This codebook was discussed with all authors who had been involved in interviews. This resulted in a number of changes. 'Revaluing fire' was replaced by 'revaluation', and the codes 'fire', 'biodiversity conservation' and 'heritage' were added under 'revaluation'. The codes 'better measures' and 'better policy-instruments' were analysed in relation to enabling a specific type of measures. The code 'actors' responsibilities' was removed (upon closer scrutiny, we realized that interviewees only spoke about actors' responsibilities outside the context of collaborative governance in the current situation) while the code 'collaborative governance' was enriched with 'place-based governance' and fine-tuned towards identifying motivations to call for such forms of governance. Finally, the code 'knowledge-gaps' was split into four types of knowledge gaps. The revised codebook was tested and used to re-code all interviews, and is displayed

Table 1. Overview of interviewed key stakeholders of the Veluwe landscape.

Actor	Responsibility in the Veluwe	Role of interviewee
Staatsbosbeheer (State Forest Management)	Large landowners and land manager, performs practical day-to-day landscape management.	Policy advisor safety and fires in areas under nature management
Gelderland Provincial Government	Legislation and subsidy schemes, which steer landscape managers' practices.	Two interviewees: (a) policy advisor environmental planning, focused on areas under nature management; (b) policy advisor nature and landscape, focused on nature restoration and invasive species
Ministry of Agriculture, Nature and Food Quality (LNV)	Developing national policies and legislation on biodiversity and conservation, in part based on European Union policies.	Strategic policy advisor on fire risk reduction
Water Board 'Valley and Veluwe'	Managing surface and groundwater levels (preventing floods) and water quality. Recent focus on drought prevention and mitigation.	Technical manager water management and drought prevention
Safety Region 'North & East Gelderland'	Fire suppression and management, stresses risk reduction of uncontrollable fires.	Two interviewees: (a) advisor fire prevention measures in landscapes under nature management; (b) project leader fire prevention in the Veluwe
Safety Region 'Gelderland Central'	Fire suppression and management, stresses risk reduction of uncontrollable fires.	Project leader fire prevention in the Veluwe
National Institute for Public Safety (NIPV)	Advisory body for the Safety Regions.	Two interviewees: (a) national coordinator of fire management in areas under nature management; (b) researcher fires in landscapes under nature management.

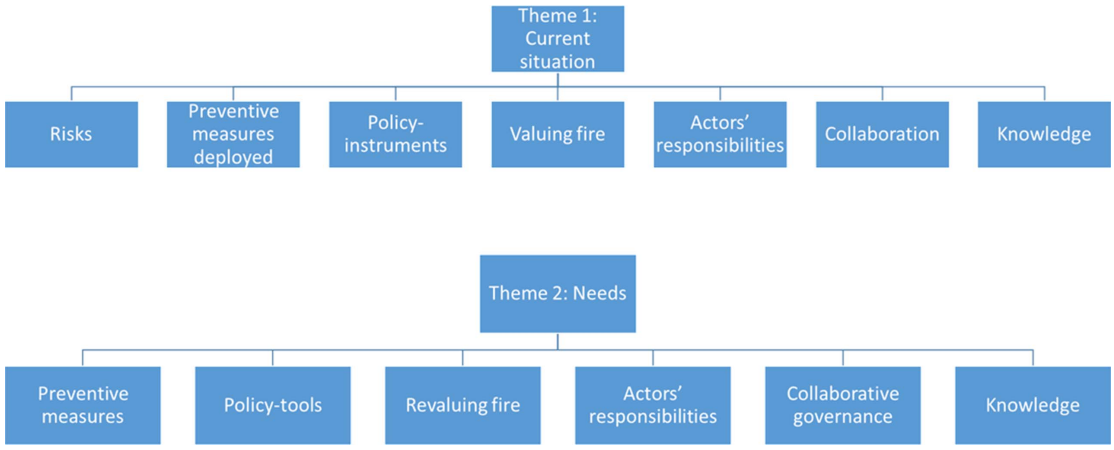

Figure 1. Initial codebook.

in figure 2. While writing the paper, we undertook the final analysis step, namely identifying cross-connections between codes pertaining to different subthemes. Throughout the text below, we indicate in-text on which interviews we draw (e.g. 'According to our interviewee from the ministry of LNV, …').

2.3. Conceptual foundations

In this paper we use the term *landscapes* under nature management to reflect our position that humans and their environments always shape each other [22]. Most literature would refer to 'nature' or 'wildlands', while we understand these terms as rooted in the idea that there is a 'wild' nature outside human influence [23, 24]. With anthropogenic climate change impacting every corner of the globe, and particularly in an area like the Veluwe, it makes little sense to separate the 'human' from the 'wild': the Veluwe landscape is the result of intensive interactions between humans and the landscape over the course of many centuries. Furthermore, we deploy the term *fires* rather than wildfires, because the latter concept carries the same connotations as wilderness. This is problematic because human engagement with the landscape plays crucial roles in when, how and what fires take place [25].

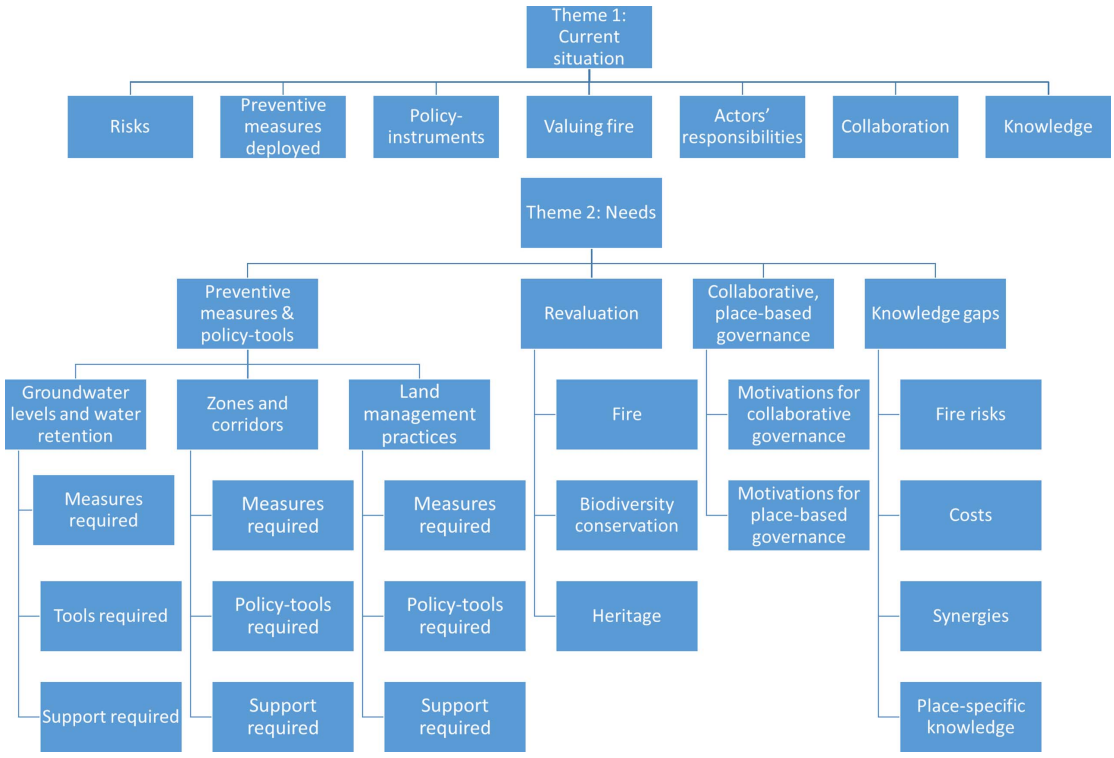

Figure 2. Final codebook.

3. The Veluwe area

Our study domain included the forests and semi-natural area of the Veluwe in the Province of Gelderland, The Netherlands. The Veluwe is characterized as the product of intense interactions between humans and topography, soils, vegetation and animals among others. During the warmer periods that followed the last ice age, prehistoric humans used the Veluwe, which was covered with forests, for hunting, farming and grazing. As it was a rather densely populated area, these forests disappeared almost entirely [26]. The forests returned when most people left this landscape towards the end of the Roman era. During the middle ages, intensive agricultural use of the landscape made most of the forest disappear again, resulting in a patchy heathland landscape with small settlements. Only in the 20th century were large parts of the area planted with coniferous trees for wood production [26]. The area does not have a history of significant fires [12].

Today, the Veluwe covers approximately 90 000 ha of largely connected broadleaved, needleleaf, and mixed forests, grasslands, and heathlands that are enclosed by built-up area and infrastructure (figure 3(b)). The forests are dominated by European beech (*Fagus sylvatica*), Japanese larch (*Larix kaempferi*), Douglas fir (*Pseudotsuga menziesii*), Scots pine (*Pinus sylvestris*), and Norway spruce (*Picea abies*) [27]. The zoning design influences the accessibility of the Veluwe area to different groups (e.g. private property, military bases, areas under intense nature protection, etc) (figure 3(c)).

4. Results: stakeholders' needs

4.1. Measures and policy-tools

Box 1

Stakeholders' needs with regard to improving currently implemented measures centre around revaluing fire, nature conservation and risk governance (section 4.2), better governance (section 4.3) and knowledge (section 4.4). Fire risk reduction measures 'changing publics' use of the area' and 'prescribed burning' are controversial and less popular.

Our interviewees mentioned a variety of fire risk reduction measures that are already being implemented, albeit largely in isolation from each other. These measures pertained to: (a) increasing ground water levels and water retention; (b) creating zones and corridors; and (c) changing land management practices (e.g. removing fire-prone dead biomass or enhancing diversity of vegetation type, age, moisture content, etc). In this section, we outline the needs that our interviewees expressed with regard to strengthening

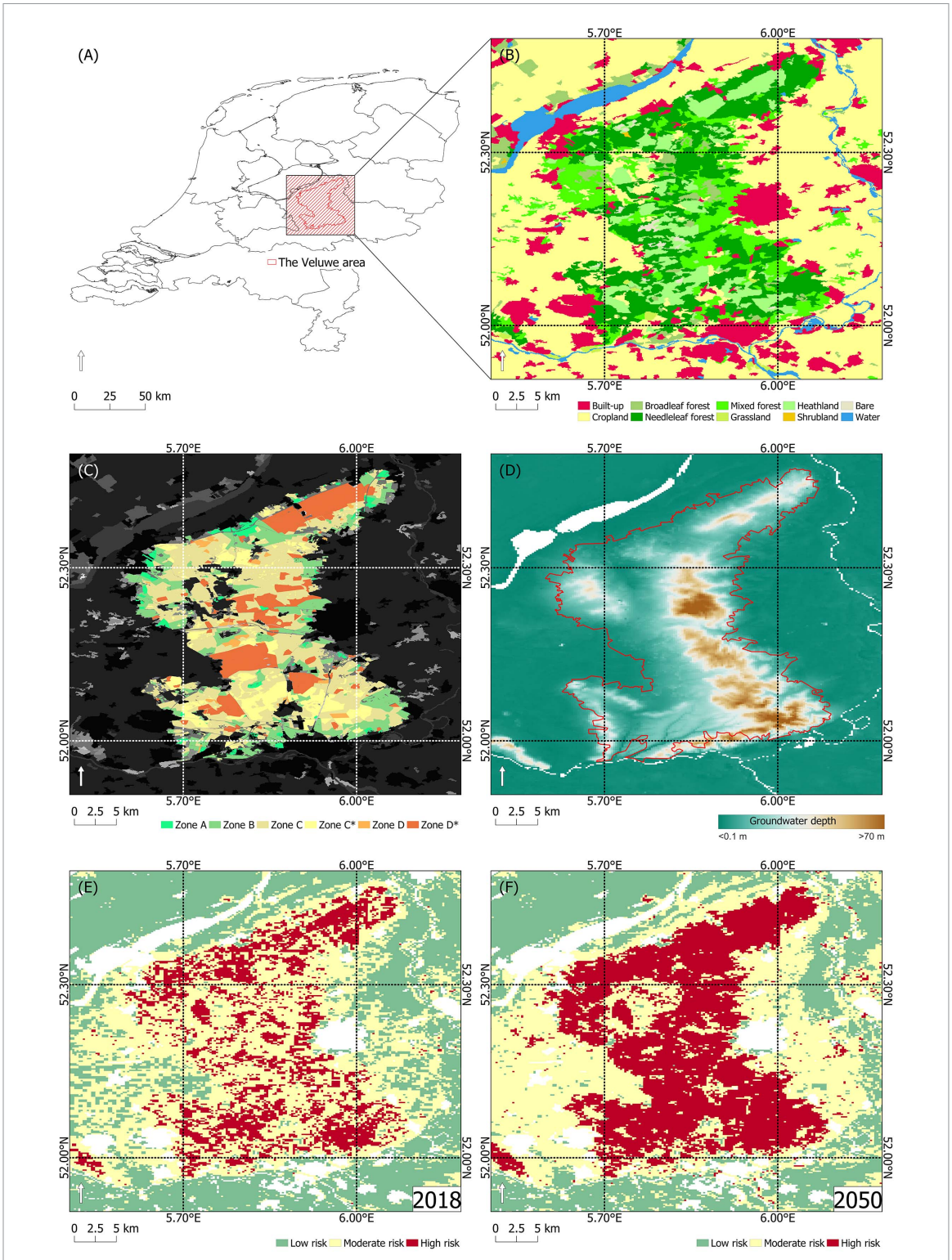

Figure 3. (a) Overview map of the Netherlands, the inset box (red hashed lines) shows the extent of panels (b) through (d). The extent of the Veluwe area is delineated with the red line; (b) land-use land cover map of the Veluwe area showing a dense wildland–urban interface and mosaic of different vegetation types using the 2018 Copernicus land-use land cover map at 100 m resolution; (c) zoning map that shows the degree of accessibility and recreational use across forest and semi-natural areas in the Veluwe area. Zone A: intensive recreational use, zone B: moderately intense recreational use with shared use, zone C: extensive recreational use with shared use in a sensitive ecosystem, zone C*: extensive recreational use with shared use in an extremely sensitive ecosystem, zone D: no/limited recreational use during breeding seasons, zone D*: no recreational use (military use, protected ecosystems services, private property). Source: Gelderland Provincial government, the Netherlands. See supplementary S.1 for details regarding the zoning classes. Background image: grayscale display of the 2018 land-use land cover map as shown in panel (b); (d) estimated groundwater depths under a scenario of extreme summer drought (precipitation deficit of 361 mm). The spatial distribution stems from interpolated groundwater well observations and shows the average of the lowest three groundwater levels during the drought from 1976. Source: Klimaateffectatlas. (e) Fire risk across the Veluwe area under current climatological conditions (2018); (f) estimated fire risk across the Veluwe area under future climatological conditions (2050). Source: Klimaateffectatlas/van Marle and Agricola [10].

these three existing sets of measures. We note that some of these needs stretch beyond improvements to the measures themselves.

With regard to the first set of measures, all interviewees pointed out that the severe droughts experienced in the Netherlands increase fire risk, and most noted that this also decreased the availability of water to suppress fires, thereby further increasing the risk of a fire becoming uncontrollable. In the Netherlands, the Water Board is primarily responsible for water- and groundwater-level management, and our interviewee expressed that the Water Board has expanded its focus from preventing floods to also preventing droughts, and thereby fire, by increasing ground water levels and the area's water retention capacity. To do so, the Water Board collaborates with the Provincial government, Safety Regions and agrarian land owners. Our interviewee from the Water Board expressed that his organization is content with the results of these efforts, because water- and groundwater-levels are increasing, but is also keen on a more integrated approach to water management that extends into parts of the area that are under nature management or used for industrial purposes, such as paper production: 'Take the example of re-using recycled sewage. There is a large paper factory […] in Renkum, which uses a lot of groundwater. Our sewage treatment plant is right next to that factory […]. With post treatment, such water could be used to produce paper. This would get you a very nice circular water system'.

The second set of measures concerns creating zones (spaces) from which fire is unlikely to spread to other areas because of the presence of corridors. Corridors are passages with low fuel density between vegetation zones. They can follow roads or trails or can be explicitly created with the sole purpose of reducing fire spread. Because of the low fuel density, fires often stop at corridors, or they decrease in intensity. This helps preventing the spread of fires from one vegetation zone to another. Creating zones and corridors was primarily considered a priority by our interviewees from the Safety Regions. They explained that the Safety Regions collaborate with provincial authorities to realize such zones and corridors, because the provincial authorities are responsible for much of the area's physical infrastructure such as roads. The Safety Regions also collaborate with land owners and land managers, and land managers to realize corridors in practice. However, all interviewees experienced current collaborations to be impeded by dispersed responsibilities, as illustrated by the following expression by one of the interviewees from NIPV: 'it's such a complex actor field… the more responsibilities are spread across a larger number of responsible organizations, the more they point at each other'. (Also see section 4.3).

With regard to the third set of measures, changing land management practices, we note that the ministry of LNV and the Provincial government are in the lead: these institutions develop policy-instruments to steer land managers' practices by providing funding to practices that are considered beneficial for these institutions' policy priorities. According to our interviewees from these two institutions, current policy instruments primarily serve the following policy priorities: biodiversity conservation, protecting habitats, reducing nitrogen levels, and conserving specific vegetation types and cultural landscapes. They do so via the National nature- and landscape conservation subsidy scheme (the 'Subsidiestelsel Natuur en Landschap', in short: the SNL scheme [28]), Natura2000-related schemes [29], and schemes set up to redress the ecological damage created by excessive nitrogen levels in soil and groundwater. Given that fire risk reduction is not a policy-priority in itself for the Ministry of LNV and the Provincial government, our interviewees from these institutions indicated that the Ministry of LNV and the Provincial government only contribute to fire risk reduction by subsidizing measures that that realize synergies between fire risk reduction and the aforementioned priorities. One of our interviewees from the Provincial government stated: 'the core task of the province is nature. Also in our subsidy schemes. But we constantly look for win-wins. Where can we include the prevention of large fires?'

All interviewees agreed that identifying more synergies between existing conservation measures and reducing uncontrollable fire risk would be helpful in the absence of uncontrollable fire risk reduction as a distinct policy priority (see section 4.2). We argue that this requires collaboration between relevant stakeholders because for landscape conservation are spread across diverse stakeholders (section 4.3) and more integrated knowledge on how existing measures that contribute to both existing policy priorities could be mobilized for fire risk reduction (section 4.4). Table 2 displays an overview of common fire risk reduction measures' potential trade-offs and synergies between management priorities. We refer to supplementary S.2 for an elaborate discussion thereof.

According to our interviewees from the ministry of LNV and the Provincial government, including land management strategies that contribute primarily to fire risk reduction in current subsidy schemes requires making the financial, ecological and safety benefits of such measures more visible in order to secure more political and financial support. In addition, our interviewees from the ministry of LNV and the Provincial government also expressed the need for more specific knowledge on the kinds of measures that would be needed in the area, and where (see section 4.4). They expect the Safety Regions and NIPV (which advocate for incorporating such

Table 2. Effects of fire risk reduction measures on different landscape management priorities (green means positive effects, red means negative effects, white means no effect). A multi-coloured box indicates that either multiple simultaneous or mutually exclusive (opposing) effects can arise. To interpret this table, it is important to note that specific effects of a measure are highly context-dependent, as well as on diverse stakeholders' interpretations of priorities. Additionally, the table's landscape management priorities are non-exhaustive. Cultural and historical values of the landscape have not been included: these values are particularly actor-dependent and malleable. We refer to supplementary S.2 for an elaborate overview of the effects of and interactions between different measures and for information on measures that were not included in this table, such as backfilling ditches, a measure highly specific to the Veluwe area, as well as the creation of zones and corridors.

	Water availability	Ecological quality and biodiversity	Effects of nitrogen deposition	Agriculture	Flood risk	Selected sources
Artificial groundwater recharge						[31–37]
Creating local water sources for fire extinguishing purposes						[33, 34, 36, 38, 39]
Prescribed low-intensity burning						[40–43]
Grazing						[40, 44–47]
Replacing coniferous trees by deciduous trees						[33, 34, 36, 38, 48, 49]
Strategically addressing smouldering fires						[33, 36, 38, 50]
Fire suppressing chemicals						[51, 52]
Removing asphalt roads in quiet nature areas[a]						[53, 54]
Improving the road network in fire prone areas[b]						[53, 54]

[a] Lowers wildfire hazard by reducing ignition probability, but increases the wildfire vulnerability through decreased accessibility for fire trucks.

[b] Lowers the wildfire vulnerability by improving accessibility for fire trucks, but increases the ignition probability.

measures in land management subsidy schemes) to provide such expertise. However, our interviewees from the latter organizations expressed they do not have such expertise.

To end, we observe that some strategies were controversial and rarely deployed by our interviewees, particularly prescribed burning and changing publics' use of the area to prevent human-induced ignition. With regard to the latter, the controversy revolved around whether preventing human-induced ignition in an area where the vast majority of fires are ignited by human behaviour [30] is helpful when the goal is not to prevent fires from taking place to prevent fires from becoming uncontrollable. With regard to prescribed burning (regularly burning small patches of land in a controlled manner to prevent uncontrollable fires), our interviewees from NIPV and State Forest Management noted that not all stakeholders agree on the effectiveness or appropriateness of fire as a risk reduction method, given that particular species are vulnerable to fire. Our interviewee from State Forest Management explained that this topic is also subject to debate within State Forest Management: 'where one says "it's not a big deal, fire benefits nature", the other says "fire is always detrimental to the same species"'. Moreover, they considered Dutch legislation restrictive with regard to how much land can be burned and at which time interval (see section 4.2), and that experience and knowledge on prescribed burning is therefore limited.

4.2. Revaluing fires, nature conservation and heritage

Box 2

Rendering uncontrollable fire risk reduction a key priority requires rethinking the notion of nature conservation and the role of fires therein: from static notions of biodiversity and nature conservation to dynamic and future-proof notions, in which fire features as an integral element of landscape management.

Reducing the risk of uncontrollable fires did not feature as a key priority in most interviewees' organizations according to our interviewees. For instance, our interviewee from the Water Board argued that fire risk reduction is considered inherent to the organizations' water- and groundwater level management programs, and not as something that deserved attention on its own. Our interviewee from the Provincial government explained that for the Provincial government to support fire risk reduction measures, such measures would have to contribute to conservation: preventing uncontrollable fires was considered as a bonus (see section 4.1). Our interviewee at the ministry of LNV expressed that the topic had recently started gaining traction at the ministry in response to the 2020 Peel fire. Public discussions on fire risk reduction during the fire's aftermath had resulted in an effort by LNV

to facilitate collaboration on the theme among stakeholders. However, the theme did not figure as a policy priority for LNV itself (see section 4.3). And our interviewee from State Forest Management told us that reducing uncontrollable fires was on the organization's agenda, but that organizational policy and concrete measures were yet to materialize.

To place uncontrollable fire risk reduction more firmly on everyone's agendas, stakeholders expressed the need to rethink the notion of conservation and the role of fires therein. Indeed, we argue that nature protection legislation is focused on protecting *current* biodiversity, but appears rigid in the context of climate *change*. Dynamics in circumstances urge stakeholders to rethink what is 'native' (in the context of biodiversity) and 'authentic' (in the context of cultural heritage). For example, our interviewees from State Forest Management and the Safety Regions argued that the concept of conservation would need to stretch: from merely creating and maintaining the right ecological conditions for a diversity of species in the present, to also protecting the area against likely (yet not entirely foreseeable) future ecological events such as uncontrollable fires. For our interviewee at the NIPV, today's ecological challenges require rendering static notions of biodiversity and landscape's cultural value dynamic, and using historical elements of the landscape to strengthen landscape's resilience to fire risk today. As our interviewee from the Water Board stated: 'you should look at what the area was like in the past'. For example, this interviewee suggested replacing coniferous trees (which are currently considered to be typical for the Veluwe) with deciduous trees on the grounds that deciduous trees dominated the area before they were replaced with coniferous trees 'around 1900 for construction purposes in mines', or reconstructing water bodies that were present in the area in the past, in order to improve moisture retention.

Indeed, we argue that the past constitutes a helpful source to rethink the role of fires in nature conservation. For example, our interviewees from the Safety Regions, NIPV and the Provincial government stressed that small-scale fires have long been an integral element of landscape conservation, and that this can be a fruitful strategy to reduce the risk of uncontrollable fires when sensibly deployed. However, we also observe that such use of fire is contested. Our interviewee from State Forest Management expressed that the use of fire as management strategy was controversial to many in his organization: although fires were deemed integral in landscapes by some, others argued that such fires can have unacceptable impacts on specific species in the context of static biodiversity goals. Moreover, Dutch legislation makes the strategic use of fire as a prevention measure difficult, reflecting the caution with which the use of fire is approached across the Netherlands (see section 4.1). This tendency is not only visible in the Netherlands, but also the European Union's approach to fire in landscapes under nature management has been highly repressive [55] and it is even argued to be a global problem [19].

4.3. Collaborative, place-based governance

Box 3

Rendering uncontrollable fire risk reduction a key priority among stakeholders and developing effective risk reduction measures requires collaborative governance (identifying synergies and balancing unwanted trade-offs) and a place-based approach, tailoring policy-tools and measures to the Veluwe's specific socio-material characteristics.

The interviewed stakeholders unanimously agreed on the need for tight collaboration to reduce the risk of uncontrollable fire effectively. Interviewees' calls for such governance emerged from the recognition that developing risk reduction measures cuts across the responsibilities and expertise of individual stakeholders. In addition, given the diverse priorities that ought to be taken into account, our interviewees expressed that increased collaboration would help to develop context-specific, effective measures that prevent unwanted trade-offs and which contribute to both fire risk reduction and the issues that are a key priority within the organizations involved.

Interviewees also argued that collaborative governance would help placing uncontrollable fire risk reduction more firmly on *all* stakeholders' agenda: for example, according to our interviewees from the Safety Regions, some organizations (such as the Provincial government), were hesitant to prioritize fire risk reduction because not all relevant stakeholders had done the same. These interviewees also said that they were very keen on collaborative governance in order to render uncontrollable fire risk reduction a shared responsibility, in part because their organizations do not have any mandate in landscape and water management. The ministry of LNV initiated a network to collaborate on fire risk reduction in landscapes under nature management across the Netherlands, but this network is still in an early phase. At the same time, the ministry is exploring whether, and if so, how, to play an active role beyond bringing stakeholders together on the issue according to our interviewee from this ministry: 'for now, we work on the basis of the affirmation by the Minister, who said she will explore what role she can take up, so that is what we are doing'.

In addition to collaboration, our interviewees stressed the need for a place-based approach to fire risk reduction throughout the Netherlands, explaining that 'no two areas are the same' as each area consists of particular vegetation types, soils,

water systems and other specific policy questions (LNV interviewee), with implications for the design of a workable and effective combination of measures tailored to these characteristics. Place-based refers to an approach which takes physical characteristics of an area into account (e.g. material, geographical and environmental characteristics, as well as institutional characteristics, social dynamics and local practices [56, 57]).

4.4. Knowledge gaps and knowledge infrastructures

Box 4

Stakeholders have four concrete knowledge questions:

(a) How often are uncontrollable fires likely to take place in the Veluwe area, now and in the future?
(b) What are the economic, ecological and social costs of not preventing such fires?
(c) Which risk reduction measures are particularly promising in realizing synergies between existing land management priorities and reducing the risk of uncontrollable fires?
(d) Which measures can be implemented where, and how, in the Veluwe area?

Lastly, the interviewees raised a number of concrete knowledge questions. First, our interviewees from the Safety Regions particularly ask for more precise estimates of how frequently an uncontrollable fire is likely to take place in different parts of the Veluwe area now and in the future. They argued that such knowledge would increase the comprehension and urgency of fire for stakeholders, and therefore provide support to prioritize fire management in their agendas. In addition, our interviewees from State Forest Management and the Ministry of LNV expressed the need for more in-depth knowledge on the economical, ecological and social costs of uncontrollable fires, compared to the costs and effectiveness of different available measures. They expect that such knowledge helps to create (political) will to invest in fire risk reduction measures, especially when combined with a comprehensive overview of where measures are expected to be most needed.

Furthermore, across all interviewees, we noted an interest in research that would support the development of measures that realize synergies between stakeholders' diverse interests. Our interviewees from the Provincial government and the Ministry of LNV were particularly interested in measures that realize synergies with biodiversity conservation, while the Safety Regions and NIPV were keen on synergies between fire prevention, fire management needs (e.g. accessibility of the area at the time of a fire) and biodiversity: 'We try to identify win-win situations. […] We are not in favour of clear-cutting, we want reform. We try to understand how one can contribute to biodiversity' (interviewee Safety Regions). We argue that such questions requires research to bring together insights from different domains, including stakeholders' knowledge.

Finally, our interviewees were keen on more in-depth knowledge on which measures could be implemented where, and how exactly, in the area. Examples included knowledge on more effective use of zoning and corridors for different parts of the Veluwe area, in accordance with such areas' vegetation types, hydraulic conditions, etc. Such knowledge, and infrastructures to develop and share such knowledge, is currently missing.

5. Discussion

The results section identified the needs of stakeholders in the Veluwe area to reduce the risk of uncontrollable fires. Cutting across the four types of stakeholder needs is the necessity of an integrated (cross-domain), dynamic and place-based approach to fire risk reduction. This section hones in on the implications thereof for future research.

First, risk reduction measures bring about synergies and trade-offs with different domains (as shown in table 2). To allow for an integrated approach to fire risk reduction and to render fire risk reduction inclusive in terms of meeting diverse stakeholders' interests [4, 58], research must combine diverse economic, ecological and social dimensions on the effects of fire risk reducing measures. This requires collaboration between scholars from diverse disciplinary backgrounds across the natural sciences, social sciences and humanities as well as with non-scientific actors (e.g. to bring diverse understandings of landscape management values to the table). Furthermore, this calls for integrating fire risk research more strongly in fields of research where fire is not the primary focus (e.g. biodiversity conservation; water management; heritage studies, etc). Taking an integrated approach includes research on deliberative governance processes to foster stakeholder collaboration (e.g. to combine diverse measures effectively). Finally, the term 'integrated' should be approached with caution: recent scholarship has argued for the importance of doing integration without reducing the insights of diverse disciplines to one specific logic, as this would make it difficult to express the effects of specific measures across diverse dimensions [59].

Second, the term *dynamic* refers to a shift in the way in which the Veluwe area and fire therein are valued in research, in terms of the area's ecological (e.g. biodiversity, water), heritage, social (e.g. the role of place in residents' and visitors' lives) and

economic characteristics. For example, biodiversity conservation's success is often benchmarked against static lists of species that are considered to be native to a certain ecosystem (e.g. the Natura2000 system). Similarly, preserving cultural heritage is based on static monument lists and an implicit ideal of a pictorial cultural landscape prior to urbanisation and industrialisation. However, generating liveable futures in the context of today's ecological challenges requires continuous adaptation of our ideas on ecologically, socially, culturally and economically valuable landscapes. This requires, amongst others, that research develops and uses adaptive biodiversity conservation guidelines, and mobilizes landscapes' histories as a source of inspiration rather than a benchmark [60, 61].

Finally, a place-based approach to fire risk-reduction requires research tailored to a particular area's physical, institutional and social characteristics, and research that is responsive to stakeholders' needs and interests. The former implies fire risk reduction measures ought to be studied in the context of specific places and their characteristics. The latter implies moving away from purely academic research towards transdisciplinary, collaborative research with non-academic stakeholders that aligns research more closely to stakeholders' daily practices and needs. This can take various forms, such as providing input to define the research problem, sharing relevant experiential knowledge or collaborating in the development of site-appropriate research methods [62–64]. Of course, this raises questions around the extent to which research should be influenced by stakeholders' agendas. In this context, it may be helpful to consider that defining what to study, and how to do so, inevitably requires making value-laden choices. These choices become particularly visible and tangible when conducting research with stakeholders, and we argue that it is therefore crucial that those involved in such research discuss and critically reflect on the research choices made.

6. Conclusion

This letter asked: what do stakeholders in the Veluwe area need in order to reduce the risk of uncontrollable fires? And what are the implications thereof for future research on fire risk reduction strategies? We conclude that stakeholders generally agree on the need to preserve the Veluwe area, but that their strategies reveal different ideas about what values should be prioritized. Stakeholders' needs could be categorized in terms of (a) measures and policy-tools; (b) the valuation of fire, conservation and heritage; (c) governance; and (d) knowledge. Cutting across these four categories is the need for an integrated (cross-domain), dynamic and place-based approach to fire risk reduction, not only in practice but also in academic research. These findings are not only relevant to the Veluwe area specifically, but equally relevant to other densely populated and increasingly fire-prone areas, which are particularly common in Northwestern Europe.

Data availability statement

The data that support this study are available upon request from the first author of the paper.

The data that support the findings of this study are available upon reasonable request from the authors.

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