

The Role of International Resource Sharing Arrangements in Managing Fire in the Face of Climate Change

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Abstract: Changing global fire regimes including extended fire seasons due to climate change may increase the co-occurrence of high-impact fires that overwhelm national fire suppression capacities. These shifts increase the demand for international resource sharing to supplement national fire suppression efforts. In this paper, we explore the development and evaluate the effectiveness of international resource sharing arrangements of three regions: (1) The United States, Canada, and Australia (“Big Three”); (2) Europe; and (3) Southeast Asia by conducting a literature review of gray and peer-reviewed literature in combination with key informant interviews. For the “Big Three” and Europe, international resource sharing is perceived as necessary, effective, and continuously improving. Converging fire management processes and training and developing more effective administrative procedures facilitate these relationships. In Southeast Asia, political tensions and limited firefighting capacities have hampered effective cooperation. Formalized agreements of country-to-country support for fire management are nascent and evolving, and there is evidence that demand for expanding and improving these partnerships is increasing.

Keywords: fire management; climate change; resource sharing; suppression; global; season length; simultaneity



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1. Introduction

Global fire activity has changed in recent decades [1], partially associated with increased fire weather extremes and extended fire weather seasons [2,3]. Increased fire danger across broad geographic scales has not only enabled historic regional fire seasons, for example, in Canada [4] and the United States [5], but also the co-occurrence of impactful fires across disparate geographies [6,7]. Climate change is partly driving this development and is projected to continue to cause increasing fire danger in the coming decades [8]. Changing fire risk patterns have implications for international collaboration regarding resource sharing for fire suppression. Increased local-to-regional fire danger can lead to a greater internal demand for suppression resources such as firefighting crews, equipment, ground vehicles, and aircrafts, as well as fire management resources from partnering countries when national resources are sparse. At the same time, the increasing simultaneity of fire occurrence in different regions can increase the demand for fire resources from partner nations that may be overwhelmed with fire.

Figure 1 outlines a schematic framework representing how climate change and international resource sharing relate. The figure illustrates the impact of climate change on fire activity in terms of: (1) more large fires co-occurring at local, regional, and global scales [6,7]; (2) the increased likelihood of the occurrence of fires that escape the initial

attack and become high-intensity fires due to increased extreme fire weather [9–12]; and (3) the influence on fire regimes in terms of when and where large fires occur [13,14]. Climate change is projected to increase the length of fire seasons in specific regions and potentially increase the likelihood of fires in previously non-fire-prone regions [13–17]. The majority of peer-reviewed papers on fire and climate change are from North America [18]. Similarly, the majority of papers analyzing past or future changes in fire season length pertain to North America and Australia, with some additional research for Europe and at the global scale with little attention to regions such as Southeast Asia.

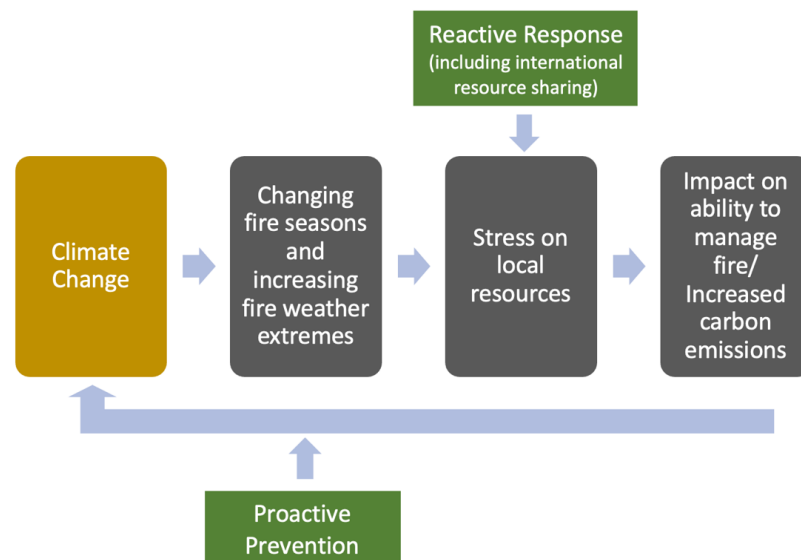


Figure 1. Framework for potential interaction between climate change and international resource sharing for fire management.

Changing fire patterns can stress local resources and increase the demand for resource sharing while potentially lowering the supply of resources to be shared [13,18,19]. These factors can, in combination, impact the ability to manage or prevent fire and increase carbon emissions, contributing to further climate change. For example, forests are turning into net carbon emitters in countries such as the United States, Australia, and Indonesia [20].

Two strategies are available to tackle this problem: (1) proactive prevention and (2) reactive response. Proactive prevention can include mitigation and adaptation activities such as prescribed burning, thinning, peatland, and primary forest management to reduce fire impact and potential emissions [21]. Fire response activities include both suppression and fire management. This paper will specifically focus on fire response and suppression efforts as they relate to international resource sharing. When local resources are insufficient to manage fires in a country, agreements have been coordinated to allow for sharing resources such as firefighting and fire management personnel, aircrafts, and equipment from partner nations via bilateral or multilateral mechanisms. There may be times when resource sharing impacts the capacity for proactive planning in the country that is sending resources; however, this is beyond the scope of this paper.

This paper explores how international resource sharing arrangements have developed. We first outline a brief history of international collaboration agreements with a case study of three sharing regions that are subject to high-impact fires that directly affect communities [22,23]: (1) The United States, Canada, and Australia, dubbed the “Big Three” countries [24]; (2) Europe; (3) Southeast Asia. Second, the paper will present illustrative descriptive statistics on resource requests for these three sharing regions. Third, we will summarize literature and key informant interviews with fire managers to outline the policy relevance of this research and discuss the strengths and weaknesses of different resource sharing models. Finally, the paper will discuss resource sharing trends, the potential impact of climate change on international resource sharing arrangements, and identify areas for

further research and policy implications. To the best of our knowledge, this is the first peer-reviewed paper to capture formal international resource sharing for fire suppression. As such, it is positioned to fill an important gap in the literature as these sharing arrangements have gained prominence in recent decades.

1.1. History of International Collaboration Agreements

Since the 1990s, countries have worked to formalize international resource sharing arrangements to help manage fires and the threat they pose to lives and property [25] (see Figure 2). Though some informal resource sharing occurred previously, extreme fire events (such as the 2000 fire season in the United States and the 1997–1998 haze event in Southeast Asia) prompted nations to formalize international resource sharing arrangements to make them more effective, reliable, and efficient [25]. These resource sharing arrangements are still nascent and are constantly undergoing change. Different regions have set up different types of agreements. For example, the “Big Three” countries depend on bilateral agreements with each other and additional partner nations. Europe, on the other hand, relies on a multilateral agreement. Although, in Southeast Asia a legal agreement has been set up to prevent the negative consequences of fire, such as haze amongst the Association of Southeast Asian Nations (ASEAN) (see Table 1).

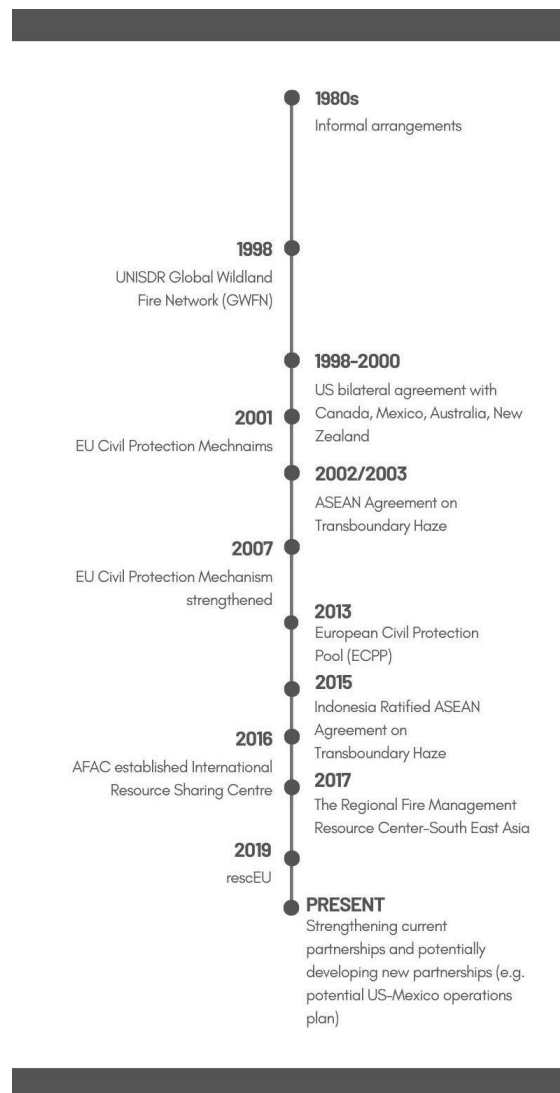


Figure 2. Timeline of international resource sharing arrangements for fire management.

Table 1. International resource sharing arrangement types.

Region	Agreement	Type of Agreement	Sub-Arrangements to Facilitate Resource Sharing
The United States, Canada, Australia, New Zealand	Australia/New Zealand/US International Agreement (2000); Canada/US Northwest Wildland Fire Protection Agreement (1998)	Bilateral	Operating Plans
The United States (states) and Canada (provinces)	Regional Forest Fire Protection Compacts	Multilateral (local international)	<i>(beyond the scope of this paper)</i>
Europe/European Union	Sharing amongst European nations	Bilateral	<i>(beyond the scope of this paper)</i>
	European Union Civil Protection Mechanism (2001)	Multilateral	European Civil Protection Pool, rescEU, cost sharing
Southeast Asia/ASEAN	Humanitarian aid from aid agencies or European Union Civil Protection Mechanism	Bilateral	
	ASEAN Agreement on Transboundary Haze (2002/2003)	Legal Environmental Agreement	A complementary mechanism to facilitate capacity building and information sharing is the Regional Fire Management Resource Center–Southeast Asia

1.1.1. Global

At the global level, the Global Wildland Fire Network (GWFN) was founded in 2004 with the support of the former Inter-Agency Task Force for Disaster (IATF/DR) of the United Nations International Strategy for Disaster Reduction (UNISDR) [26]. The Global Fire Monitoring Center (GFMC) was established in 1998 as recommended by the UNECE/FAO/ILO Seminar Forest, Fire, and Global Change and several other international conferences and inaugurated at the FAO Meeting on Public Policies Affecting Forest Fires. The GFMC is the Secretariat of the GWFN, the UNISDR Wildland Fire Advisory Group, and the International Fire Aviation Working Group. The focus of the GFMC is information sharing, setting up early warning and monitoring systems (especially for countries initially lacking this capacity), and supporting the development of international and regional training tools, protocols, and guidelines [25]. The GFMC also functions in a decentralized way with regional fire networks to bridge science and policy for wildland fire management [27]. The GFMC does not share any physical resources, and there is no global pool of firefighting personnel; however, there have been emerging discussions about the potential feasibility of having a global pool of aircrafts to manage fire suppression efforts [28]. Currently, the private sector often acts as an intermediary for “pooling” aircrafts, as many nations have contracts with private companies for part of the year during their primary fire season. Meanwhile, multiple national governments may hold contracts with an individual company, especially if their fire seasons do not overlap.

1.1.2. “Big Three”: US, Canada, Australia

The United States tends to rely on bilateral agreements mainly with Canada and Australia/New Zealand, although Mexico has sent an increasing number of resources in recent years. These resource sharing arrangements were set up between 1998 and 2000 [25]. Canada has similar arrangements and additionally has set up partnerships with South Africa, a fellow commonwealth nation [29]. The United States continues to build on the formalized agreements, for example, through a Canada/United States Reciprocal Forest Fire Fighting Arrangement Operating Plan dated 11 April 2022. This plan stipulates that requests are placed by the United States’ National Interagency Coordination Center (NICC) to the Canadian Interagency Forest Fire Centre (CIFFC) and addresses issues around

personnel reimbursement, equipment and supplies protocols, and aircraft protocols and is regularly updated. The receiving agency reimburses salaries, overtime and hazard compensation, and travel costs to the sending agency. It should be noted that sharing arrangements between US states and Canadian provinces also occur through Regional Forest Fire Protection Compacts but are not coordinated at the federal level and are outside the scope of this paper [29]. Additionally, we acknowledge but do not detail the diplomatic missions providing fire suppression humanitarian aid and capacity building efforts that tend to be coordinated by national aid agencies such as USAID and AusAID.

In the United States, at the federal level, the US Forest Service's Fire and Aviation Management national headquarters, in cooperation with the Department of the Interior Office of Wildland Fire, coordinates international resource sharing in the United States. This coordination is accomplished through the National Multi-Agency Coordinating Group, which consists of federal and state wildland fire representatives, in collaboration with the NICC to submit and fulfill requests by external partners. In the United States, preparedness level 5 is equivalent to "the highest level of wildland fire activity where at least 80% of the country's incident management teams and wildland firefighting personnel are committed to wildland fire incidents," whereas preparedness level 4 refers to days when three or more geographic areas are experiencing large, complex fires to which about 60% of wildland IMT's and wildland firefighting personnel are committed [30]. In the United States, international resource sharing becomes a consideration when the country reaches preparedness level 4 and above.

In 2016, the CIFFC created a new Strategic Planning Unit to strengthen strategic planning processes with federal agencies and international partners. In addition, a new Canadian Multi-Agency Coordination (CMAC) group was established for national planning. These are activated when national preparedness levels (PL) in Canada reach three or higher in light of potential international resource sharing requests, which are increasingly considered at PL 4 and 5 [29]. In Canada, the preparedness levels are set subjectively based on qualitative assessments of agency fire hazard, current fire load, anticipated load, agency resource level, the ability of CIFFC to respond to mutual aid, and the potential for international assistance [29].

In Australia, the AFAC National Resource Sharing Center was set up to coordinate domestic and international resource sharing. Though resource sharing existed between Australian states and other nations, the AFAC National Resource Sharing Center formally began coordinating all international deployments starting in 2016 except those arranged for humanitarian aid [31]. The AFAC National Resource Sharing Center also coordinates resources for New Zealand, as New Zealand is part of the National Council. Currently, AFAC's main international partners are the United States and Canada.

1.1.3. European Union

In Europe, the 27 member countries of the European Union, along with Iceland, Norway, Serbia, North Macedonia, Montenegro, and Turkey, participate in a multilateral arrangement called the European Union Civil Protection Mechanism to help monitor, prevent, and respond to humanitarian emergencies such as fire [32]. Before the European Union Civil Protection mechanism was founded in 2001 and strengthened in 2007, international resource sharing for fire suppression was largely informal [33]. It should be noted that bilateral exchanges are conducted between EU member states, whereas the EU Civil Protection Mechanism also provides humanitarian aid to countries not participating in the agreement; however, these arrangements are beyond the scope of this research.

The European Union Civil Protection Mechanism acts as a coordination hub for exchanging resources amongst member states that participate voluntarily. In 2019 the European Commission also set up rescEU in recognition of increasing fire season severity [34]. The rescEU is a pooled set of reserve assets such as firefighting aircrafts utilized when Member States are overwhelmed. The European Union Civil Protection Mechanism has a three-stage response to emergencies. First, there are spontaneous offers whereby a member

state voluntarily offers its support. These are coordinated via the Mechanism or bilaterally, with offers extended by geographical neighbors. Second, the European Civil Protection Pool (ECPP), a reserve of emergency response teams and capacities established in 2013, is available [32]. Twenty-five countries are voluntarily providing more than 100 resources (resources can include rescue or medical teams, experts, specialized equipment, or transportation) to the ECPP. Third, rescEU firefighting planes and helicopters on standby may be deployed [32]. In 2021 rescEU consisted of 15 aerial forest firefighting capacities, including airplanes and helicopters, along with a medical stockpile [35]. Nations are responsible for determining their resource needs and when to request help.

It is customary, given the EU's solidarity culture, that partner nations providing spontaneous offers cover most of the cost of resources shared to assist burdened and overwhelmed requesting countries. Additionally, the Regulation (EU) 2021/836 of the European Parliament and of the Council of 20 May 2021 (amending Decision No 1313/2013/EU on a Union Civil Protection Mechanism) establishes that the European Union funds may cover 75% of transport costs for spontaneous offers, and may cover 75% of operational costs which include transport for the ECPP and may cover 100% of costs for rescEU capacities outside the EU and 75–100% of operational costs inside the EU along with 100% of transport costs [36].

1.1.4. Southeast Asia/ASEAN

In response to a widespread high-impact fire in Indonesia in 1997–1998 that caused an extended haze event around Southeast Asia, the Association of Southeast Asian Nations (ASEAN) (which includes Brunei, Cambodia, Indonesia, Lao PDR, Malaysia, Myanmar, Philippines, Singapore, Thailand, and Vietnam) adopted the ASEAN Agreement on Transboundary Haze in 2002. However, the agreement was only ratified by all ASEAN member states in 2015. The legally binding agreement stipulated that ASEAN member nations should cooperate to prevent, monitor, and mitigate haze. As part of this agreement, nations committed to developing monitoring, assessment, and early warning systems, exchanging information and technology and providing mutual assistance, responding to information requests, and taking legal, administrative, or other actions to implement their obligations under this agreement. Furthermore, since 2006 ASEAN has developed a Standard Operating Procedure (SOP) for Monitoring Assessment and Joint Emergency Response that provides guidelines for monitoring and assessing joint emergency response [37]. To complement the agreement and SOP, in 2017, the Global Fire Monitoring Center set up the Regional Fire Management Resource Center–South East Asia, housed at the University of Bogor [27].

2. Materials and Methods

We reviewed both gray and peer-reviewed literature in combination with key informant interviews to assess the effectiveness of international resource sharing arrangements. We interviewed stakeholders involved in making resource requests and making decisions about and coordinating international resource sharing for fire management from the three sharing regions described here (see Table 2). Additionally, we gathered data on fire suppression resources shared between countries from a variety of sources. These sources included annual reports from fire management coordination centers, provided by internal staff from these agencies, or downloaded from publicly available online resources such as daily update maps and news stories (Appendix B).

Table 2. List of agencies interviewed.

Agency	Country/Region	Number
National Multi-Agency Coordination Group (NMAC)	United States	(2)
Department of the Interior	United States	(4)
US Forest Service, USDA	United States	(2)
National Interagency Coordination Center (NICC)/National Interagency Fire Center (NIFC)	United States	(2)
Australasian Fire and Emergency Service Authorities Council (AFAC)	Australia and New Zealand	(1)
Canadian Interagency Forest Fire Center (CIFFC)	Canada	(1)
Emergency Response Coordination Center, European Commission-DG ECHO	European Union	(1)
Regional Fire Management Resource Center	Southeast Asia	(1)
Food and Agricultural Organization of the United Nations (FAO)	Indonesia/Global	(1)
Global Fire Monitoring Center (GFMC)	Global	(1)
Total Representatives Spoken With		15

Gray and peer-reviewed literature evaluating the effectiveness of international resource sharing models was analyzed. Perhaps in part due to the newness of formalized international sharing agreements, limited peer-reviewed literature was identified. Stakeholder interviews confirmed a substantial need to document and evaluate the models that have been developing over time and how to improve them in the future. Gray literature entailed national and multilateral reports evaluating resource sharing models, self-assessment reports, conference proceedings, and previous stakeholder interview findings from particular agencies. The limited body of peer-reviewed literature highlighted several challenges associated with the adoption of the ASEAN Agreement on Transboundary Haze and the usefulness of the agreement as a governance tool. The literature also included a study evaluating fire management in Canada; however, it did not focus on evaluating the effectiveness of sharing fire suppression resources internationally. Text analysis was conducted to extract qualitative information related to common barriers and enablers for resource sharing.

Additionally, stakeholder interviews were conducted with fire managers and policy-makers from national and multilateral agencies in the United States, Australia, Canada, the European Union, Southeast Asia, and global agencies (see Table 2). Stakeholders from the “Big Three” and the European Union were selected based on their leadership roles. Most are directly responsible for coordinating international deployments or developing protocols to facilitate deployments. Stakeholders from GFMC and FAO were selected based on their knowledge of international collaboration for fire management, including information exchange, capacity building, and regional knowledge of Europe and Southeast Asia. Efforts to reach out to ASEAN Agreement on Transboundary Haze focal points were met with no response. The interviews were conducted via video and teleconferencing and entailed a structured protocol of open-ended questions. Questions were organized around resource sharing decision-making for fire suppression in terms of both making requests for fire suppression support and providing personnel and equipment to requesting countries. The interview protocol can be found in Appendix A. These interviews were analyzed for common themes around the strengths and weaknesses of international resource sharing mechanisms and perceptions around the role of international resource sharing in the face of climate change. The review of gray and peer-reviewed literature, supported by stakeholder statements and responses, helped elucidate some of the key strengths and weaknesses or challenges of the various sharing models and identified priority areas for further development.

3. Results

3.1. Illustrative International Resource Sharing Figures

Illustrative figures are presented for the level of resources sent between the United States, Australia, and Canada, in terms of personnel and aircrafts per year, and how this relates to fire season characteristics for each year. Figure 3 shows the total number of personnel shared amongst the “Big Three” countries between 2015–2021, whereas the arrows indicate which nations have formal bilateral agreements and the direction of resource flows. Figure 4 explicitly shows the total number of resources sent to the United States annually from Australia and Canada in terms of personnel and number of aircrafts from 2002–2021. The personnel category includes both specialized staff (incident management teams (IMTs) and liaison officers) and fire fighting staff (crews). The total number of personnel sent to the United States by Australia and Canada is quite variable, ranging from 0–500 per year. The number of aircrafts sent to the United States by Australia and Canada ranged between 0 to 8. Additionally, Figure 4 highlights the number of days the United States was at PL 4 and PL 4 or 5 (indicating high levels of domestic deployment) for a given year.

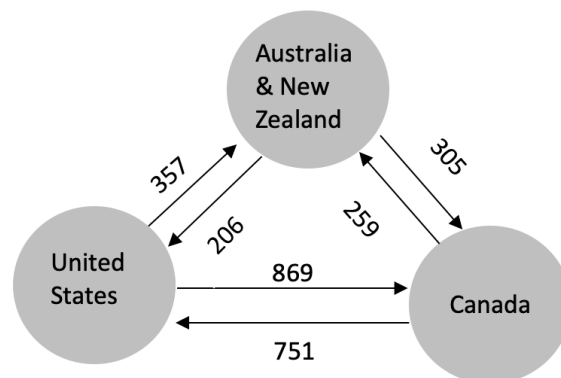


Figure 3. Cumulative exchange of personnel between United States, Canada, and Australia/New Zealand during 2015–2020. The number indicates the total number of personnel exported from one country (end of the arrow) to another (head of the arrow).

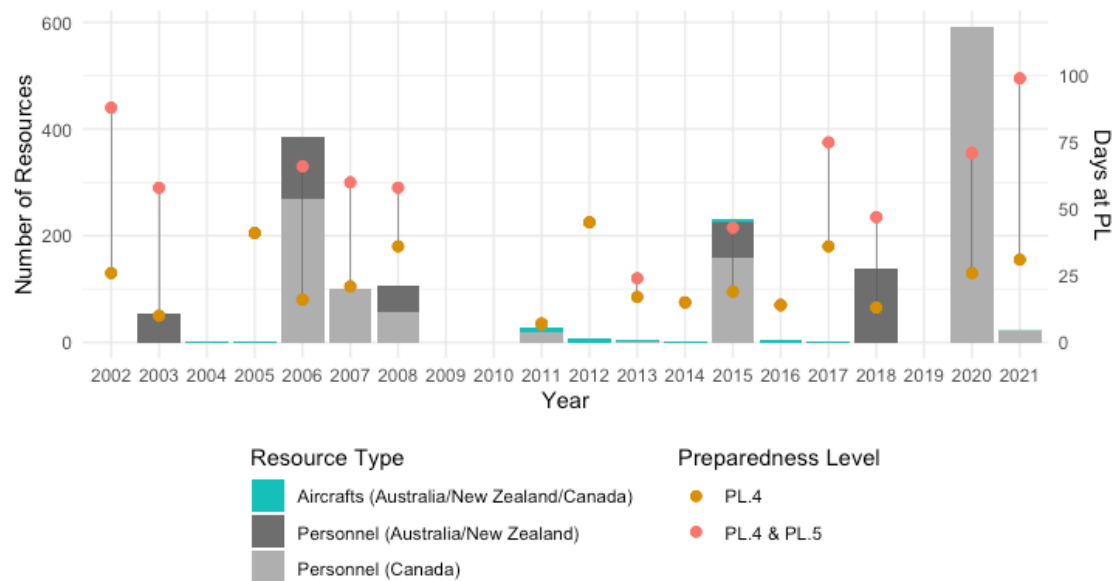


Figure 4. Resources exported to the United States from Canada and Australia/New Zealand during preparedness levels 4 and 5 (2002–2021). Note that the data are stacked and that 0 personnel and aircrafts were sent to the US by Canada and Australia in 2002, 2009, 2010, and 2019. Only NIFC coordinated resources are listed. The data sources are NIFC Annual Reports 2001–2021.

Expert interviews revealed that it is not only the number of days that the United States is at PL 4 or 5 but also the timing of these high-intensity periods that increase the likelihood that international resources will be requested. If preparedness levels are at PL 4 early in the “typical” fire season, then it is likely that resources will be severely constrained during the peak of the summer, and partners are more likely to be called upon with requests for support. Similarly, if PL 4 or PL 5 occurs late in the “typical” fire season when less staff are retained, it is also likely that international resources will be requested. For example, in 2020, the US remained at PL 4 or PL 5 from 18 August to 14 October, which was quite late in the fire season, contributing to the need for additional resources.

Figure 5 shows how frequently the EU Civil Protection Mechanism was activated in Europe for forest fires between 2007–2021. The number of activations per year ranged between once in 2020 and 18 times in 2017. Further, we observe that this frequency correlates with the total number of hectares burned in Southern Europe (specifically Italy, Portugal, Spain, Greece, and France) where most high-impact forest fires occur in Europe.

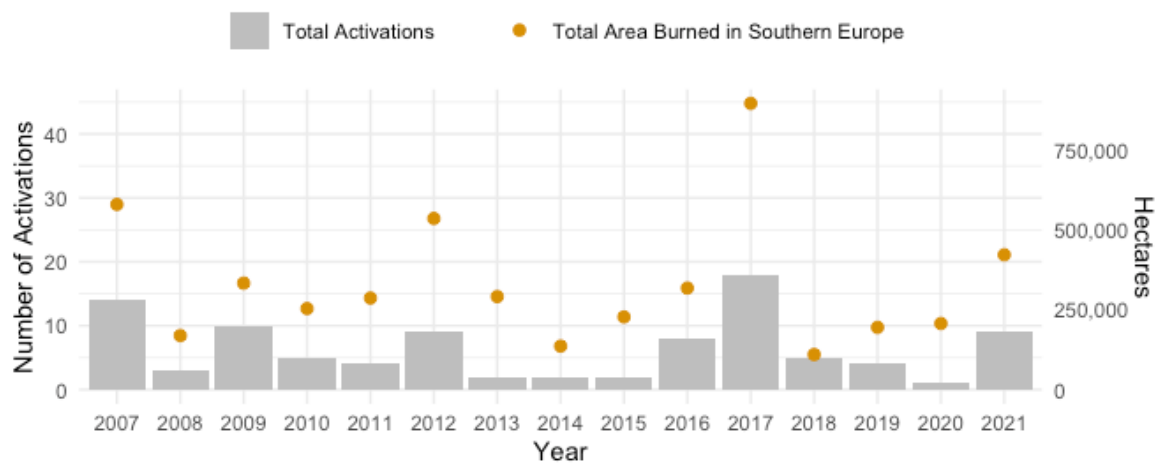


Figure 5. Trends Overtime in EU Civil Protection Mechanism Activations —area burned Southern Europe (hectares). Data source: EU Civil Protection Mechanism Annual Activity Reports (2001–2021); (ICF, 2014); (ICF, 2017); (provided by DG ECHO staff). EU Civil Protection Mechanism; Activation = when an affected country in the EU requests assistance from the Mechanism through the Emergency Response Coordination Center (ERCC) for any form of assistance related to forest fire management; Southern Europe = France, Greece, Italy, Portugal, Spain.

In addition to evaluating the frequency of EU activations and the number of resources sent per year for the “Big Three,” we also noted the timing of resources being sent. Table 3 shows which months resources were sent between Australia and New Zealand, Canada, and the United States, and what part of the year the EU Civil Protection Mechanism was most frequently activated from 2001 to 2021. For the United States, Canada, Australia and New Zealand, partnership resources have been sent: (1) between November and April from the US to Australia and New Zealand; (2) between June and August from the US to Canada; (3) between August and September from Canada to the US and Australia and New Zealand to the US (see Table 3). The EU Civil Protection Mechanism is typically activated (>3 times between 2013–2020) between June and November. Resource sharing amongst the “Big Three” relies on the idea that when fire resources are overwhelmed in one nation, such as the United States, resources can be imported from other countries not experiencing high fire activity. If fire seasons lengthen or shift to increase overlap, traditional sharing partners may become unavailable.

Table 3. Timeline of when resources are shared amongst the “Big Three” and EU. The data sources include NIFC Annual Reports, CIFFC Annual Reports, and AFAC News (for “Big Three”) and ERCC DG ECHO Daily Map 18 May 2021 and UCPM Copernicus EMS activations for wildfires: 2013–2020 (for Europe).

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
US to Australia and New Zealand												
US to Canada												
Canada to US												
Australia and New Zealand to US												
EU Civil Protection Mechanism activated >3 times												

3.2. Case Study of Fire Management in Southeast Asia

During major forest fires in Indonesia and regional Southeast Asian haze events in recent decades, such as in 1997 and 2005, firefighting equipment and personnel have been sent to Indonesia by ASEAN nations (e.g., Malaysia and Singapore) and also the United States, Australia, Canada, and Japan [38–40]. Still, diplomatic emergency aid for fire suppression has not always been effective at eliminating forest fires and, at times, has been viewed as threatening national sovereignty. In fact, during a very significant fire and haze event in Southeast Asia in 2015 [41], fires burned in Indonesia from June to October, and daily emissions in October exceeded emissions from the entire US economy [42]. Approximately 2.6 million hectares were burned during this time, an area equivalent to 4.5 times the size of Bali [43]. These forest fires led to weeks of haze across Southeast Asia with significant impacts on morbidity, mortality, and the economy [44]. Countries such as Singapore and Australia provided multinational support, although not immediately [45,46]. News reporting suggests that the Indonesian government rejected initial offers to send firefighting resources as the situation was thought to be under control [45]. A similar situation occurred in 2019 [46–48]. It is unclear whether earlier support and even what kind of support could have been effective in limiting the harmful effects of fire and smoke in these cases.

3.3. Evaluation of Sharing Models

The literature review results and key informant interviews are outlined below and summarized in Table 4. In Southeast Asia, political tensions and limited firefighting capacities nationally challenge effective cooperation. Meanwhile, for the “Big Three” and Europe, it is clear that international resource sharing has been effective and continuously improving and expanding. These relationships are improved by converging processes, as well as training and developing administrative procedures. Illustrative quotes from stakeholders on the ground in the “Big Three” and Europe confirm this positive view of international resource sharing.

“yeah yeah, it is definitely useful because there is no country that can have all the resources they need to deal with every situation. It just, you know, it wouldn’t be feasible, it wouldn’t be cost effective. They’d have what’s been called rust out because they’re, you know, on slow fire seasons. You know idle hands make for you know those, those cliches so. But when things are really bad, there needs to be a mechanism to get help from your neighbors, if you will, and these international agreements are just that . . . that assistance from their point of view was critical there’s no way they could have managed that fire season on their own.”

“It has proven that it is very useful and effective and it’s quick, and by sharing the resources it’s better, it’s cost effective because . . . by sharing, we can reduce the number and you can use them more effectively, so it’s even cost reduction . . . international resource sharing it’s only one way to be prepared for the for the biggest emergency, because there is no way that each country could build independently a response system.

It is just going to be too expensive, it's going to be too big a burden for one country to handle it."

"I don't think it's practical for anyone to keep a standing army of people who are only ever used once every ten years. So there's a clear logic in sharing resources internationally and it, it helps those people who end up deploying. It helps them grow. It's a great opportunity for people to see how things are done elsewhere in the world. Every time I send people, they come back saying, look, it was fantastic, I learned so much, and you know we were also able to share some of the things that we do that maybe people haven't encountered before that's a really good idea."

Table 4. Strengths and weaknesses of international sharing arrangements.

	Strengths	Weaknesses/Challenges/Barriers	Future Directions
Bilateral agreements Australia, Canada, United States	<ul style="list-style-type: none"> Common use of Incident Command Systems (ICS, NIMS, AIIMS) Strong personal relationships Long history of collaboration Highly trained personnel/maturity of wildland fire management sector Similar settings and language Operating Plans Planning efforts Considered effective Debriefs conducted Liaison officers Sharing made easier as frequency of exchange increases 	<ul style="list-style-type: none"> Requesting resources is expensive Different protocols, e.g., fatigue management, equipment use Incomplete convergence of training protocols Inefficient process and system of identifying personnel for deployment in US Distance between partners Travel challenges (new context, visas, legal requirements, logistical issues) 	<ul style="list-style-type: none"> Potential need to expand number of partners—challenges in identifying Improving processes and systems for identifying personnel for deployment Creating guidebooks and orientation packages for resource sharing
EU Civil Protection Mechanism	<ul style="list-style-type: none"> Pooling of resources Institutional framework Solidarity Fast response Considered effective Resource sharing is cost effective Exchange of information and good practices Evaluation protocols Continuous systematic incremental improvement 	<ul style="list-style-type: none"> Training and familiarity not always adapted to setting of requesting country Different national fire management systems Different languages More resources potentially needed 	<ul style="list-style-type: none"> Potentially expanding and improving capacities of Civil Protection Pool and rescEU Improving convergence of training and systems
Southeast Asia/ Diplomatic Missions	<ul style="list-style-type: none"> Political solidarity 	<ul style="list-style-type: none"> Can be minimally effective Can be seen as threat to national sovereignty 	<ul style="list-style-type: none"> Improving local fire management capacities Improving legal systems Potentially improving collaboration efforts and convergence of training and systems

3.3.1. United States/Canada/Australia Strength and Role

Multiple stakeholders and evaluations confirmed that one of the main strengths of the United States, Canada, and Australia's international sharing arrangements is the common use of the incident command system [25,39,49]. The Australasian Inter-service Incident Management System (AIIMS) [31] is based on the Incident Command System (ICS) used in the United States, Canada, and Mexico [50,51]. This common framework helps ensure resources are shared in a safe and coordinated manner, whereas moves to deviate from this system have been strongly discouraged [49]. Without this common ICS, it can be too risky to provide aid as the lack of organization, coordination, and the potential existence of multiple plans can have dangerous and catastrophic outcomes, according to stakeholders. This risk may be one of the reasons that humanitarian aid missions showing political solidarity with countries not sharing these systems have been minimally effective. According to

stakeholders, the United States, Canada, and Australia have sophisticated and mature wildland fire management sectors, highly trained personnel, and a common language (English) that further facilitates their sharing arrangements.

Additionally, the United States, Canada, Australia/New Zealand, and other partners' bilateral sharing arrangements rely fundamentally on strong personal relationships according to stakeholders. There is a long history of collaboration that began in the 1950s through the North American Forest Commission Fire Management Working Group (FMWG) and the Australasian Forest Fire Management Group (FFMG), which conduct bi-annual study tours between the regions [49,52]. These relationships have led to formalized agreements facilitated by operating plans. Representatives from different nations meet virtually, sometimes even weekly, to keep each other informed of fire developments in their respective nations. This consistent communication allows for coordination amongst nations fulfilling requests versus just bilaterally. During resource exchanges, liaison officers often accompany other types of support from the providing country. Several interview participants mentioned that these sharing arrangements have become easier over time as their flexible and cooperative nature allows lessons learned to be implemented in further iterations [50].

Barriers

Though resource sharing is perceived as helpful and vital, arrangements are continuously evolving. Stakeholders identified several issues that create barriers to exchange, including logistical issues. One of the main limitations of international resource sharing amongst the North American and Australasian nations is the cost. When a country requests a resource, they are expected to provide reimbursement. Distance between certain partners was also noted as a limitation. Although these nations have similar language and cultural practices, some norms may differ. For example, issues around traveling were considered a common barrier in multiple ways. Anything from driving on opposite sides of the road to challenges in obtaining international cellphone plans, delays in getting travel approval, passports and visas, and most recently, COVID-19 protocols may complicate partnerships. Different protocols around fatigue management were also noted as a concern, e.g., in Australia, firefighters are guaranteed more frequent days off than in the United States, which can lead to liability concerns.

Further, though the different nations use ICS, there are some differences in the roles and responsibilities attached to similar job titles. To address these issues, partners are creating guidebooks and orientation packages to ensure this information is readily available [50]. Additionally, the US is improving systems for identifying and clearing personnel for international mobilizations. During the 2019–2020 deployment of US and Canadian resources to Australia, it was noted that the US resources took several more days than those of Canada.

3.3.2. European Union Strength and Role

Prior to the strengthening of the European Union Civil Protection Mechanism, there was evidence that bilateral agreements were preferred in some cases [53]. However, now, the Mechanism is well accepted and increasingly utilized [25,33]. The Mechanism has been incrementally improved over time, has a unique funding structure, has cultivated a strong culture of solidarity among member states, and is perceived by member states as efficient, effective, predictable, flexible, and reliable [33,54–56]. The European Response Coordination Centre that manages the European Civil Protection Mechanism is staffed by trained duty officers that provide real-time monitoring 24 h a day, seven days a week [55]. The Mechanism is also able to provide assistance within hours of notice. Stakeholders have emphasized the strength of the aerial support system, which is managed by a small group of highly trained and experienced pilots familiar with EU forest fire challenges [55]. In the past, it was noted that sometimes bilateral channels were faster and more effective; however, this was not the case during an increase in the simultaneity of forest fires in the

EU region [54]. The EU has, in recent years, tried to increase reserve resources and improve coordination processes systematically, facilitated by regular evaluation. Additionally, the unique funding structures reduce cost burdens.

Barriers

One of the main challenges of the EU Civil Protection Mechanism is that the member states have diverse national fire management structures. Thus, they may benefit from harmonizing systems, standard operating procedures, and training protocols [24,33,57]. Stakeholders also noted that some ground crews might be less familiar with tackling forest fires across a variety of European landscapes. Additionally, the civil protection pool and spontaneous bilateral agreements are voluntary and can be uncertain, which is why the rescEU reserve pool was created [33,55]. The rescEU has grown since its inception and may need to expand in the future. Previous reports noted that the timing of requests could also reduce the effectiveness since those called upon as a last resort face a more difficult challenge in reducing the fire risk than those called upon earlier [33]. Although the EU helps coordinate support, it is up to individual countries to assess their need. Even if the EU has tried to increase the buffer capacity of the Civil Protection Mechanism, there may need to be additional capacity during high regional co-occurrence of fire.

3.3.3. Southeast Asia/ASEAN

Barriers

One of the biggest challenges to regional cooperation in Southeast Asia is that fire management is a politically contentious topic. For example, countries have been observed to walk out during ministerial level meetings regarding transboundary haze [24]. There is a stronger emphasis on national sovereignty versus regional interests among ASEAN member states [58]. The ASEAN Agreement on Transboundary Haze was ratified with significant delays even though it was a soft agreement with minimal enforcement mechanisms [38,59,60]. The agreement was ratified by Indonesia only after media reports shifted blame for a significant haze event to the government and the palm oil industry instead of placing responsibility on a drought induced by the El Niño–Southern Oscillation (ENSO). The ASEAN Agreement on Transboundary Haze has been criticized for its minimal effectiveness, but since all major stakeholders have ratified it, it has gained political support [38,61].

Another major constraint is that many Southeast Asian nations like Indonesia are low and middle-income countries with limited capacity and funding to manage fire risk [24,60,62]. The Indonesian government has argued that Indonesia should have the right to develop economically before it faces the same burdens of improving environmental sustainability as high-income countries [60]. Fire suppression efforts largely rely on the personnel and equipment hired and supplied by larger palm oil companies bound by law to retain these. It can be difficult to hold companies and smallholders legally responsible for forest fires, but there have been ongoing training efforts to improve the identification of those responsible for fires [27,60]. Several interviewed stakeholders noted the positive shift in increased government commitment to preventing deforestation and haze.

International development funds are still relied on to combat haze problems in Southeast Asia [63]. Some have argued that ASEAN should focus on controlling peat fires versus promoting a zero-burning regime [64]. Diplomatic missions of providing personnel or other resources during an emergency can be minimally effective or seen as a threat to national sovereignty despite political solidarity. Furthermore, diplomatic missions from more sophisticated firefighting sectors may be constrained due to Indonesia's limited firefighting capacity and uncommon standard operating procedures.

3.3.4. Climate Change Impact on Resource Sharing

All stakeholders acknowledged the potential strain climate change and changing fire regimes will have on resource demand and the growing need for strengthening and

expanding international partnerships. Increasing fire frequency and fire season length associated with climate change are projected for the United States, Canada, Australia, and Europe [8,13,15,16,65]. The International Panel on Climate Change (IPCC) found ‘high confidence of increase’ in projected fire weather in the Western United States, Mediterranean Europe, and Australia and ‘medium confidence of increase’ in projected fire weather in Canada, the Eastern United States, and Central Europe [65]. Additionally, for other resource sharing partner nations of the United States and Canada, the IPCC finds ‘high confidence of increase’ for projected fire weather in parts of Mexico and South Africa. In Canada, climate change is projected to increase suppression costs by 60–199% [29]. In Europe, the southern countries such as Portugal, Spain, France, Italy, and Greece are traditionally the most fire-prone. However, in recent years Nordic European countries such as Sweden have experienced unprecedented forest fires [32].

Although fire historically was not a common feature in the tropical rainforests of Southeast Asia and specifically Indonesia, there are some concerning trends [24]. Fire activity is hard to predict in Southeast Asia as it is more correlated with precipitation and weather phenomena such as droughts induced by ENSO [41] and it is unclear what the impact of climate change will be [65,66]. Many forest fires are started by human activity, such as through agricultural activity of slash and burn, and these trends can be difficult to predict [41]. Approximately 98% of avoidable carbon emissions emanate from the tropics, whereas three-quarters are only from three countries (Brazil, Indonesia, DRC) [67]. In addition, fires are now occurring in regions in Indonesia that did not previously see fire [68].

Deforestation fires in Indonesia and Brazil were estimated to cause 7% of global greenhouse gas emissions in 2019 and 3.5% in 2020. Further, a recent study found that deforestation greenhouse gas emissions had previously been drastically underestimated in peatlands [69]. Therefore, preventing the escalation of large fire and haze events may also be considered a climate change mitigation strategy. Improved policy enforcement and the recent global recession have reduced deforestation in the short run. However, it is unclear what will happen in the future, as much of the fire risk is tied to more unpredictable anthropogenic changes from policy, to the economy, to prevention [69]. For example, it is unclear how COVID-19 impacts and the Indonesian government’s plans to move the capital to Kalimantan (where a large share of the country’s tropical forests is located in Indonesia and where many forest fires start) will affect fire management in Indonesia. Disparities in fire suppression capacities of different nations worldwide must be reduced while also acknowledging the role of prevention and fuel management strategies [70].

4. Discussion and Conclusions

In this research, we have analyzed a substantial number of connections, agreements, documents, and transcripts. Our synthesis suggests that international resource sharing arrangements are nascent, continuously evolving, and take on different forms in different regions. These arrangements are influenced by the economic, historical, cultural, ecological, and wildland urban interface conditions in these geographies. For the “Big Three” and Europe, international resource sharing is perceived as necessary, effective, and continuously improving. These relationships are facilitated through converging processes and training (e.g., ICS), close personal ties, and the development of more effective administrative procedures.

The sharing of resources is constrained when countries have overlapping fire season peaks. For example, if Canada and Australia are experiencing overlapping fire seasons with the United States, this will affect what resources can and will be requested. There were similar amounts of acres burned and the number of days at high PL in 2017 as in 2020 in the United States. However, fewer resources were shared as Canada was also undergoing a severe fire season from early July to mid-September. Canada had received support from Australia, New Zealand, and Mexico, but in mid-September, as domestic fire activity subsided, Canada was able to send resources to the United States. It should also be

noted that in 2017 the US was at PL 4 or 5 from mid-July to the end of September, which resulted in some requests being fulfilled with resources controlled by the US military.

Fire season lengthening and an increasing occurrence of impactful fires due to climate change in “the Big Three” nations and Europe, is already leading fire managers in the “Big Three” to identify new potential partner nations and strengthen current relationships. For example, the United States is currently drafting the first Standard Operating Procedure with Mexico. Meanwhile, the EU has been expanding the pool of resources at its disposal.

In Southeast Asia, ongoing efforts by local governments and international partners, including development agencies, are needed to reduce disparities and improve fire management capacities in low and middle-income countries. The feasibility of more effective international suppression resource sharing in this region is unclear, considering the political tensions, uncertainty in fire trends, economic benefits of slash and burn agriculture and other deforestation activities, and constraints around providing aid due to costs and lack of shared systems. Worrying trends such as increased fire potential of forest landscapes and shifting demographics indicate that governments may need to explore additional ways to prevent large haze events. High-income country bias in current fire research often neglects low- and middle-income regions such as in Southeast Asia, which would benefit from further inquiry.

As a result of a very modest body of peer-reviewed literature, this work relies heavily on gray literature. In addition, the literature review was supported by key informant interviews and schematic figures. The main limitations of this paper are related to an overall paucity of information about international resource sharing and the limited availability of public data. Therefore, we hope that this synthesis provides an overview for researchers and practitioners and helps incentivize much-needed further research. A limitation of our stakeholder interviews was that practitioners such as fire fighters and fire managers from European and Southeast Asian nations were not interviewed; however, some representation of these voices was incorporated in the gray literature reports.

This paper discusses three case studies of sharing regions for fire risk management. We show that resource demand for international resource support seems to be increasing in many nations. We also discuss the role international collaboration can play in mitigating fire risks due to climate change and the existing opportunities and barriers. International resource sharing is an ongoing area of study as even high-income countries prone to fires with sophisticated fire suppression capacities have only recently begun to formalize resource sharing efforts. Future research should be targeted to gather better data (such as regarding how and which types of resources were deployed during specific date ranges by regional, federal, and local state or provincial international partners) as this information becomes available. At the same time, policymakers should open up public access. These data can support identifying drivers of international resource sharing, the current impact and potential impact, and limitations of international resource sharing on fire management.

Furthermore, future research should identify the metrics of fire season length overlap that are correlated with resource sharing needs for specific regions and project potential future needs/gaps. Other potential research strategies could include modeling efforts that identify the most effective forms of resource sharing arrangements in terms of timing, resource pooling, level of coordination, and the number of countries per network. Although this research focuses on fire suppression needs, it acknowledges that prevention efforts are critical and that governments need better tools to identify the tradeoffs between investing in better fire response efforts and prevention efforts. Stakeholder interviews highlight the importance of global cooperation for information exchange and fire suppression; however, there may be a need to explore further the role of more global cooperation in terms of proactive fire management. More research evaluating how to improve capacity building efforts may help make programs more effective. International resource sharing arrangements are still nascent but indicate a growing need for policymakers to improve effectiveness. Improvements could include strengthening bilateral or multilateral response,

investments in capacity building, addressing policy barriers, improving data management, and potentially increasing global cooperation for proactive efforts.

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Appendix A. Interview Protocol

WELCOME and INTRODUCTION

- Thank you for making this time for us
- Introductions
- Background on the project
- What we hope to accomplish in this meeting
 - I will be asking you a set of interview questions that we have prepared
 - Our questions are organized around resource sharing decision-making for fire suppression in terms of both making requests for resources or assistance for fire suppression and providing personnel and equipment to requesting countries

Questions:

1. What is your involvement and/or your organization's involvement with international resource sharing for fire suppression?
2. How has international resource sharing evolved over time for your country/region/organization? Have fire seasons lengthened in your location and has there been a greater need or demand for international resource sharing? (*If country*) Is your location making more demands/requests now than in the past? (*If multilateral organization or country*) Are others making more requests of you than in the past?
3. (*If country*) Does international resource sharing affect your country's decisions around planning and pre-positioning resources ahead of the season? Does your country have a certain amount of resources that should be on hand at all times prohibiting

- or limiting when resources are able to be sent abroad? (*If multilateral organization*) How do you determine how many resources should be pooled or available prior to a fire season?
4. How do you go about making requests (*if country*)? Is it a hotline? A web form? Do you call your counterpart? Other? How do others make requests of you (*if multilateral organization or country*)?
 5. What are the circumstances under which requests for international assistance and back up are made? (E.g., Last resort, shared pool of assets.)
 6. What information do you utilize to make decisions about:
 - a. international resource sharing requests? (Database, conditions necessary for resource sharing, political, other?)
 - b. Providing resources to partner nations?
 7. What type of characteristics of fire seasons are likely to lead to international resource sharing requests? (E.g., Large area burned, large number of fires, location of fires, flame length, etc.)
 8. What is the administrative process for requesting and providing international resource sharing assistance for fire management? (Communication process and tools, conditions, levels of authority, and types of approval required.)
 9. For bilateral agreements, how do you decide which country to request resources from first?
 10. What are the strengths of the international resource sharing program that you are involved with?
 11. What are the weaknesses and/or barriers for the international resource sharing program?
 12. How can international resource sharing be improved?
 13. What do you believe should be the role of international resource sharing in the future? Does the projected impact of climate change and/or simultaneity affect your decision making?

Appendix B. Data and Methodology for International Resource Sharing Trends Figures and Case Study

Illustrative figures related to resource sharing trends over time specifically between the United States, Canada, and Australia and New Zealand are presented using data from national fire agency annual reports and news stories. It should be noted that these data did not contain resource sharing between other partner countries and contained neither sub-national state-to-state nor province sharing. Data on the number of personnel and aircraft sent per year from one country to another and the timing of typical resource transmission were collected from the United States NIFC Annual Reports between 2001–2021, Australian Government AFAC News from 2015–2021 and Canada CFFC Annual Reports from 2013–2021. Data on personnel sharing included crews and overhead. Additionally, data were collected on the number of days with each preparedness level for the United States and Canada, and the area burned per year for the United States, Canada, and Australia.

Additionally, illustrative figures related to sharing within Europe based on the number of times the European Union Civil Protection Mechanism was activated specifically for forest fire emergencies were produced using data provided by DG ECHO staff, DG ECHO Daily Maps, DG ECHO annual activity reports (2014–2021) and from an ICF report titled the Evaluation of Civil Protection Mechanism-Case study report-Forest Fires in Europe (2014). Data for the total number of activations within EU and non-EU countries were examined, however, these did not include resource sharing that may have occurred between nations via bilateral agreements. Additionally, data on the number of areas burned and the number of forest fires in southern member states were collected from the JRC Technical Reports of the European Commission on Forest Fires in Europe, Middle East and North Africa.

In Southeast Asia, a case study of significant fire years, e.g., 2015, is examined to identify some of the barriers and opportunities that may exist around resource sharing and fire management in the region. Information was obtained from newspaper reporting on

international resource sharing and peer-reviewed literature related to this topic assessing the ASEAN Agreement on Transboundary Haze. Data for yearly resource sharing activities were not easily obtainable for Southeast Asia and specifically Indonesia where a large amount of forest fire occurs in the region as they are not systematically documented for public consumption. Considering the nonlinear nature of fire in the region, the fact that Indonesia only recently ratified the ASEAN Agreement on Transboundary Haze (in 2015), and that the Regional Fire Management Resource Center–Southeast Asia was only established in 2017, a trend analysis may not be appropriate as many resources shared with Indonesia from international partners is often still ad hoc and not coordinated via ASEAN per se. Therefore, a qualitative case study format was used to illustrate some of the trends and challenges around resource sharing for low- and middle-income countries in Southeast Asia.

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