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The People and the Fire Tree: Co-Designing a Bushfire Early Warning System to Meet the Sustainable Development Goals

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Abstract

Australian rural communities face significant climate challenges including catastrophic bushfires. In line with the UN sustainable development goals (SDGs), to build resilience in the face of bushfire threats, communities need to increase adaptive capacity while maintaining the community's integrity. To build community resilience, they should harness the hybridity between digital technology and non-technological practices. Building community resilience is gaining attention in rural human–computer interaction to ensure those who are vulnerable to disasters strengthen their ability to address adversity even in the absence of formal government assistance. How they apply digital technology into practice to ensure it meets their needs is crucial. We outline a case study of a rural Australian bushfire-impacted community. A series of co-design workshops was conducted to understand local bushfire preparation activities and the role of digital technologies in these activities. Three creative participatory design activities supported the co-design of an early-warning bushfire system. The workshop participants co-designed and merged two solutions: first The Fire Tree, a conceptual map of a preventative information system fed and validated by the community itself; second, The People System identifies and harnesses government resources to feed and generate a rich, dynamic, and constantly updated information environment. The final solution based on the two concepts is Bushwire, a communication facilitator designed and used by participants in workshops four and five. Bushwire is a co-designed web-based collective platform that leverages citizen-science behaviours, enabling them to share local knowledge and prepare for bushfire threats. The system became a communication facilitator, a space to share detailed local information and connect; fed by locally produced elements including digital technologies, weather/road conditions, and on-the-ground instructions. This case study explores how Bushwire responds to a range of UN SDGs by seeking to build sustainable communities (SDG11), to address climate action (SDG13) for this rural Australian bush-fire-prone community, and

harmonises life on land (SDG15) through multi-stakeholder partnerships (SDG17). We envisage that urban planners may derive value from listening and responding to messages from nature, and from citizen-scientists embedded in rural communities as depicted in this case study.

Keywords
bushfires; climate action; co-design; human–computer interaction; life on land; resilience; sustainable cities; sustainable communities; sustainable development goals

1. Introduction

Bushfires are a fundamental part of the dynamics and cycles of some habitats, as they regulate biomass and renew existing plants. For instance, there are seedpods that require smoke to germinate, native grasses that regenerate following low-intensity fire, and bird species that use strategic opportunities to repopulate (Lavery et al., 2024; Williamson et al., 2023). However, since the appearance of human settlements adjacent to bush areas, fires become a disturbance as they have massive disruptive effects on the coexistence of communities in terms of people's daily activities and interaction with their environment. The costs associated with fires go beyond infrastructure in terms of reconstruction, and mitigation planning, since fires can affect all aspects of everyday life for those who are part of these communities.

Although there are practices and policies developed by governments to solve the primary needs of the inhabitants of rural communities once the disturbance has occurred, they are primarily focused on solving problems of housing and supplies. These measures tend not to properly consider the individual needs of each community, much less prepare the community for a new disturbance. A better understanding of community activities that support living with the bushfire threat has the potential to help communities build their resilience over time.

This research aims to develop more holistic strategies and design solutions, including the use of technologies, to support communities in facing ongoing threats and recovering from bushfire events. It is at this exact point where this work connects with four of the 17 sustainable development goals (SDGs) defined on the website of the Department of Economic and Social Affairs of the United Nations Organisation (United Nations, n.d.). First, SDG 11 (sustainable cities and communities) since rural communities (including the group in this study) demonstrate deep interest and knowledge in sustainable practices to preserve their livelihood and healthy lifestyle. Second, SDG 13 (climate action) since the group of participants had experience facing past bushfire seasons and have been active agents in preserving nature and their environment. Third, SDG 15 (life on land) is relevant since it involves the knowledge the members of the community have about their own environment, and therefore its needs. And fourth, SDG 17 (partnerships for the goals) since the members of the communities understand how important it is to nurture internal relationships and open communication channels with local service suppliers (e.g., the country fire authority) and governmental institutions.

Driving this study was our research question: How can co-designed digital technology support rural communities to build resilience to coexist in the face of bushfires? The aims of the project are: First, to identify what digital communication activities generate rural resilience; second, to determine how these digital communication activities can be harnessed in the face of bushfire threats in rural communities; and

third, to co-design a digital resource with a rural community that builds on local knowledge, and utilises citizen science behaviours, to serve as an early bush-fire warning system. Muashekele, et al. (2019, p. 127) suggest that given its methodological characteristics, "co-design approaches strengthen the emphasis on user's needs, aspirations and limitations." Therefore, to explore and gain accurate, contextual information about these three questions, a series of co-design workshops were conducted with members of a rural Victorian, bushfire-impacted, and bushfire-threatened community. The final outcome from these workshops was a co-designed website named Bushwire, introduced below.

The co-design solutions presented here demonstrate how proficient the participants are in developing flexible strategies and tools to strengthen community resilience using technology. This concurs with Muashekele, et al. (2019, p127) as they explain how "working directly with rural communities allows for their voices to be heard and integrated into the design, anticipating a higher rate of acceptability." Our solution took the form of an early warning system through observation and monitoring of local conditions, and sharing this information, thus creating awareness of the state of nature via a communication tool based on community posts. These early co-design ideas were the foundation for the development of a website called Bushwire where the participants could capture changes in nature and share experiences and knowledge about the local environment, with a view to sustaining a harmonious relationship between the environment, i.e., the wildlife, the bush, and the people residing within it. We discuss how this can also provide learnings for the SDGs.

This article includes several sections related to five workshops conducted in rural Victoria. First, unpacking the background, where we examine existing research and methodologies related to resilience building in communities. The second section is the case study, where the activities were conducted, and the results and solutions are described. Third is the discussion section where the findings are explored and finally, the conclusion where design guidelines are proposed based on the previous sections.

2. SDGs and Community Resilience

The UN 17 SDGs are focused on sustainable cities and communities. As is explained in the Department of Economic and Social Affairs of the UN website (United Nations, n.d.). The 2023 Agenda for Sustainable Development adopted by all UN member states in 2015 provides a shared blueprint for peace and prosperity for people and the planet, now and into the future. At its heart are the 17 SDGs, which are an urgent call for action by all countries—developed and developing—in a global partnership. Specifically, they are concerned with making human settlements inclusive, safe, resilient, and sustainable. While typically the SDGs are more focused on urban rather than rural settlements, some mechanisms identified to support sustainable communities (SDG 11) speak particularly to rural Australian bushfire-prone communities, such as addressing sustainability through risk assessment. This case study illustrates how a rural bushfire-prone Australian community seeks to build community resilience, including through climate action that aims to capture and report disaster risk strategies. We argue that, in Australia, this is leveraged through multi-stakeholder partnerships, including local government, local community members, and the local environment colloquially known as "the bush" (Davis et al., 2020, p. 250). In this case study we highlight the role of a cultural probe and a technology probe (Bushwire) in capturing and supporting this activity for one rural bushfire-prone community.

Resilience is not a static attribute of a system, it changes, adapts, and modifies according to the environment and the type of stressors involved just as a community may do when it is necessary. For Balvanera et al. (2017, p. 142) the concept of resilience arises from the empirical study of the systems that surround us, from the observation of phenomena that operate at multiple spatial and temporal scales, such as environmental phenomena and their consequences. Similar to Southwick et al. (2014, p. 4), this study subscribes to what Panter-Brick and Leckman understand as resilience, since they describe it as "a process to harness resources to sustain well-being." This definition is relevant here since the identification and harnessing of resources has the potential to allow communities to constantly strengthen resilience over time. Such an understanding of resilience is also relevant to the increased interest in urban resilience with citizens facing growing environmental challenges (Meerow et al., 2016). Research on urban resilience promotes nature-based solutions (Bush & Doyon, 2019). We believe our research can play a role in informing such trends as we show rural communities understand and interpret interactions with nature as part of their daily life (Bush & Doyon, 2019).

Research found that a lack of knowledge increases bushfire threats as it leads to unsuitable forest management practices (Gammage et al., 2021). Also importantly, according to Foth et al. (2024), a main issue in bushfire planning and preparation practices is "a focus on human life and property" which:

Does not account for the health of the forest or the natural systems that rely on it. As a result, there is an uneasiness in the communities about the extent to which residents can or should rely on external systems for protection. (Foth et al., 2024, p. 321)

This is where our research aims to enable rural communities through technology to grow and share knowledge and hence increase their resilience.

Technology has been one fundamental tool for the subsistence and development of rural communities. How the characteristics of this tool can be harnessed needs to be understood under a singular lens, this is where human–computer interaction (HCI) becomes relevant for this study. According to McKay and Buchanan (2022, p. 144) HCI is defined as "how people interact with technology, and how technology changes society." This description is relevant to this study since digital technologies are a facilitating agent that keeps these communities connected with the world, a highly necessary link because "the unique socio-economic structure of rural areas makes them particularly vulnerable to incipient or unfolding disasters" (Doke & Yuan et al., 2020, p. 5). This is particularly pertinent when a community must face the challenges of developing its activities in a rural context under the constant threat of natural events like bushfires. Blackler et al. (2024, p. 124) also emphasise the important role and opportunities of technology in preparing communities for natural disasters through increased "situational awareness and risk perception."

According to Hughes and Sarzynski (2015, p. 2), to increase resilience, communities need to increase adaptive capacity to maintain the community's integrity. As Taylor and Cheverst, (2010, p. 218) argue, "Rural areas are a particularly interesting environment for the study of technology," especially for exploring the hybridity between technology and non-technological customs, habits, and practices (Hardy et al., 2019, p. 196). Basak et al. (2020) argue that building community resilience is gaining attention whereby all communities, especially those who are vulnerable to disasters, seek to become empowered to strengthen their ability so that they can address adversity even in the absence of formal government and other external assistance (Basak et al., 2020, p. 2).

It is crucial to explore how rural communities understand and use technology, particularly how they adapt it in practice to meet their needs. Understanding the local knowledge of rural communities is pivotal to the development of strategies that evolve and ensure, sustainable, resilient future communities. As Muashekele et al. (2019, p. 127) suggest, "involving target users, (in this case from a rural context,) provides a better understanding of how best to implement and introduce technologies to rural and co-located communities." Therefore, we call upon the deep knowledge of the local environment in order to develop strategies that resonate with the lived experiences of the community. Williamson et al. (2023, p. 7) provide a good example in the context of Indigenous studies, explaining how "Indigenous environmental data is produced through connections to the earth, cultural identity, language, traditional kinship systems and the valuing of cultural knowledge holders within a community."

In this article, we will review how the contributions of the members of a rural community helped shape a prototype for an early warning system by harnessing the knowledge they have and engaging them in the process of creation in a series of co-design workshops. We value the contributions of the members of the community since we consider their knowledge foundational in building more resilient communities facing the threat of extreme natural events. As Hespanhol (2017, p105) suggest, "By promoting the engagement of citizens, communities can build coping mechanisms that can address potential disturbances with greater preparedness… utilising a wider range of creative input from citizens to ideate future solutions."

In the next section, we will review the methods used at the different stages of the study and describe the activities of the workshops conducted in Regional Victoria, Australia.

3. Methodology

This case study was conducted with members of a community utilising a participatory research approach. The field of participatory design continues to provide a vibrant environment for the discussion and dissemination of new tools and techniques (Sanders & Stappers, 2014, p. 146). The series of workshops were held over 14 months between 2022 and 2023 in Regional Victoria in Australia. Research suggests that there is much scope to apply a participatory design approach within HCI to address the SDGs (Fredericks et al., 2019, p. 3). All the participants were members of one small community, and we were able to work with them in-depth. They completed a short demographic questionnaire at the first workshop. Table 1 summarises the basic demographics of the participant group. Participants' identities have been anonymised for the purpose of this study and pseudonyms are used. The names assigned to the participants are Annie, Diana, Gail, Hank, and Tony. This section, and further, includes participant quotes from the workshops.

Table 1. Demographic description of the participants group.

Name	Age range	Years in the community
Annie	55–66	20+
Diana	65–74	25+
Gail	65–74	25+
Hank	25–34	20+
Tony	75+	25+

The participants in this series of workshops were recruited from a rural community in Victoria, Australia. One of the authors belongs to a neighbouring community and was the initial link between the participants and the research team. All the participants were active members of the community and lived in the region for over 20 years, the age of the participants is typical for this community.

The workshops were conducted in Kangaroo Hills (the area has been anonymised). Established in the late 1800's, it is located in Victoria, Australia. According to the 2021 Australian Bureau of Statistics census, Kangaroo Hills' population is around 360 members. Kangaroo Hills was one of the communities affected by the Black Saturday bushfires which were Victorian bushfires in which 173 lives were lost across several communities and another 414 people were injured, impacting local areas (Country Fire Authority, 2023). The workshop participants have all experienced the Black Saturday bushfires and reside in a rural bushfire-prone area with large areas of dense bush and biodiversity including wildlife such as kangaroos, koalas, wombats, echidnas, and other species.

The workshops were informed by activities including focus group conversations. We designed a cultural probe kit (see Figure 1). McDougall and Fels (2010, p. 58) explain that cultural probes:

> Create insights by going beyond more traditional user study techniques that rely on what people say and do (questionnaires, interviews and observation studies). Probes combine interpretation, ambiguity and fun, inspiring and stimulating probe users, who in turn, stimulate the designers to tell stories about what they get back from the places probed.

A cultural probe activity was conducted in workshops 2 and 3 and participants engaged with the cultural probe in their own time in between these workshops. A digital cultural probe called "Bushwire" (see Figure 5) was discussed in workshops 4 and 5 (see Section 5) and interacted with between the workshops.

Figure 1. The analogue journal kit.

This article includes data from workshops 1 to 5 (see to Figure 2) and activities between them that took place over a year. Cultural probe activities in workshops 1–3 are explored more thoroughly elsewhere (Munoz Rivas et al., 2024). This activity explores workshop participants' co-design, use, and evaluation of Bushwire, a socio-technology probe used to capture the participants' interaction with their environment for bushfire preparedness and response.

3.1. Data Collection and Analysis

The workshops constituted two major sets of activities (see Figure 2) and were planned on a participatory design basis, as "participatory design is a natural partner to community based participatory research, which seeks to incorporate community members as co-researchers and co-developers of projects in order to reflect the lived realities of research populations" (Hardy et al., 2019, p. 196). First, the analogue data collection, which includes the workshops' face-to-face activities and the cultural probe activities (journal entries, briefly described in the next section), occurred both within and between workshops. To process the workshop and analogue journal data, a thematic analysis approach was utilised. As Braun and Clarke (2006, p. 5) suggest, this qualitative method of analysis provides the flexibility compatible with the qualitative character of this study. Thematic analysis is a method for identifying, analysing, and reporting patterns (themes) within data. It minimally organises and describes data sets in rich detail (Braun & Clarke, 2006, p. 6). The workshops were audio-recorded, and the transcriptions of these recordings were used to employ categorisation of the themes raised during the sessions. Through this initial categorisation of the themes the entries compiled in the journal (cultural probe) helped to shape the categories that finally can be observed in Table 2.

Second, in the digital data collection stage (see Figure 2) participants created entries in Bushwire organically building a collective database with knowledge about the local environment documenting changes, knowledge, and concerns about nature and climate change (described in Section 5). The digital data from the entries was processed by using content analysis. For Sheydayi and Dadashpoor (2023, p. 2) "qualitative content analysis is a systematic analysis of qualitative data in which the latent values and meanings in a text

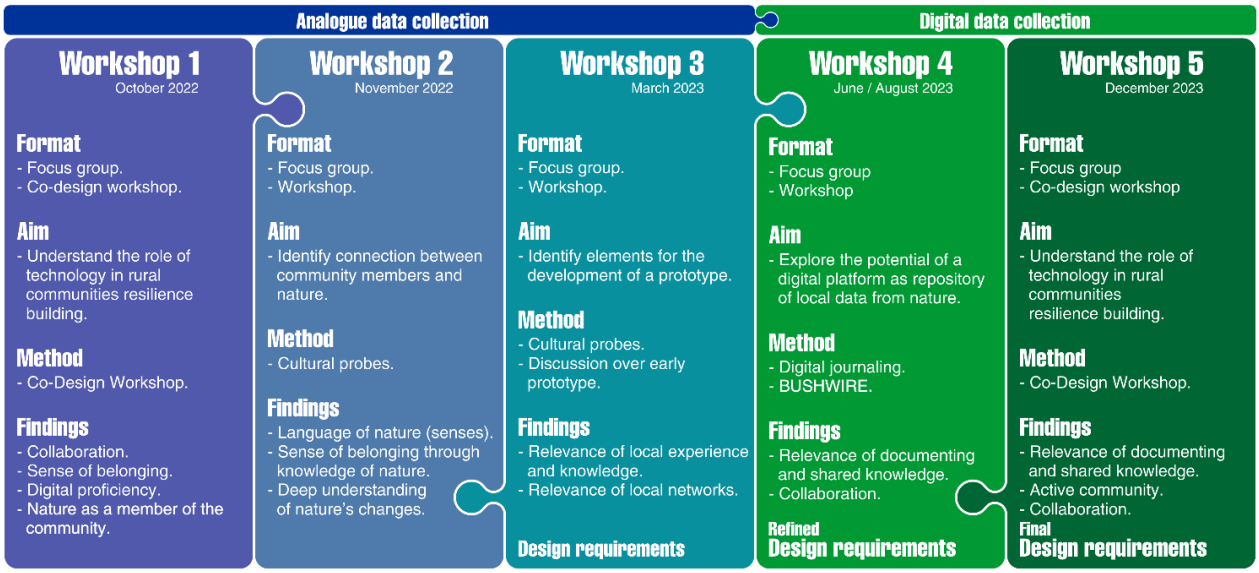

Figure 2. The activities and aims of the workshops conducted in regional Victoria.

are identified, described, and interpreted." For Krippendorff (2019, p. 18), "content analysis is a scientific tool. As a research technique, content analysis provides new insights, increases a researcher's understanding of phenomena, or informs practical actions." This qualitative content analysis approach helped to define and organise categories based on the characteristics of the digital entries as seen in Table 2. This approach helped to develop terminology to identify the different types of entries described in Section 5.

In both cases (analogue and digital) there are five categories but with small differences due to the format (see Table 2). For the analogue data, the categories are: reflection, poem/haiku, drawing, recounting, and found object. The digital categories are: reflection, poem/haiku, uncategorised, recounting/report, and comments.

3.2. Case Study in Rural Victoria, Australia

The first activity aimed to gain insights regarding the meaning of being part of the community. All participants articulated how living in a rural area was and is beneficial for their physical and mental health. Most of them had moved to the area when they retired, and their sense of belonging is strong. In the words of Gail: "Living here for so long makes me feel healthy and that I belong to something bigger than me." The common experience among the participants was that, as they adopted a simpler lifestyle, (or this "lifestyle adopted them") they progressively understood how valuable the environment was for them, and by extension their community.

The second activity concerned the methods of how community members participate and connect within the community (e.g., volunteering, neighbourhood chats, school drop-offs, and social media participation). Participants recognised that technology and social media are important to maintaining a flow of communication between the community members, coping with challenges, and helping to clarify who they consider to be a part of the community. Participants referred to their environment as an important member of their community and discussed the importance of caring for it, as they would other neighbours. Regarding the use of digital technologies, the participants talked about a variety of digital platforms and apps they use for bushfire awareness: "I rely on things like the Emergency Victoria websites, and I usually use meteorology websites" (Tony). Diana is an active user of the local Facebook group, since it allows her to connect with other members of the community: "When we started this up all those years ago, just a few of us talking on Zoom [there were] about half a dozen to 10 people. We've now got over 250 members on Facebook." Annie commented about how relevant Facebook has become important as an online resource for community connectivity "I'm a member of not just the Kangaroo Hills Facebook page, because that helps me know what's happening when it's in the local area."

Concerning bushfire threats the answers focused on digital resources and pointed to some existing governmental resources, but also uncovered a lack of local and up-to-date resources to inform them about the immediate situation. Annie stated: "In terms of online resources, e-mail and phone. I rely on the Country Fire Authority. The Be Safe app on the phone, which tells you when some things [bushfire conditions/activity] are about to blow up." The third activity Draw, Map, or Ideate, aimed to generate a solution for an early warning system to alert community members about bushfire threats. The participants had complete freedom to devise a system according to their own needs, experience, and knowledge.

4. Workshop One: Co-Designed Solutions

4.1. Solution 1: The Fire Tree

A conceptual map was developed and named by the participant, Gail, as The Fire Tree—a preventive local information system, fed and validated by the community itself (see Figure 3a). Gail explains the motivations behind her model: "I'm thinking of something that's gonna give people an advance [warning] so that they know what's happening and whether it's safe to evacuate. [It should be] something like this that is locally based." The system is a communication facilitator, locally based, controlled by locals, and that responds to local conditions. It aims to be a reliable source of information and communication that informs the community effectively about the status of nature locally and a potential natural event so that the community members can make decisions or receive instructions in case of a bushfire.

The concept has information support from the government, which makes it possible to contrast the information, since it may contain details that are beyond what the members of the community can generate. However, the emphasis is on the community knowledge and experience. Each new piece of information is easily received and distributed among the community members.

4.2. Solution 2: The People System

This conceptual map, named by the participants simply as People, largely identifies the resources provided by the government and harnesses these as an integral part of the system, to feed and generate a rich, dynamic, and constantly updated information environment. Diana's group elaborates on the effectiveness of an early warning system: "Ideally this works based on the people of the community. Someone or something to ring them up on the phone and say, 'go away,' 'run away now.' Vic Emergency is good, but they can't do everything." The system becomes a communication facilitator (see Figure 3b), with a space to share information and connect; this idea is shared in both conceptual models. In addition, other elements are

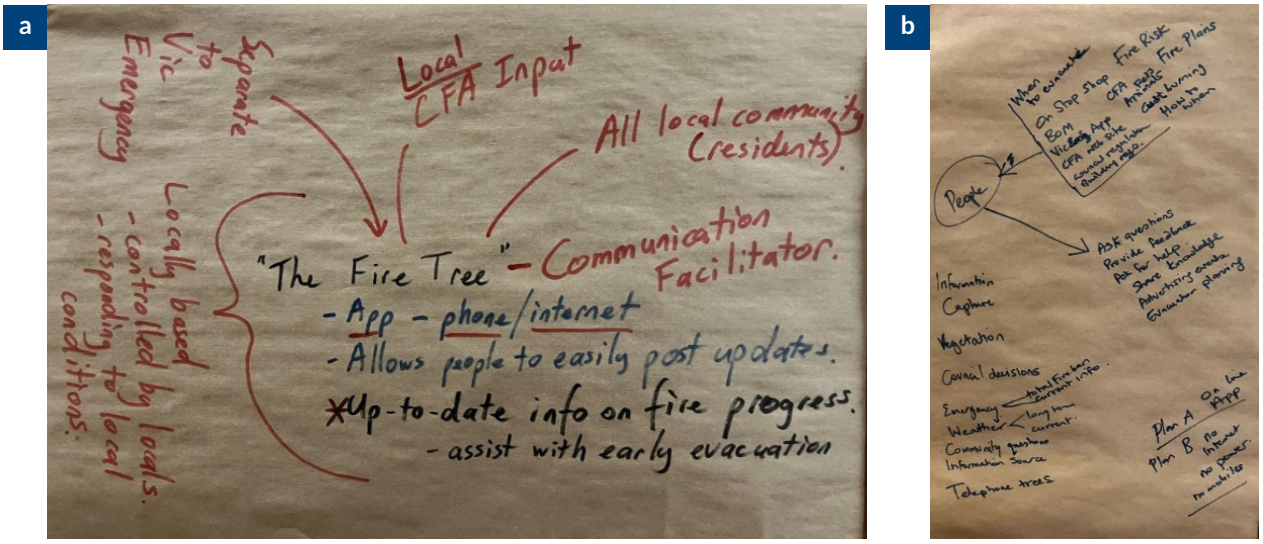

Figure 3. Conceptual maps for the Fire Tree (a) and the People system (b), developed by the participants during the first workshop.

relevant to ensure functionality and reliability such as digital technologies, weather conditions, natural event status, road conditions, and instructions are present in each system.

4.3. Merging the People System and the Fire Tree to Envisage a Socio-Technical System of the Ecosystem

From the conversation in activity one and the presentation of the conceptual ideas of the participants, there is evidence that the participants share a similar perception about how the members of a rural community create and generate their own dynamics with and within their local environment. In both models, (see Figure 4) the information and experience of community members is relevant to keep their members informed. The interaction between the members of the community through these systems puts people first in a synergistic circle of information provision and retrieval. The final solution proposed is a co-designed collective platform hosted on an interactive website called Bushwire that without representing a radical change in the behaviour of community members, enables them to share local knowledge online in a natural and holistic manner.

The workshops provided insights across three specific points. First is the healthy collaborative dynamics observed within the community. There are bonds deeply rooted in years of collaboration and active participation in activities of the members of the community, a space where nature plays an important role and is considered another member of the community because its behaviour impacts the decisions of the participants. Tony pointed out: "Communities like this consider the bush and the environment as part of the neighbourhood. One of us." The relationship the participants have with their environment requires deep knowledge so they can understand and read changes and respond accordingly. Tony elaborates on this idea: "The Bush is a major part of the community."

Secondly, the workshop underscores the important role of digital technologies in fostering healthy social networks. Considering this, a digital platform based on trust could be used for exchanging local knowledge and building resilient relationships in the community. In this regard, a significant finding at this stage is the proactive use of digital platforms such as Facebook by community members, characterised by a keen adaptability to local urgent or important events and cultural customs. This adaptability was particularly evident during activity three when participants were asked to develop the early warning system. When

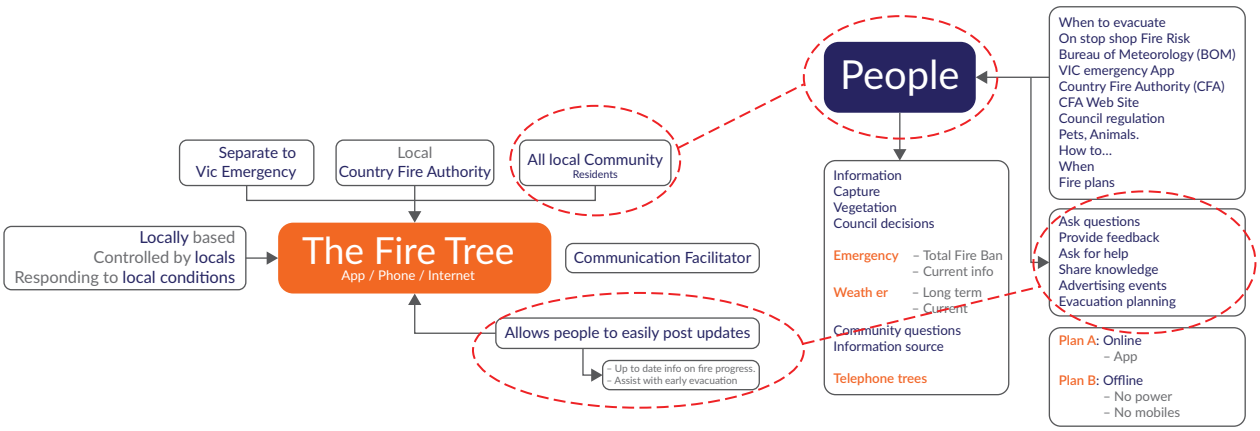

Figure 4. Shared elements in both proposals.

technological and budget restrictions were eliminated, the participants proposed a comprehensive system, based on information generated by the community itself and supported by information from local and federal government.

By using these digital platforms participants converge to collate and disseminate information about their respective environments, generating a collective narrative nurtured by the wisdom of its users. It is through these shared experiences that narratives emerge, enriching the communal identity fostering a sense of belonging, and actively contributing towards a sustainable community. Tony elaborates on this idea: "So, we've been involved with activities that enhance and improve the preservation [of nature] because by living here we realize it can disappear." The participants acknowledged that life in rural areas is good, calm and beneficial. In this regard, Gail stresses that "the opportunity is to prove that you can live in a simple sustainable lifestyle and prove to yourself that you can cope and enjoy living beyond suburbia."

5. Findings From Bushwire: Community Narratives

Based on the information retrieved in this series of co-design workshops and, in particular, the two design concepts, the first author developed an interactive website prototype called Bushwire. Bushwire served as both a research tool and a digital cultural probe (Hutchinson et al., 2003, pp. 17–24) to address and respond to some of the concerns captured in the SDGs (e.g., sustainability, community resilience, and knowledge sharing).

Bushwire's home page, that we can see in Figure 5a, was designed as a repository for hosting valuable information about the local environment, to support the collection and sharing of this knowledge to sustain the local bush environment. The name of the prototype (Bushwire) was chosen since it resonates with the idea of a colloquial source of information. The name comes from the amalgamation of the word "bush" (this is the natural surroundings of an Australian rural community), and "wire" (word used colloquially to state connection among others using technology). Together the word "Bushwire" sounds similar to "bushfire" but evokes more positive images and envisages a sense of community whose information needs are supported to prevent and respond to bushfires. Derived from the elements present in the Fire Tree and the People system developed by the participants, Bushwire was developed to achieve two complementary goals. First, a way to preserve and share local knowledge about nature, registering changes in the local environment. And second to serve as a link between the members of the community, including nature, since it is recognised as a member of the community, too.

By serving as a repository for multimedia content capturing environmental changes, Bushwire enables community members to archive their observations and insights for future reference. Through the act of documenting and sharing experiences on the platform, community members develop a deeper appreciation for their natural surroundings and a heightened awareness of environmental changes. Bushwire is still active (at the time of publication) and available for participants to revisit and provide contributions.

Bushwire's main functions include posting content in various formats: audio (.mp3, .mp4, wav, among others), text, video (.avi, .mov, among others), and images (.jpeg, .jpg, .png, among others) to support sharing of observations about changes in nature. The website is a clean, responsive, up-and-down scrollable design without background music, although videos embedded within the site can play sound.

The design of Bushwire's interface focused on making the user experience as familiar as possible to the participants: "It makes sense to say that the experience of an interactive system of any kind, is heavily influenced by who is experiencing it and hence, the designer has to respect and work with that identity" (Morales Díaz, 2022, p. 2). The posting process is similar to other digital platforms. Uploading media, such as pictures or videos, takes place through a private user account, by dragging or uploading it into place. It can be accessed by any laptop, PC, or mobile device connected to the internet. After a new entry is created, all the members of the community can visit and create comments about it. The website has been designed with four different areas: home, weather, journal, and activities.

Regarding home, the front page of Bushwire (see Figure 5a) is where visitors can explore the latest entries from other members of the community. In the banner, at the right top of Bushwire, the visitors also can find a weather widget with local information on temperature, humidity, wind, and cloudiness.

As for weather, this section is an expanded version of the weather widget in the banner (see Figure 6b). It uses a local map to better illustrate weather conditions. The weather section of Bushwire (see Figure 6a) includes information about wind (speed and direction), humidity (percentage), pressure (in millibars), cloudiness (percentage), precipitation (rain in millimetres), and visibility (in kilometres).

The journal section (see Figure 5b) is the repository of all the digital entries ever posted on Bushwire. Images, videos, audio, and text are stored in this section by date. Using any electronic device with access to the internet and by selecting the entry the visitors can explore it. Additionally, by clicking on "comment" the visitors can review and comment on other participants' entries. This is important as participants wanted to use their own devices.

The activities section (see Figure 5c) was included in Bushwire to serve two purposes. First, as a means to keep the participants engaged with the project through activities between workshops 4 and 5 (such as the recommended number of entries per week and encouraging them to comment on each other's posts). Second, the activities section includes guidance on how to use the website in case the participants needed help remembering the steps to create new entries and comment on other participants' posts.

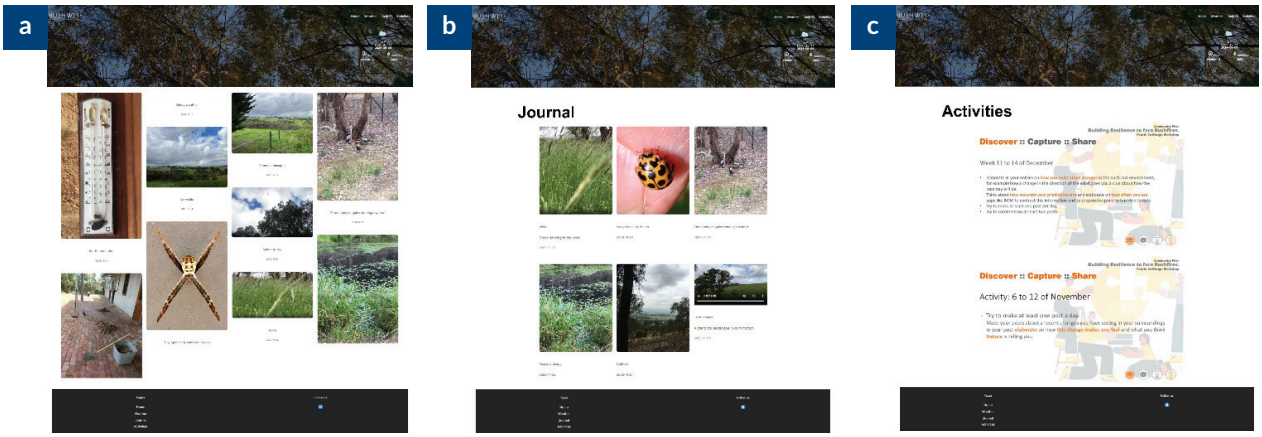

Figure 5. Bushwire's different sections: Home page (a), journal (b), and activities (c).

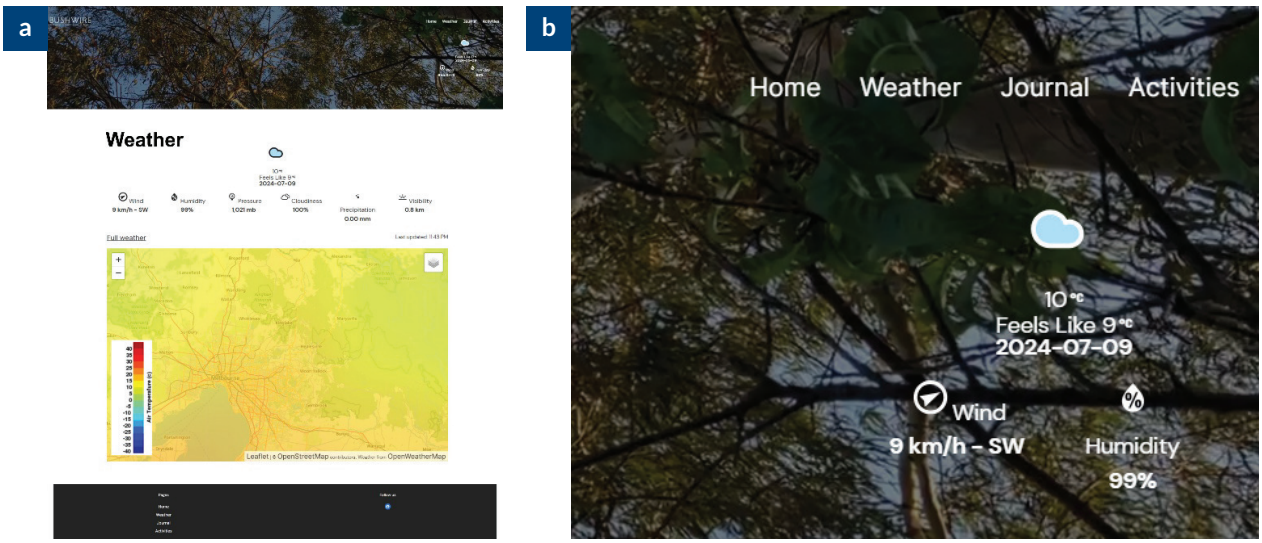

Figure 6. Weather section (a) and widget of Bushwire (b).

5.1. Bushwire: Opening the Conversation About Nature, Conservation, and Sustainability

Based on the data obtained in previous workshops, the Bushwire prototype intended to amalgamate technological advancements with community engagement needs. By creating a user account, all the participants were able to access the website at any time, including from their mobile devices. By integrating multimedia functionalities encompassing photos, videos, and audio recordings, this version of Bushwire aimed to transcend traditional narrative formats such as Facebook, affording users a dynamic canvas to articulate their encounters with nature's capricious elements. This convergence of digital media not only enhances the richness and authenticity of shared narratives but also empowers individuals to provide nuanced perspectives that extend from the confines of text description. Bushwire is still online and available to the community to share changes in nature. It is not expected and is unlikely to be used during bushfighting situations. Locals are more likely to use walkie-talkies and fire brigade links in an acute situation. The exercise of capturing changes in nature and using Bushwire to compile and share this knowledge is an opportunity for the participants to explore their surroundings, rediscover flora and fauna and be sensitive to changes in nature. There was a total of 54 entries during the duration of the activity (see Table 2) with five categories including poems, recounting, reflection, report, and a miscellaneous section of data that did not fall into a category. This section includes images, thoughts, and comments posted by the participants.

Through the platform, participants engaged in sharing recent experiences captured in photographs, some of which intrigued and surprised the group. These initial entries prompted active reflection, with participants writing comments and sharing their impressions.

5.2. The SDGs Through the Lens of Bushwire

Dolejšová et al. (2021, p. 1) state that "increasingly, researchers are pointing to the need for a wider rethink of humanity's impact on the earth as a whole." In line with this idea this collective approach has the potential to "play a pivotal role in bringing us toward more positive sustainable futures" (Dolejšová et al., 2021, p. 1).

Table 2. Number of entries in the analogue journal and on Bushwire.

Analogue data collection overview					
Participant	Reflection	Poem/Haiku	Drawing	Recounting	Found Object
Annie	35	–	8	–	16
Diana	1	1	–	34	–
Gail	6	6	–	10	–
Hank	2	2	–	10	1
Tony	2	2	–	3	–
Total entries	46	11	8	57	17
Digital data collection overview					
Participant	Reflection	Poem/Haiku	Uncategorised	Recounting/Report	Comments
Annie	1	–	10	3	–
Diana	1	1	5	1	–
Gail	2	6	4	1	–
Hank	1	2	2	1	–
Tony	1	2	6	1	–
Total entries	6	11	27	7	82

Bushwire was introduced to the participants to explore the knowledge they have about nature and to understand how they perceive and interpret changes in their local environment. While the Bushwire website was not created to directly respond to SDGs, the context in which the content (entries, images, videos, comments) was created for, and shared within, responds to some of these goals on a community level. The content of Bushwire was analysed to understand the knowledge and needs of the community from their posts and comments. Through their contributions to Bushwire, the members of the community can be viewed as active agents in the process of community resilience building.

It is relevant to consider that while the SDGs do not explicitly mention rural and regional areas, we know these are disadvantaged across a wide variety of criteria, including digital and non-digital infrastructure. According to the Australian Institute of Health and Welfare (2024) website, around 7 million people, or 28% of the Australian population, live in rural and remote areas. These encompass diverse locations and communities all rural communities are not alike, nor do they have the same challenges, however many are impacted by issues of limited or intermittent internet. Doke et al. (2020, p. 5) provide an example relevant to this study, they argue that "large rural constituencies, encompassing vast and sparsely populated areas, lack broadband connectivity and rely predominantly on volunteer-based emergency workforce." In the case of large extreme natural events such as bushfires, these factors "may have effects on rural first responders' ability to access, act upon and disseminate emergency-related information" (Doke et al., 2020, p. 5). This example is important since according to Doke et al. (2020, p. 5) "(this) has an adverse effect on both residents and the agencies that serve them, as it limits residents' ability to prepare for emergencies and compromises the safety of first responders."

In this regard, there are examples captured in Bushwire about concerns (based on experience) and consequences of climatic conditions including heavy rain in rural areas (see Figure 7a and 7b). Regarding digital technologies, residents are quickly coming to recognize the benefits that the internet offers, however, connectivity is always an issue due to inconsistencies with the service. This is consistent with Taylor and

Cheverst's (2010, p. 218) view that "many rural areas are poorly connected broadband not-spots, unable to take full advantage of the latest web applications."

The SDGs are relevant for the sustainable development of vulnerable communities towards a more sustainable future. In the next section, we will review how closely the findings of this study align with four of these Goals.

5.3. SDG 11: Sustainable Cities and Communities

The connectivity of digital technologies becomes relevant in the case of extreme natural events to help the community to better know their environment and potentially prevent consequences, saving lives and time and enabling a more sustainable community lifestyle based on communication. From the workshops it was evident that the community tends to trust the knowledge and experience of its members to make decisions in cases of extreme natural events as a consequence of the ties of constant collaboration within the community over time, which contributes to strengthening community trust. The contribution of community members regarding information before, during, and after a bushfire is relevant since they are the ones who best know the environment, resources, infrastructure, and people within the community.

The entries in Bushwire illustrate how the participants perceived changes in nature and how the participants shared their experiences with their peers. Their early posts (Figure 7a) open up an opportunity for the participants to talk to each other:

> Diana: Hi Gail, is [the flooding] near our front gate?
>
> Gail: Just north of your gate.

Similar to the previous example, reports like these tend to be a simple way for participants to reflect on changes in nature, additionally providing insights about the local environment and the status of the roads before it rains. "Rain" (see Figure 7b) is a good example, posted by Diana, who explains how "Rain is welcome for the tanks and the garden. Thankfully we could still walk this morning and only got a little bit damp!"

Bushfire awareness is a major topic addressed by the participants in the Bushwire prototype. It can be categorised as a contribution to sustainability through shared knowledge. Bushfire in paradise (see Figure 7c)

Figure 7. Flooding on a local road (a), rain (b), and Bushfire in paradise (c). Notes: (a) posted by Gail on 26–10-2023, (b) posted by Diana on 14–11–2023, (c) posted by Hilary on 24–10-2023.

is a video about the aftermath of a bushfire which includes a comment as a reminder to be cautious in our interactions with nature: "This bushfire in Loch Sport is a reminder to put out your campfire!"

5.4. SDG 13: Climate Action

There is an awareness about climate change reflected in the posts, not only as comments, but also as a topic that must be considered and actively addressed by the members of the community. Bushwire played a role as a repository of these impressions by the participants. The season is changing, and the participants know from experience that it brings changes to flora and fauna in "Frog Pond" (see Figure 8a). Gail explains how "it is already drying up. Should be full this time of year. Makes me sad and worried about the impacts of climate change 😢."

The members of the community contribute with knowledge and experience to build a database that works in three areas. First, a testimony of a moment in the community's life; second as a repository of the knowledge of the community regarding changes, in flora and fauna; and third, as a source of information about conservation and sustainability. The fact that this information can be shared is important to the community members since it allows the user to generate a sense of community, connected by common interests. Comments, observations, the possibility of generating a personal database with the discoveries, and particularly the identification of specimens by other users represent an exercise in connectivity that reinforces the sense of community, even when its members are geographically in another place.

5.5. SDG 15: Life on Land

Evidenced in the entries available in Bushwire, the participants demonstrate a sense of belonging not only to the region but also to the entire ecosystem itself and that fact has a deep and lasting effect on the life of the members of the community. Gail explains: "I love living here because, I'm surrounded by the things I love, and wildlife and flora and I feel the need to protect it forever."

The members of rural communities cultivate enduring bonds of trust and collaboration. They draw upon their personal and professional backgrounds to enrich the collective understanding of their environment. Tony explains that the geographical location is relevant for him due to the distance from the urban centre: "It kind of enhances my ability to enjoy wildlife and the bush." During the evaluation of Bushwire, Gail elaborated on this idea by adding: "You live your life here, that makes me feel as if I'm part of nature."

However, not everyone within the local area is considered by the participants to be part of the community. For instance, local people who do not reside within the area, such as those in short-stay accommodation, are not viewed as part of the community. Gail noted they may not consider visitors as part of the community. She provides an example of sporadic visitors who frequently use Airbnb (short-stay rentals) when they visit the area:

> I don't know whether they feel as if they belong to a community because they're renting out these little Airbnbs. Is it everyone who physically lives in Kangaroo Hills, or is it just the people who actually interact with each other?

Further, the participants view the community as being limited to like-minded individuals, and therefore do not include, for example, property developers who are regarded as not being in harmony with nature, and potentially negatively impacting the local environment. This has implications for urban planning. It is evident that these participants view their local environment, the "Bush," as being separate or different to urban settings. They view property developers, and potentially urban planners, as having a limited understanding of the bush and its climate change messages. Further, their activities such as building and planning developments not in keeping with the bush are viewed with suspicion and seen as negatively impacting local fauna, flora, and the community.

Bushwire is viewed by the participants as an opportunity for the community members to contribute to the good practices in the area they coexist in. In Annie's post (see Figure 8b) she explains by giving an example of "making sure the build-up of leaves doesn't create a fire hazard." This is a clear example of the community leaving knowledge for posterity and at the same time a testimony of a specific moment in a significant place for the community which reinforces the need to care about the local environment.

Figure 8. Awareness about nature surroundings from two different perspectives: Frog pond (a); "Making sure the build-up of leaves doesn't create a fire hazard" (b). Notes: (a) posted by Gail on 15–11-2023, (b) posted by Annie on 14–12–2023.

5.6. SDG 17: Partnerships for the Goals, to Address Bushfire Awareness and Response

The fact that the participants consider the environment as another member of the community is relevant since the information obtained from the environment has the potential to be used as a reference point for decision-making in preparing for, and responding to, extreme natural events. This could be interpreted as nature bringing its own knowledge as a valuable input to be considered when the community takes long-term decisions, such as seasonal controlled burning programs, the creation of parks and reserves, and

the selection of crop types. It is at this point that the rural community can start a resilient dialogue with nature, and with other key stakeholders such as local government, to inform policy. Dart (2018, p.7) suggests that place-based partnership is "a collaborative, long-term approach to build thriving communities delivered in a defined geographic location. The approach is ideally characterised by partnering and shared design shared stewardship, and shared accountability for outcomes and impacts." Thus, this represents an opportunity to develop a relationship between nature, local residents, local government, policymakers, and others that transcends individual and community transactions to become an interaction mutually beneficial for all in response to the SDGs call for action.

Direct communication among the members of the community strengthens the bonds between them and the environment where there are values of collaboration and empathy. Annie expanded on this comment during the workshop: "I think one of the positive things of the community is that there's a lot of shared values." Common phrasing from the participants, for example, "love living here in the bush," "calm and comfortable," "privileged," "unique simple lifestyle," and "community," reflect how the participants perceive their environment and the commitment to constantly care for it, which in the case of Bushwire includes knowledge contributions.

Bushwire's interactive features served two purposes. First, participants used the platform to collect, capture, and share their own individual data (images, videos, and text) anytime and in any location that had internet connectivity. Secondly, as part of a collaboration, Bushwire allows members to comment on and engage with each other's contributions, enhancing the sense of community ownership and participation. The Frog Pond (see Figure 8a) shows an example of this interactivity and concern about climate change as Gail commented "I'm sad—and worried about the impact of climate change too! Anything we do now to remedy the situation, will take decades to take effect!"

The workshop participants valued the role of Bushwire as a facilitator for knowledge preservation concerning nature and the immediate environment and therefore nurtured a culture of resilience around that knowledge. There was a deep understanding that the local ecosystem reflects on a small-scale global problem. Gail wondered about the large-scale challenges of the planet in a concrete way. She is part of a climate action group that evolved from people who had experienced and survived bushfires with the aim of creating awareness and the need for climate action. She not only has given interviews to the media but has undertaken several trips to the Australian capital, Canberra, to speak to federal politicians. Her actions show that people living in rural areas can have an impact and visibility that reaches far beyond local rural concerns to building national partnerships from the bottom up.

The participants refer to the environment as another member of the community, with which they can empathise, listen to, and obtain information. Through the entries written in their journals and captured on the digital platform Bushwire, we can observe that the participants know and perceive the changes in their local environment effectively. Further, the participants trust these messages derived not only from their own experiences and relationships with the bush, but also read and respond to messages from the bush itself.

6. Conclusion

Building community resilience is gaining attention in the rural HCI field, as we need to ensure that those who are vulnerable to natural disasters, harness their digital and non-digital resources to prepare for and

respond to them even in the absence of formal government assistance. This case study shows how in one small rural community, community members harness digital and non-digital hybridity to co-design an early bushfire warning system to meet their needs. We outline a case study of a rural Australian bush-fire-impacted community. The workshop participants co-designed and merged two solutions: The Fire Tree and the People system. The final solution was a co-designed web-based citizen-science platform, Bushwire, that participants used to capture, share, and reflect upon local knowledge, alongside messages from the bush, to prepare for bushfire threats. This point is particularly relevant since it involves the active participation of members of a community in the development of an outcome that includes identity and local knowledge. As Herodotou et al. (2024, p. 68) explain, "the term citizen science has been used to denote the inclusion of the general public or non-professionals or volunteers in research practices and the production of scientific knowledge."

This case study explored how a co-designed digital platform such as Bushwire can respond to the UN SDGs. Specifically, Bushwire seeks to build sustainable communities (SDG11), through local citizen science climate action (SDG13) for this rural Australian bush-fire-prone community. Thus, it also seeks to harmonise life on land (SDG15) through multi-stakeholder partnerships (SDG17), including between local residents (both human and non-human) and policymakers.

As discussed in Section 5, the SDGs are relevant for the development of sustainable resilience practices and policies in rural communities. This is particularly the case in communities such as Kangaroo Hills, which are prone to natural disasters, or more heavily impacted by climate change. A good example of this relationship is the need for connectivity and appropriate use of digital technology in preparing for and responding to extreme natural events. While rural communities are often perceived as rustic or disadvantaged, the findings from this case study demonstrate that the members of rural communities adapt and embrace digital technology flexibly when it is relevant to their needs and wants, and when it is culturally and contextually embedded. The participants in this case study harnessed community practice that involved a good understanding of technologies and a deep knowledge of the local environment. This can be observed in how naturally they expressed knowledge regarding bushfire risk mitigation, land care, and in the interest they manifested in their public spaces, including the local flora and fauna, particularly as found on their own properties including cultivated land and native bush.

These two elements (familiarity with the use of technologies and knowledge about the local environment and weather) are actively present in rural communities, and they represent an opportunity for governments to co-design and work with local rural communities to develop policies that more deeply resonate with, and respond to, the needs of these communities. We suggest that despite the complexity of SDGs it is important to encourage and support individuals' and communities' contribution. This case study has shown the relevance of local rural knowledge in reflecting and being actively involved in contributing to a range of SDGs. It is easy to imagine that such efforts could be scaled up—in particular, if similar tools to Bushwire are made available to urban environments for mutual exchange and learning. Urban planners should acknowledge the importance of citizens' relationship with nature through citizen-science and other creative embedded activities. These citizen-science activities and the harnessing, sharing, and reflecting on local knowledge through digital technology provide opportunities to embrace and sustain pockets of flora and fauna beyond the bush, in urban communities and cities. We imagine a world in which urban environments and cities recognise and respond to messages from the bush itself, and the communities that reside within them.

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Conflict of Interests

The authors declare no conflict of interests.

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