Celebrating 20 years of Community DustWatch

Department of Climate Change,
Energy, the Environment and Water

Acknowledgement of Country

Department of Climate Change, Energy, the Environment and Water acknowledges the Traditional Custodians of the lands where we work and live.

We pay our respects to Elders past, present and emerging.

This resource may contain images or names of deceased persons in photographs or historical content.

Artist and designer Nikita Ridgeway from Aboriginal design agency Boss Lady Creative Designs created the People and Community symbol.

Cover photo: Dust storm 13 January 2016 at Koolaman Station north of Balranald. Lisa O'Keefe/Koolaman Designs

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1. Introduction

Dust is a key sign of environmental health. When dust storms sweep across the land, they strip away valuable topsoil leaving behind degraded and less productive soils. Monitoring and tracking these storms help us understand and manage their economic, health and environmental impacts. Since its formal launch in 2005, the DustWatch program has played a vital role in raising public awareness about dust storms and their negative consequences. It has also helped improve land management practices and air quality in rural areas.

Today, DustWatch operates 39 monitoring stations across rural southern Australia (Figure 1). The program's success depends on the dedication of the more than 100 volunteers that have helped the program over the past 20 years. These volunteers maintain equipment, observe local conditions and share insights to help scientists understand how dust storms form and affect the landscape. In one case, DustWatch has a 'second generation' volunteer who has taken over their parents' role in instrument maintenance – showing how the program is being passed down through generations.

DustWatch data has been used in scientific research, government policy and environmental reports. For example, DustWatch helped show the 23 September 2009 dust storm, the largest to impact Sydney since the 1940s, transported 2.5 million tonnes of dust offshore and cost the New South Wales (NSW) economy around $300 million (Leys et al. 2011; Tozer and Leys 2013). The data reveals that dust storms are more than 4 times less frequent today than they were during the 1940s (Leys et al. 2023a).

Over the past 2 decades, DustWatch has become a leading example of citizen science and collaborative environmental monitoring. It has helped communities better understand wind erosion and dust events in local communities in rural southern Australia, with more than half of those engaged in the program changing how they manage their land and their attitudes to land management. The program's impact has been recognised with awards, including winning the NSW Science and Engineering Award in 2011, and receiving a nomination for the 2016 Eureka Prizes for Innovation in Citizen Science.

DustWatch continues to play a vital role in providing data that shapes and supports research, informs policy and raises awareness of air quality across rural NSW. It shows how long-term investment in citizen science programs can deliver real benefits for people and the environment.

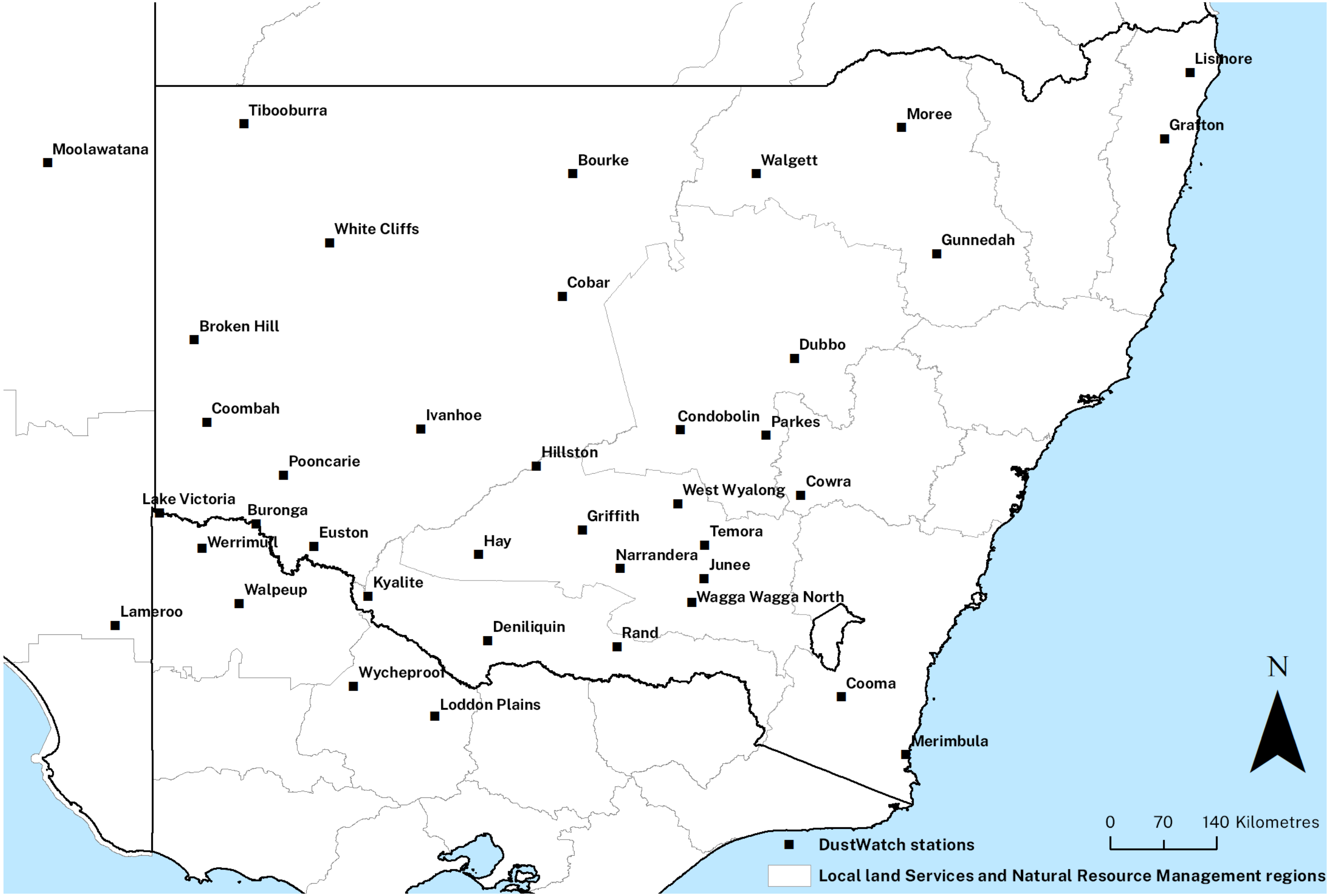

Figure 1 Community DustWatch station locations as of July 2025

2. Background

2.1 The Community DustWatch program

The Community DustWatch program (DustWatch) began collecting dust data in 2002 to better understand dust storms in rural NSW. The significant economic, environmental and health impacts of dust storms mean monitoring them is essential for understanding and managing their impacts.

Photo 1 Dust storm near Gunnedah. Photo: Pip Murray

Dust is a key indicator of environmental health. When dust storms blow through, they carry away valuable topsoil and soil carbon from paddocks, leaving them degraded and less fertile. By monitoring and reporting dust levels, the DustWatch program has helped raise awareness about the damage dust storms and wind erosion can cause. The data collected has also informed scientific research and helped shape better land management practices and policies.

Over the past 20 years, DustWatch has grown into a highly successful citizen science program. Since 2005, more than 100 volunteers have dedicated their time recording local dust events and maintaining instruments at the 39 permanent stations (Figure 1). DustWatch has also collaborated with state and federal agencies, universities, the Commonwealth Scientific and Industrial Research Organisation (CSIRO) and local communities.

Recent droughts have highlighted just how important it is to continue this community dust monitoring. With 2 decades of data already collected, new insights from DustWatch continues to provide valuable insights into the impacts of changes to land management practices on the Australian landscape and natural hazards like drought.

2.2 The establishment of Community DustWatch

The DustWatch program started as far back as 1990 when daily dust sampling began in Buronga, NSW. This station, initially managed by Dr John Leys and Professor Grant McTainsh, is thought to be the longest-running dust data record outside an Australian capital city. Today, sampling at Buronga is managed by Associate Professor Craig Strong from the Australian National University, with support from Local Land Services (LLS) staff.

In 2002, a series of dust storms – including a major one on 23 October – prompted a request from the Minister for the Environment for more information about recurrent dust events. Dr Leys responded by gathering more than 100 dust observation reports from colleagues in the months leading up to the October 2002 dust storm. This was the largest dust storm to impact eastern Australia in 40 years (McTainsh et al. 2005). However, the number of these observation reports dropped off in subsequent months, highlighting the need for a network of instruments and ad hoc observations to record local dust events and capture dust and other important weather phenomena such as fog and smoke for local communities (Leys et al. 2008).

Although formal monitoring began in 2002 after the October dust storm, the DustWatch instrument network was formally established in 2005. Funding from several NSW Catchment Management Authorities, now the LLS, and later the Desert Knowledge Cooperative Research Centre helped to expand the program across Australia.

In 2017, DustWatch merged with the NSW Department of Climate Change, Energy, the Environment and Water's (the department) air quality monitoring network, with funding for a major instrument upgrade across the network in 2019. This enabled the network to monitor smoke as well as dust. Since the merger, DustWatch instruments have been critical in the department's emergency air quality monitoring response as they can be set-up quickly and easily. During the summer bushfires of 2019–20, 7 emergency response stations were set up to monitor smoke impacts. Four of these stations, located at Lismore, Grafton, Cooma and Merimbula have since been retained in the permanent DustWatch network (Figure 1).

The department has also invested in instruments and methods to ensure crucial environmental descriptors such as dust, fog and smoke could be more easily identified and considered in the analysis of the network's data (Chang et al. 2018). This capability was further enhanced in 2021 when weather instruments were installed at each station.

2.3 The contribution of Community DustWatch volunteers

Since 2005, more than 100 volunteers have dedicated their time and expertise to maintain instruments and submit dust observations. Volunteers and members of the public also provide observations of local conditions. These observations often include dust or smoke sightings and photographs (see Photo 2). This, along with volunteers' detailed knowledge of their local environments, provide critical context in helping to identify the causes and sources of dust or smoke.

Photo 2 Dust storm 13 January 2016 between Hay and Balranald. Photo: Mick Smith

Photo 3 Dr John Leys and volunteer Audry Sheehan at Moolawatana in June 2008. Photo: DustWatch

2.4 What Community DustWatch monitors

DustWatch primarily monitors dust. Dust contains particles (or particulate matter) from a variety of sources, including naturally bare arid zones, farming, grazing, mining and other earthworks and urban dust. Other particles in the air can also come from bushfires, hazard reduction burns or household wood heaters. The airborne particles recorded at DustWatch stations are mostly topsoil from agricultural land and arid to semi-arid ecosystems, as well as naturally silty environments such as floodplains and dry watercourses (De Deckker et al. 2014; O'Loignsigh et al. 2017).

While dust from bare ground is the most common source of particles observed by DustWatch, fine smoke particles from fires are occasionally detected as well. These fine particles can negatively impact human health. For more information, visit NSW Health (see References).

DustWatch collects data on a range of particle sizes to differentiate between dust and smoke:

- total suspended particles (TSP): includes particles of all sizes and sources
- particles less than 10 micrometres (μm) in diameter (PM10): mostly airborne dust from bare ground and mining
- particles less than 2.5 μm in diameter (PM2.5): includes small particles of dust. High concentrations of PM2.5 most often come from smoke.

DustWatch also collects weather data, including temperature, rainfall, humidity and wind speed and direction.

Photo 4 DustWatch station at Moolawatana, South Australia. Photo: DustWatch

3. Key events and trends

3.1 DustWatch data summary

Table 1 DustWatch station statistics for dust hours, groundcover and climate for 2005 to 2025

Dust records	Date or location	Dust hours
Dustiest month (average dust hours)	January 2020	52
Dustiest year (average dust hours)	2019	189
Least dusty year (average dust hours)	2011	2
Top 5 dustiest stations (annual dust average)	Werrimull	186
	Tibooburra	105
	Euston	94
	Hillston	90
	Wagga Wagga North	80
Top 5 least dusty stations (annual dust average)	Lismore	9
	Merimbula	13
	Grafton	16
	Cooma	22
	Rand	28
Groundcover and climate	Statistics	Date
Lowest monthly average groundcover	46%	December 2019
Highest monthly average groundcover	99%	May to June 2011
Monthly average groundcover	82%	July 2005 to April 2025
Wettest year for NSW	863.6 mm	2022
Driest year for NSW	250.2 mm	2019
Average rainfall	492.4 mm	2005 to 2024
Warmest year	19.23 °C 1.93 °C above average	2019
Coolest year	17.48 °C 0.18 °C above average	2022

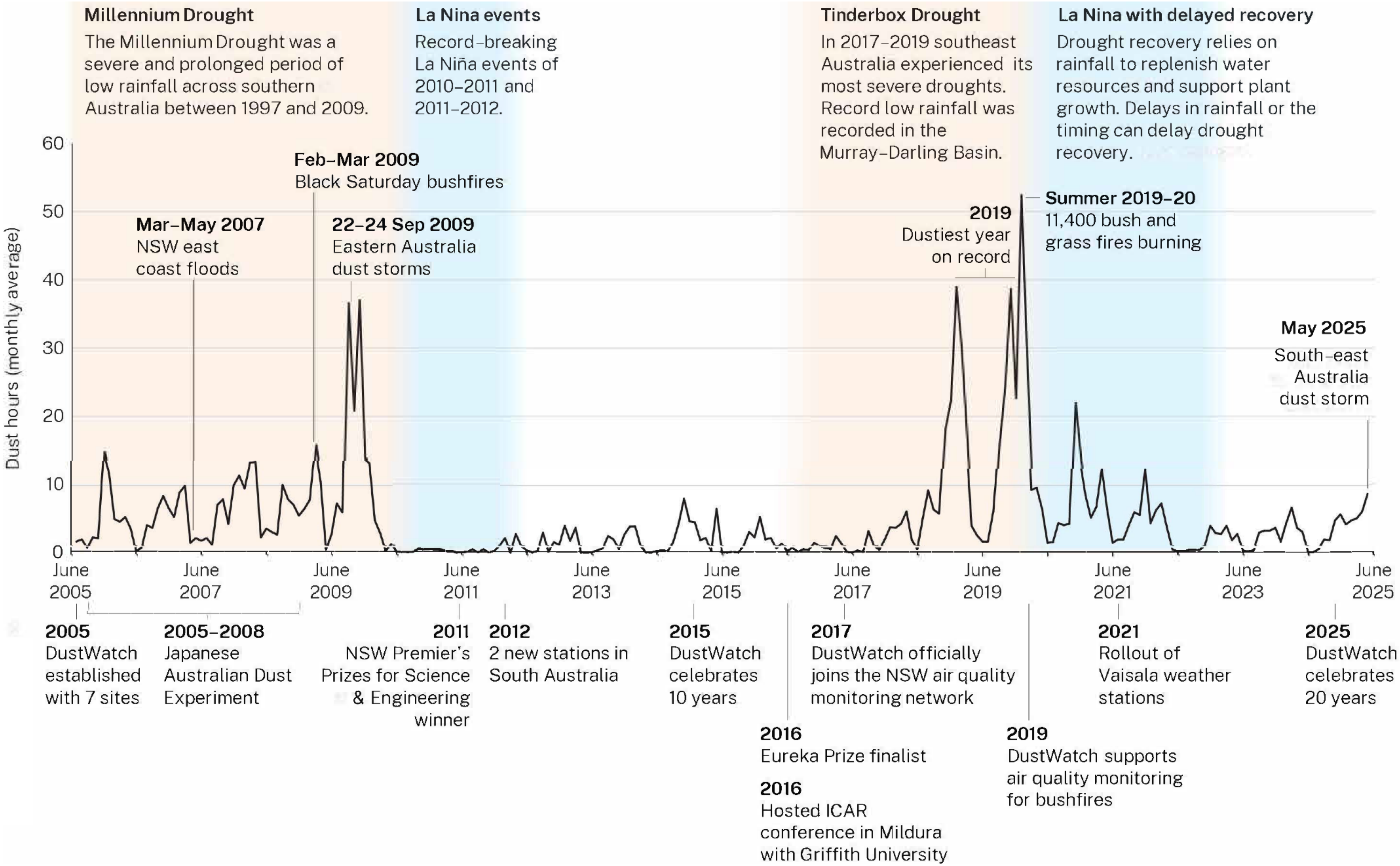

Figure 2 **Timeline of significant events recorded by DustWatch**

3.2 DustWatch findings over the past 20 years

Twenty years of data show dust hour trends are highly cyclical and correlate well with El Niño cycles, groundcover and rainfall. For example, periods of low groundcover during the Millennium Drought (2001 to 2009) and the Tinderbox Drought (2017 to 2019) coincide with the highest dust hours recorded during DustWatch's 20-year history, as well as low rainfall (Figure 2 and Table 1).

In NSW, 2019 was both the driest (250.2 mm) and warmest (1.93 °C above average) year on average since the start of the DustWatch network in 2005 (Table 1). 2019 was also the dustiest year, with an average of 189 dust hours per station. Further, February 2019 recorded the highest dust hours of any month with 216 dust hours recorded at Tibooburra. In addition, 6 of the 12 natural resource management regions (NRMs) with DustWatch stations recorded their dustiest year in 2019.

Furthermore, January 2020 was the dustiest month on record (52 dust hours per station), immediately following December 2019, which had the lowest statewide average for groundcover for the 2005 to 2025 period, with a monthly average of 46% across all regions (Table 1).

In contrast, 2011 had the fewest recorded dust hours, with an average of just 2 dust hours per station. This coincided with New South Wales recording above average rainfall, and the highest average monthly groundcover value for the DustWatch network of 99% in May to June 2011 (Table 1).

After 20 years of operation, Werrimull (northwest Victoria) was found to be the dustiest place in the network, averaging 186 dust hours per year since installation in 2018 (Figure 3). Dust hours are defined as hourly averages of PM10 that reduce visibility to less than 10 km. Rounding out the top 5 are Tibooburra (105), Euston (94), Hillston (90) and Wagga Wagga North (80).

In contrast, Lismore was the least dusty station in the network, averaging 9 dust hours per year since monitoring began in 2020. Installed initially as an emergency monitoring station during the 2019–20 bushfire season, Lismore was retained in the permanent network after the bushfires, along with Merimbula, Grafton and Cooma. Lismore's low dust hours are likely due to its subtropical coastal climate, heavy rainfall and flooding since the bushfires, and its relatively recent installation. Of the long-term stations (those that were installed in 2007 or earlier), Hay has been the least dusty over the past 20 years, with an annual average of 33 dust hours.

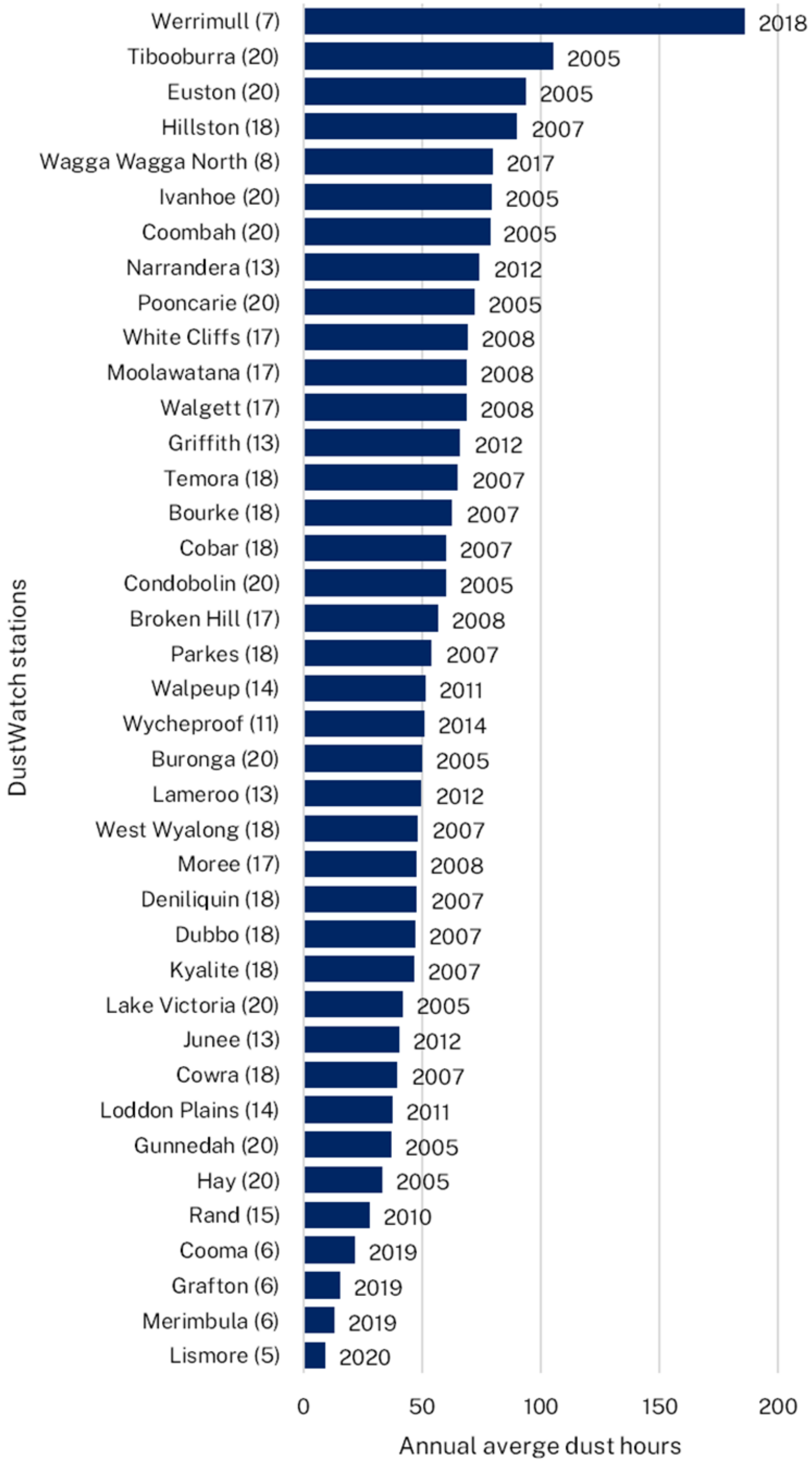

Figure 3 Average dust hours per year for each DustWatch station since installation

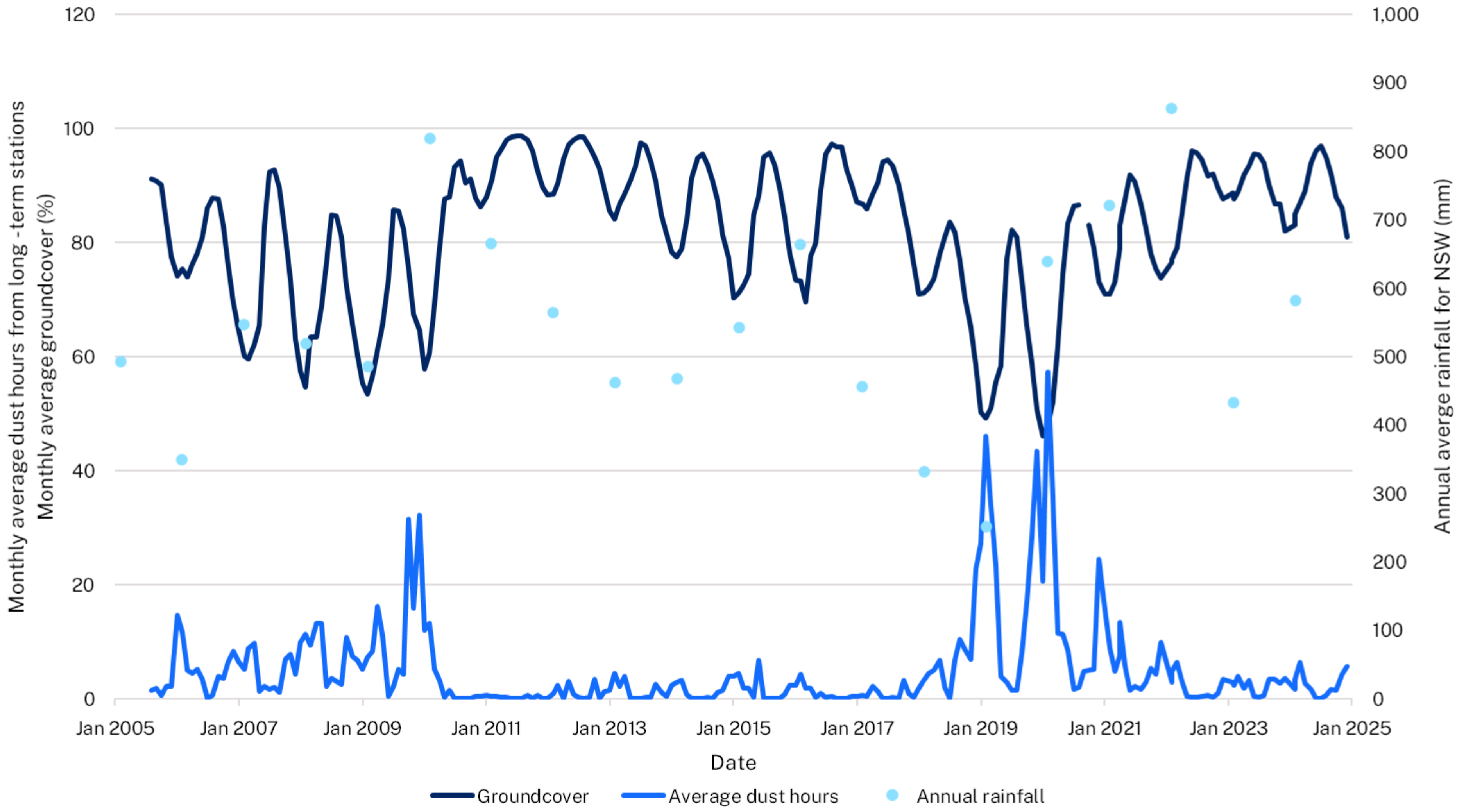

Figure 4 **Monthly average groundcover for NSW monthly average dust hours from long-term DustWatch stations and NSW-wide annual average rainfall between January 2005 and December 2024**

3.3 Key events

3.3.1 The Millennium Drought 2001 to 2009

The Millennium Drought was the worst on record for south-eastern Australia at the time (van Dijk et al. 2013). The southern Murray–Darling Basin was the most severely affected part of the state, with Figure 5 showing rainfall was generally very much below average to lowest on record. These rainfall deficiencies also occurred over a protracted period, as 2008 was the eighth consecutive year with below average rainfall for the Murray–Darling Basin (BOM, 2009). These rainfall deficiencies were a catalyst for the creation of the Murray–Darling Basin Authority (MDBA, 2025).

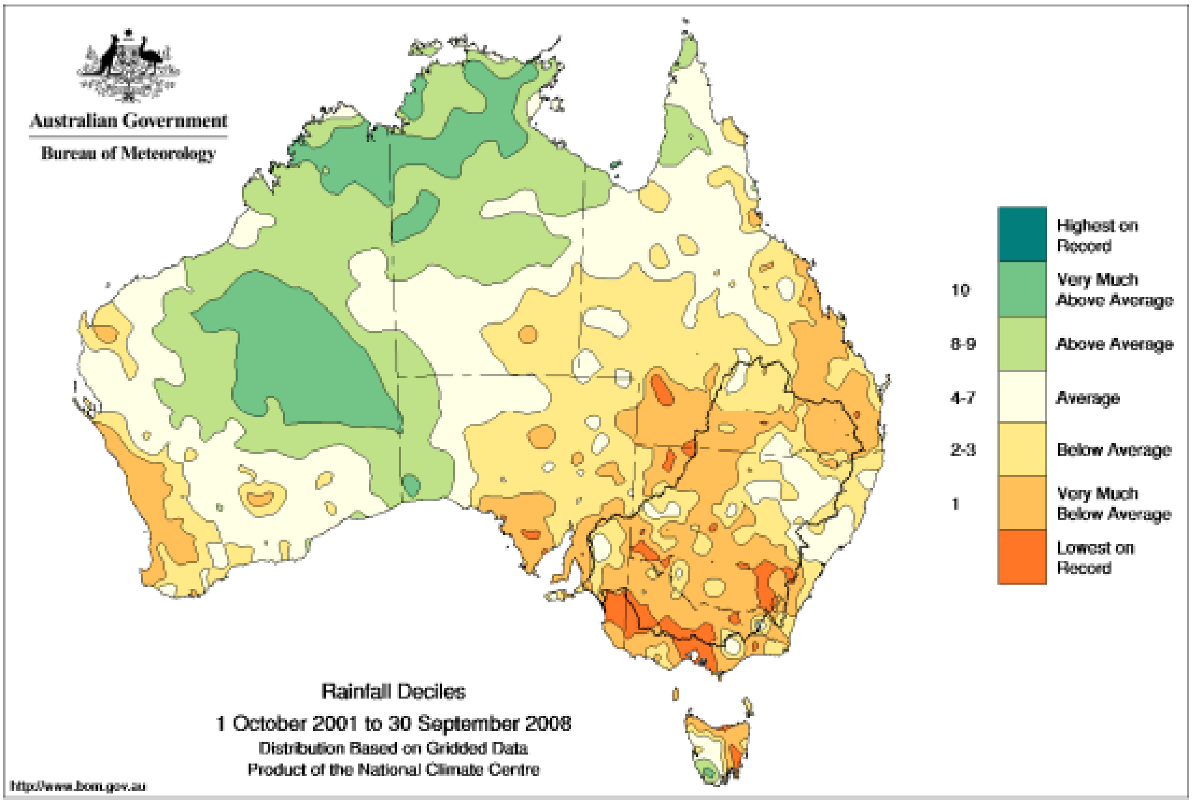

Figure 5 **Rainfall deciles across Australia between October 2001 and September 2008 (BOM, 2009)**

Photo 5 **Darling River at Tilpa in 2003. Source: 3CR Radio**

Throughout the drought, groundcover gradually decreased from the north-west towards the south-east of NSW. Although network-averaged groundcover dropped to nearly 50% in January 2009 (Figure 4), groundcover was lowest in large parts of western NSW, as shown in Figure 6. In NSW, despite average groundcover during summer falling steeply from January 2006 to January 2009, summer groundcover in parts of western NSW remained below 50% throughout the drought until the end of 2010.

DustWatch stations in the southern Murray–Darling Basin shared similar spikes in dust hours to Tibooburra in the state's north-west throughout much of the drought (Figure 7). Monthly dust hours during the drought ranged from 7 at Buronga to 12 at Hillston. For Hillston, this is 12 times higher than the monthly average dust hours recorded between January 2010 and December 2016. Overall, the outcome of the Millennium Drought supports DustWatch's aim to increase groundcover. As low rainfall causes drought (Figure 5), which translates into low groundcover (Figure 6), this results in high levels of dust, as there is less vegetation protecting the topsoil from wind.

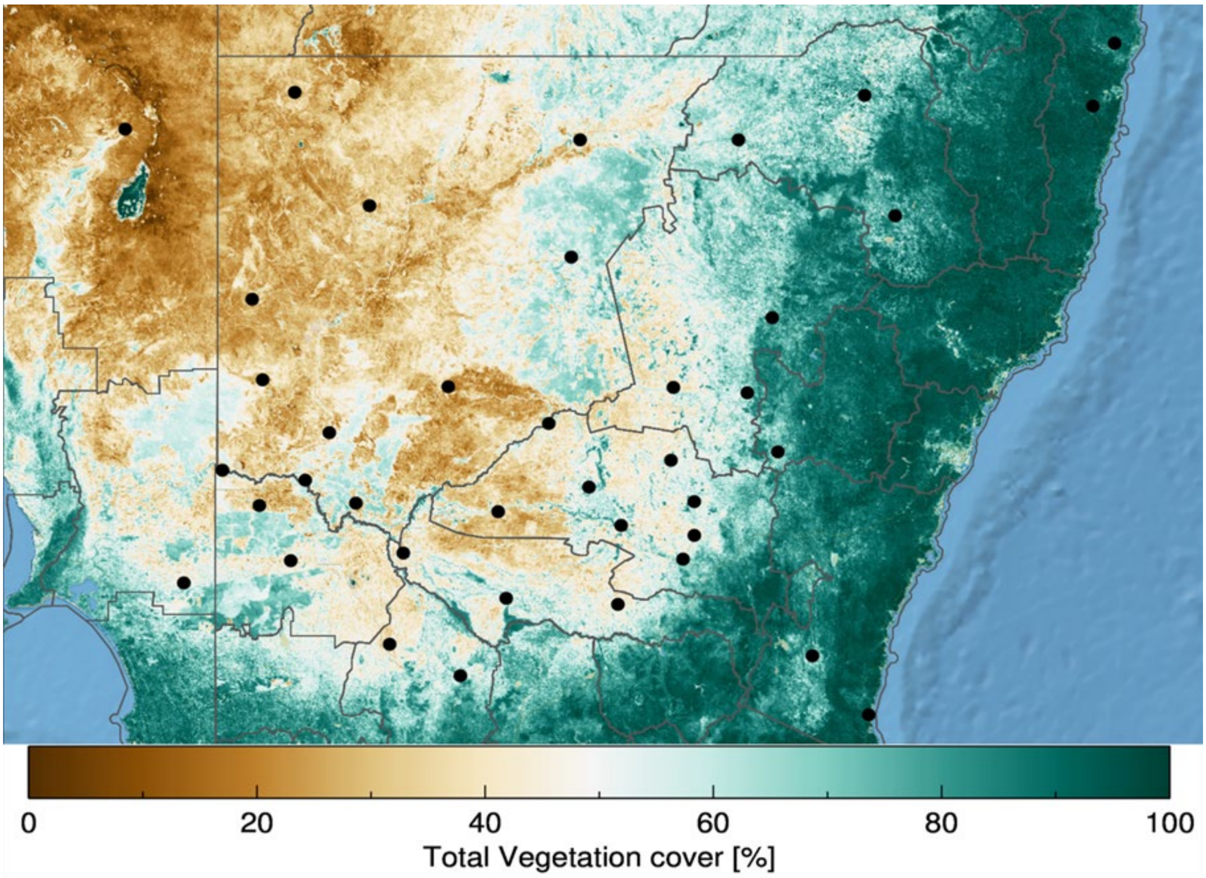

Figure 6 **Groundcover shown as total vegetation cover in south-eastern Australia in January 2009. Black dots indicate DustWatch stations and black boundaries indicate Australian natural resource management regions. Source: CSIRO GeoGlam RaPP**

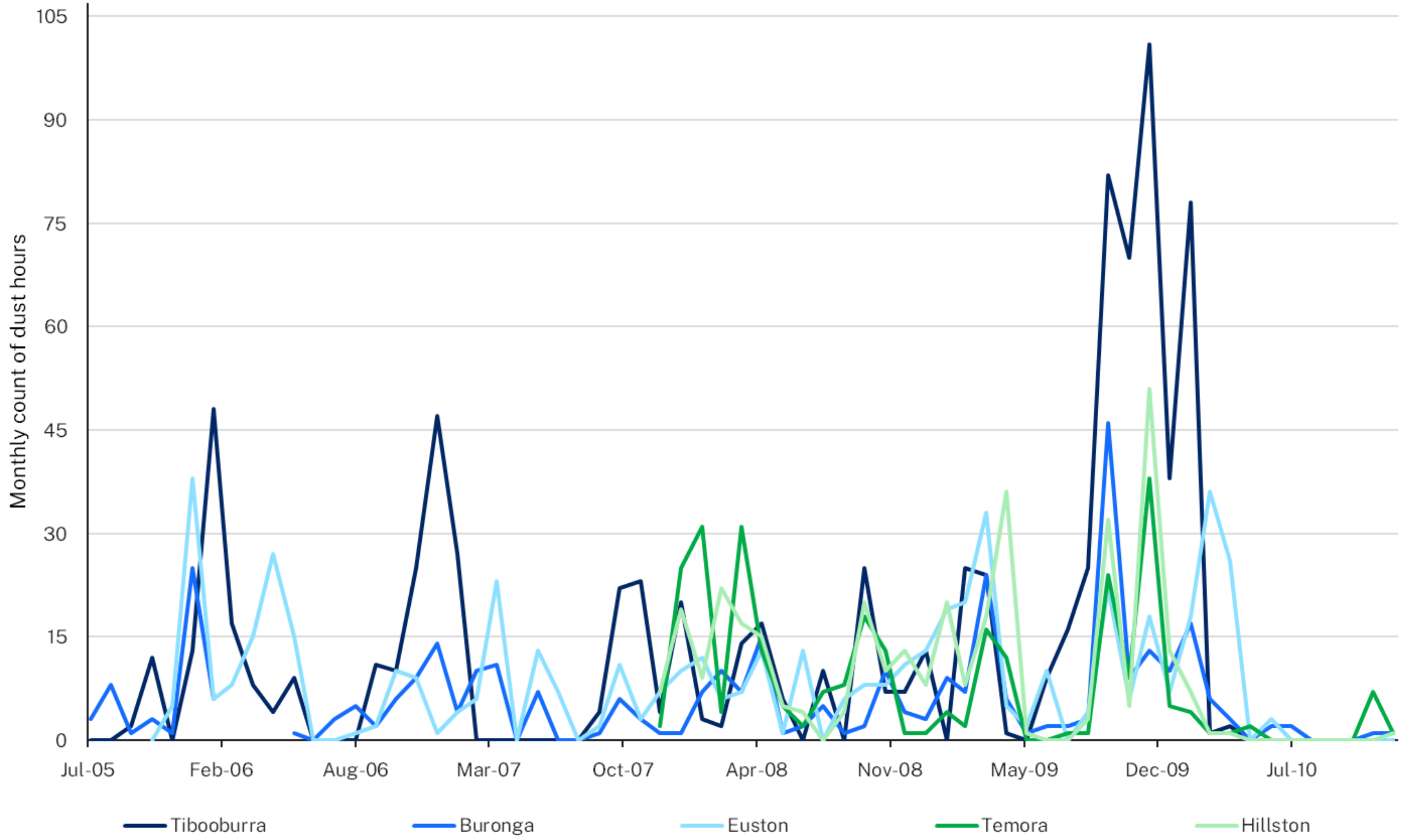

Figure 7 **Count of monthly dust hours for selected DustWatch stations in western NSW between 2005 and 2010**

3.3.2 September 2009 dust storm

The 22 to 24 September 2009 dust storm was one of the largest dust events in Australia since the 1940s (Leys et al. 2011). A strong cold front and low-pressure system swept across southern Australia. Strong winds transported about 2.5 million tonnes of dust from the Lake Eyre Basin and western NSW out to the Pacific Ocean and New Zealand (Figure 8). The dust storm resulted in Sydney being shrouded in red dust (see Photo 6) and cost the NSW economy around $300 million (Tozer and Leys 2013).

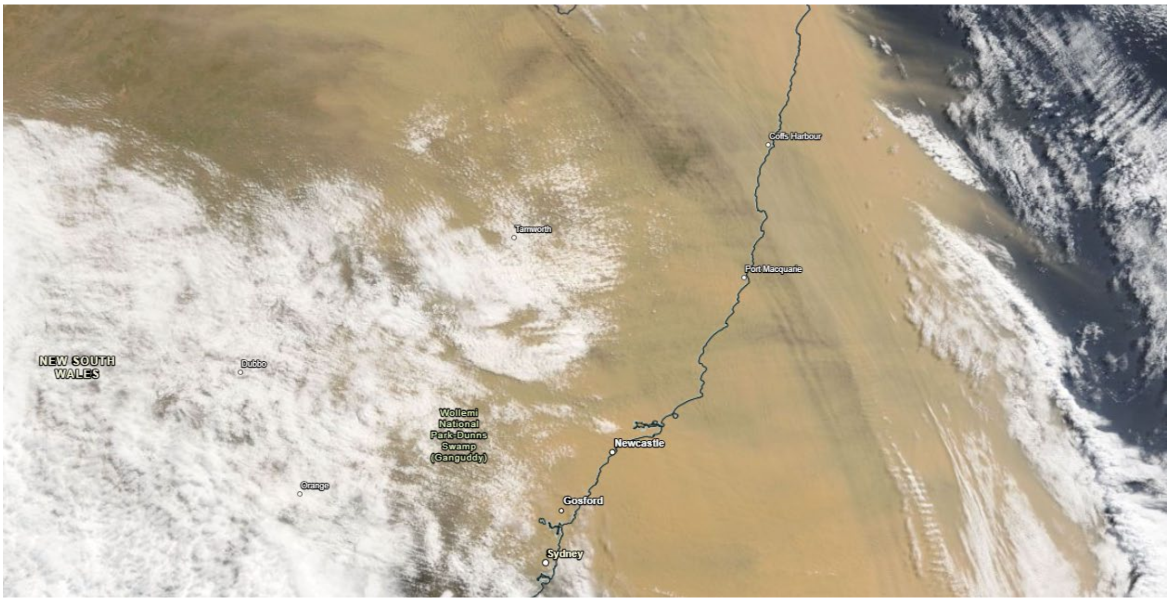

Figure 8 **Terra MODIS satellite image of the 'Red Dawn' dust plume over the NSW east coast on 23 September 2009. Source: NASA Worldview**

Photo 6 **Sydney Harbour Bridge on the morning of 23 September 2009 during the 'Red Dawn' dust storm. Photo: Colin Wynter Seton/DCCEEW**

In the lead up to the September 2009 dust storm, groundcover levels in NSW had been declining. From late 2006, an area around the Lake Eyre Basin and far west NSW experienced low groundcover, trending to less than 20% by September 2009 (Figure 9). Semi-arid areas downwind of the Lake Eyre Basin, including Tibooburra, Broken Hill and Cobar, also experienced groundcover of less than 30% at times.

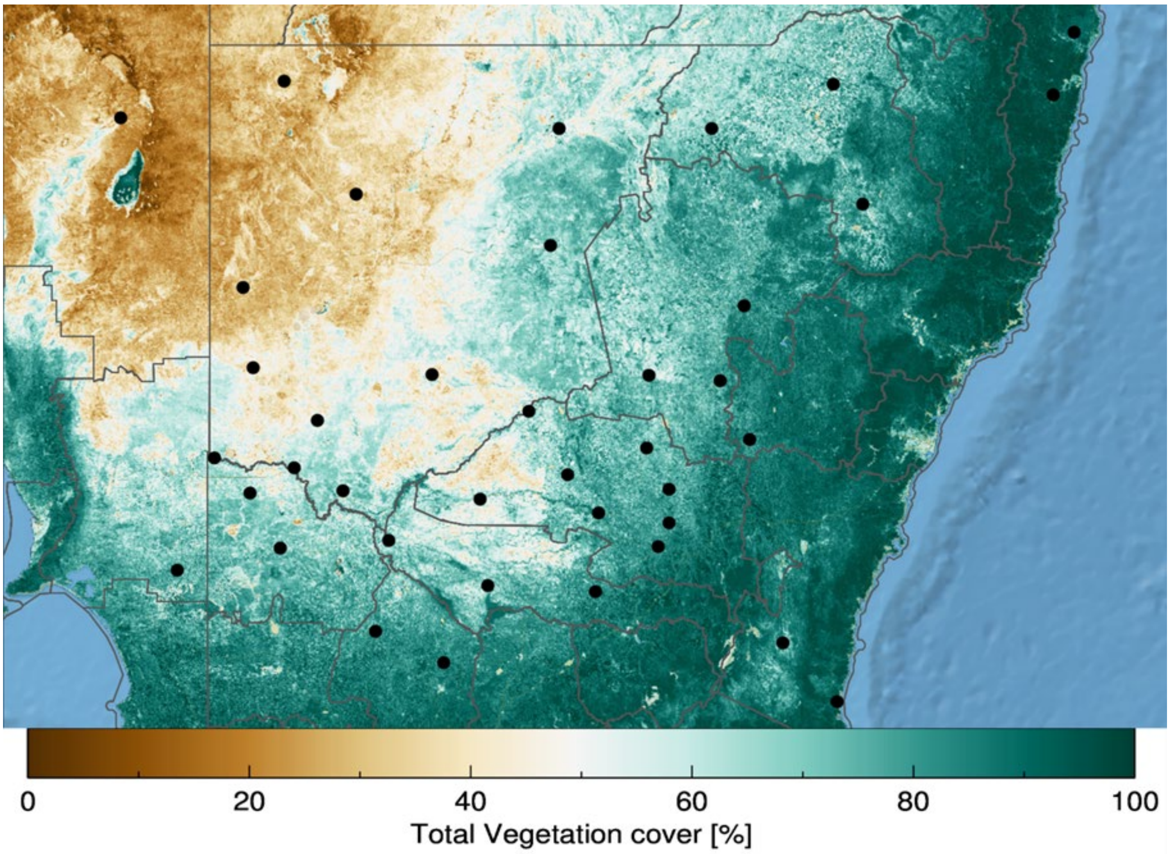

Figure 9 **Groundcover shown as total vegetation cover in south-eastern Australia in September 2009. Black dots indicate DustWatch stations and black boundaries indicate Australian natural resource management regions. Source: CSIRO GeoGlam RaPP**

Figure 10 shows isolated plumes of dust passing through Broken Hill and Tibooburra on 21 September and early on 22 September 2009, respectively. The main plume arrived on the afternoon of 22 September, passing through Broken Hill and Tibooburra at the same time. Concentrations of total suspended particles (TSP) increased to almost 3,500 micrograms per metre cubed (μg/m³) at Broken Hill. Figure 10 then shows TSP levels spiking at Bourke, Walgett and then Moree as the dust storm moves east overnight on 22 September and into the morning on 23 September.

A second, less intense dust storm occurred on 25 to 26 September and follows a very similar pattern to the dust storm a few days earlier. Dust was first recorded in Broken Hill, again peaking above 3,000 μg/m³, before passing through Tibooburra, Bourke, Walgett and then Moree. The concentrations of TSP observed during these events are very high. For example, concentrations of TSP at all stations in Figure 10 before, between and after the 2 dust storms are near or just above 0 μg/m³, showing just how low TSP levels can be when dust storms are not occurring, even in periods of severe drought.

Despite the dust storms in September, November 2009 was the dustiest month at many DustWatch stations during the Millennium Drought. Tibooburra recorded 101 dust hours in November, which was the highest monthly total since the network began.

Photo 7 **Volunteer Doug Banks at the Broken Hill DustWatch station in October 2008. Photo: Louise Goggin**

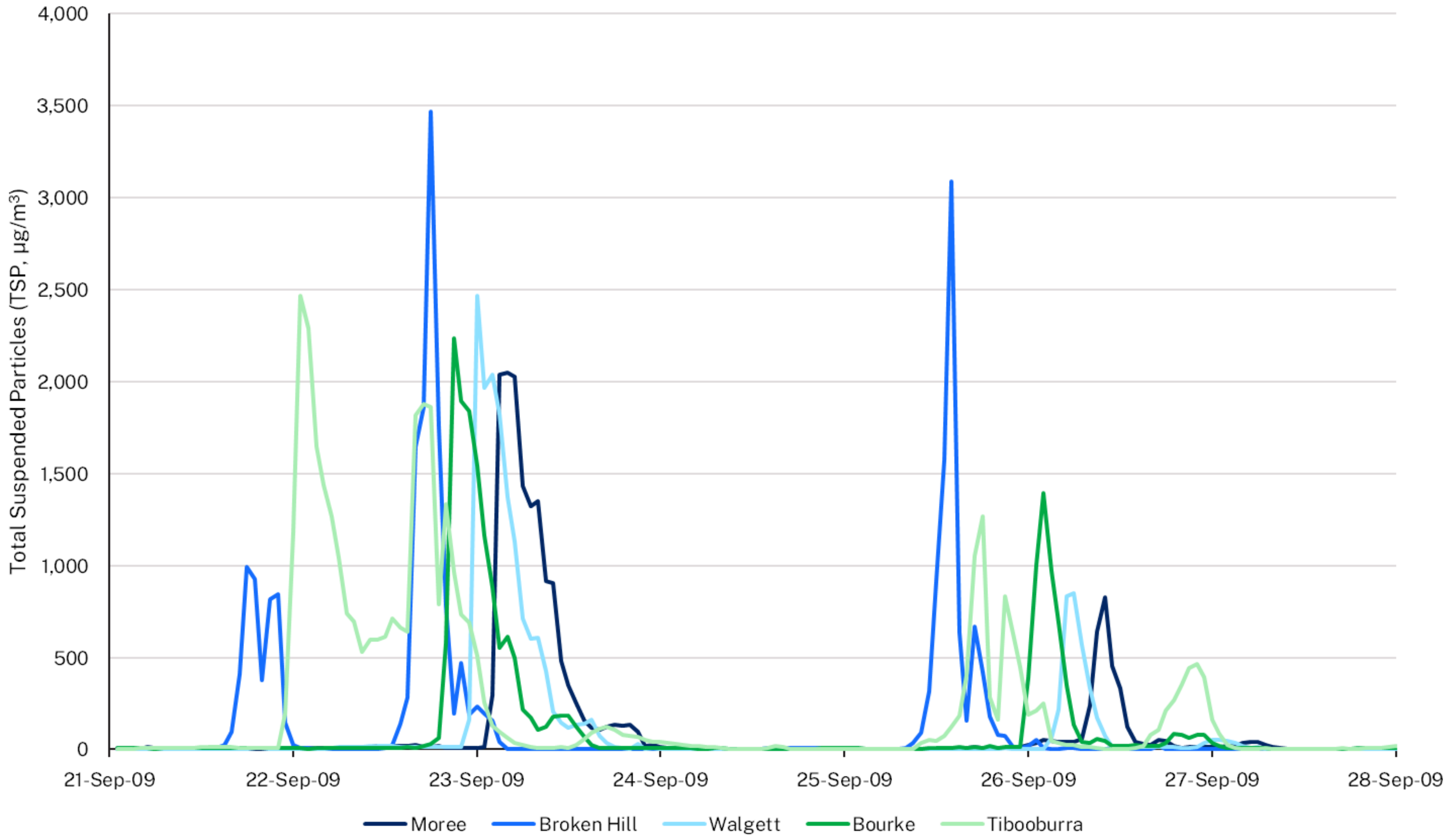

Figure 10 **Concentrations of Total Suspended Particles (TSP) at selected sites in western NSW for 21 to 28 September 2009**

3.3.3 Tinderbox Drought 2017 to 2019

The Tinderbox Drought was the driest 3-year period on record for the Murray–Darling Basin and coincided with 2019 being Australia's driest year on record (Devanand et al. 2024; BOM 2020b). For NSW, 2017, 2018 and 2019 were each successively the warmest year on record (BOM 2018; BOM 2019; BOM 2020a). This led to numerous dust storms throughout the drought, including during the 2019 to 2020 summer bushfires.

Photo 8 **Dust storm in Condobolin on 18 August 2019. Photo: Richard MacCallum**

Photo 9 **Dust storm passing through Mildura on 7 May 2019. Source: *The Sydney Morning Herald***

Across the network, groundcover deteriorated quickly (Figure 4). From a peak of nearly 100% in July 2016, winter groundcover fell to 80% in July 2019. And, by January 2020, it had fallen to approximately 45% – the lowest average groundcover recorded over the past 2 decades. Large parts of the state's Central West had less than 50% groundcover by August 2019, which continued to worsen throughout 2019, likely resulting in this region becoming a source for some dust (Figure 11). Groundcover in December 2019 (Figure 11) shows a greater severity of reduced groundcover during the Tinderbox Drought compared to the Millennium Drought in January 2009 (Figure 6).

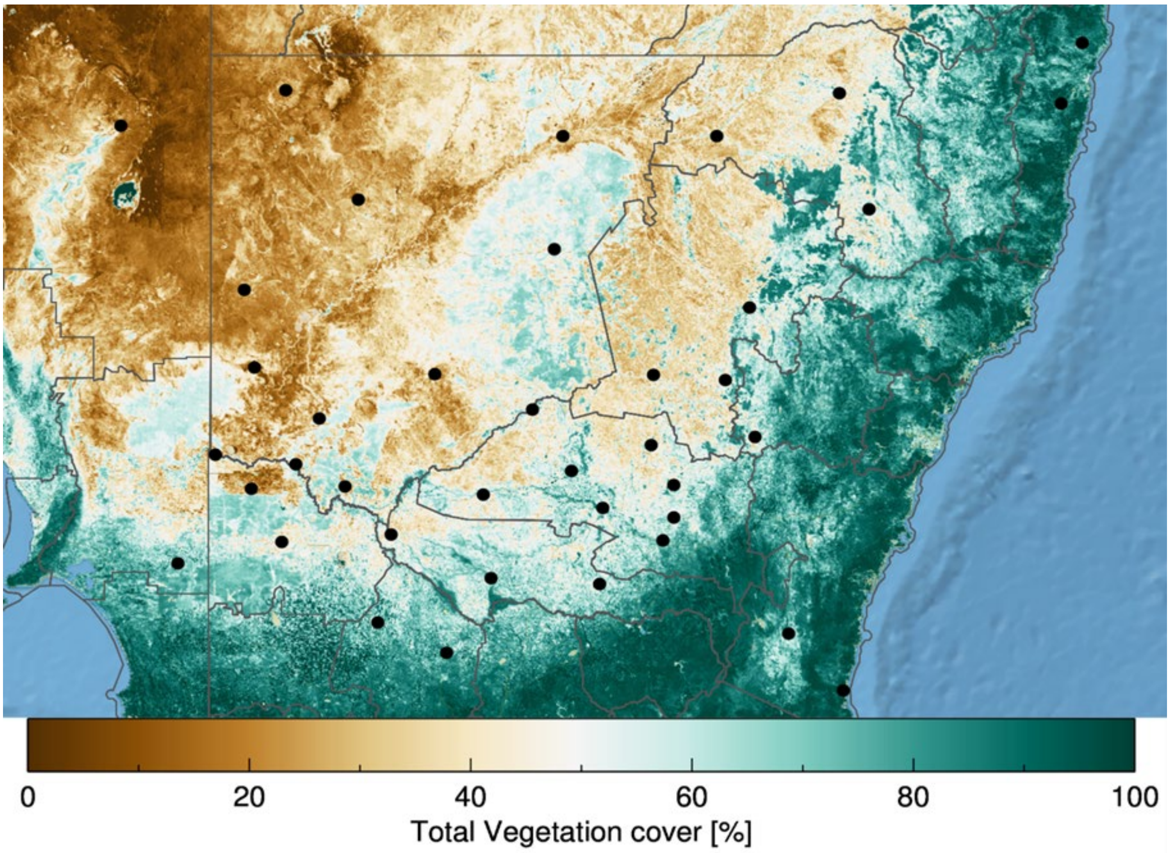

Figure 11 **Groundcover shown as total vegetation cover in south-eastern Australia in December 2019. Black dots indicate DustWatch stations and black boundaries indicate Australian natural resource management regions. Source: CSIRO GeoGlam RaPP**

Dust hours across the network began to rise by October 2018, with many long-term stations recording a spike in dust hours between October 2018 to April 2019 (Figure 12). During February 2019, Tibooburra recorded 216 hours of dust. This is the highest number of dust hours recorded since the network began operation in 2005. While Table 1 shows 2019 to be the dustiest year since the network began, it also shows 2011 was the least dusty, with an average of 2 dust hours per station during that year. Compared to the 2016 dust hours recorded just at Tibooburra in February 2019, this, along with monthly dust hours per station well below 50 dust hours in the lead up to October 2018 in Figure 12, emphasises the scale of the unusually high dust hours recorded during the Tinderbox Drought.

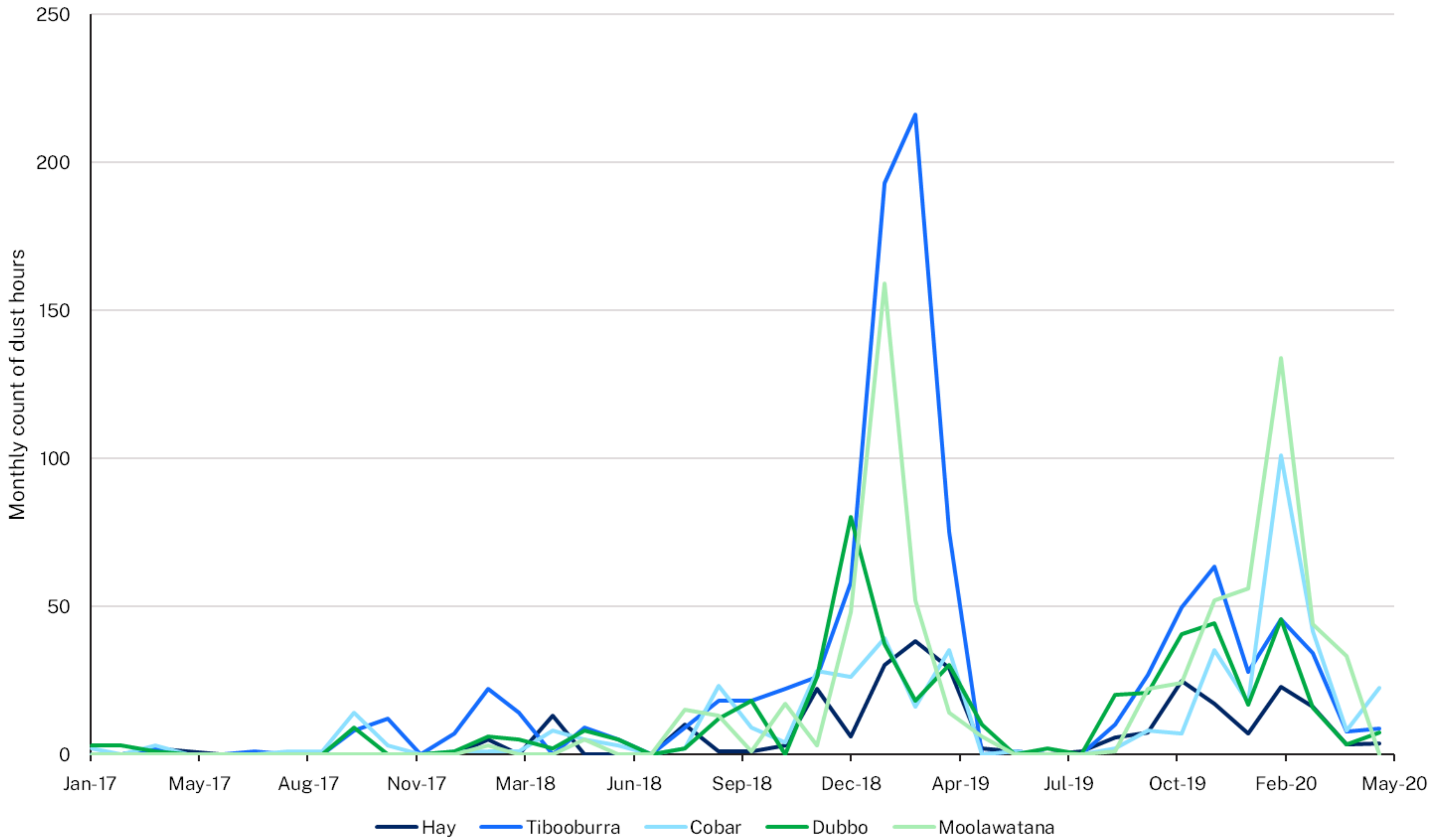

Figure 12 **Count of monthly dust hours for selected sites in the DustWatch network between 2017 and 2020**

3.3.4 2019–20 bushfire season

The rapid drying triggered by the Tinderbox Drought culminated in the eastern Australian 2019–20 bushfire season between September 2019 and February 2020. While 6.2% of NSW burned, large parts of western NSW were also regularly impacted by dust storms owing to hot and dry conditions over spring and summer (Australian Disaster Resilience Knowledge Hub n.d).

During the bushfire period, large portions of NSW experienced groundcover below 40%, with groundcover in western NSW falling below 20% (Figure 13). Between October 2019 and February 2020, long-term stations recorded an average of 77 dust hours.

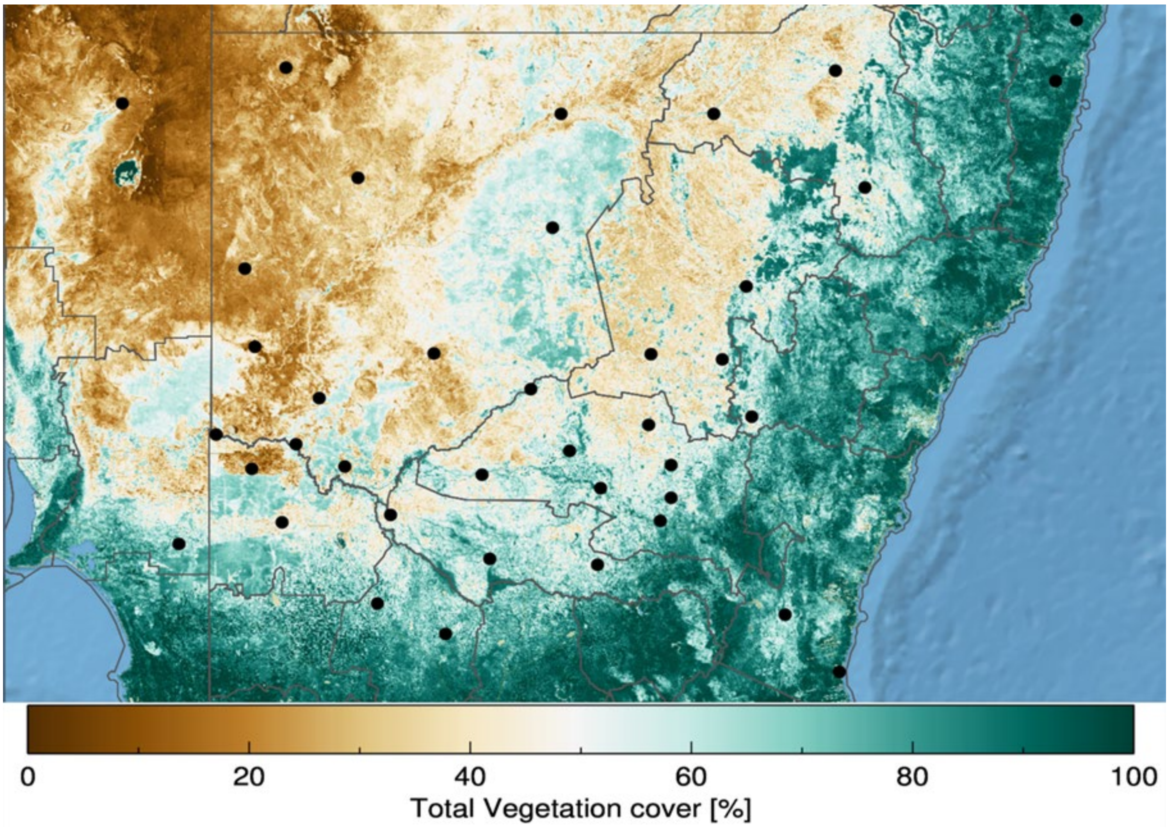

Figure 13 **Groundcover shown as total vegetation cover in south-eastern Australia in January 2020. Black dots indicate DustWatch stations and black boundaries indicate Australian natural resource management regions. Source: CSIRO GeoGlam RaPP**

Although primarily set up to record air quality impacts of dust, the DustWatch network also observed significant and widespread smoke impacts, which were identified by elevated PM2.5 concentrations. Due to the ease with which the instruments can be set up, 7 additional emergency response stations were set up to monitor smoke during the bushfires. Figure 14 shows elevated PM2.5 concentrations at Moree and Cobar from November 2019 to January 2020, as well as data from Merimbula and Grafton emergency stations, which were later permanently retained in the DustWatch network. The daily average of 270 µg/m^3 recorded at Merimbula in January 2020 (Figure 14) is almost 3 times higher than the highest PM2.5 concentration recorded at Merimbula since the 2019–20 bushfire season.

Photo 10 **Terra MODIS satellite image of multiple bushfire smoke plumes along the NSW east coast on 4 December 2019. Source: NASA Worldview**

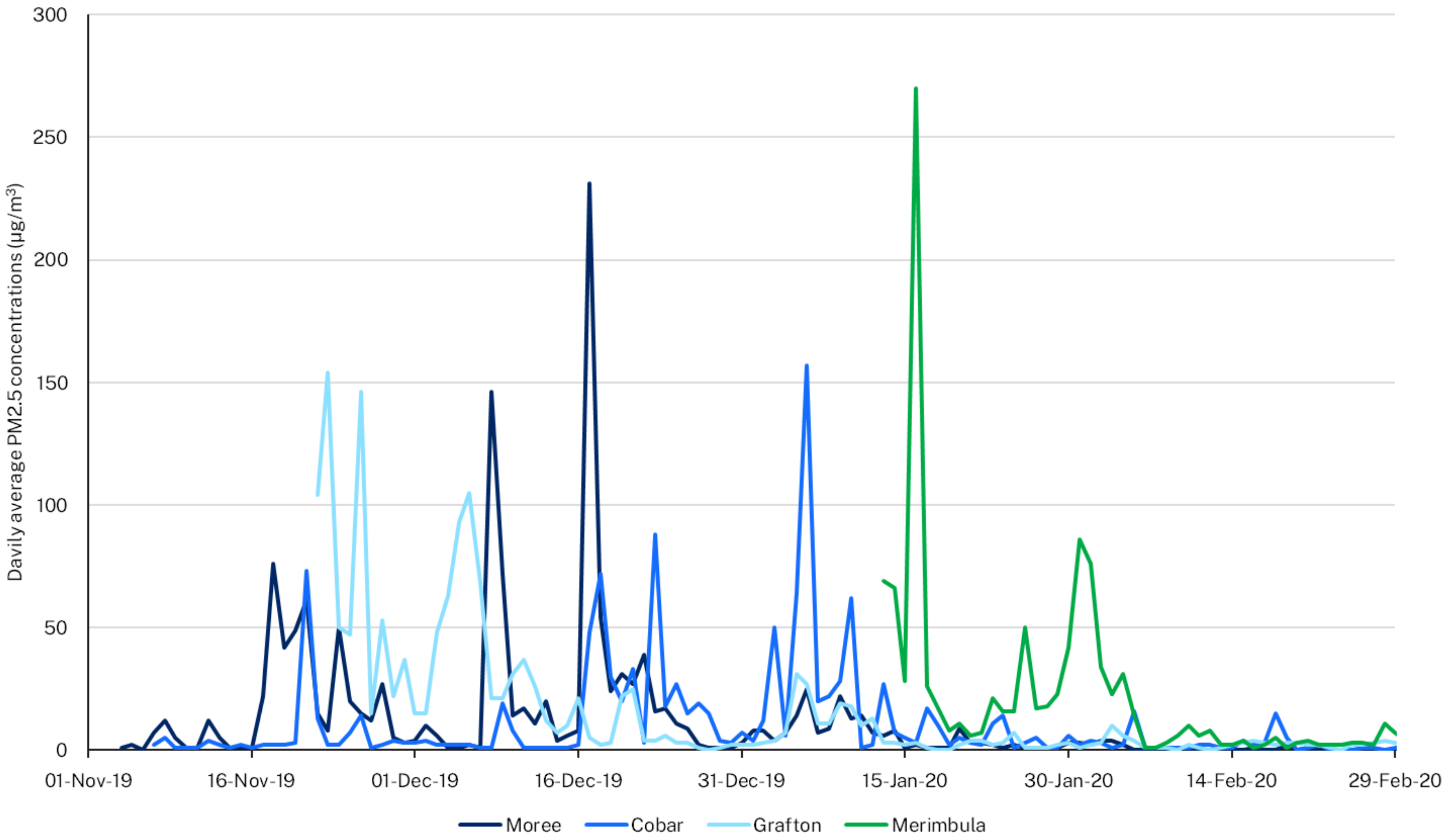

Figure 14 **Daily average PM2.5 concentrations from selected DustWatch stations between November 2019 and February 2020**

4. Impacts and purpose of DustWatch

4.1 Progress made by DustWatch

4.1.1 Contribution to public policy

Dust is used as an environmental indicator because its presence indicates soil degradation. By monitoring and reporting on dust levels, DustWatch has highlighted the link between groundcover and dust, and provided a means to evaluate state and federal programs designed to influence land management practices.

The financial support of natural resource management regions, such as the Lower Murray Darling Catchment Management Authority (CMA), has helped DustWatch to inform policy and influence community attitudes. The Lower Murray Darling CMA was the first to invest in DustWatch, funding 6 monitoring stations. As more CMA regions followed, they used DustWatch data to help set locally relevant groundcover and dust targets to evaluate vegetation and erosion control programs.

DustWatch was adopted as a means of monitoring and reporting wind erosion in a review by the federal Department of Agriculture, Fisheries and Forestry (DAFF) (Leys et al. 2009). Following this recommendation, DAFF funded DustWatch stations in Western Australia, South Australia and Victoria. To help DustWatch monitor the cause of wind erosion, the CSIRO assisted in the development of satellite-based groundcover monitoring and modelling of wind erosion (Guerschman et al. 2015). These products were utilised as part of the monitoring and evaluation of several national programs, including the National Landcare Program and the Natural Heritage Trust.

4.1.2 Land management changes and roadside surveys

The DAFF review identified roadside surveys as a method of identifying sources of dust and low groundcover. Roadside surveys are a quick method of tracking changes in soil conditions and land management practices across 260 sites using 17 variables (Leys et al. 2016). The surveys are conducted every kilometre from a stationary vehicle in cropping zones using GPS locations. DustWatch has conducted roadside surveys since 2003 for the Western and Murray LLS (and their predecessor agencies) to monitor wind erosion and land management practices. LLS uses these surveys to evaluate progress toward strategic goals, such as increasing the number of properties that are working to achieve a groundcover layer of 50% or more (LLS, 2022). Fifty per cent cover is a significant threshold for managing wind erosion and is achieved by adopting best management practices (BMPs) (Leys et al. 1999; Leys et al. 2023b).

BMPs are generally defined as guidelines for the sustainable management of agricultural land and have been shown to improve groundcover and reduce wind erosion (DPI, 2006). Research undertaken in the Western LLS found that as the use of BMPs increased from 14% to 75% between 2003 and 2022, wind erosion fell in these areas from 23% to 9% (Leys et al. 2023b). This result, in combination with the success of DustWatch in raising awareness of wind erosion, demonstrates the program’s success in improving groundcover and land management practices through policy and community engagement.

The 2016 roadside survey in the Western LLS found that rainfall totals for the previous 36 months in summer best explained groundcover conditions (Leys et al. 2016). In addition, recent research using DustWatch data found that current groundcover can be best explained by rainfall totals from less than 12 months prior to more than 3 years, depending on factors such as vegetation type and land use (Guerschman et al. 2020).

4.1.3 Community awareness improvements

At its core, DustWatch is a long-running citizen science project. Its successes and longevity are largely due to the more than 100 volunteers who have participated in the DustWatch program.

Regular collaboration between researchers, landowners and government agencies that rely on DustWatch data has helped cement the relationship between good land management practices and lower rates of wind erosion. A survey of DustWatch subscribers in March 2016 found that more than 90% of respondents had a greater understanding and knowledge of wind erosion, land management and groundcover thanks to DustWatch newsletters. Crucially, 54% of respondents reported that DustWatch had helped change their attitudes to land management, and 38% had changed their behaviour (Leys et al. 2016).

Photo 11 **Dr Stephan Heidenreich and volunteer Graham Welling. Photo: Louise Goggin**

Respondents also noted that DustWatch data had reinforced the importance of sustainable land management practices and maintaining groundcover. Landowners who access DustWatch data are more likely to prioritise groundcover on grazing properties, often choosing to de-stock to prevent soil degradation, as they better understand the importance of groundcover in soil conservation.

Overall, the work by DustWatch and its volunteers has played a significant role in helping to gradually change community attitudes about land management practices from the "pioneering" mindset of the 1940s towards a more scientifically considered approach focused on sustainable development. This change in attitude is demonstrated by dust storms being more than 4 times less frequent than during the 1940s (Leys et al. 2023a). In turn, attitude changes lead to more groundcover for longer periods and, ultimately, less dust emissions.

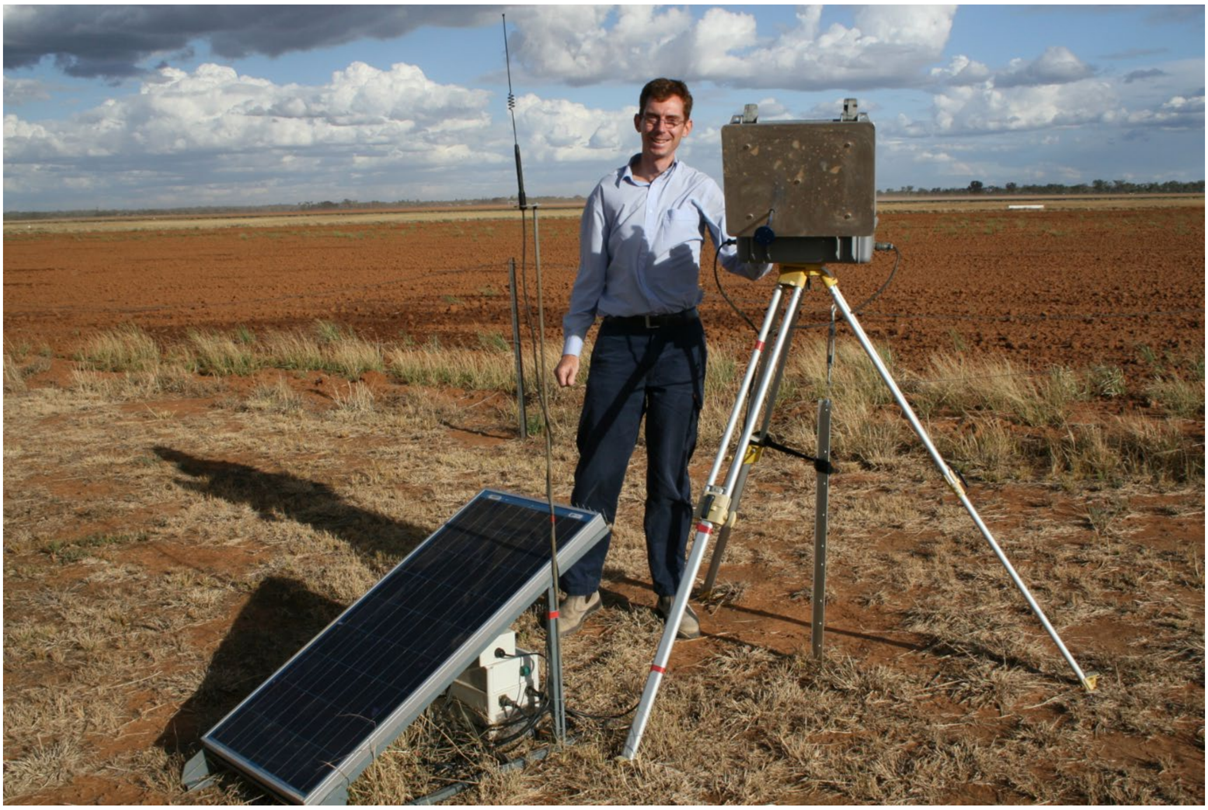

Photo 12 Volunteer at Deniliquin in February 2008. Photo: DustWatch

4.2 Research and publications using DustWatch data

Data collected by DustWatch over the past 20 years has been used in numerous research projects across various disciplines, including:

- dust storm analysis:
  - two studies on the February 2019 dust storm found that dust from arid Australia reached New Zealand and Antarctica and may have resulted in 4 premature deaths in NSW (Nguyen et al. 2019; Arangou et al. 2021)
  - meteorological analysis of the October 2013 dust event found that frontal systems passing over the Lake Eyre Basin can transport dust from the 3 distinct wind directions associated with frontal systems (Baddock et al. 2015)
  - the September 2009 dust storm was the largest to pass into the Tasman Sea since the 1940s and likely cost the NSW economy around $300 million (Tozer and Leys, 2013)
- two long-term analyses of dust storm characteristics in western and south-western NSW both found that land use plays an important role in dust storms occurring (Love et al. 2019; Leys et al. 2018). One of these studies also found that a 100 mm increase in rainfall between 250 mm and 650 mm of annual rainfall can reduce dust hours by 10 dust hours (Leys et al. 2018)
- impacts on wind erosion and land management practices
  - dust storms are more than 4 times less frequent since the 1940s, which has been aided significantly by improvements in land management practices, including through increased community awareness raised by DustWatch (Leys et al. 2023a; Ley et al. 2023b)
  - the development of a wind erosion susceptibility model (Webb et al. 2009)
  - how ground surface conditions impact the quantity of dust emitted (Ishizuka et al. 2014).

DustWatch data has also been published in monthly DustWatch newsletters, the NSW Department of Climate Change, Energy, the Environment and Water's (the department) seasonal air quality newsletters for the Namoi/North West Slopes region, and State of the Environment reports (McTainsh et al. 2011; Emmerson and Keywood 2021).

4.2.1 Using satellite data to monitor groundcover

The work done in conjunction with CSIRO to improve satellite-based groundcover monitoring products eventually became the Group on Earth Observations and its Global Agricultural Monitoring Rangeland and Pasture Productivity (GeoGLAM RaPP; see References).

GeoGLAM RaPP data is derived from the National Aeronautics and Space Administration's (NASA) Moderate Resolution Imaging Spectroradiometer (MODIS) and Landsat products, which are combined to produce a remote sensing product that more accurately reflects vegetation groundcover by capturing green and woody vegetation, as well as leaf litter. The maps in Figure 6, Figure 9, Figure 11 and Figure 13 are examples of GeoGLAM RaPP outputs.

4.2.2 Japanese Australian Dust Experiment

Approaching the peak of the Millennium Drought, the DustWatch program began a major international collaboration with the Japanese Meteorological Agency through the Japanese Australian Dust Experiment (JADE) in April 2005. The project aimed to gain a deeper understanding of complex wind erosion processes. Field experiments were planned for cultivated and pastoral land in the Lower Murray–Darling Catchment (Ishizuka et al. 2008).

The project found that soils in this area, which formed a weak, dry crust following light rainfall, had lower dust concentration emissions than dry soils without a crust. The experiment also provided high-resolution dust particle size emission data that was used in various international research publications to improve dust emission modelling. This research provided valuable insights into the fundamental processes of dust emission and the impact of dust on the global climate.

Photo 13 **A dust storm occurring on the first day of the JADE field study on 23 February 2006. Photo: John Leys**

Photo 14 **Wind tunnel in action during the JADE field study on 28 February 2006. Photo: Stephan Heidenreich**

4.3 Recognition of Community DustWatch

4.3.1 Winner: NSW Science and Engineering Award 2011

NSW Premier's Prizes for Science and Engineering aim to recognise excellence in science and engineering, and reward leading researchers for their cutting-edge work that has generated economic, environmental, health, social or technological benefits for the state. DustWatch was awarded the prize for Innovation in Public Sector Science and Engineering in 2011.

Photo 15 Dr John Leys and Professor The Honourable Dame Marie Bashir AD, CVO at the NSW Premier's Prizes for Science and Engineering Awards in 2011. Credit: DustWatch

4.3.2 Eureka Prizes 2016 nominee for Innovation in Citizen Science

The Australian Museum Eureka Prizes are the country's most comprehensive national science awards, honouring excellence across the areas of research and innovation, leadership, science engagement and school science. The Eureka Prizes raise the profile of science and science engagement in the community by celebrating outstanding achievement. In 2016, DustWatch was a nominee in the Innovation in Citizen Science category.

Photo 16 DustWatch team members and other departmental staff at the Eureka Prizes presentation in 2016. Photo: DustWatch

4.3.3 ICAR – International Conference on Aeolian Research

The International Society for Aeolian Research (ICAR) was created to promote collaboration among scientists undertaking research in aeolian processes and landforms. This society has held the International Conference on Aeolian Research (ICAR) in various locations around the world since 1985. Dr Leys has presented at every conference since 1990.

DustWatch organised the 9th ICAR conference in Mildura, Victoria, in 2016. Both Dr Leys and Dr Stephan Heidenreich presented at the conference. The conference also acknowledged the contributions of volunteers by presenting them with 10th anniversary awards.

Photo 17 Attendees at the 9th ICAR conference in Mildura in 2016. Photo: DustWatch

5. Summary

DustWatch is a significant citizen science and environmental monitoring program operating across south-eastern Australia, established formally in 2005. The valuable work of more than 100 volunteers has resulted in the collection of air quality data from 39 permanent stations over 20 years. DustWatch data is used to inform newsletters, scientific research and public policy development to improve land management practices, and raise community awareness about wind erosion and dust storms.

Significant milestones of the program include:

- studying the impact of improving land management practices on higher levels of groundcover. This has resulted in less wind erosion and fewer dust storms (Leys et al. 2023b; Leys et al. 2016)
- adoption of DustWatch by DAFF (Leys et al. 2009) to monitor wind erosion as part of a comprehensive national monitoring framework
- raising awareness about wind erosion and dust storms in local communities. This is evident through a survey which found increased community awareness led to greater adoption of sustainable land management practices (Leys et al. 2016)
- monitoring smoke as well as dust across rural south-eastern Australia, especially during the 2019–2020 bushfires
- winning the NSW Science and Engineering Award in 2011 and receiving a nomination for the 2016 Eureka Prizes for Innovation in Citizen Science
- integration of the DustWatch network in the NSW air quality monitoring network to form an expanded capability including an improved emergency monitoring response.

Environmental impacts from recent droughts and bushfires illustrate the importance DustWatch and its citizen scientists will have in monitoring the impact of a changing climate in the years to come. The NSW and Australian Regional Climate Modelling (NARCliM) project identifies factors that are expected to lead to increased dust emissions, worsening in the years up to 2080. Compared to a baseline period of 1990 to 2009, NSW is expected to experience increases in annual temperatures by 1.3°C, a 10% reduction in annual rainfall totals and an increase in soil erosivity (Adapt NSW n.d.; OEH 2015). DustWatch continues as a vital part of the NSW air quality monitoring network and this will enhance our understanding of air quality and changing land management practices.

6. References

Adapt NSW (n.d.) *Interactive climate change projections map* [website], accessed 30 May 2025.

Aragnou E, Watt S, Nguyen Duc H, Cheeseman C, Riley M, Leys J, White S, Salter D, Azzi M, Tzu-Chi Chang L, Morgan G and Hannigan I (2021) 'Dust Transport from Inland Australia and Its Impact on Air Quality and Health on the Eastern Coast of Australia during the February 2019 Dust Storm', *Atmosphere*, 12(2): 141, doi:https://doi.org/10.3390/atmos12020141.

Australian Disaster Resilience Knowledge Hub (n.d.) *Bushfires – Black Summer; New South Wales, July 2019 – March 2020* [website], accessed 29 May 2025.

Baddock MC, Parsons K, Strong CL, Leys JF and McTainsh GH (2015) 'Drivers of Australian dust: a case study of frontal winds and dust dynamics in the lower Lake Eyre Basin', *Earth Surface Processes and Landforms*, 40(4):1982–1988, doi:10.1002/esp.3773.

Bureau of Meteorology (2008) *Special Climate Statement 16 – Long-term rainfall deficiencies continue in southern Australia while wet conditions dominate the north* (PDF 364KB), Bureau of Meteorology, accessed June 2025.

Bureau of Meterology (2009) Annual Climate Summary for New South Wales, Bureau of Meterology, accessed 7 May 2025.

Bureau of Meterology (2018) Annual Climate Summary for New South Wales, Bureau of Meterology, accessed 7 May 2025.

Bureau of Meterology (2019) Annual Climate Summary for New South Wales, Bureau of Meterology, accessed 7 May 2025.

Bureau of Meterology (2020a) Annual Climate Summary for New South Wales, Bureau of Meterology, accessed 7 May 2025.

Bureau of Meteorology (2020b) *Special Climate Statement 70 update – drought conditions in Australia and impact on water resources in the Murray–Darling Basin* (PDF 1.6MB), Bureau of Meteorology, accessed April 2025.

Chang LTC, Leys J, Heidenreich S, Koen T (2018) 'Determining aerosol type using a multichannel DustTrak DRX', *Journal of Aerosol Science*, 26:68–84, https://doi.org/10.1016/j.jaerosci.2018.08.009.

De Deckker P, Munday CI, Brocks J, O'Loignsigh T, Allison GW, Hope J, Norman M, Stuut J-BW, Tapper NJ and van der Kaars S (2014) 'Characterisation of the major dust storm that traversed over eastern Australian in September 2009; a multidisciplinary approach', *Aeolian Research*, 15:133–149, https://doi.org/10.1016/j.aeolia.2014.07.003.

Devanand A, Falster GM, Gillett ZE, Hobeichi S, Holgate CM, Jin C, Mu M, Parker T, Rifai SW, Rome KS, Stojanovic M, Vogel E, Abram NJ, Abramowitz G, Coats S, Evans JP, Gallant AJE, Pitman AJ, Power SB, Rauniyar S, Taschetto AS and Ukkola AM (2024) 'Australia's Tinderbox Drought: An extreme natural event likely worsened by humancaused climate change', *Science Advances*, 10(10), https://doi.org/10.1126/sciadv.adj3460.

Emmerson KM and Keywood MD (2021) 'Australia state of the environment 2021: air quality', independent report to the Australian Government Minister for the Environment, Commonwealth of Australia, Canberra, doi:10.26194/k7x7-0j76.

GeoGLAM RAPP (n.d) *GeoGLAM RaPP* [website], accessed 2 April 2025.

Guerschman JP, Scarth PF, McVicar TR, Renzullo LJ, Mathus TJ, Stewart JB, Rickards JE and Trevithick R (2015) 'Assessing the effects of site heterogeneity and soil properties when unmixing photosynthetic vegetation, non-photosynthetic vegetation and bare soil fractions from Landsat and MODIS data', *Remote Sensing of Environment*, 161:12–26, https://doi.org/10.1016/j.rse.2015.01.021.

Guerschman JP, Hill MJ, Leys J and Heidenreich S (2020) 'Vegetation cover dependence on accumulated antecedent precipitation in Australia: Relationships with photosynthetic and non-photosynthetic vegetation factions', *Remote Sensing of Environment*, 240, https://doi.org/10.1016/j.rse.2020.111670.

Ishizuka M, Mikami M, Leys J, Yamada Y, Heidenreich S, Shao Y and McTainsh GH (2008) 'Effects of soil moisture and dried rain droplet crust on saltation and dust emission', *Journal of Geophysical Research*, 113(D24212), https://doi.org/10.1029/2008JD009955.

Ishizuka M, Mikami M, Leys JF, Shao Y, Yamada Y and Heidenreich S (2014) 'Power law relation between size-resolved vertical dust flux and friction velocity measured in a fallow wheat field', *Aeolian Research*, 12:87–99, doi:10.1016/j.aeolia.2013.11.002.

Leys JF (1999) 'Wind erosion on agricultural land'. In 'Aeolian environments, sediments and landforms', 1st edition, pp 143–166. (Chichester, John Wiley & Sons).

Leys J, McTainsh G, Strong G, Heidenreich S and Biesaga K (2008) 'DustWatch: using community networks to improve wind erosion monitoring in Australian', *Earth Surface Processes and Landforms*, 33:1912–1926, https://doi.org/10.1002/esp.1733.

Leys J, Smith J, MacRae C, Rickards J, Yang X, Randall L, Hairsine P, Dixon J and McTainsh G (2009) 'Improving the capacity to monitor wind and water erosion: a review', The Australian Government Department of Agriculture, Fisheries and Forestry, Commonwealth of Australia.

Leys JF, Heidenreich SK, Strong CL, McTatinsh GH and Quigley S (2011) 'PM10 concentrations and mass transport during "Red Dawn" – Sydney 23 September 2009', *Aeolian Research*, 3:327–342.

Leys J, Heidenreich S, Koen T and Colson I (2016) 'DustWatch Network and Roadside Survey 2016', Local Land Services.

Leys J, Strong C, Heidenreich S, Koen T (2018) 'Where she blows! A ten year dust climatology of western New South Wales, Australia', *Geosciences*, 8(7):232–246, https://doi.org/10.3390/geosciences8070232.

Leys J, Heidenreich S, White S, Guerschman J and Strong C (2023), 'Dust-storm frequencies, community attitudes, government policy and land management practices during three major droughts in New South Wales, Australia', *The Rangeland Journal*, 44(5-6):343–355, https://doi.org/10.1071/RJ22059.

Leys JF, Shields T, Murphy SR and Koen T (2023) 'Changes in land management practices have reduced wind erosion in the cropping areas of far south-western NSW, Australia', *The Rangeland Journal*, 44(5–6):309–319, https://doi.org/10.1071/RJ22028.

Love BM, Leys JF, Strong CL and McTainsh GH (2019) 'Dust climatology of Mildura, Victoria, Australia: transport direction'. *Earth Surface Processes and Landforms*, 44:1449–1459, doi:10.1002/esp.4587.

McTainsh G, Chan Y-C, McGowan H, Leys J and Tews K (2005) 'The 23rd October 2002 dust storm in eastern Australia: characteristics and meteorological conditions', *Atmospheric Environment*, 39:1227–1236, https://doi.org/10.1016/j.atmosenv.2004.10.016.

McTainsh GH, Leys JF, O'Loingsigh T and Strong CL (2011) 'Wind erosion and land management in Australia during 1940–1949 and 2000–2009'. Report prepared for the Australian Government Department of Sustainability, Environment, Water, Population and Communities on behalf of the State of the Environment 2011 Committee, Canberra: DSEWPaC, 2011.

Murray–Darling Basin Authority (2025) Basin Plan timeline and history, Murray–Darling Basin Authority, accessed June 2025.

Nguyen HD, Riley M, Leys J and Salter D (2019) 'Dust Storm Event of February 2019 in Central and East Coast of Australia and Evidence of Long-Range Transport to New Zealand and Antarctica', *Atmosphere*, 10(11):653, doi:doi.org/10.3390/atmos10110653.

NSW Department of Primary Industries (2006) *Best Management Practices for Temperate Perennial Pastures in New South Wales* (PDF 1.5MB), NSW Department of Primary Industries, accessed 4 June 2025.

NSW Health (n.d.), Particulate matter (PM10 and PM2.5) NSW Health, accessed 3 June 2025.

Office of Environment & Heritage (2015) *Soil Erosion: Climate Change Impact Snapshot* (PDF 5.9MB), Office of Environment & Heritage, accessed 30 May 2025

O'Loignsigh T, Chubb T, Baddock M, Kelly T, Tapper NJ, De Deckker P and McTainsh G (2017) 'Sources and pathways of dust during the Australian "Millennium Drought" decade', *Journal of Geophysical Research: Atmospheres*, 122:1246–1260, https://doi.org/10.1002/2016JD025737.

Tozer P and Leys J (2013) 'Dust storms – what do they really cost?', *The Rangeland Journal*, 35(2): 131–142, https://doi.org/10.1071/RJ12085.

van Dijk AIJM, Beck HE, Crosbie RS, de Jeu RAM, Liu YY, Podger GM, Timbal B and Viney NR (2013) 'The Millennium Drought in southeast Australia (2001-2009): Natural and human causes and implications for water resources, ecosystems, economy, and society', *Water Resources Research*, 49(2):1040–1057, https://doi.org/10.1002/wrcr.20123.

Webb NP, McGowan HA, Phinn SR, Leys JF and McTainsh GH (2009) 'A model to predict land susceptibility to wind erosion in Western Queensland, Australia', *Environmental Modelling & Software*, 24(2):214–217, doi:10.1016/j.envsoft.2008.06.006.

Western Local Land Services (2022) *Western Region Strategic Action Plan: Supporting document for the Western Local Strategic Plan 2021-2026* (PDF 5.2MB), Western Local Land Services, accessed 2 April 2025.