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The Journey of Long Paddock: A Teaching Case of Digital Platform Innovation for Climate Adaptation

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Abstract:

High climate variability and the ongoing impacts of climate change are increasing the complexity of decision-making in grazing land management across Australia and many other countries. These challenges highlight the growing need for innovative solutions to support climate adaptation. One such initiative is the Long Paddock, a digital platform developed by the Grazing Land Systems (GLS) team within the Queensland State Government. As a pioneering digital solution, Long Paddock integrates climate data, scientific models and other critical digital infrastructure to support decision-making for grazing community and other related stakeholders. This teaching case introduces the Long Paddock platform and reports its innovation journey. It examines key challenges encountered by the GLS team in developing and sustaining the platform, and outlines the strategies the team employed to address different tensions that emerged throughout the innovation process. This case is intended for undergraduate and postgraduate students in Information Systems, as well as executive managers and policymakers, to provide insights into how digital platform innovation can be leveraged to address complex sustainability challenges.

Keywords: Digital Platform Innovation, Climate Adaptation, Land Management, Digital Sustainability, Teaching Case.

[Department statements, if appropriate, will be added by the editors. Teaching cases and panel reports will have a statement, which is also added by the editors.]

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1 Introduction

It was early February on a typical Queensland grazing property in Australia, and the air scorched with a dry heat. Peter, a third-generation grazier, leaned against his veranda railing, staring at the horizon where dust clouds had long replaced the summer rains. The ground he stood on was cracked, the grass brittle and grey. His cattle moved slowly toward the troughs, ribs visible beneath their hides, a quiet reminder of how long this drought had lasted.

Peter had seen droughts before, some of them had almost broken his business, but this one felt different, less predictable. Should he sell part of his cattle herd now, or wait to hope the next rain would save his pastures? He knew that every decision carried risk, so he had to be very careful. To seek guidance, Peter turned to the Long Paddock (https://www.longpaddock.qld.gov.au/), a free-to-access digital platform designed to address the critical need for climate-related decision-making support, as shown in Figure 1.

Figure 1. Screenshot of The Long Paddock Platform (https://www.longpaddock.qld.gov.au/)

Using the FORAGE tool (see Figure 2), he generated a report and explored the maps and data showing declining ground cover and soil moisture across his property. The reports suggested that conditions would not improve soon and that many graziers would need to sell off their cattle herds in response to the worsening drought. Anticipating that this increase in market supply would drive prices down, Peter made a difficult decision to sell part of his herd early. After a couple of weeks, when it failed again to rain, that tough decision proved to be a smart move that kept his business alive.

Peter's decision-making dilemma reflects the challenges faced by many graziers across Queensland, Australia, whose livelihoods depend on timely and reliable climate information. In recent decades, climate change has intensified Queensland's already variable weather patterns, bringing more frequent and severe droughts and floods that can reduce soil moisture and degrade pastures if stock is held, and floods that can also threaten rural livelihoods (McKeon et al., 2021). These escalating pressures urge the need for comprehensive and sustainable solutions that can help land managers make informed decisions in an increasingly unpredictable environment. The Long Paddock is one of these digital solutions established as part of the Queensland Government's Drought and Climate Adaptation Program (DCAP). This platform is designed and operated by the Grazing Land Systems (GLS) team within the Queensland Department of the Environment, Tourism, Science and Innovation (DETSI).

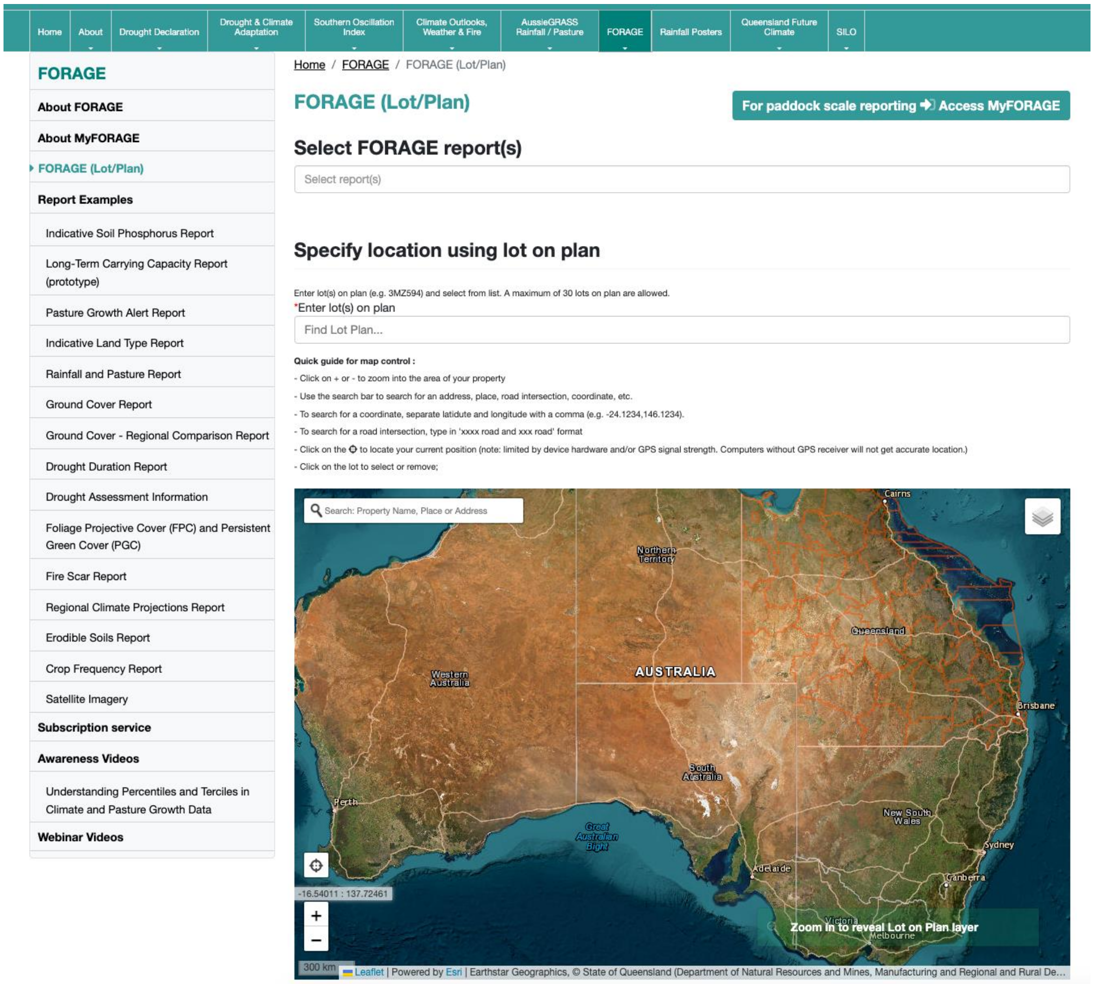

Figure 2. Screenshot of FORAGE tool (https://www.longpaddock.qld.gov.au/forage/about/)

For the GLS team leader, stories like Peter's are daily reminders of the Long Paddock's ongoing responsibility to Queensland's grazing communities. As he explained:

> *We are keen on assisting farmers and graziers. We want to see a profitable rural sector that can make good money, and in which people can make a decent living. And we also want to see that the natural environment is well looked after.*

Over time, the platform expanded in scope and sophistication, incorporating new datasets and developing new tools to better reflect the complexity of Queensland's grazing systems. Yet nearly three decades after its launch, the platform innovation now faces pressing challenges related to data quality, product design and team succession. These issues have brought the GLS team to a critical juncture: how can they sustain innovation and uphold scientific credibility amid evolving institutional constraints and shifting user needs? To ensure the platform's continued relevance and impact, the GLS team leader began reflecting on the Long Paddock's past achievements and struggles to envision a sustainable strategy for its future, one that allows the platform to keep evolving and supporting land managers in climate adaptation[1].

This reflection marks the starting point of this teaching case: a story of how Long Paddock was created, developed, and now strives to sustain its innovation and impact by integrating science, policy and practice in Queensland's diverse grazing landscape. This teaching case invites students to step into the role of the GLS team leader and explore critical questions, such as: How did Long Paddock become a successful

[1] The aim of establishing Long Paddock is for climate adaptation, not climate change. The relationship between climate change and climate adaptation is that climate change provides an important background context that provides general information, but climate adaptation refers to how landholders modify their land management practices to cope with climate variability, which emphasises the actionable insights. By strengthening their capacity to manage such variability, it is considered that they are better positioned to handle the long-term effects of climate change.

platform? What factors have enabled its continuous innovation to adapt to climate variability? What obstacles has it encountered, and how have these been overcome? Exploring these questions offers valuable insights into the complexities involved in leveraging digital platform innovation to address climate adaptation challenges. Through analyzing the teaching case, students are encouraged to reflect on the case and to propose innovative solutions that could help the GLS team to sustain and improve Long Paddock.

To provide a holistic understanding of the Long Paddock's innovation and development, the teaching case is framed through a socio-technological-ecological perspective (Ahlborg et al., 2019; Ixmeier et al., 2024). This framing highlights how ecological, social and technological factors collectively enable and shape the digital platform innovation for climate adaptation. Therefore, the remainder of the case is structured as follows: it first introduces the ecological context of Queensland's grazing lands that motivated the platform's establishment, then illustrates the major actors involved in the innovation and its key technological components, followed by the journey of the Long Paddock's innovation, highlighting the challenges encountered by the GLS team and the solutions developed to address them. The teaching case concludes with a discussion on the platform's ongoing challenges and its generalizability beyond the Long Paddock.

2 Ecological Context of Queensland

Australia's landscape is incredibly diverse with both drought and flood cycles (see Long Paddock's suite of posters[2]). The famous Australian poet Dorothea Mackellar captured this dynamic climate in her poem My Country (see Figure 3), celebrating the country's natural beauty, its seas, forests, and mountains, while acknowledging the harsh realities of fires, floods, and droughts.

My Country

The love of field and coppice,
Of green and shaded lanes,
Of ordered woods and gardens
Is running in your veins.
Strong love of grey-blue distance
Brown streams and soft, dim skies-
I know but cannot share it,
My love is otherwise.

I love a sunburnt country,
A land of sweeping plains,
Of ragged mountain ranges,
Of droughts and flooding rains.
I love her far horizons,
I love her jewel sea,
Her beauty and her terror-
The wide brown land for me.

The stark white ring-barked forests
All tragic to the moon,
The sapphire-misted mountains,
The hot gold hush of noon.
Green tangle of the brushes,
Where lithe lianas coil,
And orchids deck the tree-tops
And ferns the warm dark soil.

Core of my heart, my country!
Her pitiless blue sky,
When, sick at heart, around us
We see the cattle die-
But then the grey clouds gather,
And we can bless again
The drumming of an army,
The steady soaking rain.

Core of my heart, my country!
Land of the Rainbow Gold,
For flood and fire and famine,
She pays us back threefold.
Over the thirsty paddocks,
Watch, after many days,
That filmy veil of greenness
That thickens as we gaze...

An opal-hearted country,
A wilful, lavish land
All you who have not loved her,
You will not understand-
Though earth holds many splendors,
Wherever I may die,
I know to what brown country
My homing thoughts will fly.

by Dorothea Mackellar

Figure 3. Poem "My Country" (Mackellar, 1908)

[2] https://www.longpaddock.qld.gov.au/rainfall-poster/

This timeless reflection of Australia's environmental challenges is particularly relevant to regions like Queensland, where climate extremes shape both the landscape and livelihoods. The state's vast grazing and rangelands cover more than 85% of Queensland's total area (over 150M ha) and form the foundation of its primary industries, including beef and sheep enterprises, mixed agriculture activities, as well as fisheries and forestry. Together, these industries contribute billions annually to the state's economy, with an estimated $24.48 billion for 2024-2025 (Queensland Government, 2024).

However, these economic gains are constantly threatened by Queensland's highly variable climate. Extended droughts and flash floods, along with varied continual grazing pressure, often occur within the same decade, leading to pasture degradation, soil erosion, woody weed invasion and declining biodiversity (McKeon et al., 2004). This challenge is especially pronounced in the Grazing Sector, where climate variability interacts with complex ecological and environmental factors, significantly impacting livelihoods and the national economy. As the founding team leader of the GLS team explained:

> *The grazing system is complex because not only does it have climate, you've got grass, trees, domestic livestock, soils, carbon in the soils, native herbivores like kangaroos, and then you've got feral animals like goats, donkeys and camels. In terms of science, there's a lot of simulation modelling and statistics, but there's also satellite remote sensing. So you've got a complex bit of biology and complex scientific tools.*

In this context, effective grazing land management depends on access to accurate and up-to-date climate information. Yet, for many land managers, scientific data remains fragmented, overly technical or difficult to interpret. This growing information gap between scientific research and on-the-ground practice has made clear the need for a digital solution capable of integrating, simplifying and communicating complex climate knowledge to support science-based decision-making across Queensland's grazing sector.

3 Motivation for the Establishment of Long Paddock

Against the challenging ecological background, the Queensland Government developed a series of climate-related initiatives that aim to support policymakers and other stakeholders (e.g., land managers) in adapting to climate variability, such as the Drought and Climate Adaptation Program (DCAP)[3] and the Queensland Government's Reef Water Quality Program[4]. One of the most significant initiatives is the Long Paddock. It is designed to provide climate data, decision-making tools, and long-term support for the grazing industry at the property scale. The name Long Paddock draws inspiration from Australia's national stock route network, "the longest paddock in the world". As the founding team leader explained:

> *We called it "Long Paddock" as a pun on Australia's old stock routes – the longest paddock in the world. In the past, graziers move their livestock along these routes in search of grass, often travelling for weeks across the country. The name captures the spirit of exploration that you never quite know where the journey will take you. Likewise, on this digital journey, we are going to meet new ideas, people, and opportunities through the platform.*

The Long Paddock was initiated in the early 1990s in response to the government's urgent need for an objective assessment of drought and climate conditions. At the time, digital and spatial tools, such as GIS visualizations, were still in their infancy, and most government systems relied heavily on text-based reports that provided limited analytical capabilities. Recognizing these constraints, early GLS leaders asked a fundamental question: *What do governments and land managers truly need to make informed decisions?*

Drawing on the experiences of an early leader in the cotton industry, they recognized the need to develop an information system capable of assessing current conditions, quantifying the extent of climate impacts, and translating complex scientific data into actionable insights for policymakers and land managers. Driven by this vision, the past team leaders and later the GLS team combined their expertise in science, data modelling, and fieldwork to develop the foundational tools and datasets needed for such a system. Their collaborative effort ultimately led to the establishment of the Long Paddock.

[3] The details of DCAP can be found at: https://www.longpaddock.qld.gov.au/dcap/
[4] The details of the program can be found at: https://www.qld.gov.au/environment/coasts-waterways/reef/reef-program

4 Overview of the Long Paddock

Long Paddock was initially developed to host the Southern Oscillation Index[5] (SOI, see Figure 1), a standardized index of the barometric pressures over Darwin, Australia and Tahiti. Building on this foundation, climate and agricultural scientists expanded the scope of Long Paddock by leveraging the SOI to develop products such as seasonal climate outlooks, including rainfall probabilities and pasture growth forecasts. These tools offer graziers and land managers free access to critical climate insights, enabling informed decision-making.

Over time, the Long Paddock has evolved into a comprehensive digital platform that integrates various climate-related resources. A senior manager from DCAP described Long Paddock as a multi-dimensional resource for users by explaining:

> *It's a one-stop shop for climate information, forecasts, modelling, and tools that help landowners manage their pastures. It hosts useful resources from various agencies within the DCAP program, allowing users to access all climate and drought-related information in one place.*

Appendix A provides an overview of the major products and tools available on the Long Paddock, including their functions and the responsible agencies (as of January 2026).

4.1 Major Social Actors Involved in the Platform Innovation and Development

The GLS team serves as the innovator and orchestrator of the Long Paddock within a complex platform ecosystem, holding primary responsibility for the platform's innovation, development, delivery and ongoing maintenance. The team is small, but highly skilled and experienced – including Pasture and Climate scientists, an Extension Scientist, and several other Scientific and Web programmers. Despite its size, the GLS team performs multiple roles and brings extensive industry experience, including 'hands-on' field work. This combination of multifaceted roles and field experience equips the team with deep insights into the practices and real-world needs of the grazing community, as well as a strong scientific understanding of the natural systems they are working with. As a result, the team is able to develop innovative solutions that are both scientifically robust and highly relevant to their users.

At the same time, the Long Paddock platform is the outcome of collective efforts. It relies on a broad network of government and non-government partners who provide essential data, technical infrastructure and scientific expertise. These contributions support the GLS team's work and enable the platform to function as a public resource for climate adaptation. Figure 4 illustrates the major actors involved in Long Paddock's innovation and their interrelationships, and Table 1 summarizes their respective roles and contributions to the platform's innovation and ongoing development.

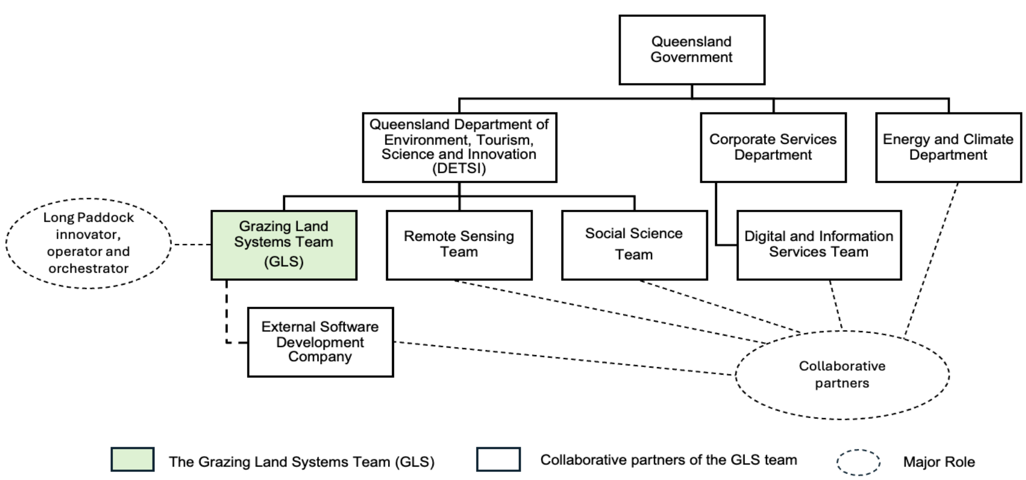

Figure 4. Major Actors Involved in the Long Paddock's Innovation and Development

[5] SOI serves as a critical tool for climate scientists in assessing the strength of the El Niño Southern Oscillation phenomenon (or ENSO), which influences nearly 25% of Queensland's year-to-year rainfall variability (Long Paddock, n.d.)

Table 1. Major Actors and Their Contributions to the Long Paddock's Innovation and Development

Major Actors	Primary Roles	Key Contributions to Long Paddock
Queensland Government, Department of Environment, Tourism, Science and Innovation (DETSI)	Leadership and program oversight, funding agency	(1) Providing strategic leadership and governance, (2) Aligning Long Paddock with government climate and land management objectives, and (3) securing institutional support and funding for the ongoing platform development.
Grazing Land Systems Team (GLS)	Platform innovator, operator, and orchestrator within platform ecosystem	(1) Developing and refining core scientific models and algorithms, ensuring scientific rigor and adaptation to evolving data and technologies. (2) Developing decision-support tools and applications based on scientific models, aligned with user needs and informed by ongoing feedback from product extension activities. (3) Translating scientific outputs into accessible products and guidance, supported by active engagement with graziers to inform user-centered design and continuous platform innovation and improvement.
External Software Development Company	Application development (execution-focused)	Supporting innovation by implementing development tasks specified by the GLS team.
Remote Sensing Team	Environmental data provision and processing	Collecting and processing satellite imagery into high-resolution datasets that underpin Long Paddock tools and reports.
Social Science Team	User insights provider	(1) Providing insights into user practices, needs and adoption challenges. (2) supporting user-centered design and effective communication of platform outputs.
Corporate Services Department, Digital and Information Services Team	Digital infrastructure provider	Providing IT services, data storage, system security, and high-performance computing (HPC) infrastructure required for scientific model execution, platform innovation and operation.
Energy and Climate Department	Database management and data provider	(1) Managing and maintaining SILO database. (2) Ensuring data availability, consistency and quality for Long Paddock products.

4.2 Key Technological Components Enabling and Driving Innovation on the Long Paddock

The Long Paddock's innovation is enabled and driven by three key technological components that ensure the information generated by its tools is scientifically accurate and reliable. These components include scientific data, scientific modelling and infrastructural technologies. Each has been crucial in driving innovation and shaping the platform's ongoing evolution.

4.2.1 Scientific Data

Scientific data is the lifeblood of Long Paddock, serving as a key foundation for its models and decision-support tools. The platform integrates high-quality and continuously updated datasets to ensure its outputs' accuracy, reliability and relevance. There are five primary data sources managed and maintained by different stakeholders to enable and support the innovation of Long Paddock:

1. **SILO Climate Database** is a collaborative project between the Queensland government and the BoM (Jeffrey et al. 2001). It provides Australian climate data from 1889 to the day before the current date. Using mathematical interpolation techniques, SILO constructs spatial grids and infills gaps in time-series datasets to ensure a reliable record. It provides data on daily rainfall, maximum and minimum temperatures, solar radiation, estimates of relative humidity, and more. SILO serves as an essential source of climate data for several Long Paddock tools, including FORAGE and AussieGRASS (Zhang & Carter, 2018; Carter et al. 2000).
2. **Bureau of Meteorology (BoM) Climate Data** is a crucial data source for SILO, providing raw climate and rainfall data that SILO processes daily to suit various modelling needs for internal products (e.g., AussieGRASS and FORAGE) and other external users. This data is accessible through SILO on Long Paddock, with additional access available via APIs.

3. **Consistent Climate Scenarios (CCS) Data** draws on OzClim methodologies and historical climate data from SILO to provide climate projections for 2030, 2050 and 2070 at the same spatial resolution as the SILO database (Zhang & Carter, 2018). These data are available as daily time series in a format suitable for most biophysical models, and output supports the FORAGE climate change report and many other modelling users.
4. **Remote Sensing Dataset** is collected, managed and updated by the DETSI Remote Sensing Team, a key collaborative partner of the GLS team. The dataset is generated by processing raw satellite imagery from multiple satellite platforms. This processing produces high-resolution imagery, maps and datasets that are incorporated into Long Paddock products and reports, providing users with critical insights into land condition, ground cover changes, woody cover and fire frequency over time.
5. **Geographic Information System (GIS) Data** provides spatial information that enables the platform to access maps, cadastral boundaries and land types, necessary for providing location-specific information to users. One source of GIS data is the Spatial Information Resources (SIR) database which contains a wide range of vector and raster datasets, including property cadasters, roads, rivers, soils, and other spatial information for Queensland and Australia (Zhang & Carter, 2018). The Long Paddock also integrates other GIS datasets. For example, it uses an ESRI-based API to access geographic data services, allowing the platform to retrieve map data, geographic boundaries, and additional spatial information to enable product innovation and enhance functionality.

In addition to the major data sources mentioned above, the GLS team also integrates datasets from other sources, such as soil phosphorus and soil erodibility data from the DETSI Soils group. These datasets are important for developing useful products and enhancing the reliability of derivative modelling outputs. By continuously incorporating updated datasets and refining their models, the GLS team ensures that Long Paddock remains scientifically robust and practically valuable.

4.2.2 Scientific Modelling

Scientific modelling is an essential component for Long Paddock's ongoing innovation and development. These models are built on scientific theories and empirical data and are developed to explain, predict and analyze climate data using mathematical equations, algorithms or simulations. They provide the ability to examine grazing system components and ecosystem functions across past, present and future conditions. They represent core intellectual capital that differentiates Long Paddock from many private-sector platforms or tools that lack peer-reviewed scientific validation. This commitment to scientific rigor ensures that users receive high-quality, research-based insights they can trust.

The most important model for Long Paddock is the GRASP model – a grass pasture production model (it is the foundation model for the FORAGE system and the AussieGRASS spatial model). GRASP is a dynamic and process-based simulation model designed to analyze and predict pasture growth and other associated outputs (e.g., soil moisture, ground cover) and assess grazing system productivity in northern Australia (e.g., estimating how many cattle can be sustainably supported for a given property area). This model integrates various environmental and management factors to simulate pasture growth and biomass accumulation.

Since its development in the 1980s, GRASP has undergone continuous refinement for four main reasons. First, ongoing scientific advancements have led to improvements in the algorithms that underpin the model. Second, to take advantage of high-performance computing, the spatial version of GRASP (AussieGRASS) has been refined to maximize parallelism, so that all 5km grid cells in Australia can be run at high speed. Third, the availability of new and improved data sources has enhanced the model's accuracy. Finally, the integration of real-world environmental conditions, particularly remote sensing, has further strengthened the model's precision.

Together, these refinements have not only improved the scientific robustness of GRASP but also expanded its functional and computational capabilities. As a result, GRASP has become a scalable foundation upon which new digital products and services can be developed. This ongoing development enhances existing products and unlocks new possibilities for innovation, thereby enhancing the platform's ability to adapt to emerging challenges and evolving user needs.

4.2.3 Digital Infrastructural Components

Scientific models alone are not enough, they must be hosted and supported by a robust digital infrastructure to enable such high-volume climate data processing, seamless accessibility, easy usability, and calibration and validation procedures. The effectiveness of Long Paddock, therefore, depends on a strong digital infrastructural foundation, including High-Performance Computing (HPC), cloud computing, and a range of digital resources from open-source communities.

Unlike typical platform companies with centralized systems, Long Paddock's infrastructure is highly distributed, with key components operating across multiple systems. As a result, control over the platform is more decentralized, reflecting the collective efforts of government agencies, research institutions, and external contributors in its development and ongoing management.

The HPC system is at the platform's core which serves as its computational backbone. The HPC is managed and maintained by a centralized government IT team in the government. It powers scientific modelling and large-scale data processing, running key scientific models and frameworks such as GRASP and AussieGRASS. It also handles large volumes of data from sources like the SILO climate database, remote sensing imagery and GIS datasets, enabling the platform to generate accurate scientific outputs that support climate adaptation and land management decisions.

Complementing the HPC is the most recent capability of cloud computing, now primarily managed through Amazon Web Services (AWS). AWS is a cloud computing platform that provides scalable infrastructure and services for hosting, storing and processing data. Long Paddock's website interface and user information are hosted on AWS, enabling users to access real-time climate data and generate different outputs through the platform's suite of tools. By leveraging AWS, Long Paddock benefits from greater flexibility, speed and reliability in innovation and operations. This allows the GLS team to scale services efficiently and respond quickly to evolving user needs, without the burden of developing or maintaining its own IT infrastructure.

In addition, Long Paddock leverages open-source digital resources to enhance functionality and support ongoing innovation. The HPC and AWS environments utilize some open-source tools and libraries, which are integrated through APIs to enable seamless data processing and delivery. For example, the GLS team utilizes jQuery, a widely used JavaScript library, and Bootstrap, a popular CSS framework, to design and build responsive, user-friendly web interfaces. By incorporating these open-source technologies, they can efficiently create intuitive and visually appealing digital tools while benefiting from ongoing community support and updates.

Together, these technological components provide Long Paddock with a robust and scalable platform infrastructure, ensuring it continues to deliver scientific knowledge-based decision-support tools for land managers, policymakers and researchers. Appendix B illustrates the relationship between key components of the Long Paddock's digital infrastructure and visualizes the end-to-end information flow.

5 The Innovation Journey of Long Paddock

Innovation on the Long Paddock has been an ongoing journey, evolving alongside scientific advancements, technological developments, and the continuous accumulation of field experience. Prior to its establishment, graziers relied largely on fragmented and predominantly text-based information sources and personal experience when making critical land management decisions. These sources offered limited integration and provided little support for interpreting and responding to highly variable climatic conditions.

The emergence of the Long Paddock marked a significant shift by bringing together scientific data, digital technologies, and practice-based knowledge into a platform that supports science-based decision-making. Rather than a single breakthrough, Long Paddock has evolved through a continuous process of refinement to ensure its tools remain scientifically robust and practically relevant. The platform's innovation journey can be divided into five major stages. Figure 5 provides an overview of these stages.

Although these stages are presented sequentially, the development of Long Paddock has been inherently iterative, with feedback from later stages continually reshaping the development trajectories. The dotted feedback loop in Figure 5 highlights this continuous refinement and adaptation process. The following sections examine the key events in Long Paddock's evolution, the challenges encountered at each stage, and the strategies the GLS team employed to address them.

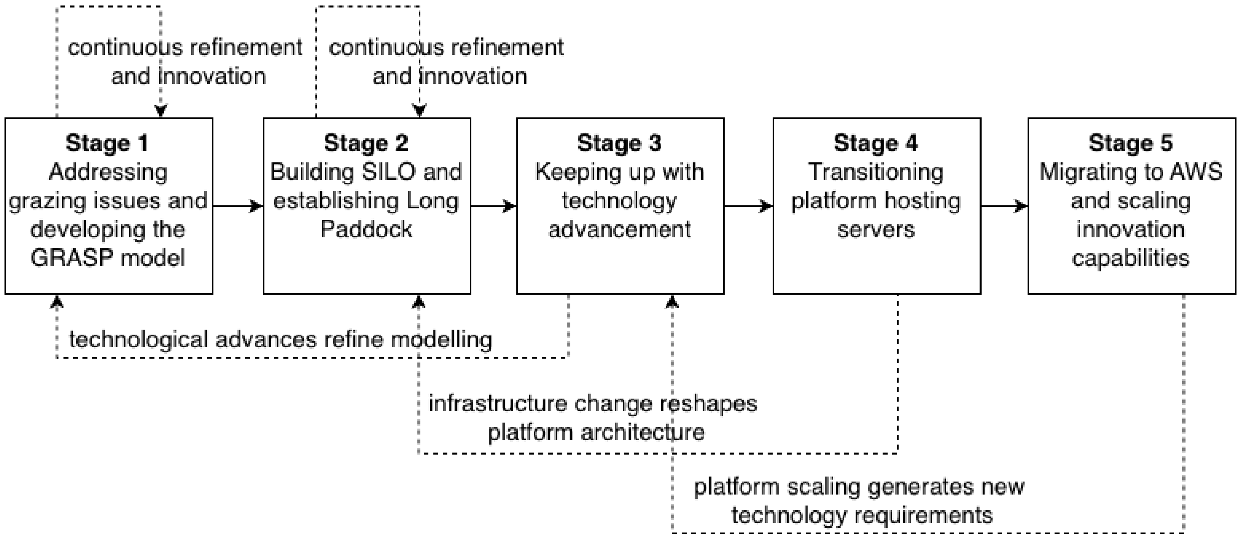

Figure 5. Five Major Stages of the Long Paddock Innovation Journey

5.1 Stage 1: Addressing Grazing Issues and Developing the GRASP Model

The story of Long Paddock is a convergence of multiple developments that have unfolded over the past 50 years, each within its history, yet evolving simultaneously. Among these, two factors were particularly crucial in initiating the project and shaping the early foundation: (1) the grazing problems that underscored the urgent need for sustainable land and pasture management; and (2) the development of foundational scientific models that established the computational framework for climate and pasture data analysis. These elements laid the groundwork for what eventually became Long Paddock.

The primary driver behind this initiative is the grazing industry, one of Australia's most important economic sectors. Queensland has Australia's most significant land area dedicated to grazing and is home to the country's most dynamic and diverse climate environments. However, as the founding leader of the GLS team recalled, policymakers initially lacked a clear understanding of how climate variability affected grazing systems:

> *Over time, a variety of questions would have arisen, like: What is drought? Where is the drought? Is it happening now? Can we do anything about it? Can we predict what's coming? How many animals should we run if the climate is variable? What impact will climate change have? These questions didn't arise all at once but emerged gradually over time.*

As these concerns intensified, there was a pressing need to develop a deeper understanding of land dynamics to support sustainable grazing practices and inform decision-making for grazier communities. In response, a founding scientist in the GLS team began developing complex models that simulated the intricate relationships between rainfall, grass growth and animal grazing. This scientific effort was enabled by broader technological investments within the Queensland Department of Primary Industries (DPI), which at the time was at the forefront of technological advancement across Australia's agricultural sector.

Recognizing the great potential of supercomputing for scientific research, DPI invested in advanced digital infrastructure that allowed the scientists and researchers to push the boundaries of what was technologically possible in their research. Leveraging these capabilities, the GRASP model was developed and used in increasingly sophisticated ways.

Building on GRASP's principles and algorithms, the GLS team later translated this scientific model into practical digital tools such as AussieGRASS, FORAGE and MyFORAGE. Each application adapted the modelling framework into more accessible and user-friendly decision-support tools for land managers. This marked a critical turning point in the platform's evolution, transitioning from a single scientific model to a comprehensive suite of decision-support tools that could directly assist grazing communities in navigating climate variability.

5.2 Stage 2: Building Climate Databank SILO and Establishing Long Paddock Platform

During the initial stages, one of the critical challenges for successfully running the model was the availability of continuous daily climate data. At that time, such data was not readily available from the BoM, as it did not consistently record or compile the information required for GRASP and other agricultural modelling, particularly for Queensland. This created a significant obstacle, as climate models rely on uninterrupted datasets to produce reliable results. One of Long Paddock's early contributors illustrated the issue:

> *For example, for the 5th of May 1991, you want maximum/minimum temperature, rainfall, solar radiation, or potential evaporation. This data was hard to get in the past. For modelling, you can't have any missing data, when you're trying to run a model, the computer expects data to be there daily. So the challenge was: "We want to set up a system that can make modelling easy, so can we put all this together? A system where you type in a location and get all the data back.*

To solve this problem, a climate databank was built on a Digital PDP-11, an early computer machine with tape drives and small hard discs for data storage. The data were collected from major weather stations across Queensland, and the scientists wrote codes to extract information from each station and generate rainfall records. This marked the first automation of recording and storing climate data in Queensland, a significant step forward in the field of science and climate modeling.

Over time, this early databank evolved into what is now known as the SILO database. Compared with the previously fragmented and inconsistent datasets, SILO offered a more consistent and complete climate record. The availability of this long-term dataset significantly strengthened climate modelling efforts and enabled a broad range of users to access consistent climate information for research and decision-making.

As Long Paddock products evolved, the National Drought Policy introduced in the early 1990s further emphasized the need for drought management. Understanding rainfall patterns over time has become increasingly important for managing drought conditions in real-time. This posed a significant challenge in how to create accurate percentile rainfall maps that could inform decision-making and policy responses. To address this, the GLS team developed an interpolation routine to collect and process climate data, an ambitious task at a time when advanced computing technologies were not yet widely available. Using an HP desktop, they performed complex calculations and leveraged a Tektronix color printer to produce detailed rainfall maps. This approach was innovative and groundbreaking, as no one else in Australia was creating drought maps at the time. Such a pioneering method was only possible due to the availability of government technology support during that period.

Recognizing the importance of their work, the GLS team further secured government funding to validate their research and digitize their resources. These funding agencies in the government not only provided financial support but also guided the platform's development to align with government priorities and drought policies. One GLS team member explained the role of these funding agencies:

> *We're funded by the government, under other government groups. So they say, "You put a proposal to us, and we'll say yes or no. And if we say yes, we'll check that you're doing all the parts of the project." So even though it's government, it's not external funding, but we're still held to do what we've said we'll do.*

Hence, this support from government agencies allowed the Long Paddock to transition from a research initiative into a fully operational digital platform, integrating scientific models, climate data, and policy frameworks to better support land management decisions. With institutional backing secured, the next challenge shifted to digital technology, specifically, how to ensure the platform could evolve in line with advances in computing and data processing to meet growing scientific and user demands.

5.3 Stage 3: Keeping Up with Technology Advancement

For the GLS team, this stage was marked by both excitement and uncertainty. The scientists knew that their vision for a state-wide modelling system could only be realized if they harnessed cutting-edge computing power. A collaboration with the University of Queensland gave the group access to one of the early Cray supercomputers. This powerful (at the time) processor was instrumental in performing complex rainfall interpolations and running models across a grid spanning the entire state of Queensland. The Cray supercomputer's processing power also enabled the team to analyze larger datasets and run more complex models, which were crucial for gaining a deeper understanding of grassland dynamics and assessing drought conditions across the state.

As projects evolved, the team expanded its focus to map trees and monitor land clearing. This new direction required the creation of detailed tree and soil maps, as well as mapping animal populations and tree density. To support this expanded scope, the team invested in additional hardware, including another Cray supercomputer, which further increased their computational capacity and enabled them to continue pushing the boundaries of agricultural modelling for the grazing community.

To ensure the platform's operational efficiency and accuracy, the GLS team leveraged Unix scripting to automate processes and minimize manual labor. This strategic decision allowed them to focus their resources and time on improving the underlying models and generating innovations, rather than getting bogged down by repetitive tasks. By streamlining their workflows, the team continuously enhanced the platform's capabilities and delivered more value to citizens. Ultimately, these advancements were driven by rapid technological evolution and the team's ability to stay at the forefront of innovation. One GLS team member illustrated this idea by reflecting on a recent product innovation:

> *The MyFORAGE online mapping tool has now become possible over the last few years. Back when paddock-based modelling was being developed, computing technology wasn't there to support it. Now, you can click and draw things on the screen and go through to other levels of models. So it's probably an alignment between technology and what we wanted to do…the advance into what we have now is just a logarithmic rise in ability to gather, process and spit out information and process stuff. So all this [technology] groundwork has made it easier for our team to develop such a tool.*

These developments underscore how the Long Paddock has continually evolved in tandem with technological progress. What began as a simple web-based resource for drought and pasture information has transformed into an integrated digital platform that leverages automation, advanced computing, and interactive tools. By aligning scientific expertise with technological capabilities, the GLS team has not only enhanced the accuracy and accessibility of climate information but also strengthened the platform's capacity to support science-based decision-making for Queensland's grazing community.

5.4 Stage 4: Transitioning Platform Hosting Servers

Since the start of the Long Paddock, the GLS team has received sufficient support from the Queensland Government regarding funding and access to advanced technologies such as the HPC hosted by the government. This support was crucial for the development and continuous improvement of the platform. In addition to the government's resources, the team proactively sought out useful open-source tools and technologies for the platform's development. For example, they extensively used the Fortran programming language, which was well-suited for scientific computing and numerical analysis. The combination of government support and the team's proactive use of open-source resources enabled them to create an efficient platform for complex modeling and data processing for Long Paddock innovation and development.

However, the GLS team faced significant challenges when it came to hosting their platform, as they were forced to change host servers multiple times, often due to circumstances beyond their control. These shifts moved the platform between externally controlled infrastructure (a form of outsourcing) and internally managed hosting (backsourcing), with different implications for its innovation autonomy. At the earliest stages, the platform was hosted by an outside local government agency. This arrangement provided the team with a stable foundation to launch their platform. Later, the platform was moved to the state government's server, where the team had reasonable control over the platform. However, at one point, the platform was unexpectedly transferred to a different department. The move brought negative consequences for the team as they lost control over the server, database and even the platform's codebase.

The lack of direct access to these critical infrastructural components made it extremely difficult for the team to develop and maintain the platform. Specifically, every update or change to the platform had to go through a lengthy approval process, which could take several weeks to implement. One team member explained:

> *We lost access control because somebody else was running the infrastructure. We didn't run it ourselves, and that was a big problem – if somebody else prioritized programmers' time, it could take six weeks to get something small done, you couldn't even put a banner notice up.*

This slow and bureaucratic process severely hindered the team's ability to fix bugs, update features, and drive innovation in a timely manner. A significant breakthrough came in 2018, when the GLS team regained control of the platform's hosting. This backsourcing decision restored infrastructure control and dramatically improved the team's capacity for innovation and platform evolution. This move allowed them to take back control over the codebase and platform autonomy, giving them the freedom to make necessary updates, improvements and innovations without the lengthy approval processes. Furthermore, regaining control over the platform was a turning point for Long Paddock, as the autonomy eased the limitations and restrictions previously experienced, fostering a more agile and innovation-friendly environment for the platform's continued development.

5.5 Stage 5: Migrating to AWS and Scaling Innovation Capabilities

After regaining control of the platform's hosting, the GLS team made a strategic decision to redevelop and revitalize it. This decision was made because the team realized that the platform had become outdated, overloaded and difficult for users to navigate and utilize effectively. They moved the platform hosting to AWS to improve its performance and make it easier for the team to maintain and innovate. AWS is a widely used and reliable cloud computing platform that offers a range of services and features designed to support the development and deployment of web applications. By migrating to AWS, the team could easily leverage its features to manage and develop the platform. The programmer in the GLS team explained:

> *AWS is pretty mature now. It's not like five years ago, they still pop up all these new things. Right now, most likely, the top things people use are Amazon EC2 (Elastic Compute Cloud) and RDS (Relational Database Service). That covers pretty much everything for product development.*

One of the reasons the team selected AWS is that it provides a "scalable service" where computing resources are directed as required. This means that more processors are automatically brought online when demand increases, ensuring the platform can handle increased traffic and usage without experiencing performance issues.

However, moving to AWS did not mean migrating every component of the platform infrastructure. The GLS team only moved the web portal and user data to AWS while keeping the scientific models and data internally on the government's HPC. The team did attempt to move the SILO database to AWS, but it failed due to the enormous volume of scientific data and models, and the high maintenance costs associated with hosting it on AWS. The SILO database contains a vast amount of historical climate data, so it requires significant storage capacity and computational power to process and analyze. The GLS team realized that storing and managing this data on AWS would be prohibitively expensive compared to keeping it on the government's HPC, which is specifically designed for handling large-scale scientific data. Furthermore, the scientific models used by Long Paddock, such as the GRASP model, are computationally intensive and require the power and efficiency of HPC systems to run effectively. Therefore, by keeping these scientific models and data on the government's HPC, the team could ensure optimal performance and minimize the costs of running these complex simulations on AWS.

Since moving to AWS, the GLS team has gained more flexibility in product innovation and development. One significant outcome of this was the update of AussieGRASS. Furthermore, the team developed MyFORAGE, an updated version of FORAGE that enables users to interact directly with the applications on the platform, providing them with the ability to draw their property with paddocks, then generate customized reports (compared to "whole" property reports requested through the Long Paddock), and access a broader range of information specific to the user's exact location and needs.

6 Ongoing Challenges for Long Paddock

By reflecting on Long Paddock's achievements and struggles, the GLS team leader recognized that the platform had delivered significant innovation and successfully overcome numerous technical and organizational challenges. Yet, despite these accomplishments, he is now confronting a new set of challenges that would shape the platform's future direction. To ensure the platform's ongoing innovation and impact, he needs to articulate and pursue a forward-looking strategy. These challenges can be categorized into three key areas: (1) data quality, (2) product design, and (3) team succession.

6.1 Data Quality Challenge

One major challenge is the declining availability and reliability of meteorological data, which is critical for continuous, accurate climate modelling. The BoM has recently made decisions about weather station locality placements, primarily based on cost-saving issues or political directives rather than scientific needs. This has led to a reduction in the number of rainfall stations, especially in Queensland. As a result, climate models increasingly rely on interpolation and imputation techniques to fill data gaps, which often introduces potential inaccuracies in rainfall estimates and climate predictions. A scientist in DCAP highlighted the profound implications of this issue:

> *Providing reliable datasets is critical for accurate modelling and national productivity. In one case, interpolated SILO data estimated only 3 mm of rain for a site, while the actual rainfall was 200 mm due to missing BoM data. Such discrepancies can lead to major errors in carbon accounting and financial losses when audits reveal inaccuracies.*

In addition, climate data are inherently dynamic due to meteorological and climatic variability, seasonal changes and environmental fluctuations. These characteristics make such data unevenly distributed across time and space, and difficult to collect and maintain consistently. As a result, climate datasets often rely on interpolation and gridded data structures, which introduce additional challenges related to data resolution and granularity. For example, climate data in SILO are gridded at 0.05 degree (cells approximately 5 km x 5 km) across Australia. While finer grids (e.g., 1 km resolution) have been considered, the GLS team notes that such refinement offers little improvement in accuracy given the limited number of recording stations nationwide. Instead, improving data quality provides greater scientific value. Furthermore, some climate models continue to rely on outdated datasets rather than transitioning to newer, higher-quality ones, thereby further eroding the accuracy of their outputs.

At the same time, these data limitations can also directly affect land managers' decision-making. While climate models operate at regional or grid-based scales, graziers such as Peter must make highly localized paddock-level decisions regarding stocking rates, pasture use and drought responses. When rainfall estimates or pasture growth forecasts are based on coarse or imprecise data, users may overestimate available forage or delay critical drought actions, increasing financial risk and environmental stress. This ongoing tension between scientific data granularity and the precision required for practical land management highlights how data quality challenges not only affect modelling accuracy but also have tangible consequences for graziers' decisions. Thus, ensuring consistent, reliable and well-maintained scientific datasets is essential for preserving the scientific credibility of Long Paddock.

6.2 Product Design Challenge

Product design challenges primarily involve bridging the gap between scientific complexity and practical usability for users, particularly graziers and land managers. While Long Paddock is built on advanced scientific models, translating these scientific insights into accessible and actionable information remains a persistent challenge for the team. One of the key difficulties is that scientists and end-users think differently. As a GLS team member explained:

> *Our users have different levels of expertise and knowledge, while scientists tend to think in more abstract, technical terms. Sometimes, we develop products that may be too complex for the users to understand. Certain concepts seem simple to scientists and can be difficult or points are missed for graziers. For example, the term "percentile" - for scientists, it's a straightforward term, but for graziers, they often ask, "What is a percentile?" or "Is that the same as a percentage"?*

Similarly, scientific jargon and abstract visualizations can make the data inaccessible to those who need it most. For instance, Long Paddock provides maps of "relative" (i.e. percentile) rainfall, pasture growth or ground cover to compare current conditions to historical rankings. However, graziers often struggle to interpret these maps, as they are not absolute values but show relative changes over time.

Beyond interpretation difficulties, users often struggle with navigating the platform itself. As the platform expands, finding relevant information becomes increasingly challenging, leaving users often feeling lost in a sea of data. The GLS team provides clues and guidance, directly engaging with users to educate them about new products and tools. However, the platform's usability remains challenging for some users who lack experience with this type of information. In addition to the complexity, too much information can be just as problematic as too little. The GLS team has found that while some users demand greater detail, others prefer simplified outputs. This creates tension between delivering enough information and not overwhelming users. A scientist in the GLS team reflected on this contradictory expectation:

> *We over-deliver at times. At any one time, maybe 50% of the information in a report is actually used by a user. The next person may use a different 50%, but some parts may never be looked at. We spend a lot of time carefully crafting reports generated by our tools, because if we don't include details, people complain there's not enough information. But if we provide too much, they say it's overwhelming – it's a conundrum to get the balance right.*

To address these design and usability challenges, the GLS team has tried different approaches, such as breaking output reports into smaller, more digestible segments and developing educational videos. However, finding the right balance between scientific complexity and actionable simplicity remains an ongoing challenge that requires continuous product design refinement, user engagement strategies, and communication methods. This is a key focus for Long Paddock in the near future.

6.3 Team Succession Challenge

The GLS team also faces institutional challenges threatening its ability to sustain and drive innovation on the platform. One of the most pressing concerns is the lack of a succession plan. A number of core team members have been working on Long Paddock for over 20 years and are approaching retirement age. However, there is no structured pipeline to bring in new talent to maintain the Long Paddock dynasty. The GLS team leader described the difficulty of replacing skilled staff:

> *Within our own experiences, people in grazing, ecology, or programming, it isn't easy to replace us. We don't have succession plans. Because in government, there's no open option to hire graduates or undergraduates to "learn the trade". Plus, finding people who want to stay in this line of business long-term is very hard.*

Moreover, the institutional constraints make it difficult to attract highly skilled talent, particularly in fields like climate science. Graduates entering public service often start at lower pay than in the private sector, making recruitment even more challenging. As one GLS team member explained:

> *The government limits the number of public servants to maintain its credit rating with voters. Since resources are directed toward hiring more police, teachers and nurses, this puts significant strain on science areas.*

Despite the individuals' experience, the team is mature and aging, and therefore the Long Paddock faces serious risks to its long-term sustainability. The concern is not just about maintaining existing systems but also about ensuring there is continued innovation and adaptation information for users operating in Queensland's variable climate. However, without institutional support for knowledge transfer and dedicated staff renewal, there is uncertainty about whether the Long Paddock will remain a leading digital platform for climate adaptation in the decades to come.

To sum up, although the Long Paddock has made groundbreaking achievements providing innovation for climate adaptation in Queensland and Australia-wide, it continues to face ongoing challenges that could impact its long-term sustainability. The GLS team leader now stands at a pivotal moment where decisions about data quality, platform design priorities, sustained funding, user engagement, institutional barriers and team succession will determine whether the platform can continue to deliver scientific value to the citizens. How these interconnected challenges are navigated will shape not only Long Paddock's long-term sustainability but also its capability to remain a trusted digital platform for climate adaptation.

7 Conclusion

The story of the Long Paddock has evolved in response to persistent climate variability and intensifying climate change affecting Queensland and Australian grazing systems. In recent years, increasingly frequent and severe droughts, floods and bushfires have increased uncertainty for land managers and policymakers across Queensland and beyond, reinforcing the need for science-based decision-support tools. These mounting pressures have prompted the GLS team leader and his team to reaffirm their commitment to continuous innovation and recognize the need to evolve the Long Paddock in support of climate adaptation.

By bridging scientific climate knowledge with practical decision-support tools, the Long Paddock has played a transformative role in supporting policymakers, land managers and researchers in navigating Queensland's highly variable climate. Yet sustaining and evolving the platform over time remains an ongoing challenge. Looking ahead, the GLS team leader must consider the future direction of Long Paddock. He and his team must determine how the platform should evolve in the next phase, including how to continue improving data quality, develop and redesign products, and ensure organizational sustainability. The central question is how they should shape the next phase of the platform's development to ensure its long-term sustainability and impact while continuing to meet the evolving needs of users and stakeholders.

Finally, although the Long Paddock is deeply rooted in Queensland's unique ecological and institutional context, its lessons can be extended far beyond it. Many regions worldwide face similar challenges of balancing data complexity, stakeholder diversity, and environmental uncertainty. For instance, in the United States, the OpenET platform leverages satellite imagery and cloud computing to provide farmers and water managers with accurate data on crop water use, supporting sustainable irrigation and water resource management (Melton et al., 2022). Similarly, other digital platforms in Europe are emerging to translate climate science into actionable insights for land and resource management. Thus, the case offers valuable insights into how digital platforms can integrate scientific knowledge, stakeholder engagement, and adaptive innovation processes to address pressing digital sustainability challenges. By studying this case, students can appreciate not only how a digital platform contributes to climate adaptation, but also how similar approaches can be extended to other sectors and regions seeking resilience through digital innovation.

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Declaration of AI

During the revision of the teaching case and the teaching notes, the author used Grammarly and ChatGPT 5 in order to improve grammar, clarity, and overall writing quality.

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Appendix A

Table A1. Major Products and Tools on the Long Paddock

Product/Tool	Description / Major functions or products	Responsible agency	Key digital components
Southern Oscillation Index (SOI)	The Long Paddock team calculates Daily SOI data (automated) from 1991 and presents 30-day, 90-day and monthly SOI data from 1876 up to present day; data files available in CSV format, graph of historical values. Major products include: SOI Dashboard, SOI data files, SOI monthly graphs.	Long Paddock is the hosting platform.	Platform interface, climate data, scientific algorithms and modelling
Drought & Climate Adaptation Program (DCAP)	Information and tools that are included in the DCAP page with the aim to help producers better manage drought and climate impacts. Major products include: DCAP M&E annual reports, Climate news, Grazing industry information (reports, case studies, projects and tools), Cropping industry (case studies, projects, web links), Horticulture industry (reports, case studies, projects, tools), News and Media on DCAP updates.	Individual projects and products are created and maintained by DCAP operatives: climate scientists, government and non-government agencies, producers and industry leaders. Long Paddock is the hosting platform.	Platform interface, climate data
AussieGRASS	AussieGRASS is a spatial implementation of Queensland Government's GRASP (Grass Production) model (Carter et al. 2000). It monitors key biophysical processes associated with pasture growth (i.e. degradation and recovery) at regional scales (e.g. local government areas or bioregions). It provides long-term time-series of rainfall and pasture growth information, as well as projections for the season ahead, which are useful for forage budgeting, assessing the impacts of drought, and bushfire risk. Major products include: AussieGRASS environmental calculator, regional drought analysis, rainfall and pasture growth maps, time series graphs of sub-IBRA and Shire/LGA regions, and much more.	Developed and maintained by the GLS Team.	Platform interface, climate data, scientific algorithms and modelling, High Performance Computer (HPC), Amazon Web Services (AWS)
FORAGE	FORAGE (Zhang & Carter 2018) is an online system that generates and delivers customized PDF reports containing essential information for rural Lots on Plan (>1ha). The system integrates multiple data sources, including SILO climate data, satellite imagery, land types, soils data and modelled pasture growth, to provide property-scale insights. These reports, delivered via email in an easy-to-understand format, support decision-making in grazing land management and environmental planning. Major products include: Land management reports (14 currently) including Long-Term Carrying Capacity Report, Pasture Growth Alert Report, Ground Cover Report, and several more.	Developed and maintained by the GLS Team.	Platform interface, climate data, scientific algorithms and modelling, High Performance Computer (HPC), Amazon Web Services (AWS)

Product/Tool	Description / Major functions or products	Responsible agency	Key digital components
MyFORAGE	It is an interactive mapping tool that enables users to import an existing paddock file or create property paddocks to attain more customized mapping in FORAGE reports that show more detailed and improved content, which can invariably improve grazing land management decisions. Major products include: Long-Term Carrying Capacity Report, Pasture Growth Alert Report, Ground Cover Report, and several more.	Developed and maintained by the GLS Team.	Platform interface, climate data, scientific algorithms and modelling, High Performance Computer (HPC), Amazon Web Services (AWS)
Suite of Rainfall/ Pasture Growth Posters	The Australia's Variable Rainfall, Tropical Cyclone (and Pasture Growth) Posters depict twelve monthly rainfalls (April-March) in maps for the years 1890 through to current including a graph of Southern Oscillation Index and Interdecadal Pacific Oscillation values (Stone et al. 2019). The Queensland's Wet and Dry periods poster relate these periods from 1889 to current (McKeon et al. 2021). Major products: El Niño–Southern Oscillation year classification documentation, Rainfall & Pasture Growth Map App, link to Pasture Degradation and Recovery in Australia's Rangelands: Learning from History.	Developed and maintained by the GLS Team.	Platform interface, climate data, scientific algorithms and modelling, High Performance Computer (HPC), Amazon Web Services (AWS)
SILO	It is a database of Australian climate data from 1889 to the present (Jeffrey et al. 2001). It provides daily meteorological datasets for a range of climate variables in ready-to-use formats suitable for biophysical modelling, research and climate applications. Major products: Introduction of SILO database, Viewpoint Data, Get Point Data, Access Gridded Data, Fortnightly Rainfall Mapping, Application Programming Interface (API) to access data.	SILO is delivered by the Climate Projections and Services team within the Queensland Treasury Department. The datasets are constructed from observational data obtained from Bureau of Meteorology (BoM) and other climate data suppliers such as The Department of Natural Resources and Mines, Manufacturing, and Regional and Rural Development. Long Paddock is the hosting platform.	Platform interface, climate data, scientific algorithms and modelling, High Performance Computer (HPC)

Appendix B

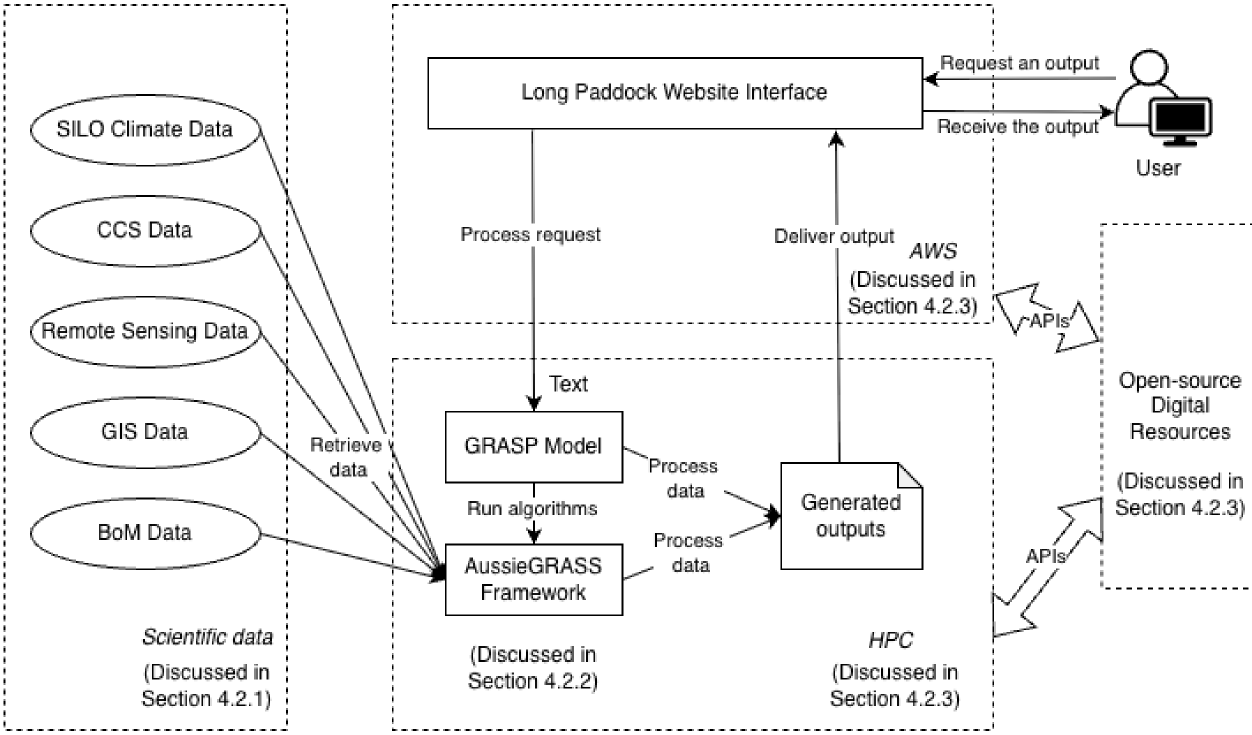

Figure B1. Digital Infrastructure of Long Paddock and Its Information Flow

The information flow begins when a user submits a request through the Long Paddock website (hosted on AWS). The request is routed to HPC, where relevant scientific data is retrieved. These datasets are then processed using the GRASP model, which runs core algorithms to generate key outputs. The results are further refined and spatially integrated through the AussieGRASS framework. The processed outputs, such as pasture growth and ground cover estimates, are then returned via the web interface, providing users with accurate and accessible information for decision-making.

About the Authors

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