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A history of CSIRO's Central Australian Laboratory 2, 1980–2018: interdisciplinary land research

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ABSTRACT

In the first 27 years of the Central Australian Laboratory (CAL), to 1980, research focussed almost entirely on the needs of the pastoral industry. By the 1980s, ongoing campaigns for Aboriginal land rights and demands to conserve biodiversity plainly showed that there were other land uses deserving research attention. Initially CAL's research agenda expanded to include conservation in spinifex grasslands and grazing lands but remained biophysical in nature. It subsequently became clear that people's roles in decision-making about land use and management should be part of research. By the 2000s, scientists were able to build trusting relationships with Aboriginal people and organisations and undertake collaborative studies to improve livelihoods and wellbeing on country. Over the 38 years from 1980 to 2018, CAL's research activities responded to diverse societal expectations but it was not enough to prevent the laboratory's eventual closure as public investment in rangelands dwindled.

Keywords: Aboriginal livelihoods, conservation, pastoralism, socio-ecological systems, sustainability, tourism.

Introduction

The first paper in this two-part series outlined the development of research at the Commonwealth Scientific and Industrial Research Organisation's (CSIRO) Central Australian Laboratory (CAL) from its inception in 1953 until 1980.[1] During that phase the research was directed almost solely at supporting the pastoral industry and improving the management of grazing resources. Beginning in the 1970s, societal interest in management across the inland moved beyond livestock grazing as the primary land use. In response, research at CAL broadened into other fields, such as conservation and Aboriginal land use, while continuing work for the pastoral sector.

Numerous CSIRO divisions and business units were responsible for oversight of the laboratory during these decades, as described in the first paper of this series.[2] Likewise, the facility's title underwent various modifications, but for convenience we use the term Central Australian Laboratory (CAL) throughout. Until the late 1960s there was only one, or sometimes no, resident research scientist at CAL, after which time numbers grew episodically, reaching a peak of fourteen in late 1990.

This second paper of a two-part series traces the development of a widening range of land use and management research from 1980 until the closure of the facility in 2018. For a glossary of terminology see Supplementary Material S1 in part 1, and for a map of named research sites and regions see fig. 1 in part 1.

[1]Friedel and Morton (2022).
[2]Friedel and Morton (2022).

Shifting societal expectations about land use

The initial focus on pastoral research was consistent with CSIRO's long-term agricultural strengths, which in turn from a 'settler science' tradition.[3] This situation had begun to change by the late 1970s: legislation recognised Aboriginal land rights in the Northern Territory and northern South Australia, and Aboriginal affairs policy shifted away from assimilation and toward self-determination. Change accelerated in the 1990s with decisions by the High Court of Australia confirming that Aboriginal native title rights persisted and could co-exist on pastoral leasehold land. Throughout this period the pastoral sector found itself at the centre of national attention, sometimes critically.[4]

Challenges to the pre-eminence of pastoral land use further intensified as societal interest in biodiversity conservation and ecosystem services widened from the 1980s onward. Rangeland management was an early focus for the growing environmental movement. As the organisers of a National Arid Lands Conference in Broken Hill in 1982 explained:

> The development of this new interest in the arid lands was not before time. … land tenure … was the most hotly debated topic. Not far behind was the question as to how badly the arid lands are degraded and who should be held responsible.[5]

The tourism sector was also growing rapidly from the mid-1980s. In central Australia, increasingly popular natural attractions such as Uluṟu-Kata Tjuṯa National Park and the MacDonnell Ranges suggested alternate forms of land use could be economically successful, thereby supporting national park expansion. In short, new interests in land management gained public attention and a new economy began to emerge, challenging pastoralism to accommodate alternative land uses.

Responding to these trends, CAL's research managers strove to expand under-developed fields of research—for example conservation—and build on existing work. At the same time, rangeland science itself was evolving through the 1980s to include people as an integral part of rangeland systems, leading eventually to the emergence in the 1990s of the science of sustainability, human-environment or social-ecological systems, and resilience. The following sections outline developments in key research fields as CAL scientists grappled with these challenges.

Pastoral research

By the 1980s, valuable insights had been gained from previous research at paddock and multi-station scale,[6] and from examination of historical evidence, relating to Aboriginal land use and fire, and the impacts of grazing cattle, changed fire regimes and rabbits.[7] As research proceeded, it was clear that environmental change was discontinuous in both time and space, and that it was identifiable at different temporal and spatial scales.[8] Moreover, there were multiple factors influencing change, including rainfall, grazing and fire, as well as physical features such as soils and topography that enhanced or limited ecological responses.[9] In 1989, a landmark paper by Westoby and others argued that the widely accepted model of linear succession in vegetation composition following disturbance—resulting in a predictable climax vegetation—did not fit what they observed.[10] Instead, they proposed that one ecological state could transition to a second in response to a pressure, yet removing that pressure might see that second state transition to a third, depending on seasonal or other factors, not simply return to the original. Multiple states and transitions were possible. These insights produced new theoretical underpinnings for further developments particularly in pastoral and conservation research.

Fortuitously, software packages enabling multivariate analysis on mainframe computers became readily accessible so that, for example, rainfall as the predominant influence on species composition could be separated from the influence of soil type and the impacts of grazing or fire.[11]

Ecology of grazing lands

Increased scrutiny of pastoral land use highlighted the need for a better understanding of the ecological impacts of grazing and for improved methods of range assessment. In collaboration with rangeland extension officers, studies in diverse vegetation types identified the most consistent and realistic methods for assessing the ground layer and overstorey.[12] A seven-year study by Marg Friedel of vegetation change along gradients of grazing pressure initially demonstrated the importance of stratifying for landscape type, for detecting grazing impacts.[13] Subsequently, following variable rainfall events over the whole period, it was clear that some vegetation change was effectively irreversible. This led

[3]Robin (2007).
[4]Holmes (2002).
[5]Messer and Mosley (1983) pp. 6–7.
[6]Friedel and Morton (2022).
[7]Griffin and Friedel (1985).
[8]Friedel (1990).
[9]Foran and others (1986). Friedel and others (1993).
[10]Westoby and others (1989).
[11]For example, Ross and others (1983).
[12]For example, Friedel and Shaw (1987*a*) and Friedel and Shaw (1987*b*).
[13]Friedel (1997).

researchers to ask what was the underlying mechanism for this outcome.

When grazing gradients were subdivided into geomorphic strata according to soil texture and runon/runoff criteria, it was apparent that the further a site was from watering points, the greater was the degree of landscape organisation and soil productive potential.[14] Increasing soil erosion closer to watering points and loss of stable sites to trap resources led to decoupling of water and nutrients. At a landscape scale, key nutrients were likely to be lost as grazing pressure increased, rather than simply being redistributed. Although water infiltration increased, runoff probably also increased due to the loss of barriers to flow. Any increased production in confined drainage lines capturing runoff was unlikely to compensate for lost production on surrounding broader slopes.[15] Since this transition from one state to another was not readily reversed, the system had crossed a threshold;[16] early management intervention would be necessary to avoid costly remediation. The concept of thresholds went on to be influential in the development of theory underpinning rangeland management and health.

Related studies showed how heavy grazing affected the size and composition of soil seed reserves by destabilising soil and broad-scale resource traps; changes to the soil preceded changes to the vegetation, suggesting that soil-based indicators in this system provided a better early warning of degradation than vegetation-based indicators.[17] Further, Craig James and his colleagues examined plant and animal diversity along grazing gradients, and concluded that grazing-sensitive species were likely to need protection because habitats far distant from waterpoints were becoming increasingly scarce.[18]

Remote sensing for rangeland monitoring

Remote sensing research had commenced at CAL in the 1970s when Bob Millington and colleagues attempted to upscale ground-based measurement of vegetation characteristics using colour aerial photography.[19] Barney Foran continued this research in the early 1980s but then progressed to the analysis of digital Landsat multispectral scanner (MSS) data in conjunction with Geoff Pickup. Pickup was appointed in 1981 to develop remote sensing technologies for analysis of erosion processes and landscape stability. An early achievement was the implementation of erosion modelling software on a user-friendly microcomputer-based image processing package allowing image processing technology to be decentralised to branch offices of government departments or to agricultural consultants.[20]

Concurrent data collection using field techniques, aerial photography, airborne radiometry and subsequent analysis with contemporaneous Landsat MSS data by both Pickup and Foran led to an index of vegetation cover that was suitably robust across a wide range of seasonally variable cover levels, soil colours and transient photosynthetic activity.[21] This index allowed vegetation cover to be routinely monitored across pastoral regions. Using an explicit definition of grazing-related land degradation and through examining spatiotemporal patterns of vegetation-cover dynamics, Pickup and Vanessa Chewings then developed a suite of grazing gradient techniques that allowed the longer-term impact of grazing management to be monitored in large paddocks across the arid zone.[22] Members of the team then tested these techniques in the southern Northern Territory and subsequently implemented the method through a series of ‘technology transfer’ projects with agency partners in northern South Australia, the Barkly Tablelands and in Rajasthan, India. Pickup’s leadership in developing new spatiotemporal analyses of land degradation achieved global attention and contributed to negotiations towards the United Nations Convention for Combating Desertification in the early 1990s.

Later remote sensing research developed and tested airborne digital multispectral videography (DMSV) for utility in upscaling ground-based validation of satellite-based remote sensing in heterogenous landscapes. In collaboration with CSIRO colleagues elsewhere, DMSV imagery was used to upscale site-based Landscape Function Analysis which, in turn, led to a ‘leakiness index’ based on the analysis of vegetation cover derived from Landsat Thematic Mapper and digital elevation data.[23]

The final phase of remote sensing research at CAL saw the development and implementation of a largely automated method for analysing the dynamics of remotely-sensed ground cover across very large areas.[24] This work was conducted in close collaboration with Queensland Government colleagues to meet a need identified by the Australian Collaborative Rangeland Information System (ACRIS) for better reporting

[14] Tongway and others (2003).
[15] Sparrow and others (2003).
[16] Friedel (1991).
[17] Kinloch and Friedel (2005).
[18] James and others (1999). Landsberg and others (1999). Landsberg and others, (2003).
[19] Millington and others (1977).
[20] Pickup and Chewings (1986).
[21] Pickup and Foran (1987). Pickup and others (1993).
[22] Pickup and others (1994).
[23] Ludwig and others (2007).
[24] For example, the Queensland rangelands: Bastin and others (2014).

on the sustainability of pastoral management,[25] utilising an emerging database of nationally consistent multi-temporal fractional ground cover.

Analysis of the temporal dynamics of remotely sensed vegetation cover is now an established component of jurisdictional and regional rangeland monitoring programs in Australia.[26] Methods developed at CAL that use spatio-temporal analysis to separate grazing effects on vegetation from that due to rainfall variability are included as a component of the Australian online series of earth observation textbooks.[27] However they have not persisted as a component of rangeland condition monitoring programs of Australian states.

Decision support tools for pastoralists

In 1985, Foran and Mark Stafford Smith took up the challenge of devising computerised support for pastoral managers, initially conceptualised as an integrated model that would help pastoralists apply CAL's ecological insights. In 1986, they ran a survey and a week-long workshop with about twenty pastoralists, extension officers, economists and scientists from all rangeland states, which radically altered their research priorities.[28] These activities reinforced the fact that pastoralists face complex decisions as they deal with large properties, a diversity of landscape types and variable seasonal conditions, as well as external factors like fluctuating livestock prices and internal imperatives such as their children's education. The resulting microcomputer-based support system, *RANGEPACK*, prioritised the economics of property decision-making as informed by ecological insights, rather than the other way around, and enabled users to apply the tool to their own circumstances.

The first module was *HerdEcon*, which integrated herd dynamics and property economics, and could be tailored with data from an individual property to test a variety of real-life scenarios over multiple years. With collaborators, Foran and Stafford Smith produced many such studies, particularly focusing on climate variability. Some 200 copies of the software were also sold to pastoralists, consultants and extension officers, and there was extensive outreach through workshops, leading to case studies written up as leaflets and paper.[29] *HerdEcon* helped to show how lower stocking rates could improve profits once realistic sequences of droughts were accounted for, as well as what management should focus on (for example buying, breeding, and so on) for rapid recovery after drought in all different areas of Australian rangelands. These and related findings were absorbed into extension messages in several states and meant that economic analyses that failed to account for climate variability ceased to be acceptable.

Funding support for the research did not provide for maintenance of software and after-sales support, so *RANGEPACK* never achieved the full scope originally envisioned. A *Paddock* module was completed to help with spatial paddock design; the concepts behind this module influenced paddock design efforts, particularly in Western Australia, but the module itself never became commercially successful as research progressed. Meanwhile the *HerdEcon* module underpinned several further projects, often in collaboration with the Queensland Department of Primary Industries (QDPI). 'DroughtPlan' focused on diverse tools to assist drought management throughout the Australian rangelands, which helped to turn many findings from *HerdEcon* into rules of thumb that filtered into use widely, through uptake by extension services, a few consultants and pastoralists directly.[30] By linking *HerdEcon* to the QDPI's pasture model, GRASP, the biology underlying property economics became more realistic; *HerdGrasp* showed how short-term profitability could conflict with long-term viability and land conservation goals of concern to many pastoralists. *HerdGrasp* was also used to test the value of seasonal climate forecasting in improving productivity and financial returns,[31] and linked in a simplified form to a treatment of tax instruments in *RiskHerd*, a project supported by the National Farmers Federation and the Australian Tax Office, and which contributed to national policy decisions on drought instruments such as promoting Farm Management Deposits which *RiskHerd* had shown were neutral in terms of environmental impacts.[32]

Conservation research

As the research agenda expanded to include conservation, it was apparent that ecological insights emerging from earlier research on pastoral lands, at CAL and elsewhere, had found important alternative applications. Notably, effective conservation management in the arid zone required an understanding of landscape differentiation at large scale and consideration of the discontinuous nature of environmental change. Both these issues had become well understood through pastoral research, and from that domain also came accelerating remote sensing capacities. Conservation research at CAL began with work on fire.

[25] See Supplementary Material S1.
[26] For example, Beutel and others (2019). Anonymous (2021). Anonymous (2022).
[27] CRCSI (2021).
[28] Stafford Smith and Foran (1990).
[29] For example, Stafford Smith and Foran (1990). Foran and others (1990*a*). Foran and Stafford Smith (1991). Buxton and Stafford Smith (1996).
[30] Stafford Smith and others (1997).
[31] Ash and others (2007).
[32] Stafford Smith and others (2001). Stafford Smith (2003).

Fire

The massive rainfalls of the mid-1970s, and subsequent widespread fires, highlighted the inevitability of intermittent burning in arid Australian ecosystems driven in productivity by the El Niño-Southern Oscillation and related global climate phenomena. Graham Griffin and his colleagues examined the landscape context of the wildfires of the late 1970s, establishing that they were most frequent in the extensive swathes of spinifex grasslands, often penetrating from there into other vegetation types.[33] Griffin showed that the propensity of this grass to burn was a consequence of accumulated rainfall rather than time and argued that patch-burning of spinifex grasslands would enhance faunal and floral diversity while reducing extensive wildfires.[34] Griffin and Grant Allan worked with managers at Uluṟu-Kata Tjuṯa National Park to develop pre-emptive patch-burning regimes, consistent with traditional Aboriginal resource management.[35] A collaboration with the Conservation Commission of the Northern Territory led to repeated satellite mapping of fires across much of the southern half of the Territory, as a basis for patch-burning aimed at limiting later spread of wildfires. Allan subsequently took up employment with Bushfires NT to maintain and extend that objective.[36]

The notion of patch-burning coincided with growing realisation that fire regimes had changed markedly during the twentieth century as a result of Aboriginal people moving, or being moved, away from traditional lands. Through use of fire for multiple purposes including hunting, enhancing plant foods and meeting spiritual responsibilities for country, Aboriginal people of the spinifex lands had created a shifting landscape mosaic of small burnt patches at different stages of succession. This fine-grained mosaic had been replaced in large part by tracts either of unburnt spinifex or of country burnt by lightning-initiated wildfire,[37] a notion leading to application of patch-burning principles in many parts of arid Australia. Nevertheless, studies of the first two decades of the 2000s have cautioned against the habit of applying a mosaic-burning 'template' universally throughout a region of substantial ecological variety.[38] For example, Kimber and Friedel showed that mosaic burning was uncommon in the Simpson Desert, the practice occurring there only rarely.[39]

Conservation management

Conservation research was boosted by the arrival in 1984 of Steve Morton, whose work on fauna would readily integrate with existing plant community studies. Relationships created by work on fire at Uluṟu-Kata Tjuṯa National Park led to commissioning of a wildlife survey by staff from CAL, from 1987 to 1990. At the time, the survey was the most detailed of any part of arid Australia, and amongst the first to collaborate with Aboriginal advisors concerning traditional knowledge of the animals.[40] Research extended into responses of animals to fire-driven succession in spinifex grasslands,[41] into development of landscape models aiming to explain restriction of endangered species to isolated patches in the landscape,[42] and into approaches to monitoring of biodiversity.[43] When ecologist Chris Pavey joined the laboratory in 2011 he continued research into management of refuges for endangered species under pressure from introduced predators.[44]

Weeds

The threat of weeds further occupied the efforts of researchers. Griffin identified the risk of invasion of the Finke River by athel pine, *Tamarix aphylla*, and led a study that subsequently stimulated control efforts.[45] He was also one of the first scientists to report the conservation threat posed by buffel grass, *Cenchrus ciliaris*, which had been introduced as a pasture species and for erosion control.[46] Research showed that buffel grass disrupted existing fire regimes, encouraged further invasion, and disadvantaged certain native woody plants.[47] The work with buffel grass led CAL into contentious areas of natural resource management, for buffel grass is valued by the pastoral sector but is detrimental to conservation and Aboriginal values.[48] Friedel and her colleagues developed non-adversarial procedures to bring representatives of differing interests together to identify options for management. Common objectives were agreed for managing buffel grass on conservation reserves and on grazing lands of

[33]Griffin and others (1983).
[34]Griffin (1992).
[35]Saxon (1984).
[36]Allan and Southgate (2002).
[37]Burrows and others (2006).
[38]Friedel and others (2014).
[39]Kimber and Friedel (2015).
[40]Reid and others (1993).
[41]Masters (1996).
[42]Morton (1990).
[43]Smyth and James (2004).
[44]Pavey and others (2017).
[45]Griffin and others (1989).
[46]Griffin (1993).
[47]Miller and others (2010).
[48]Batty and others (2012)

low conservation value, with remaining contention being about management objectives for grazing land of high conservation value. The work suggested sufficient common ground existed to initiate policies for management of buffel grass.[49] Policy responses have differed amongst jurisdictions, from formal declaration of buffel grass as a weed and development of a strategic plan, to support for further planting and qualified acknowledgement of its weed potential.[50] Ultimately decisions on policy development are political, depending on the value of buffel grass to the pastoral industry, and only partially influenced by science.

Landscape management and systems thinking

Involvement of CAL staff with wider issues of natural resource management led to growing consideration of interactions within and between ecosystem components. Pickup's examination of landscape-scale structures resulting from large rainfall events led him to identify 'erosion cells' (each comprising a source-transition-sink) of mobile sediment, which were likely to be enhanced by grazing and climate change, and evidence of 'super-floods' from relatively recent times to many thousands of years old.[51] Both had implications for vegetation expression and range assessment. Morton and James attempted to explain a major feature of the arid Australian fauna—a globally-significant radiation of lizards—through connections between intermittent heavy rainfall, infertility of spinifex grasslands, and dominance by termites of the detritivore pathway.[52] Morton and others offered a regional perspective on achieving biodiversity conservation while also enabling sustainable use.[53] They proposed integrating national parks and off-reserve conservation, a way to accommodate conservation and grazing objectives, and a process for enabling all users to become land stewards. Stafford Smith and Morton applied a systems approach to create a framework for the ecology of arid Australia, a synthesis that was reconsidered and refreshed 20 years later.[54]

Systems and Desert Knowledge

Through the 1990s, CAL's research increasingly engaged with more land uses and their interactions, after an initial focus on balancing conservation and grazing.[55] Discussions during a CSIRO Board visit in 1999 additionally included multiple uses on Aboriginal lands, and regional sustainability. Concurrently there was growing pressure within CSIRO to find bigger projects—of the order of $2 m external funding instead of the more common $200 000 or so. In response CAL re-framed its strategic plan to incorporate a high-level goal of 'sustainable habitation in the rangelands', aiming to achieve integrated, larger projects. This was a challenging aspiration given declining research funding for the rangelands and the diversity of stakeholder relationships needing maintenance across all jurisdictions, industries and sectors.

In 1999, the Northern Territory government released a discussion paper on 'Alice in 10',[56] and CAL staff played a key role in establishing the idea of a 'Desert Knowledge' economy to diversify the development of inland Australia. This resulted in a decision to bid for the Desert Knowledge Cooperative Research Centre (DKCRC) as a research entity aligned with the Northern Territory Government's newly established statutory body, Desert Knowledge Australia (DKA). DKA was to be based in Alice Springs but would promote the potential for a more diversified economy across all the rangeland states.

The DKCRC bid was supported by the Northern Territory, South Australian and Western Australian governments, drawing in private sector contributions, Indigenous partner organisations and thirteen universities.[57] It was successful, achieving $27 m of new money and a total value of $91 m over 7 years. Though only one party among many, CSIRO had a significant stake. DKCRC was launched in July 2002, with Stafford Smith on secondment from CSIRO as CEO, and a small staff located in CAL. Most CAL scientists benefitted from opportunities for new collaborations and funding and for innovative research; some had roles on the management team.

DKCRC's agenda was challengingly broad, seeking to integrate natural resource-based activities with knowledge of settlement patterns and the delivery of services, as well as opportunities, such as solar energy and telecommunications, to create new regional economies.[58] Working across cultures and empowering Indigenous involvement were fundamental to the agenda and, increasingly, to CAL's research. The CRC Board included strong Indigenous representation; some legal agreements embedded the concept of *ngapartji-ngapartji*, a Pitjantjatjara term translating as 'respectful reciprocity'.

The successor to the DKCRC, the CRC for Remote Economic Participation, extended the work to 2017; Ninti One, the company established to hold intellectual property,

[49] Grice and others (2012).
[50] Cook (2007). Biosecurity SA (2019).
[51] For example, Pickup (1985) and Pickup (1991).
[52] Morton and James (1988).
[53] Morton and others (1995).
[54] Stafford Smith and Morton (1990). Morton and others (2011).
[55] Foran, Friedel and others (1990*b*). Morton and others (1995).
[56] For example, Anonymous (1999).
[57] We use 'Indigenous' from hereon, in relation to national contexts where it means Aboriginal people and Torres Strait Islanders. 'Aboriginal' is the preferred usage of regional organisations across central Australia if more specific language or group names are not appropriate.
[58] Wand and Stafford Smith (2004).

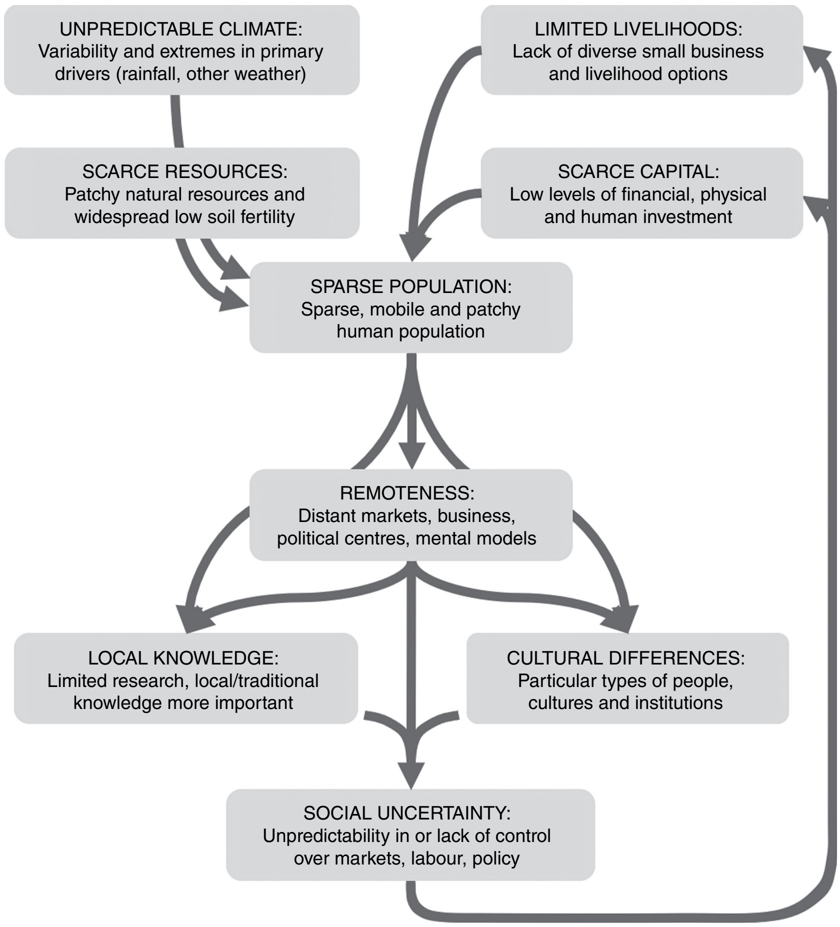

Fig. 1. The 'Desert System', a social-ecological system with feedbacks, leading to unpredictability in or lack of control over markets, labour and policy, driven by unpredictable climate, scarce and unevenly distributed resources, limited livelihood options and scarce capital, whether financial, physical or human. Diagram redrawn from Stafford Smith and Cribb (2009), courtesy of Mark Stafford Smith.

continued subsequently as an independent body.[59] The outputs included special issues of scientific journals and a substantial set of CRC reports, and considerable networks across desert Australia that linked universities and practitioners.[60] Stafford Smith finished as CEO in 2005, but other CAL staff continued in major roles throughout this period. CAL moved to the Desert Knowledge Precinct in 2009, co-locating with DKCRC, DKA, and Indigenous organisations.

A principal legacy of the DKCRC was the concept of the 'desert system'—a systems view depicting the functioning of areas that are remote from main centres of population and whose sparse populations commonly move around within the region and to and from more densely populated areas (Fig. 1).[61] The characteristics of more populous areas dominate in the mental models of political and business leaders and research organisations. When decisions, policies and programs based on these mental models are imposed on remote areas they often generate dysfunction—for example, by treating social services as discrete and separate from each other, by failing to appreciate that leveraging networks and interconnections is important to designing effective services in small population centres, by undervaluing the importance of local social connections when assessing tenders, or by disempowering local decision-making. In contrast, recognising that desert systems work differently can lead to better outcomes both locally and in terms of policy success. These insights also contributed to high profile work for drylands internationally through the AridNet network.[62]

Social-ecological systems: Aboriginal livelihoods and international projects

While efforts had also been made over several decades to undertake research of relevance to Aboriginal people, much of it had focussed on technology transfer. Griffin had begun investigating potential research in Aboriginal land management in the 1970s.[63] He advocated for two-way cultural

[59]Anonymous (n.d.*a*). Anonymous (n.d.*b*).
[60]For example, Stafford Smith and others (2008).
[61]Stafford Smith and Cribb (2009).
[62]Reynolds and others (2007).
[63]Latz and Griffin (1978).

understanding and technical knowledge transfer in support of the homelands movement.[64] He, Foran and others established a technical advisory group and, in 1986, Foran and Bruce Walker (Centre for Appropriate Technology) reported on science and technology for Aboriginal development.[65] However, these efforts did not lead to ongoing research linkages. Effective engagement and research were finally established during the 2000s, through collaborations fostered by the DKCRC, which enabled Aboriginal people to partner with CAL in exploring the connection between wellbeing, livelihoods and natural resource management.

By the mid 1990s, the Central Land Council (CLC) was implementing cross-cultural approaches to decision making on Aboriginal lands in the southern Northern Territory. Fiona Walsh, an ethno-ecologist who had led this work, was recruited by CAL in 2004 to lead DKCRC research on sustainability of wild harvest of bush foods. Soon after, through a CAL-DKCRC project on Aboriginal partnerships, geographer Jocelyn Davies highlighted the importance of relationships, participatory processes, co-design of research, accessible communication formats and flexible agendas, while pointing to likely tensions with deductive research.[66] These points were borne out in CAL's subsequent experience and reiterated nationally in CSIRO's efforts to address its poor and patchy track record of engagement with Indigenous people and organisations.

Over several years, Walsh and Charles Darwin University (CDU) researcher Josie Douglas facilitated development of guidelines for bush food industry operators through meetings of culturally authoritative Aboriginal women, who advised on awareness of and accountability to Aboriginal ways of knowing bush foods.[67] Deepening relationships laid a foundation for Walsh and Douglas to work with Arrernte elder, Perrurle Veronica Dobson, to document the Anpernirrentye framework, indicating the depth and dynamics of Aboriginal ecological knowledge through relationships between particular plant species and human, ecological and spiritual elements of social-ecological systems.[68]

CAL's first social scientist, social systems analyst Yiheyis Maru, was appointed in 2002. Maru introduced methods and conceptual frameworks for systematic understanding of how people's actions, and the impacts these have, are shaped by their life circumstances, environment and social connections. For example, his application of Elinor Ostrom's institutional development framework to governance of Alice Springs water resources highlighted factors likely to inhibit effective community engagement.[69]

Maru and Davies applied the sustainable livelihoods framework, widely used internationally but novel in Australia,[70] to a problem that Anmatjere leaders said was critical to regional development: the apparent mismatch between 'lots of jobs' and 'lots of unemployed people'.[71] Davies and others applied this framework in DKCRC research that developed principles for promoting health outcomes through Aboriginal land management.[72] Its use, in conjunction with social network concepts and social capital theory, highlighted the role played by some individuals and some ways of organising activities in bridging the gulfs between Aboriginal and non-Aboriginal values that are exacerbated by the sparseness of human populations in central Australia.[73] Initially, the Central Australian Human Research Ethics Committee (CA HREC) queried the research approach, which was novel to them. CAL's subsequent engagements with CA HREC, starting with Maru's responses to this query, generated understandings that were valued by CSIRO nationally in the development of its own social science HREC in 2010.

New insights for social-ecological systems theory were generated by Maru and collaborators, demonstrating that inflexibility in the norms and policies of dominant society caused the poverty traps generated by colonisation to persist in minority Indigenous populations;[74] and that policy support for climate adaptation by remote Indigenous communities needs to take account of both their vulnerability and their resilience.[75] CAL's strengths in participatory research led to involvement in developing management planning guidelines for Indigenous Protected Areas.[76] Research continued through Walsh's collaboration with Martu land managers,[77] and a two-way learning project with CLC, Ltyetye Apurte rangers and the Tangentyere Council on climate change adaptation.[78] Communication of such projects included videos and illustrated 'big books' for Aboriginal community audiences. With CDU support, Douglas was

[64] Griffin and Lendon (1979).
[65] Foran and Walker (1986).
[66] Davies (2007).
[67] Merne Altyerre-ipenhe Reference Group and others (2011).
[68] Walsh and others (2013).
[69] Maru and LaFlamme (2008).
[70] Davies and others (2008).
[71] Davies and others (2010).
[72] Davies and others (2011).
[73] Maru and Davies (2011). Davies and others (2017).
[74] Maru and others (2012).
[75] Maru and others (2014).
[76] Davies and others (2013).
[77] For example, Walsh and others (2016).
[78] Hill and others (2020).

appointed in 2010 as CAL's first Aboriginal research fellow: she was awarded her PhD in 2016.[79]

Scarce investment in local research on social-ecological systems led CAL scientists to join the African Food Security Initiative, an Australian development assistance program implemented by CSIRO, 2011–5 with two African research and development organisations. Davies, Maru and Kenyan collaborators used social network analysis as part of integrative investigations of the epidemiology of African swine fever.[80] With Ashley Sparrow and others, they also contributed to analysis of effective agricultural innovation systems.[81]

CAL research helped to build capacity and policy support for the Aboriginal land management movement, contributing to its growth as a vibrant force in extensive areas of rural and remote Australia. Aboriginal livelihoods in land management continues to be an innovative research field, but with relatively fewer contributions from arid Australia. Through its research on African food security issues, CAL contributed to increased productivity in some agricultural sectors, helped to strengthen capacity and leadership in several African agricultural research and development organisations, and furthered CSIRO's capacity to deliver research impact in developing countries.

Tourism and mining

CAL struggled to make research connections with two economically important industries—tourism and mining. Several initiatives addressed the environmental impact of tourism but developed no further.[82] An attempt in the 2000s to engage a regional community in tourism development by taking a whole system approach demonstrated the limited benefits of systems dynamic modelling, where resources and data were limited.[83] Directions for research on how mining might promote sustainable community development were explored in the 2010s but did not proceed. CAL's inability to establish research connections with these industries had several causes. A focal source of investment for research, similar to the rural Research and Development Corporations, did not exist for either tourism or mining, limiting potential access to pathways for building relationships. CAL's small size restricted the capacity of staff to apply the considerable, sustained effort needed to build the connections and partnerships with industry leaders, and to establish the relevance of their research skill sets, that their experience in research with Aboriginal people had shown was critical.

Conclusion

Throughout its 63 years, CAL was a principal Australian laboratory for rangeland research, collaborating extensively with CSIRO laboratories and many other institutions nationally and internationally. The first book to be published on management of Australia's rangelands was a collaboration amongst numerous researchers, including CAL's, led by CSIRO's Deniliquin laboratory.[84] Research outcomes and implementation were usually a consequence of partnerships with other researchers and organisations that enabled iterative improvements and adoption.

Established initially to improve the productivity of the pastoral industry, CAL's research developed new insights into grazing-induced ecosystem change and new methods for monitoring the condition of grazing rangelands. From the 1980s, CAL's research responded to societal needs through expansion into wider land use issues, initially through biophysical research and increasingly through social, interdisciplinary and transdisciplinary research—Figs 2, 3 show shifts in staff expertise and publication focus over time. Human values were incorporated into the study of pastoral and conservation management, and social-ecological systems. CAL's social scientists built trusting relationships with Aboriginal people and organisations, leading to joint projects aimed at enhancing livelihoods. These evolving agendas responded to societal and industry expectations, and were enabled by new technologies (such as remote sensing) and the expanding skills of staff.[85]

CAL's long-term location within a regional community ensured sustained engagement with local practitioners, with positive and mutual benefits for research directions and outcomes. That lived experience also helped generate collaborations throughout the rangelands in Australia and internationally, which enabled CAL to both drive and be driven by changing global research priorities. It was in a position to develop understanding that could also be relevant in many other less-well-endowed places globally.

As in all scientific laboratories, CAL's research themes evolved. Such evolution is an essential component of ongoing institutional support and, ultimately, of persistence. From the 1980s onward, internal CSIRO policies demanded co-investment by partners in all research. CAL's research had helped to show that pastoral production was inherently limited by the climatic uncertainty of the rangelands, an outcome not conducive to support from the pastoral industry for ongoing investment. Hence, development of wider strands of research was not only a response to societal expectations but also reflected a desire to diversify external

[79]Douglas (2015).
[80]Lichoti and others (2017).
[81]Davies and others (2018). Maru and others (2018).
[82]Griffin and Morton (1988). Friedel and others (1996). Hillery and others (2001).
[83]Friedel and Chewings (2011).
[84]Harrington and others (1984).
[85]See Supplementary Material S2 (research staff) and Supplementary Material S3 (publications).

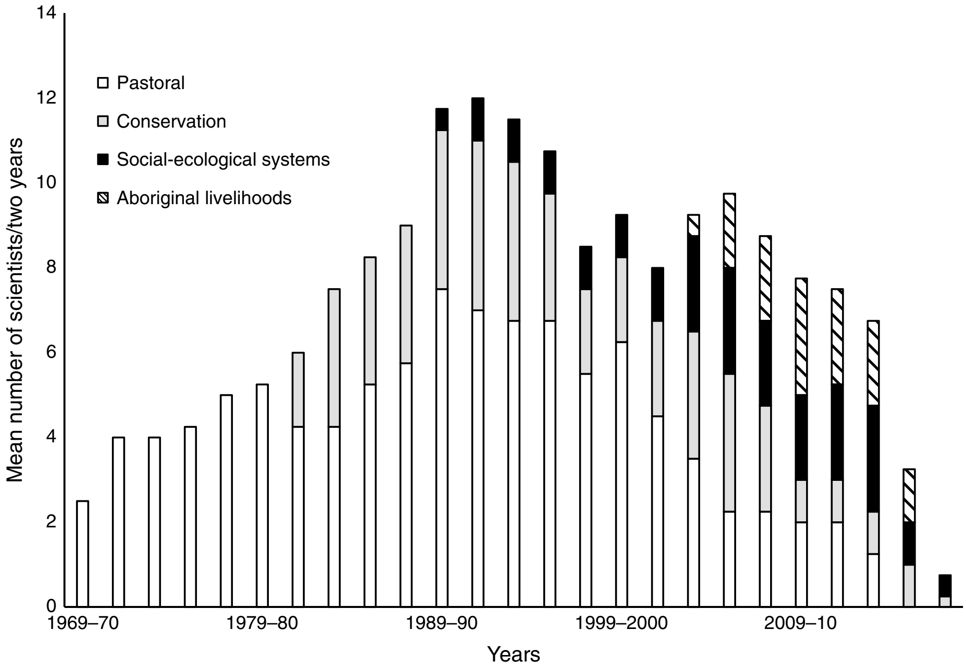

Fig. 2. Research focus of CAL scientists in two-yearly increments, between 1969–70 and 2017–8. A comprehensive list of staff, students and position descriptions at CAL 1953–2018 is available in Supplementary Material S2.

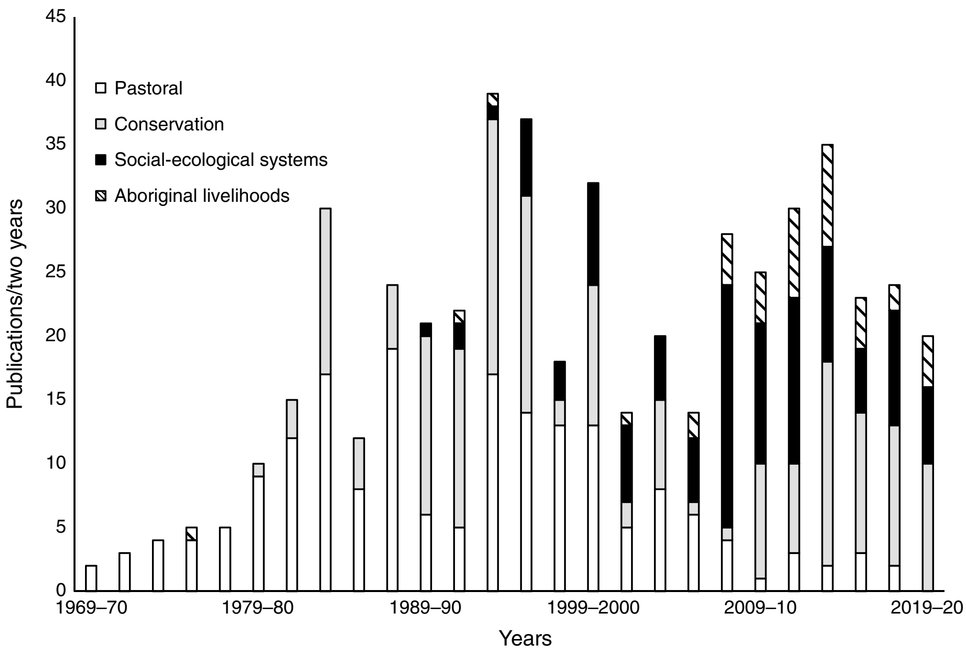

Fig. 3. Research focus of CAL publications (journals and book chapters) in two-yearly increments, between 1969–70 and 2019–20. A bibliography of publications by scientists at CAL 1969–2020, with summary statistics, is available in Supplementary Material S3.

investment in CAL's research. CAL's work in all spheres was largely supported by the public sector, whose goals included social-ecological sustainability and growth of local industries but also saving on public expenditure. At times, shifting political priorities led to loss of investment in research that had previously attracted broad support—for example the Australian Collaborative Rangeland Information System (ACRIS), a multi-jurisdictional program.[86] The challenge of maintaining external financial support for a small regional laboratory within this operational model proved insuperable, leading eventually to CAL's closure.

The termination of CAL was uncannily foreshadowed by the concept of the 'desert system'. Human society in arid Australia is shaped by uncertain climate, scarce and patchy natural resources, resulting in limited livelihoods, sparse capital and often inappropriate governance. These act to

[86]See Supplementary Material S1.

keep populations sparse, which reinforces remoteness. The system functions well when understood and accommodated, but the governance of such a system can be mismatched with that of larger jurisdictions that control resources, have different expectations of outcomes, and lack a nuanced understanding of local complexity.[87] When national organisations such as CSIRO focus on short-term economic efficiency, withdrawal of investment from sparsely populated regions to the coastal centres of economic and social influence seems inevitable. The scientific effort at CAL was ultimately ended by these systemic challenges. Nevertheless, as we have highlighted here, there is much to celebrate in its lasting contributions to knowledge of Australian and global deserts.

Supplementary material

Supplementary material is available online.

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