Northern Australia Environmental Resources Hub
National Environmental Science Programme

Environmental economic accounting for interconnected assets and ecosystem services in the Mitchell River catchment, Queensland: Pilot ecosystem accounts and supporting information

Final report

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This report should be cited as:

Smart, J.C.R., Hasan S., Curwen G.R., Saint Ange C., Dyke J., McMahon J.M., Jackson S., Barber M., Sinnamon V., Brown C.J., Burns G.L., Fleming C.M., Connolly R.M., Burford M.A. (2022) *Environmental economic accounting for interconnected ecosystem assets and ecosystem services in the Mitchell River catchment, Queensland: Pilot ecosystem accounts and supporting information*, Griffith University, Brisbane.

Cover photographs

Front cover: Mitchell River catchment, Queensland, Australia (photo: Chantal Saint Ange)

Back cover: Cattle in open woodland, Mitchell River catchment, Queensland Australia (photo: Graeme Curwen).

This report is available for download from the Northern Australia Environmental Resources (NAER) Hub website at nespnorthern.edu.au

The Hub is supported through funding from the Australian Government's National Environmental Science Program (NESP). The NESP NAER Hub is hosted by Charles Darwin University.

August, 2022

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Acronyms

ACA ....Aquatic Conservation Assessments

ALUM ....Australian Land Use and Management

AquaBAMM ....Aquatic Biodiversity Assessment Mapping Methods

AS ....Aquatic Score

BVG ....Broad Vegetation Group

EFG ....Ecosystem Functional Group

GCDI ....Ground Cover Disturbance Index

GEP ....Gross Ecosystem Product

GET ....Global Ecosystem Typology

IUCN ....International Union for Conservation of Nature

QLUMP ....Queensland Land Use Mapping Program

RDI ....River Disturbance Index

SEEA ....System of Environmental Economic Accounting

SEEA-EA ....System of Environmental Economic Accounting – Ecosystem Accounting

SNA ....System of National Accounts

SLATS ....Statewide Landcover and Trees Study

Acknowledgements

We gratefully acknowledge the assistance provided by other members of the project team in helping to generate the ideas and implementations described in these accounts. We acknowledge the assistance provided by colleagues who contributed their research experience from previous projects on multiple aspects of the Mitchell catchment under the National Environmental Science Program (NESP), National Environmental Research Programme and the Tropical Rivers and Coastal Knowledge research consortium. We thank stakeholders in the Mitchell catchment (natural resource management groups and local communities) for their enthusiastic support of this project and their willingness to contribute data and expertise. We also wish to thank the NESP Northern Australia Environmental Resources (NAER) Hub team and the NESP NAER Queensland Regional Research Coordinator for their invaluable advice and assistance.

The Kowanyama community generously provided project Research Associate and longstanding Kowanyama resident and collaborator Viv Sinnamon with information about the ways in which Traditional Owners care for Country in the lower Mitchell catchment and delta, and with details of how their ability to conduct multiple on-Country activities has been impacted by the increasing presence and prevalence of feral animals and invasive weeds. The researchers recognise that this information is valued for its cultural significance to its custodians.

Dr John Neldner of the Queensland Herbarium provided essential advice on relating Queensland’s Remnant Regional Ecosystems classifications to the IUCN Global Ecosystem Typology’s Ecosystem Functional Groups.

This project was funded through the Northern Australia Environmental Resources Hub of the Australian Government’s National Environmental Science Program.

This report contains information contributed by Indigenous Traditional Owners from the vicinity of Kowanyama in the Mitchell River delta. Information and data contributed by Indigenous Traditional Owners from the vicinity of Kowanyama in the Mitchell River delta and presented in this report as written text, tables and maps remain the property of the Traditional Owners (or of their families in circumstances where they are deceased). Information and data contributed by Indigenous Traditional Owners from the vicinity of Kowanyama must not be reproduced, nor should data be extracted and re-analysed in any way, without obtaining prior informed consent from the Traditional Owners through the Kowanyama Aboriginal Land and Natural Resource Management Office and Abm Elgoring Ambung RNTBC.

Aboriginal and Torres Strait Islander people should be aware that this report contains the names of deceased persons who are cited as authoritative sources for land management practices and ecosystem extent and condition.

Executive summary

For tens of thousands of years prior to European invasion and settlement, the ancestors of today's Traditional Owners of the Mitchell catchment socialised the landscapes of the region as they managed land and water, fulfilled custodial responsibilities under customary law and maintained an economic system that sustained their way of life. This active management by Traditional Owners continues in many localities today, albeit under constrained conditions. As one example, Traditional Owners' expertise in savanna fire management has abated carbon emissions and generated an average of $3.5 million annually across the Mitchell catchment over the past eight years through supply of global climate regulating services.

Whilst acknowledging conceptual misalignments, it is important to recognise that Ecosystem Accounts provide an opportunity for documenting and reporting the contribution of Indigenous Traditional Owners in managing Country in ways that enhance supply of many ecosystem services that benefit human society. Ecosystem Accounts, when compiled regularly, provide time series data on the state of and pressures on ecosystem assets, thus enabling tracking of ecosystem condition and the pressures that affect condition. This could be particularly relevant for Indigenous communities because of their strong relationship with and dependence upon Country and the emergence of contemporary Indigenous natural resource management in Australia over the last three decades in which traditional knowledge and mainstream science are combined.

More broadly, considerations of morality, history, and scientific accuracy make it essential to consider how Indigeneity is made visible in Ecosystem Accounts. Colonial contexts like Australia usefully highlight how an extended history of Indigenous management of landscapes has been disrupted by much shorter periods of subsequent aggressive colonisation, with consequences for landscape change, human management, and ecosystem service provision. Sensitivity to Indigeneity provides more nuanced understanding of the assumptions underlying estimates of baseline conditions, the ways in which actors and their activities are rendered (in)visible in accounting practices, and the potential future options for improvement in asset condition and service provision. As such, Ecosystem Accounting research in Australia's north – where Indigenous populations have high levels of reliance on ecosystem assets – could thus be very informative, nationally and internationally.

In line with the Australian Government's Strategy and Action Plan for Environmental Economic Accounting, this project (Project 4.6 of the National Environmental Science Program's Northern Australia Environmental Resources Hub) applied the United Nations Statistics Division's System of Environmental Economic Accounting (SEEA) methodology to produce a set of pilot Ecosystem Accounts (SEEA EA) for the Mitchell River catchment in Far North Queensland. In compiling the pilot set of accounts, lessons have been learnt regarding both construction of ecosystem accounts and their potential use for informing policy development and direction.

In addition to compiling a pilot set of SEEA EA for the Mitchell River catchment, Project 4.6 also addressed broader research questions regarding (i) whether SEEA EA-compliant condition indicators could be configured appropriately to report on the condition of interlinked ecosystem assets (e.g., rivers, floodplains and wetlands) in an environment that experiences considerable seasonal and inter-annual variability, and (ii) whether mechanisms can be developed to produce meaningful SEEA EA-compliant valuations of cultural ecosystem services relevant to Indigenous communities.

This Report focuses on the pilot Ecosystem Accounts produced for the Mitchell. Findings relating to the broader research questions are presented and discussed in more detail in the separate ‘Methodology’ report.

SEEA Ecosystem Accounts are designed to be fully compatible with the United Nations Statistics Division’s System of National Accounts (SNA) for standardised reporting of the performance of national economies. SEEA EA comprise a set of accounts, and accompanying maps, that report the *extent* and *condition* of *ecosystem assets* (individual blocks of woodland, grassland etc.), grouped by *ecosystem type*, within a defined *ecosystem accounting area*, together with tables and maps that report the *supply* of *ecosystem services* by the different ecosystem types and their *use* by businesses, households and governments (Figure ES-1). Supply and use of ecosystem services is reported in *biophysical* and *monetary* units.

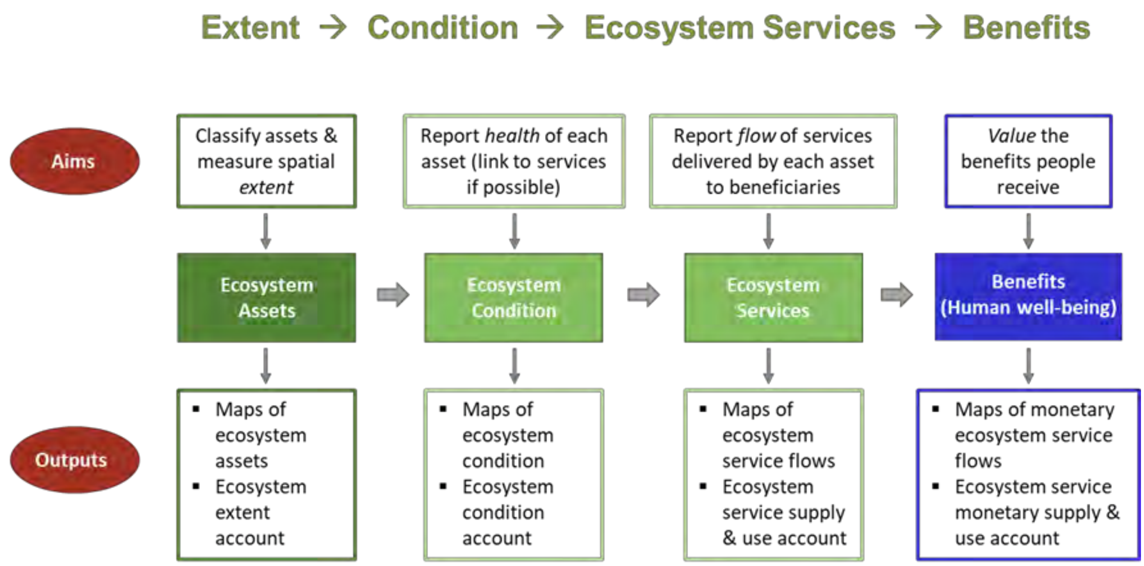

Figure ES-1. Aims and outputs of the System of Environmental Economic Accounting – Ecosystem Accounts.

SEEA EA regards ecosystem services as *ecosystems’ contributions to benefits* that are delivered to human society. Before the advent of ecosystem accounting these contributions from ecosystems were absent from, or – at best – opaque in national accounts. The ‘transactional’ and ‘linear’ interaction paradigm that underpins SEEA Ecosystem Accounts is evident in Figure ES1 – ‘benefits via contributions *from* ecosystems *to* people’. This contrasts with Indigenous Traditional Owners’ relationship with Country in which, guided by customary law, they care for Country as an ongoing manifestation of ancestral power and in recognition of their obligations to future generations. We argue a concept of *co-production* would be a more accurate expression of this relationship in ecosystem accounting terms.

The intention is that all data reported in SEEA Ecosystem Accounts should be recorded in the same year, and that the full suite of accounts will be updated regularly so that changes in ecosystem extent and condition, and in supply and use of ecosystem services, can be tracked through time. As the information base is still evolving, we have included data from different years in our pilot ecosystem accounts for the Mitchell River catchment to promote discussion about which data should be included, how data collection might best be synchronised, and how the accounts might be updated most cost-effectively.

Consequently, our pilot ecosystem accounts for the Mitchell should be regarded as a work in progress. Noting this caveat, the pilot ecosystem accounts for the Mitchell catchment produced the following results.

- The ecosystem extent account showed that three ecosystem types comprise 94% of the Mitchell catchment by area: *pyric tussock savannas* (78%), *subtropical-temperate forested wetlands* (10%) and *hummock savannas* (6%) (Figure ES-2).
- There has been only modest change in the areas of most ecosystem types pre-clearing (~1750) to post-clearing (~2015). In total 91,612 ha of predominantly *pyric tussock savannas*, *subtropical-temperate forested wetlands* and *tropical-subtropical montane rainforest* have been cleared for use as *grazing on native vegetation*, *irrigated cropping*, *irrigated perennial horticulture* and *dryland cropping*.
- A Stage 1 ecosystem condition account was compiled comprising 39 *ecosystem condition variables* reporting different aspects of ecosystems' abiotic, biotic and landscape-level characteristics. Ecosystem condition *indicators* were not reported because *reference levels* for 'best' and 'worst' condition could not be defined clearly. Condition variable data were recorded for individual years between 2003 and 2020, or as averages across multi-year periods.
- Key findings from the ecosystem condition account were:
  - Several ecosystem types are subject to considerable gully erosion.
  - The catchment's ecosystems store large amounts of carbon in above- and below-ground biomass and in the top 30 cm of soils.
  - The catchment contains large areas of woody and sparse woody vegetation.
- Data on anthropogenic pressures affecting ecosystems were compiled alongside the condition account. These data showed that:
  - Considerable areas of many ecosystem types are burnt more frequently, or less frequently, than recommended for the ecosystems concerned.
  - Habitat fragmentation is relatively modest across most of the catchment.
  - Episodic land clearing has occurred in some areas of the catchment, although the total area cleared is a small proportion of total catchment area.
  - Priority invasive species are widespread across the catchment, with cane toad, feral cat, feral pig, wild dog and rubber vine present in all ecosystem types, and the aquatic invasive weeds cabomba, hymenachne, salvinia, sagittaria, water hyacinth and water lettuce are present in all aquatic ecosystem types.
- As we explain in this report, there is a fundamental misalignment between human interactions with ecosystems as conceptualised in SEEA EA and the way in which Indigenous Traditional Owners conceptualise such interactions. Human - ecosystem interactions are conceptualised as being 'transactional' and 'linear' in SEEA Ecosystem Accounts. In contrast, Indigenous Traditional Owners' regard interactions with Country as 'relational' and 'reciprocal'; Traditional Owners have responsibilities to care for Country in order for Country to continue to contribute benefits to current and future generations. Whilst recognising the conceptual misalignment, an important component of Project 4.6 was to consider whether some aspects of Indigenous

Traditional Owners' activities and interactions with Country could potentially be represented in SEEA EA. Unfortunately, because of Covid-19 access restrictions during 2020 and 2021, only a limited amount of on-site research could be undertaken. Project 4.6 research on this topic therefore focused on the township of Kowanyama in the Mitchell delta and drew on data collected by Project 4.6 research associate Viv Sinnamon with the support of the Kowanyama Aboriginal Land and Natural Resource Management Office, Abm Elgoring Ambung RNTBC, and Kowanyama Aboriginal Council.

- These data show that – using SEEA Ecosystem Accounting concepts and terminology – Indigenous Traditional Owners benefit from many provisioning and cultural ecosystem services and facilitate supply of many regulating and cultural ecosystem services. However, Traditional Owners' ability to benefit from and supply ecosystem services in the Kowanyama area is being significantly compromised by declining ecosystem condition. Invasive weeds and feral animals are reported as significant pressures driving this decline.
- Biophysical supply and use tables for ecosystem services show that ecosystems in the catchment supply *provisioning*, *regulating* and *cultural* ecosystem services, although not all supply quantities could be established. SEEA EA requires that users must benefit from an ecosystem service if that service is to be reported in supply and use tables. A consequence for sparsely populated catchments like the Mitchell is that several services such as flood regulation that would benefit large populations in many catchments on Australia's east coast are absent from the Mitchell accounts. It is also important to note that SEEA EA's conceptualisation of humans solely as *users* of ecosystem services is not consistent with Indigenous Traditional Owners' conceptualisation of the reciprocal relationship between custodians and Country and consequently of ecosystem services being sustained through co-production.
- We note that such co-production with Traditional Owners gives rise to several different categories of cultural ecosystem services (when using SEEA EA concepts and terminology). These services can potentially be accommodated within SEEA EA, either via a link to cultural identity, or by introducing *caring for Country*, *knowing that Country is being cared for*, and *knowing that Country will continue to be cared for*, as cultural ecosystem services in their own right in the 'other cultural services' category.
- Monetary supply and use tables were compiled. In SEEA EA, only the direct or indirect *use* of ecosystem services can be valued in dollar terms. Monetary valuations are produced by multiplying the quantities of services supplied by a corresponding *exchange value-equivalent price*. Annual monetary valuations were produced for supply of the following ecosystem services:
    - *Provisioning:* Crop provisioning services to irrigated agriculture ($79 million/year), grazing biomass provisioning services to cattle rearing ($18 million/year), biomass provisioning services to the commercial barramundi fishery ($0.2 million/year).
    - *Regulating:* Global climate regulation services through carbon storage in biomass and soils ($110 million/year for carbon storage in biomass, $391 million/year for carbon storage in soils), and via carbon sequestration from savanna fire management ($3 million/year).
    - *Cultural:* Recreation-related services provided to domestic and overseas visitors ($48 million/year).

- For ecosystem services that could be valued using methods compliant with SEEA EA, the gross ecosystem product (GEP) from the Mitchell catchment totalled $649 million/year.
- The largest contributions to GEP were from *pyric tussock savannas* ($436 million/year) and the *non-remnant broad vegetation group* ($108 million/year) (Figure ES-3).
- In per hectare terms, the *non-remnant broad vegetation group* was the most valuable supplier of ecosystem services ($1,175/ha/yr), followed by *tropical-subtropical montane rainforest* ($162/ha/yr) and *temperate woodlands* ($140/ha/yr).

Important learnings and recommendations from constructing the pilot set of ecosystem accounts were:

- The importance of consulting with relevant experts when compiling the accounts.
- Considerable challenges surround selection of an appropriate suite of condition variables or condition indicators for the Condition Account. Selected variables and indicators should enable the Account to report meaningfully on ecosystem condition whilst also informing on ecosystems' capacity to supply multiple ecosystem services and being amenable to regular updating at reasonable cost.
- We found that in the Mitchell, which experiences high inter-annual variability in rainfall and river flow, a condition indicator constructed for the interlinked suite of ecosystem assets that supply a stock of catchable barramundi to the Mitchell estuary was not responsive to water extraction (as an example human-induced pressure) over sub-decadal timescales. Consequently, where inter-annual variability is high, we recommend that condition indicators should not be used to inform on reactions to human pressures that cause degradation. More responsive indicators are needed to inform actions in a timely manner. Pressure indicators themselves may be better suited to this task, and so might appropriately calibrated predictive models.
- The importance of appropriate calibration of predictive models to local context was further emphasised by our findings regarding model-derived estimates of sediment retention services in the Mitchell. We recommend that account compilers should exercise considerable caution when using readily available SEEA-orientated modelling platforms to estimate local supply of regulating ecosystem services. Wherever possible, these types of models should be calibrated and validated against locally collected empirical data in consultation with relevant experts.

Reflection suggests that SEEA Ecosystem Accounts that are compiled consistently and updated regularly over suitably lengthy time series could be useful for informing policy direction as follows:

- 'Past-to-present' trajectories of ecosystem extent, condition and supply and use of ecosystem services could help identify emerging problems and inform possible policy directions for addressing those problems.
- Tracking the effectiveness of policy interventions against pre-defined targets for ecosystem extent, condition, or biophysical service supply.

However, because ecosystem accounts only report the values of services that ecosystems supply, they are **not** well suited for informing decisions on alternative project proposals at specific locations. It is useful to note that whilst National Accounts (i.e., the SNA) are frequently used to inform policy development and direction, it would be inappropriate to use

SNA for informing project-level decision making. For example, SNA could identify that a particular sector (e.g., coal extraction) generates considerable revenue and provides significant employment in a particular region. SNA could also detect that this sector was contracting over time. In combination, this information would alert government that policies will be required to stimulate new revenue streams and employment opportunities in that locality (e.g., a structural reconstruction fund should be set up). However, when evaluating how reconstruction funding should be allocated to alternative project proposals for new industries and employment, benefit cost analysis, using project-level data collected specifically for this purpose (i.e., **not** using data drawn from the SNA), would be an appropriate mechanism for informing project-level tradeoffs and decision making.

Consideration was given to potential methods for including Indigenous-related cultural ecosystem services in SEEA Ecosystem Accounts. Covid-19-related access issues prevented full consultation with Traditional Owners on these topics. Consequently, without endorsement (or otherwise) of potential methodologies, Indigenous-related cultural ecosystem services were not enumerated in our SEEA Ecosystem Accounts.

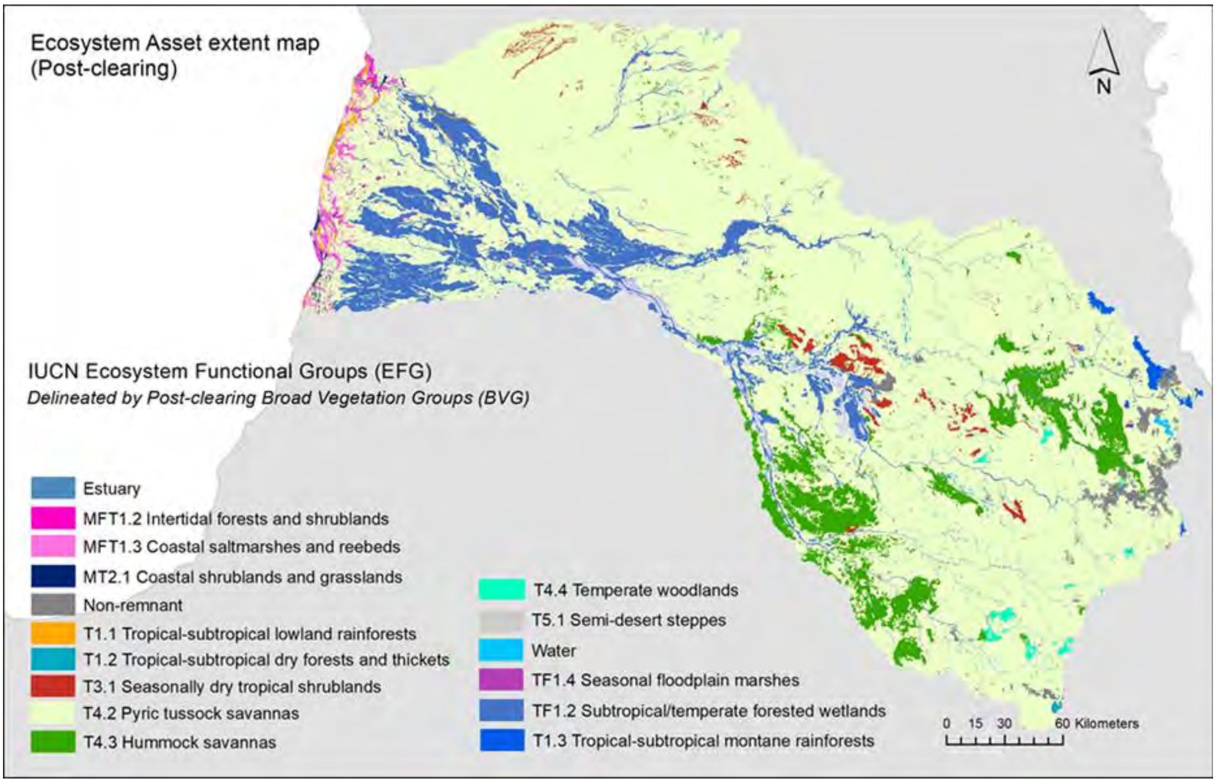

Figure ES-2. Ecosystem extents in the Mitchell catchment, by ecosystem type post-clearing (~2015).

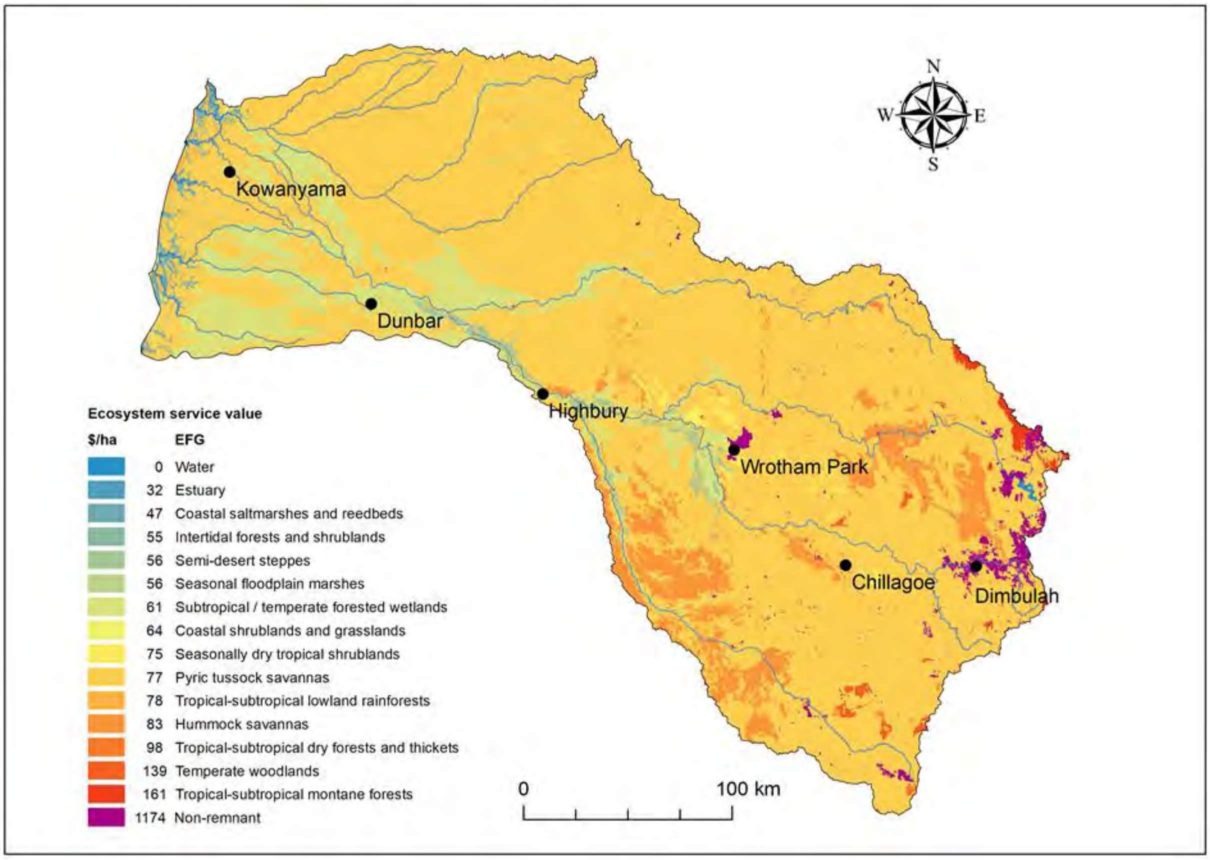

Figure ES-3. Total monetary value per hectare ($/ha) of selected ecosystem services from ecosystem types (EFGs) in the Mitchell catchment. Monetary valuations expressed in exchange value or exchange-equivalent value. Table 29, Table 30 and Table 31 report which ecosystem services are valued for each ecosystem type.

Project materials

There are three main reporting outputs from this project:

- a report detailing the pilot set of SEEA Ecosystem Accounts for the Mitchell catchment, together with relevant supporting information (this document),
- a report that provides further details of the methodologies used to produce the pilot set of SEEA Ecosystem Accounts for the Mitchell catchment, and
- a data inventory listing the data sources used to compile the pilot set of SEEA Ecosystem Accounts for the Mitchell catchment.

This document is intended to provide most of the information that a reader might require to understand how the pilot set of SEEA Ecosystem Accounts for the Mitchell catchment were compiled, together with reflections on how the accounts might best be used.

If additional information is required the reader can refer to the detailed methodologies report or the data inventory, as appropriate.

Ecosystem accounts: Key findings

For tens of thousands of years prior to European invasion and settlement, the ancestors of today's Traditional Owners of the Mitchell catchment socialised the landscapes of the region as they managed land and water, fulfilled custodial responsibilities under customary law and maintained an economic system that sustained their way of life. This active management by Traditional Owners continues in many localities today, albeit under constrained conditions. As one example, Traditional Owners' expertise in savanna fire management has abated carbon and generated an average of $3.5 million annually across the Mitchell catchment over the past eight years through supply of global climate regulating services.

We note that there are fundamental misalignments between SEEA-EA's conceptualisations of anthropogenic interactions with ecosystems and those of Indigenous Traditional Owners. SEEA-EA's conceptualisation is fundamentally 'transactional' and 'linear'. In contrast, Indigenous Traditional Owners' conceptualisation can be regarded as 'relational' and 'reciprocal'; Traditional Owners have responsibilities to care for Country in order for Country to continue to contribute benefits to future generations. The values arising from these reciprocal interactions are grounded in the fundamental *relationship* between Traditional Owners and Country.

The SEEA-EA White Cover version states that *non-use value* and *relational value* fall <u>*outside*</u> the remit of SEEA Ecosystem Accounts. As a basis for considering how these fundamental conceptual misalignments might be overcome, Project 4.6 investigated how Indigenous Traditional Owners' activities and interactions with Country in the vicinity of Kowanyama in the Mitchell Delta could potentially be represented in SEEA Ecosystem Accounts.

Due to Covid-19 access restrictions, only a modest amount of on-site research could be undertaken to investigate supply and use of ecosystem services from an Indigenous perspective in the Mitchell catchment. Consequently, our research centred on the township of Kowanyama and drew on data collected in Kowanyama by Project 4.6 research associate Viv Sinnamon, with the endorsement of Kowanyama Aboriginal Land and Natural Resource Management Office, Abm Elgoring Ambung RNTBC, and Kowanyama Aboriginal Council.

Drawing on several decades of residence and deep collaboration with the Kowanyama community, Viv Sinnamon's data collection reported that Indigenous Traditional Owners and community in Kowanyama both benefit from provisioning and cultural ecosystem services and facilitate supply of regulating and cultural ecosystem services. However, the Kowanyama community's ability to benefit from and supply ecosystem services is being compromised by the declining condition of ecosystems in the lower Mitchell catchment and delta. The primary pressures reported as causing these declines are invasive weeds and feral animals.

The layout of the pilot SEEA-EA ecosystem accounts produced for the Mitchell River catchment is shown in Figure 1. Spatially-linked data on supplementary information and key pressures are also included to support data on Ecosystem Condition.

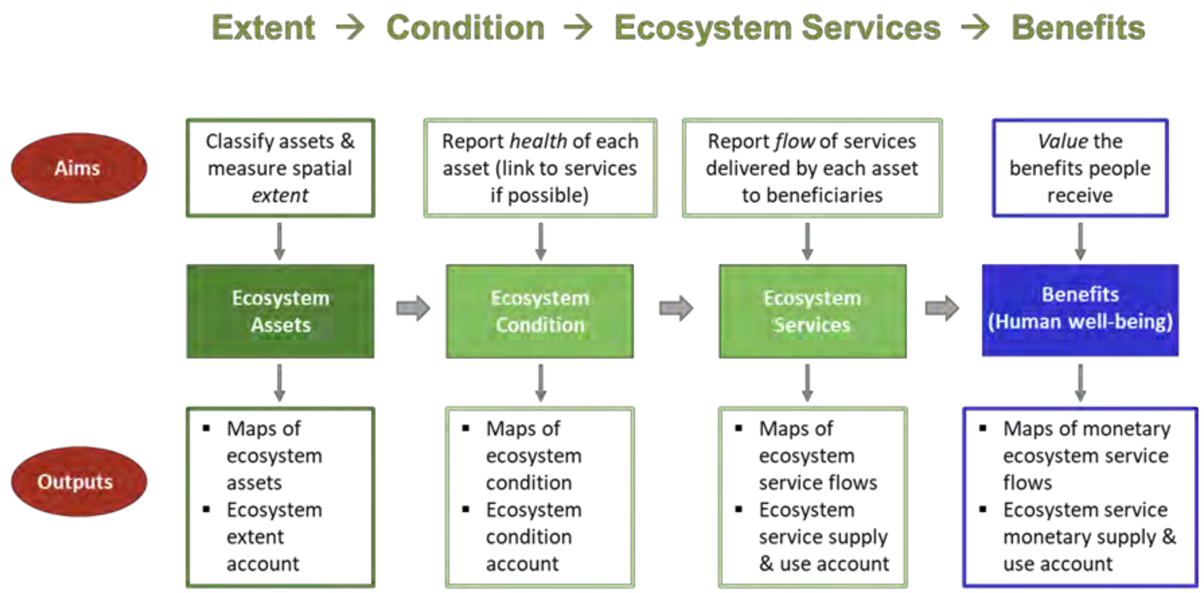

Figure 1. Layout of the SEEA-EA ecosystem accounts for the Mitchell catchment.

Key findings from the pilot accounts are below.

Extent account: Summary

- The ecosystem accounting area for the Mitchell catchment SEEA Ecosystem Accounts was defined as the watershed of the Mitchell River catchment, extending seven nautical miles from the shoreline into the Gulf of Carpentaria.
- The total area of the Mitchell catchment in the Ecosystem Extent Account is 7,172,218 ha (71,722 km^2). This represents 0.93% and 4.15% of the total land area of Australia and the state of Queensland, respectively.
- *Ecosystem assets* (i.e., individual areas of grassland, forest, wetland etc.) in the Mitchell catchment were categorised into 16 *ecosystem types*, of which 13 were matched to IUCN Global Ecosystem Typology's (GET) Ecosystem Functional Groups (EFGs) and the remaining three were allocated into the Queensland Broad Vegetation Groups (BVGs) of *water*, *estuary* and *non-remnant* (Figure 2). This correspondence was required because SEEA-EA recommend that ecosystem types should be categorised using IUCN EFGs. A cross-walk between the Queensland BVGs and IUCN GETs was informed by experts from the Queensland Herbarium. Ecosystem extent, ecosystem condition variables, and supply and use of ecosystem services in biophysical and monetary terms are all reported against these 16 ecosystem types in the Mitchell Ecosystem Accounts.

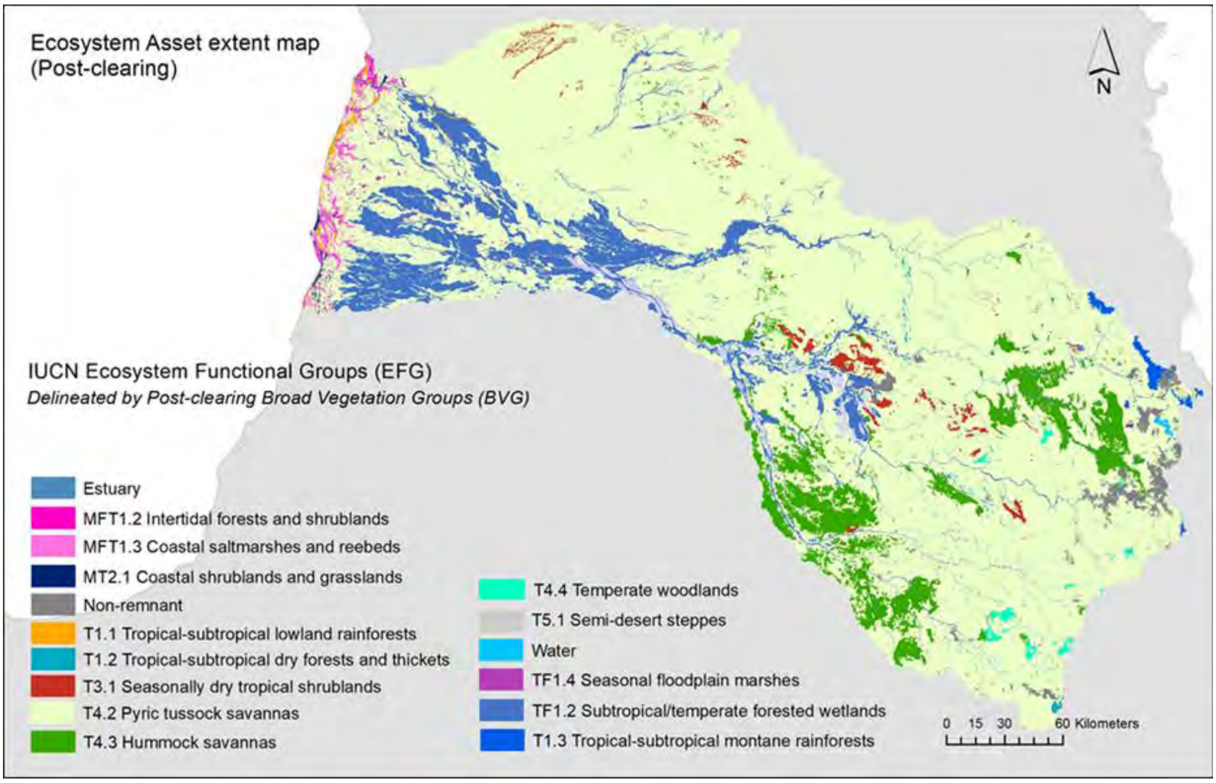

Figure 2. Ecosystem extent post-clearing (~2015), by ecosystem type.

- The extents of rivers and waterbodies are reported separately to the extents of the 16 ecosystem types in the catchment, drawing on data from Digital Earth Australia, Geoscience Australia, and Landsat satellite imagery.
- P*yric tussock savannas*, cover 78% of total catchment area, post-clearing. Together with *subtropical-temperate forested wetlands* (10%) and *hummock savannas* (6%), these three ecosystem types cover 94% of the total catchment area, post-clearing (Table 1 and Figure 8).
- Overall, there has been only relatively modest change in the extents of the 16 ecosystem types in the Mitchell catchment between the pre-clearing (~1750) and post-clearing (~2015) ecosystem extent accounts (Table 1, Table 2, Figure 7 and Figure 8). Exceptions to this are the *seasonal floodplain marshes* (43% reduction), *tropical-subtropical montane rainforests* (8% reduction), *tropical-subtropical lowland rainforests* (3% reduction), and *seasonally dry tropical shrublands* (4% increase) ecosystem types.
- The largest changes in extent, in terms of absolute area (Table 3), pre-clearing to post-clearing, are:
    - Creation of 91,612 ha of the non-remnant broad vegetation group through anthropogenic land use change.
    - Reclassification of 17,861 ha of *seasonal floodplain marshes* as *subtropical-temperate forested wetlands*.
    - Reclassification of 16,229 ha of *subtropical-temperate forested wetlands* as *pyric tussock savanna*.
    - Reclassificiation of 12,611 ha of *pyric tussock savanna* as *subtropical-temperate forested wetlands*.

- Expressing areal change as a percentage of pre-clearing area (Table 4), the largest changes are:
  - Anthropogenic conversion of 8.3% of pre-clearing *tropical-subtropical montane rainforest*, 4.3% of *tropical-subtropical lowland rainforests*, 1.5% of *pyric tussock savanna*, and 1.5% of *seasonal floodplain marshes* to the *non-remnant* BVG.
  - Reclassification of 40% of the pre-clearing area of *seasonal floodplain marshes* as *subtropical-temperate forested wetlands*.
  - Reclassification of 16.6% of pre-clearing *tropical-subtropical dry forests and thickets*, 3.3% of *seasonal floodplain marshes*, 2.2% of *subtropical-temperate forested wetlands*, 2% of *seasonally dry tropical shrublands*, 1.4% of *hummock savannas*, and 1.1% of *temperate woodlands* to *pyric tussock savanna*.

  The factors driving these reclassifications are not immediately apparent.
- Major land uses in the non-remnant BVG in 2015 comprised *grazing native vegetation* (64%), *irrigated cropping* (17%), *irrigated perennial horticulture* (6%) and *cropping* (~2%) (Table 7 and Figure 11 – Figure 16).
- Rivers and watercourse areas are categorised as estuarine (8%) and freshwater (92%). A significant proportion of *freshwater* watercourse areas are non-perennial as opposed to perennial (Figure 9). Perennial watercourse lines in the Mitchell catchment are much shorter (1,913 km) than non-perennial watercourse lines (6,852 km) (Figure 10).
- Grazing native vegetation and Conservation and Natural Environments (Managed resource protection and nature conservation) are the dominant QLUMP land uses in the catchment, occupying 81% and 15% of catchment area, respectively (Figure 17 and Figure 18).

Condition accounts: Summary

- In SEEA-compliant ecosystem accounting, the quality of an ecosystem asset is assessed "in terms of its abiotic and biotic characteristics" (United Nations et al., 2021, p.81)). SEEA-EA define a hierarchy for reporting condition that encompasses three groups of characteristics at the highest level (*abiotic*, *biotic*, and *landscape level* characteristics) and six classes of characteristics at a lower level (*abiotic physical state*; *abiotic chemical state*; *biotic compositional state*; *biotic structural state*; *biotic functional state*; and *landscape and seascape characteristics*) (Figure 19).
- Quantitative metrics that describe the state of an individual condition characteristic for ecosystem asset(s) within an ecosystem type can be included as *ecosystem condition variables* in a *Stage 1 Ecosystem Condition Account* for the ecosystem accounting area (Figure 20).
- If *reference levels* for 'best' and 'worst' condition of a characteristic can be defined for an ecosystem condition variable, that variable can be regarded as an *ecosystem condition indicator* for relevant ecosystem assets within an ecosystem type and included in a *Stage 2 Ecosystem Condition Account* (Figure 20).
- If appropriate, ecosystem condition indicators can be aggregated across ecosystem assets of the same ecosystem type to produce an overall *ecosystem condition index*

for each ecosystem type. Where this is possible, condition indexes would be reported in a *Stage 3 Ecosystem Condition Account* (Figure 20).

- In Project 4.6 we collate data on *ecosystem condition variables* for ecosystem assets within the Mitchell catchment's ecosystem types and broad vegetation groups to produce a *Stage 1 Ecosystem Condition Account* for the catchment (Table 10, Table 11 and Table 12).
- The intention in SEEA-EA is that all ecosystem condition variables in the Ecosystem Condition Variable Account would be recorded in the same year. The Account would subsequently be updated at regular intervals to enable changes in condition to be tracked. In the Ecosystem Condition Variable Account compiled for the Mitchell catchment in Project 4.6, because data on only a limited number of condition variables have been recorded in any particular year, we have deliberately reported condition variables from *different* years – and have noted the year(s) in which data on each variable were collected. This illustrates the types of condition variable that could contribute data to a Stage 1 Ecosystem Condition Account for the catchment. The intention is to promote discussion about how collection of (a subset of) the listed variables might be synchronised most cost-effectively, and whether or not Stage 2 and Stage 3 Ecosystem Condition Accounts could feasibly be produced.
- When updated at regular intervals, the Stage 1 Ecosystem Condition Account for the Mitchell could help inform policy development by:
    - Providing quantitative information about the state of an ecosystem type and how this changes through time due to anthropogenic influences.
    - Enabling quantitative data on observed ecosystem condition variables to be compared against critical thresholds and management targets (e.g., invasive species counts, remaining area of woody vegetation cover).
- As part of the Stage 1 Ecosystem Condition Account, Table 10 reports data on 11 abiotic physical state characteristics, 7 abiotic chemical state characteristics, 5 biotic compositional state characteristics, 8 biotic structural state characteristics, 6 biotic functional state characteristics, and 2 landscape characteristics. Condition variable data are recorded across a number of individual years between 2003 and 2020, or as averages across multi-year periods (e.g., 1993–2012). Several condition variables are reported for multiple years.
- Raw data on many ecosystem condition variables in most characteristic groupings are derived via remote sensing (although this is not the case for pest presence).
- Updates of publicly accessible (processed) condition variables may still be infrequent, even when raw data are derived from remote sensing. This frustrates regular compilation of Ecosystem Condition Variable Accounts, although there is continual progress in this regard (e.g., via expansion and improvement of the Queensland Government's Open Data Portal data.qld.gov.au/).
- Overall, whilst an indicative SEEA-EA Stage 1 Ecosystem Condition Variable Account has been compiled for the Mitchell catchment, absence of defined reference levels for condition variables and a lack of consistency and repeatability in data collection currently limits the usefulness of this Account for informing policy development.

Key data and findings in the Stage 1 ecosystem condition account for the Mitchell

Abiotic physical state

- *Water bodies* for 2020. Water bodies are dispersed throughout most ecosystem types in the catchment.
- *Gully erosion*: Data on erosion volumes over the period 2000–04. Several ecosystem types are subject to *gully erosion*, with substantial median estimated annual erosion volumes and tonnages (2000–04) in *pyric tussock savannas* (1,398,504 m^3/year or 2,237,606 tonnes/year (assuming a soil bulk density of 1600 kg/m^3)), *subtropical-temperate forested wetlands* (1,153,934 m^3/yr or 1,846,294 t/yr), and *semi-desert steppes* (402,192 m^3/yr or 643,507 t/yr).

Abiotic chemical state

- *Above-ground and below-ground carbon biomass* and *organic carbon content in the top 30 cm of the soil* by ecosystem type across the catchment. Data from 1993–2012, 2010 and 2019. Given the relatively high tree cover and the large area covered by many of the catchment's ecosystem types, total carbon storage across the catchment is very substantial.

Biotic compositional state

- *Potential habitat extent for iconic faunal species* per ecosystem type for 2012 (Table 11 and Figure 22).
- *IUCN species richness* (all species and threatened species only) for 2020. Four *critically endangered* and 20 *endangered* animal species are resident in the catchment.
- *Presence of pest animals and weeds* (Figure 26 and Figure 27) for 2021. Pest animals and weeds are present throughout all ecosystem types in the catchment. Please refer to the Section 5: Environmental Pressures for further details.

Biotic structural state

- *Standing pasture biomass* for 2010, 2014 and 2019.
- *Mean tree cover* as a percentage of ecosystem type area (Figure 24) 2009, 2010, 2014 and 2017.
- *Vegetation height* for 2009.
- *Areas of woody, sparse woody and non-woody vegetation* (Figure 23) for 2009, 2010, 2014, 2017 and 2018. For *subtropical-temperate forested wetlands*, *seasonal floodplain marshes*, *tropical-subtropical dry forest and thickets*, *pyric tussock savannas*, and *hummock savannas*, reductions in areas of sparse woody vegetation since 2009 coincide with increases in non-woody vegetation; this may suggest land clearing. Please refer to the Section 5: Environmental Pressures for further details.

Biotic functional state

- *Pasture growth*
- *Fireburn intensity*: Percentage extent of low intensity 'cool' fireburn as opposed to high intensity 'hot' fireburn for each ecosystem type (Figure 25); data for 2003, 2006,

2009 and 2010. A higher percentage area of *tropical-subtropical lowland rainforests*, *pyric tussock savannas*, *subtropical-temperate forested wetlands*, *seasonal floodplain marshes*, and *coastal shrublands and grasslands* experienced high intensity burns than low intensity burns in all reported years. High intensity burns occurred across 30% of the catchment's *pyric tussock savannas* and 25% of *subtropical-temperate forested wetlands* in 2009.
- *Fireburn frequency*: over the period 2000–19, relative to burn frequency guidelines for the Regional Ecosystems concerned; percentage of each ecosystem type burnt too often, not often enough, or within burn frequency guidelines. Please refer to the Section 5: Environmental Pressures for further details.

<u>Landscape characteristics</u>

- *Fireburn extent*: area of fireburn scars in each ecosystem type (in ha and as a percentage of ecosystem type area); data for 2010, 2014, 2018 and 2019. More than 20% of the area of *tropical-subtropical dry forest and thickets*, *seasonally dry tropical shrublands*, *pyric tussock savannas*, *hummock savannas*, *temperate woodlands*, *subtropical-temperate forested wetlands*, and *seasonal floodplain marshes* burnt in 2010, 2018 and 2019. More than 40% of *seasonally dry tropical shrublands* and *pyric tussock savannas* burnt in 2010. More than 40% of *subtropical-temperate forested wetlands* burnt in 2018 and again in 2019.
- *Fragmentation* (mean patch size post-clearing (~2015) vs. pre-clearing (~1750), by ecosystem type). Please refer to the Section 5: Environmental Pressures for further details.

Supporting information: Summary

The following additional information is provided to support the Stage 1 Ecosystem Condition Account:

- Aquatic Conservation Assessment (ACA) scores for watercourse lines and watercourse areas derived for the Mitchell catchment in 2018 using the Aquatic Biodiversity Assessment Mapping Method (AquaBAMM) (Department of Environment and Science, 2018) that was developed for wetlands and made available by the Queensland Government Department of Environment and Science's Wetland*Info* team. The AquaBAMM methodology draws on indicators across eight different categories to produce its ACA scores. Some categories respond to intensity of agricultural and urban land use, others respond to presence of exotic plants, fish, invertebrates and/or vertebrates in either wetlands or their surrounding catchments.
- Extent of protected areas (tabulated by ecosystem type).
- Annual rainfall (spatially mapped).

In summary, across the Mitchell River catchment, approximately 94% (~67,091 ha) and 86% (~161,662 km) of all watercourse areas and watercourse lines, respectively, were assessed to be in very good condition (AquaBAMM's aquatic scores of 'very high' or 'high') when the most recent AquaBAMM assessment of the catchment was conducted in 2018. However, 1,900 km of minor non-perennial water course lines in the mid-Palmer catchment were assessed as being in very poor condition in the 2018 assessment.

Supporting information also indicates that a high percentage of the area of *tropical-subtropical montane rainforest* in the Mitchell catchment is under some form of protection designation (75% designated as National Park, 84% as Important Bird Area, and 85% as Essential Habitat). Additionally, 25% of *tropical-subtropical dry forests and thickets* are designated as National Park and Essential Habitat, and 81% of *tropical-subtropical lowland rainforest* is designated as Important Bird Area.

Important Bird Area designations also cover very substantial proportions of the catchment's estuarine and coastal ecosystems, with 99% of *intertidal forests and shrublands*, 96% of *coastal shrublands and grasslands*, and 94% of *coastal saltmarshes and reedbeds* falling under this designation.

Environmental pressures: Summary

- Variables and indicators that report on anthropogenic **pressures** exerted on ecosystem types in the Mitchell catchment can provide valuable additional insights to help infrom policy development.
- Variables or indicators are collated for the following anthropogenic pressures acting in the Mitchell catchment:
    - **Fireburn frequency** over the period 2000–19 (relative to the frequency recommended for the Regional Ecosystem concerned) [variables (Table 17) and indicator (Table 18)]
    - **Fragmentation** [indicator (Table 18)]
    - **Ground cover disturbance** index as proxy for grazing pressure [variable Table 19 and Figure 38]
    - **Land clearing** [variable (Table 20, Table 21)]
    - **Pest animal and weed presence** [variable] – as presented previously in the Stage 1 Condition Variable Account (Table 12, Table 13, Figure 26, Figure 27)
    - **River disturbance** [variable (Table 22 and Figure 39)]

Key findings

- **Fireburn frequencies** (Table 17) between 2000–19 show that 67% or more of the area of *tropical-subtropical dry forest and thickets*, *tropical-subtropical montane rainforests*, and *seasonally dry tropical shrublands* in the catchment were burnt more frequently that the relevant Regional Ecosystems recommendations. Conversely, more than 40% of *pyric tussock savannas*, *coastal shrublands and grasslands*, and *coastal saltmarshes and reedbeds* were burnt less frequently than recommended over the same period. The fire pressure indicator (Table 18) reflects these findings.
- Moderate levels of **fragmentation** (with indicator values ranging between 58 and 70 (Table 18)) between pre-clearing (~1750) and post-clearing (~2015) have occurred in *tropical-subtropical dry forest and thickets*, *tropical-subtropical montane rainforests*, *seasonally dry tropical shrublands, pyric tussock savannas,* and *subtropical-temperate forested wetlands*. Fragmentation – as recorded by the fragmentation indicator – appears to be relatively minor across the remainder of the catchment.
- We regard the **ground cover disturbance index** (GCDI) as a loose proxy for grazing pressure. GCDI cannot be assessed for water, bare rock or where tree cover exceeds

20%. Of those ecosystem types for which GCDI could be assessed for more than 25% of their area, *hummock savannas*, *temperate woodlands* and *semi-desert steppes* were all experiencing high or very high levels of ground cover disturbance across more than 20% of their assessed area (Table 19). Figure 38 shows modest correspondence in some locations between high (proxy) grazing pressure and higher rates of gully erosion (Figure 21).

- Data from the Statewide Landcover and Trees Study (SLATS) were used to inform levels of **land clearing** in the Mitchell catchment. SLATS data report anthropogenically attributable change in woody vegetation (in ha) between successive mapping periods from 1988–1991 through to the most recent annual mapping period available (2017–18) at the time when the Mitchell Ecosystem Accounts were compiled. SLATS data (Table 20) indicate that woody vegetation clearing has occurred predominantly in *pyric tussock savannas*, *hummock savannas* and *subtropical-temperate forested wetlands*, and the *non-remant* BVG. Sustained high rates of clearing (600 ha or more) were recorded annually over the five-year period 2004–05 to 2008–09 in *pyric tussock savannas*. Generally, periods of relatively high annual rates of clearing were interspersed with periods of relatively low clearing rates in *hummock savannas* and *subtropical-temperate forested wetlands*.
- Woody vegetation cleared in *pyric tussock savanna* was predominantly used for pasture production (e.g., 98 ha in 2010–11, 202 ha in 2015–16, 170 ha in 2017–18) (Table 21). Woody vegetation cleared from *subtropical-temperate forested wetlands* was predominantly replaced by pasture and infrastructure, with *cropping* and *mining* land covers starting to appear in 2017–18. Woody vegetation cleared in the *non-remnant* BVG was generally replaced by *pasture*, *cropping*, *mining* and *infrastructure*.
- Priority **invasive species** are present across the entire Mitchell River catchment, with total invasive species richness per 18.5 km × 18.5 km grid cell ranging from 1 to 23, with a median of 6 and a mean of 6.3 (Figure 26, Figure 27).
- The most widespread priority **invasive species** are feral pig, feral cat, wild dog and rubber vine, each of which is reported to be present in 99% or more 18.5 × 18.5 km grid cells across the catchment (Figure 26, Figure 27). Rubber vine, cane toad, feral cat, feral pig, and wild dog are present in all ecosystem types (Table 12, Table 13). The aquatic invasive weeds cabomba, hymenachne, salvinia, sagittaria, water hyacinth and water lettuce are present in all aquatic ecosystem types in the catchment (Table 12).
- Ecosystem types impacted by the greatest diversity of priority **invasive species** are *seasonal floodplain marshes*, *seasonally dry tropical shrublands*, the *non-remnant* BVG, *tropical-sub-tropical dry forests and thickets*, and *pyric tussock savannas* - with a priority invasive species richness of 30, 26, 25 and 26, respectively (Table 12, Table 13, Figure 26, Figure 27).
- Invasive species in the lower Mitchell catchment and delta have significantly impacted multiple provisioning, regulating and cultural ecosystem services used by and supplied by Indigenous Traditional Owners in the Kowanyama community. As noted earlier, because of their relationship with Country and typically high level of utilisation of ecosystem services (e.g., Jackson, Finn, & Scheepers, (2014)), Indigenous communities are particularly vulnerable to adverse impacts when supply of ecosystem services is disrupted as the condition of ecosystem assets declines. Section 6.3.2 in this report, and Section 7.8.2 and Appendix A in the accompanying

Methodology Report provide detailed descriptions of the impacts that particular invasive species are having on supply of specific ecosystem services in the vicinity of Kowanyama.

- Ecosystem types with the lowest priority invasive species richness are *coastal shrublands and grasslands*, *intertidal forests and shrublands*, *coastal saltmarshes and reedbeds*, and *semi-desert steppes*, which have a priority invasive species richness of between 4 and 6 (inclusive) (Table 12, Table 13, Figure 26, Figure 27).
- **River disturbance** due to anthropogenic processes (intensity and extent of human activities in the catchment, and modifications to the flow regime) is reported using the River Disturbance Index (RDI) values developed by Stein et al. (2002). RDI data for the Mitchell catchment were obtained from the Bureau of Meteorology website for assessment year 1998 (see Data Inventory for further details). On a scale from 0 ('wild' or near-pristine) to 1 (severely degraded), all river segments in the Mitchell River catchment were found to have relatively low levels of anthropogenic-induced disturbances, with the maximum RDI value reported at 0.595 (Table 22 and Figure 39).
- At the date of the RDI assessment (1998) at least 92% of river segments in all ecosystem types in the Mitchell except *intertidal forests and shrublands*, *coastal saltmarshes and reedbeds* and *seasonal floodplain marshes*, were assigned RDI values or 0.1 or below, indicating near-pristine river condition with respect to anthropogenic-induced disturbance (Table 22 and Figure 39).
- Approximately 83% of river segments in *intertidal forests and shrublands* and *coastal saltmarshes and reedbeds* were assigned RDI values of 0.1 or below, and only 68% of river segments in *coastal saltmarshes and reedbeds* were also assessed (in 1998) to be in near-pristine condition with respect to anthropogenic-induced disturbance.
- *Pyric tussock savannas* and *subtropical-temperate forested wetlands* were the only two ecosystem types for which some river segments had RDI values of 0.4 or higher. Whilst the majority of river segments in these two ecosystem types had RDI values 0.1 or below, approximately 14 km and 54 km of river segments in *pyric tussock savannas* and *subtropical-temperate forested wetlands*, respectively, were assigned relatively high RDI values of between 0.4 and 0.6, indicating moderately degraded aquatic ecosystems with respect to anthropogenic-induced disturbance

Ecosystem services – biophysical supply and use tables: Summary

- Biophysical supply and use tables in the Mitchell catchment Ecosystem Accounts record which ecosystem types in the catchment supply which *final* ecosystem services to which users (businesses, households and government).
- Where possible, supply and use are quantified in biophysical terms (e.g., tonnes of grazing fodder, ML of water, tonnes of CO_2 sequestered, number of visitor nights).
- Biophysical supply and use of the following final ecosystem services is reported:
    - Provisioning ecosystem services
        - Crop provisioning services into irrigated agriculture (e.g., naturally occurring soil nutrients, trace minerals, soil water etc. that support production of cultivated crops).
        - Grazed biomass provisioning services into cattle rearing on cattle stations.

    - Wild fish provisioning services into the commercial barramundi fishery in the Mitchell Delta and coastal zone.
    - Note that the supply of juvenile banana prawns from the Mitchell estuary that can subsequently be caught by vessels of the Northern Prawn Fishery operating in the Gulf of Carpentaria is **not** detailed in the Mitchell supply and use accounts because (i) this is an *intermediate* service, rather than a *final* service, and (ii) the service is 'used' outside the boundary defined as the ecosystem accounting area for the Mitchell catchment Ecosystem Accounts.
    - Biomass provisioning of other animals and plants is acknowledged, but not quantified due to lack of data.
    - Water supply services (from surface water and groundwater) into irrigated agriculture.
    - Water supply services (from surface water and groundwater) for household consumption (after subsequent treatment).
- Regulating ecosystem services
    - Global climate regulation services via:
        - Carbon storage in above- and below-ground biomass
        - Carbon storage in the top 30cm of soils
        - Carbon sequestration (in the form of avoided carbon release) through manged early-season savanna fireburn utilising Indigenous Traditional Owners' expertise.
    - Soil and sediment retention services are acknowledged, but not quantified. However, drawing on prior research, an estimate of the increase in soil erosion in the catchment pre-clearing (~1750) to post-clearing (~2015) is provided.
- Cultural ecsosytem services
    - Recreation services supplied to domestic and international visitors
    - A suite of other cultural services are acknowleged, but not quantified due to lack of data: *Visual amenity services*; *Education, scientific & research services*; *Spiritual, artistic and symbolic servic*es; *Other cultural services.*
    - Co-production under the reciprocal relationship between Traditional Owners and Country gives rise to several different categories of cultural ecosystem services – when using SEEA-EA concepts and terminology. These services can potentially be accommodated within SEEA EA, either via a link to cultural identity, or by introducing *caring for Country*, *knowing that Country is being cared for*, and *knowing that Country will continue to be cared for*, as cultural ecosystem services in their own right in the 'other cultural services' category. These services were not quantified in this study.

Ecosystem services – monetary supply and use tables: Summary

- For consistency with the United Nations' System of National Accounts (SNA) globally, ecosystem accounting is based on the concept of *exchange value*. Biophysical quantities in the biophysical supply and use tables are multiplied by their respective *market or 'exchange' prices* to calculate *exchange values* for supply of ecosystem services that are reported in monetary supply and use tables.
- The intention in using exchange (or exchange-equivalent) based valuations in Ecosystem Accounts is to acknowledge and record the contributions of ecosystem services (and, by implication, the ecosystem assets that supply those services) to human wellbeing more explicitly. Before the advent of Ecosystem Accounting these contributions were absent from, or at best opaque in, national accounts.
- It is important to recognise that the $ values reported in monetary supply and use tables in Ecosystem Accounts should ***not*** be used to estimate the 'gains' and 'losses' that affected parties in society would realise from different developments at specific locations (e.g., development of a new irrigation area, or issuing concessions for timber extraction from a particular forest). The reasons for this are explained in Section 7.2.2.
- In contrast, in appropriate settings, social cost benefit analysis *could* potentially be an appropriate method for quantifying the 'gains' and 'losses' that affected parties in society would realise from different potential courses of action at specific locations. Monetary supply and use tables in Ecosystem Accounts are **not** intended to inform 'cost benefit' comparisons around specific options for development or future management.
- SEEA-EA (White cover edition) describes a suite of exchange-based or exchange-equivalent valuation methods for deriving the exchange value or exchange-equivalent value of ecosystem services, when relevant data are available.
- The following methods were used to produce valuations of the different categories of ecosystem services supplied by ecosystem types in the Mitchell catchment:
    - Provisioning services: the residual value method was used to estimate exchange-equivalent values for:
        - Crop provisioning services to agriculture
        - Grazing biomass provisioning services to cattle rearing
        - Wild fish biomass provisioning service to the commercial barramundi fishery
        - Water supply services to irrigated agriculture (bundled with crop provisioning services)
    - Regulating services:
        - Global climate regulating services supplied via:
            - Carbon sequestration (via avoided carbon release) through savanna fireburn management that utilises Indigenous Traditional Owners expertise: valued via the Austalian carbon market price for the carbon credits generated.

        - Carbon storage in above- and below-ground biomass and the top 30cm of soils: valued via the avoided damage cost approach using the social cost of carbon for Australia.
    - Cultural services:
        - Recreational services used by domestic and overseas visitors: valued via expenditures on overnight stays.
- Careful consideration was given to possible incorporation of Indigenous-related cultural ecosystem services into monetary supply and use tables in SEEA Ecosystem Accounts. However, we concluded that the significant challenges arising from contrasts between SEEA-EA's 'linear, transactional use value-based' paradigm and Traditional Owners' 'reciprocal, relational value-based' paradigm could not be resolved without careful collaboration and full consultation with Traditional Owners. Covid-19-related access issues prevented such consultations from taking place. Consequently, although potential approaches for representing Indigenous-related cultural ecosystem services in SEEA Ecosystems Accounts in monetary terms were considered, monetary valuations of Indigenous-related cultural ecosystem services were not produced in Project 4.6.
- The following valuation results were obtained for those ecosystem services for which monetary value could be estimated:
    - Mitchell ecosystems' contributions to global climate regulating services totalled 504 M$/year from carbon storage (110 M$/year from carbon storage in above- and below-ground biomass, and 391 M$/year from carbon storage in the top 30cm of soils), and an average of $3.5 M$/year from carbon sequestration (via avoided carbon release) from savanna fireburn management that utilises Indigenous Traditional Owners expertise.
    - The next most valuable ecosystem services evaluated were the crop provisioning services to irrigated production of avocado, bananas, mango and sugarcane, totalling 79 M$/year. Recreation-related services contributed 48 M$/year and grazing biomass provisioning services to the cattle rearing industry contributed 18 M$/year.
    - Accounting only for those ecosystem services that could be valued, *pyric tussock savannas* were the most valuable source of ecosystem service supply (436 M$/year) in the Mitchell catchment, followed by the non-remnant broad vegetation group (108 M$/year).
    - The *non-remnant broad vegetation group* supplied considerably higher ecosystem service value annually <u>per hectare</u> than all other ecosystem types ($1,175/ha/year), followed by *tropical-subtropical montane forests* ($162/ha/year), *temperate woodlands* ($140/ha/year), *tropical-subtropical dry forests and thickets* ($98/ha/year) and *hummock savannas* ($83/ha/year). Across the Mitchell catchment's ecosystems overall, the average ecosystem service value contributed annually per hectare was $90/ha/year.
    - An indicative *total aggregate gross ecosystem product* (GEP) for the Mitchell catchment was calculated by summing the estimated exchange value of those ecosystem services in the Mitchell whose supply and use could be quantified in monetary terms. This **total aggregate GEP was $649 million per year** in FY2020/21 AUD$. (For comparison, the total farm gate revenue generated

from irrigated cropping of avocado, banana, citrus and mango (the top four crops by revenue) in the Mitchell catchment section of the Mareeba-Dimbulah Irrigation Area was reported to be $201 million (in FY2020/21 AUD$) in 2019).

A spatial plot of the average ecosystem service value supplied annually per hectare from ecosystem types in the Mitchell is shown in Figure 3 following (repeated as Figure 48 later in the text).

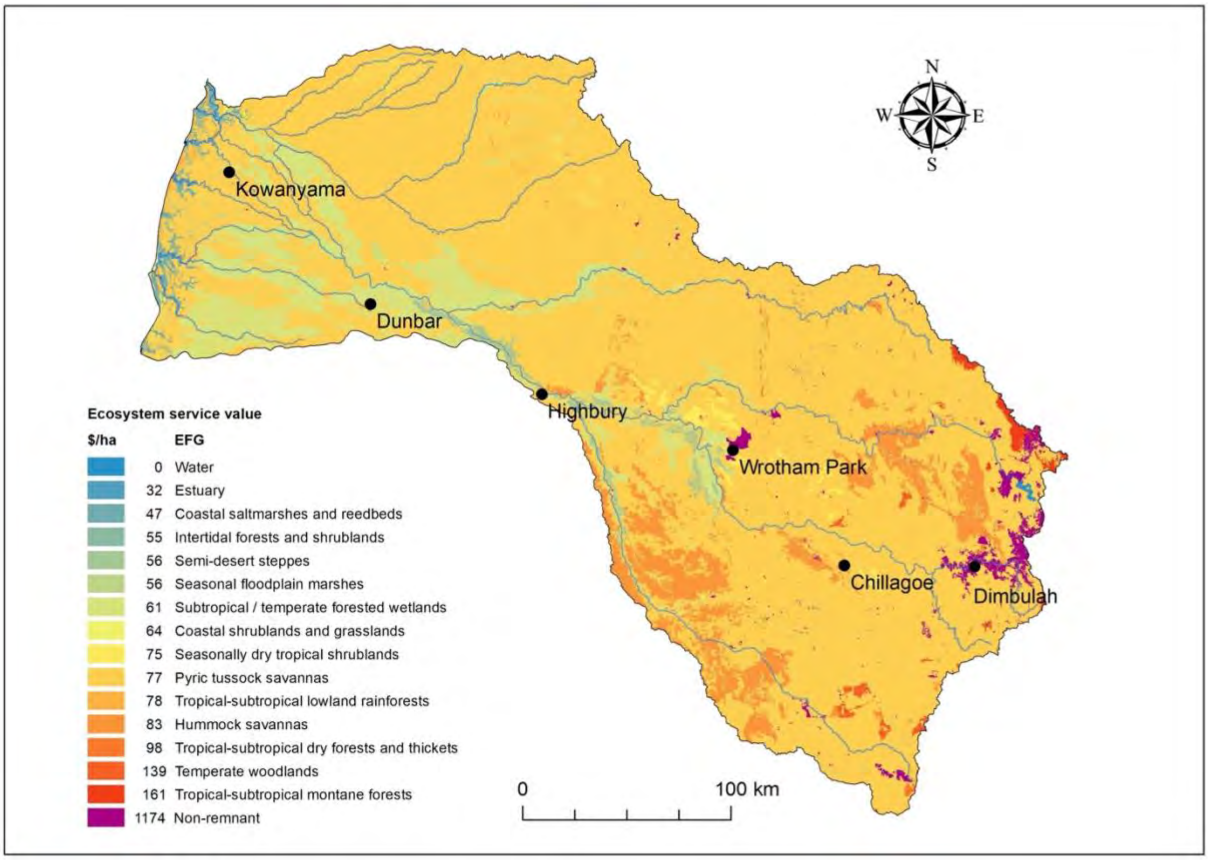

Figure 3. Total monetary value per hectare ($/ha) of selected ecosystem services from ecosystem types in the Mitchell catchment. Monetary valuations expressed in exchange value or exchange-equivalent value. Table 29, Table 30 and Table 31 report which ecosystem services are valued for each ecosystem type.

1. Ecosystem accounting for the Mitchell catchment

1.1 Ecosystem accounts

Ecosystem assets (e.g., separate stretches of rivers, wetlands and blocks of open woodland and savanna grassland) in the Mitchell River catchment in Far North Queensland supply a suite of valuable benefits via flows of ecosystem services to human society (e.g., harvestable barramundi for a commercial fishery in the Gulf of Carpentaria[1], grazing fodder for cattle on cattle stations, carbon sequestration, cultural, spiritual and recreational values from landscape and Country). Information on the extent and condition of these assets and the flows of key ecosystem services they supply, when consistently compiled over time, provides evidence of how *ecosystem assets* (grouped into mutually exclusive *ecosystem types*[2]) and *ecosystem services* are tracking alongside conventional economic indicators from Australian National Accounts (e.g., gross domestic product, consumption, investment, income and savings). Obtaining a more holistic view of how the economy *and* the environment are tracking is important for informing policy development.

The Australian Government's National Strategy and Action Plan for Environmental Economic Accounting (Commonwealth of Australia, 2018) encourages compilation of this type of information into *ecosystem accounts*. To achieve consistency and comparability nationally and internationally, ecosystem accounts should be aligned with the United Nations' SEEA-EA guidelines (United Nations et al., 2021). Information from SEEA-EA-compliant ecosystem accounts for the Mitchell catchment compiled regularly through time should improve understanding of the contributions that the catchment's ecosystems make to economic production and human wellbeing. Tracking ecosystem accounts through time should also help identify the impacts of human activities on ecosystem assets and ecosystem service flows.

The overarching objective of this project was to produce a pilot set of SEEA-EA-compliant ecosystem accounts for the Mitchell River catchment in Far North Queensland.

The layout of the SEEA-EA ecosystem accounts produced for the Mitchell is illustrated in Figure 4.

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[1] Generally described as the 'Gulf Inshore Fin Fish Fishery' which in addition to Barramundi (Lates calcarifer) includes salmon i.e., King threadfin (Polydactylus macrochir) and Blue salmon or Cooktown Salmon (Eleutheronema tetradactylum) present in the Mitchell River inshore coastal zone.

[2] Ecosystem assets are individual patches of a particular ecosystem type. Separate blocks of woodland are thus individual ecosystem assets of a defined ecosystem type e.g., temperate woodlands, or tropical/subtropical dry forests and thickets. Ecosystem types are mutually exclusive.

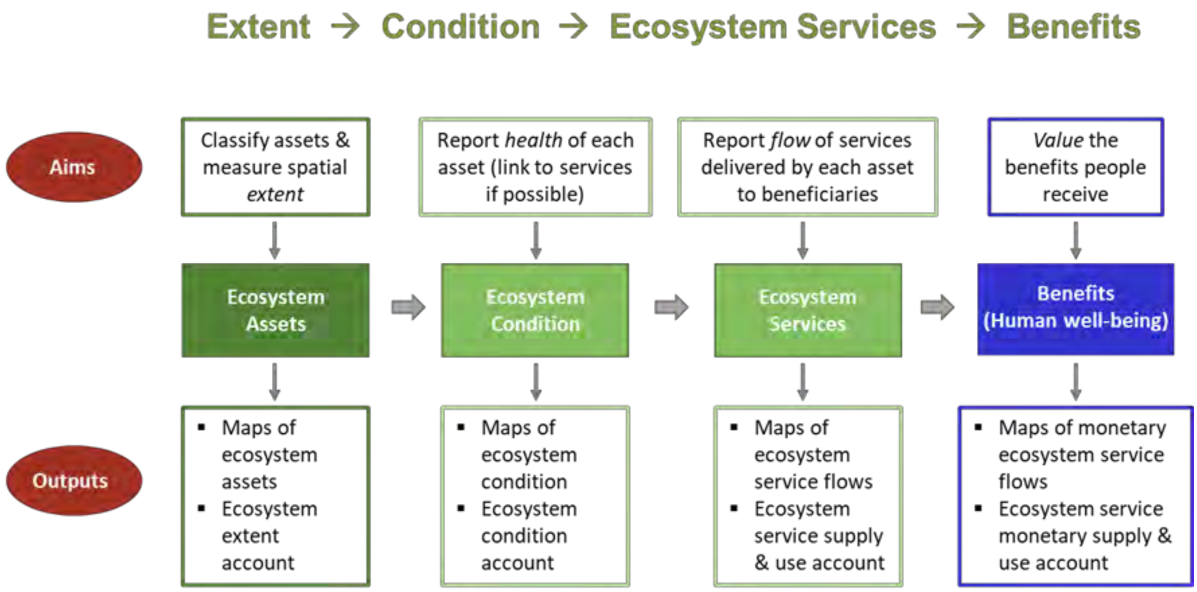


Figure 4. Layout of the SEEA-EA ecosystem accounts for the Mitchell catchment.

1.2 The Mitchell River catchment

For tens of thousands of years prior to appropriation by European settlers, the ancestors of today's Traditional Ownersowners of the Mitchell catchment socialised the landscapes of the region as they managed land and water, fulfilled custodial responsibilities under customary law and maintained an economic arrangement that sustained their way of life (Barber, Jackson, Shellberg, & Sinnamon, 2014; Barber, Jackson, Dambacher, & Finn, 2015; Jackson & Palmer, 2015). In SEEA-EA ecosystem accounts there is a requirement to select a baseline from which changes in ecosystem extent and ecological condition can be referenced. The SEEA EA (White Cover version) recognises that different forms of reference condition may be appropriate for 'natural' and 'anthropogenic' ecosystems – and it recognises that an appropriate reference condition could be a 'historical condition' (United Nations et al., 2021; Annex 5.2, paragraph A5.1 and Table A5.8, p.115).

In compiling ecosystem accounts for the Mitchell catchment we adopt estimated extents and conditions of the catchment's ecosystem types as socialised landscapes under Traditional Ownership prior to settler appropriation as our 'reference conditions'. This is consistent with use of 'pre-clearing' – which is placed historically as the year 1750 – as the reference condition for the Queensland Herbarium's Broad Vegetation Groups and Regional Ecosystems across the state (Neldner et al., 2019; State of Queensland, 2018). Consequently, we conduct a cross-walk between the Queensland Herbarium's ecosystem designations and mapping layers and the IUCN's Global Ecosystem Typology (D. A. Keith, Ferrer-Paris, Nicholson, & Kingsford, 2020) to produce spatial representations of ecosystem types in the Mitchell catchment in our SEEA-EA Ecosystem Accounts. We intend that defining reference extents and conditions in this way respectfully acknowledges that 'pre-clearing', the land and water ecosystems in the Mitchell catchment were actively managed as socialised landscapes by the ancestors of today's Traditional Owners in fulfilment of their custodial responsibilities, and that this condition can be considered a 'stable socio-ecological state' (United Nations et al., 2021; Annex 5.2, paragraph A5.1 and Table A5.8, p.115).

The Mitchell River catchment in Far North Queensland is one of the 245 catchments (National Catchment Boundary Level 2) in Australia (Stein, Hutchinson, & Stein, 2011). The catchment is situated in the tropical north of Queensland and covers an area of approximately 71,720 km^2, which representsr 0.93% and 4.15% of the total land area of Australia and Queensland, respectively (Geoscience Australia, n.d.). The catchment system consists of five main rivers: Alice, Palmer, Mitchell, Walsh and Lynd, flowing from the Great Dividing Range in the east and discharges to the Gulf of Carpentaria in the west (Figure 5).

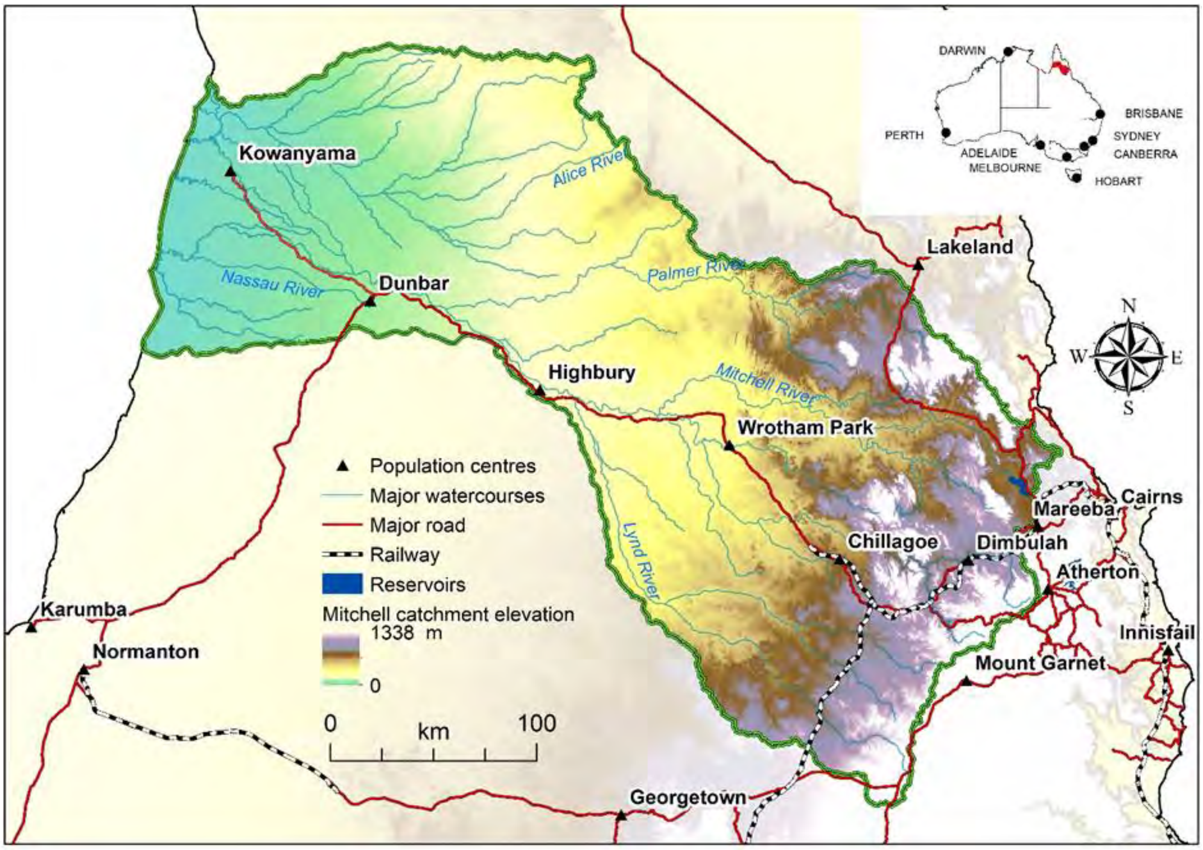


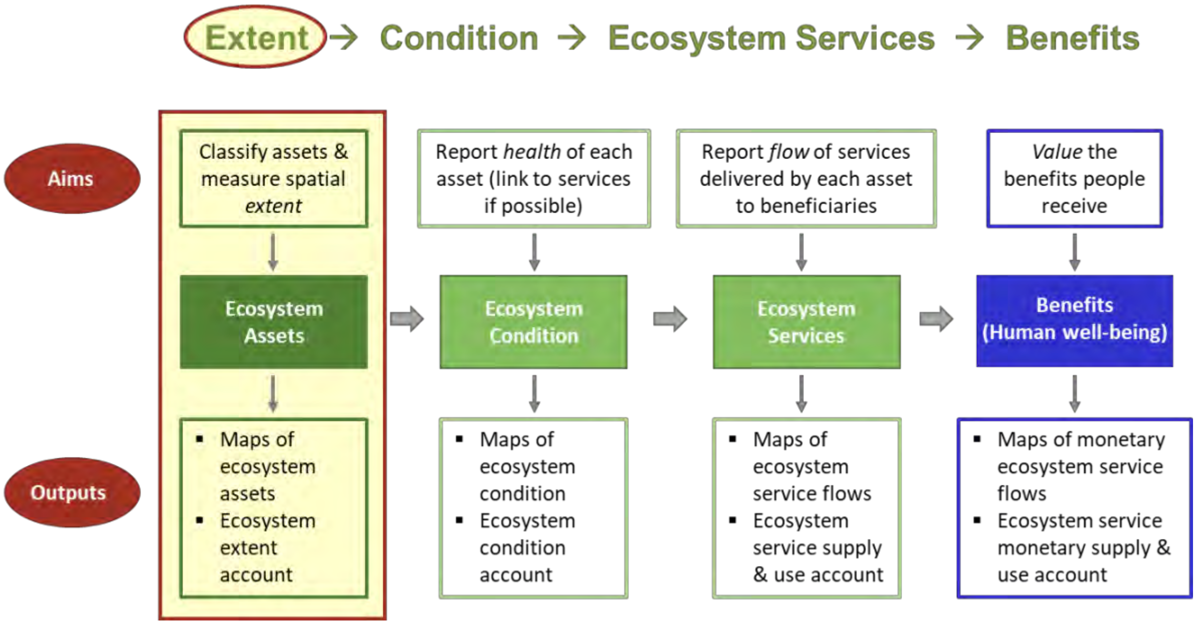
Figure 5. Topographical map of the Mitchell River catchment in Far North Queensland showing the main rivers, reservoirs, major roads and railways. The inset map shows the catchment's location within Australia.

This project produced a pilot set of SEEA-EA-compliant ecosystem accounts for the Mitchell River catchment. The accounts comprise the following SEEA-EA accounting tables, supported by relevant maps:

- Ecosystem extent account
- Ecosystem condition variable account and supplementary environmental pressures
- Ecosystem service biophysical supply and use account
- Ecosystem service monetary supply and use account

Ecosystem accounting involves compilation and reporting of data on ecosystems and ecosystem services in a standardised format, in accordance with the guidelines provided in the SEEA-EA framework (White Cover version) (United Nations et al., 2021). To maintain consistency with the project's presentation in the Main Technical Report and in the accompanying Data Inventory, accounting tables are presented in the sequence shown in Figure 4. Subsequent chapters of this document present ecosystem accounts for the Mitchell catchment, following the sequence shown in Figure 4.

2. Extent accounts



2.1 Summary

- The ecosystem accounting area for the Mitchell catchment SEEA Ecosystem Accounts was defined as the watershed of the Mitchell River catchment, extending seven nautical miles from the shoreline into the Gulf of Carpentaria.
- The total area of the Mitchell catchment in the Ecosystem Extent Account is 7,172,218 ha (71,722 km^2). This represents 0.93% and 4.15% of the total land area of Australia and the state of Queensland, respectively.
- Ecosystem assets (i.e., individual areas of grassland, forest, wetland etc.) in the Mitchell catchment were categorised into 16 ecosystem types, of which 13 were matched to IUCN Global Ecosystem Typology's Ecosystem Functional Groups (EFGs) (Keith, Ferrer-Paris, Nicholson, & Kingsford, 2020) and the remaining three were allocated into the Queensland Broad Vegetation Groups (BVG) of water, estuary and non-remnant (Neldner et al., 2019) (Figure 6). This correspondence was required because SEEA-EA recommend that ecosystem types should be categorised using IUCN EFGs. A cross-walk between the Broad Vegetation Groups of Queensland (Neldner et al., 2019) and IUCN GETs was informed by experts from the Queensland Herbarium. Ecosystem extent, ecosystem condition variables, and supply and use of ecosystem services in biophysical and monetary terms are all reported against these 16 ecosystem types in the Mitchell Ecosystem Accounts.

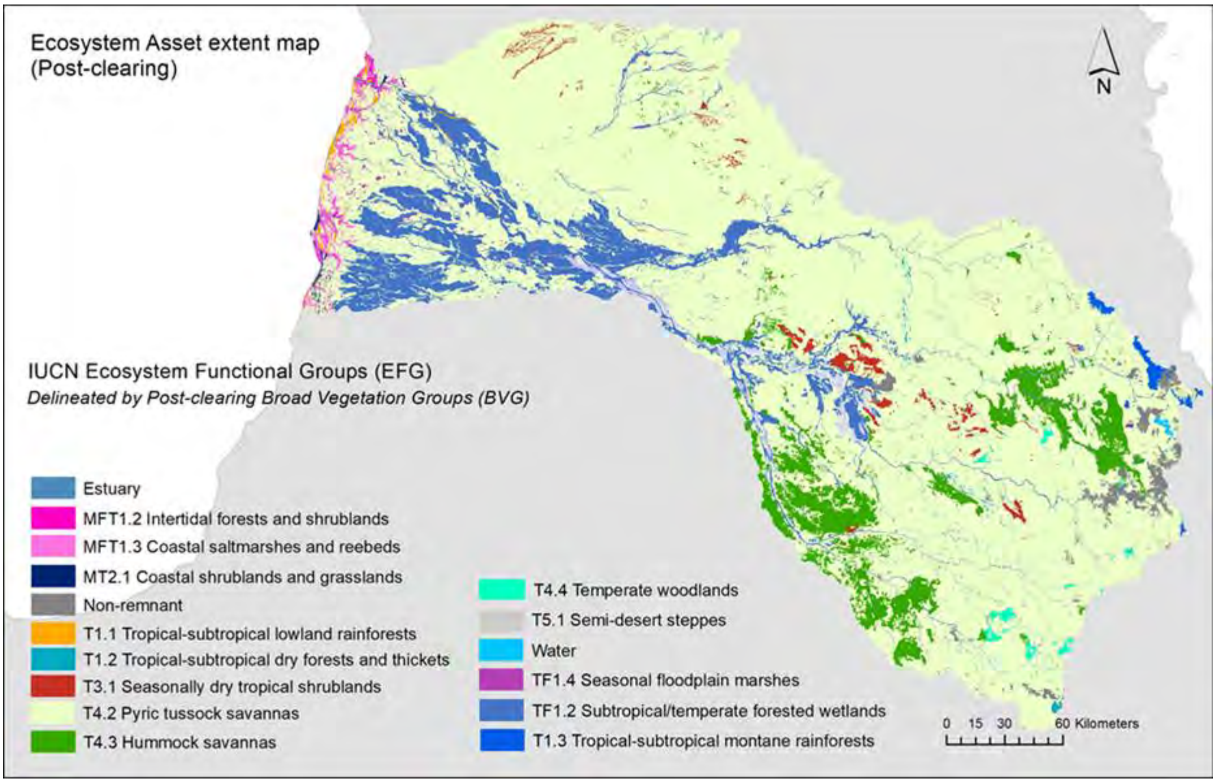


Figure 6. Ecosystem extents post-clearing (~2015), by ecosystem type.

- The extents of rivers and waterbodies are reported separately to the extents of the 16 ecosystem types in the catchment, drawing on data from Digital Earth Australia, Geoscience Australia, and Landsat satellite imagery.
- Pyric tussock savannas, cover 78% of total catchment area, post-clearing. Together with subtropical-temperate forested wetlands (10%) and hummock savannas (6%), these three ecosystem types cover 94% of the total catchment area, post-clearing (Table 1 and Figure 8).
- Overall, there has been only relatively modest change in the extents of the 16 ecosystem types in the Mitchell catchment between the pre-clearing (~1750) and post-clearing (~2015) ecosystem extent accounts (Table 1, Table 2, Figure 7 and Figure 8). Exceptions to this are the seasonal floodplain marshes (43% reduction), tropical-subtropical montane rainforests (8% reduction), tropical-subtropical lowland rainforests (3% reduction), and seasonally dry tropical shrublands (4% increase) ecosystem types.
- The largest changes, in terms of absolute area (Table 3) are:
  - Creation of 91,612 ha of the non-remnant broad vegetation group through anthropogenic land use change.
  - Reclassification of 17,861 ha of seasonal floodplain marshes as subtropical-temperate forested wetlands.
  - Reclassification of 16,229 ha of subtropical-temperate forested wetlands as pyric tussock savanna.
  - Reclassificiation of 12,611 ha of pyric tussock savanna as subtropical-temperate forested wetlands.

- Expressing areal change as a percentage of pre-clearing area (Table 4), the largest changes are:
    - Anthropogenic conversion of 8.3% of pre-clearing tropical-subtropical montane rainforest, 4.3% of tropical-subtropical lowland rainforests, 1.5% of pyric tussock savanna, and 1.5% of seasonal floodplain marshes to non-remnant.
    - Reclassification of 40% of the pre-clearing area of seasonal floodplain marshes as subtropical-temperate forested wetlands.
    - Reclassification of 16.6% of pre-clearing tropical-subtropical dry forests and thickets, 3.3% of seasonal floodplain marshes, 2.2% of subtropical-temperate forested wetlands, 2% of seasonally dry tropical shrublands, 1.4% of hummock savannas, and 1.1% of temperate woodlands to pyric tussock savanna.

  The factors driving these reclassifications are not immediately apparent.

- Major land uses in the non-remnant BVG in 2015 comprised grazing native vegetation (64%), irrigated cropping (17%), irrigated perennial horticulture (6%) and cropping (~2%) (Table 7 and Figure 11 to Figure 16).
- Rivers and watercourse areas are categorised as estuarine (8%) and freshwater (92%). A significant proportion of freshwater watercourse areas are non-perennial (52,130 km^2) as opposed to perennial (13,149 km^2) (Figure 9). Perennial watercourse lines in the Mitchell catchment are much shorter (1,913 km) than non-perennial watercourse lines (6,852 km) (Figure 10).
- Grazing native vegetation and Conservation and Natural Environments (Managed resource protection and nature conservation) are the dominant QLUMP land uses in the catchment, occupying 81% and 15% of catchment area, respectively (Figure 17 and Figure 18).

2.2 Ecosystem assets within the Mitchell catchment based on IUCN Global Ecosystem Typology

SEEA-EA indicate that ecosystem types should be categorised using the IUCN Global Ecosystem Typology (IUCN GET) (D. A. Keith et al., 2020). A cross-walk between the Broad Vegetation Groups of Queensland (Neldner et al., 2019) and IUCN GETs was therefore conducted, in consultation with experts at the Queensland Herbarium. This cross-walk produced 13 IUCN ecosystem functional groups (EFGs) and 3 Broad Vegetation Groups (BVGs) of estuary, non-remnant and water for the Mitchell catchment.

The ecosystem extent account based on the 13 IUCN GETs and the 3 BVGs comprises the following maps and tables:

- Figure 7 shows the extent of each ecosystem type (i.e., the 13 EFGs and 3 BVGs) for the pre-clearing (~1750) period.
- Figure 8 shows the extent of each ecosystem type (i.e., the 13 EFGs and 3 BVGs) for the post-clearing (~2015) period.
- Table 1 shows the ecosystem extent account table for pre- and post-clearing periods.
- Table 2 shows another variant of ecosystem extent account which reports the change in extent between pre- and post-clearing periods.

- Table 3 shows ecosystem types change matrix between pre- and post-clearing, expressed as a percentage change in extent between the two periods.

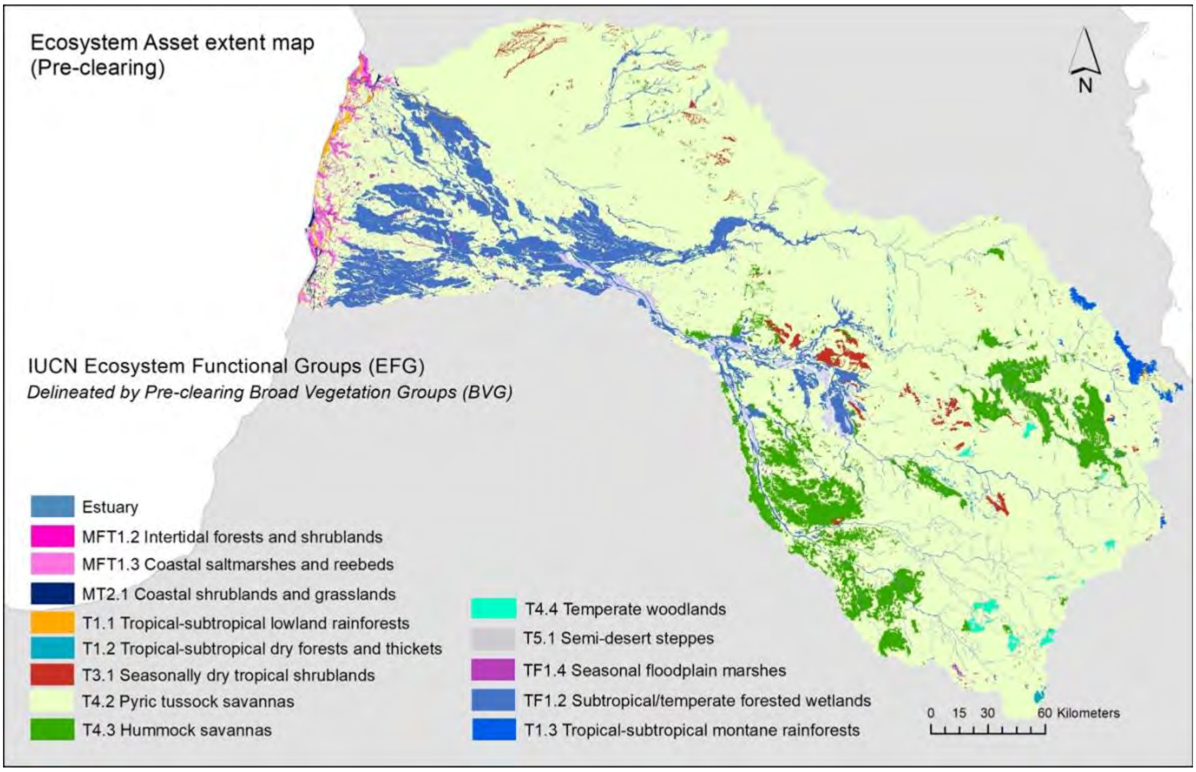


Figure 7. Extent by ecosystem type, pre-clearing (~1750).

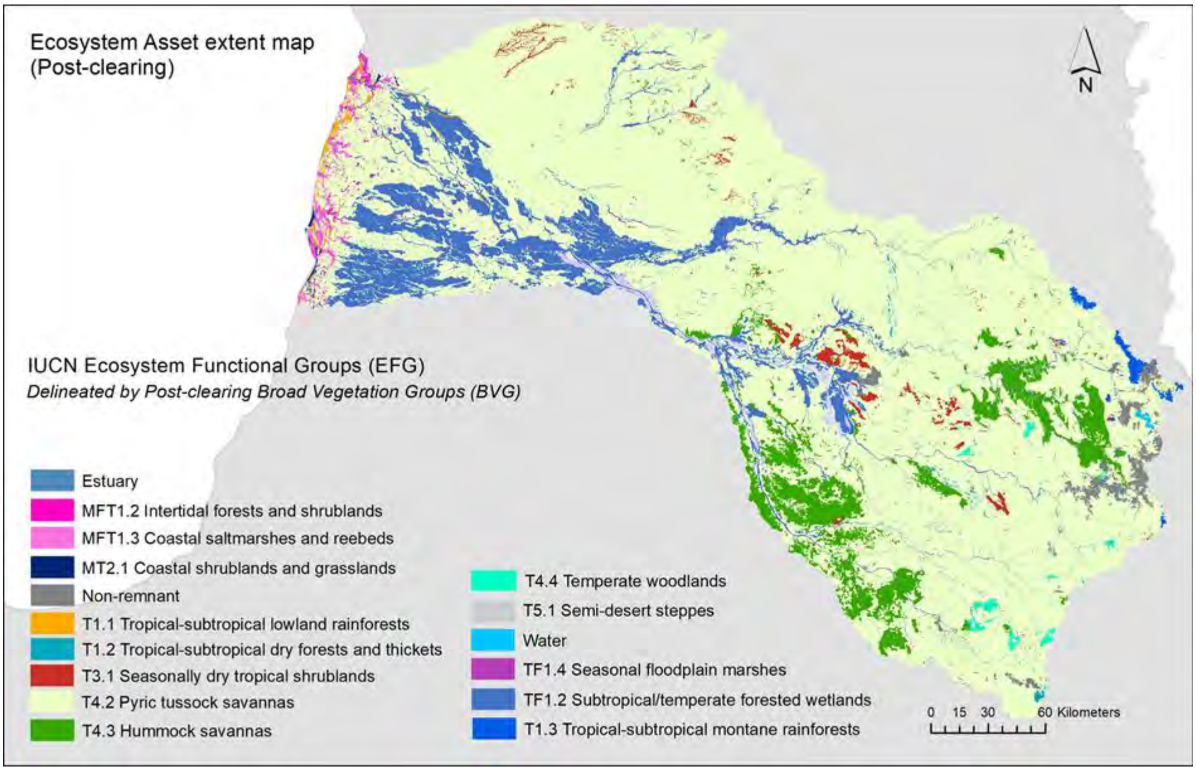


Figure 8. Extent by ecosystem type, post-clearing (~2015).

Table 1. Ecosystem extent account for the Michell catchment for pre- and post-clearing time periods.Area of each ecosystem type is expressed in hectares. The remaining extents of ecosystem types that are still present today are reported in the final column as percentages. Gray shaded cells indicate that the relevant extent was not available. EFG refers to ecosystem functional group.

IUCN EFG Name	IUCN EFG code	Pre-clearing extent (ha)	Post-clearing extent (ha)	Pre-clearing remaining (%)
Terrestrial				
Tropical-subtropical forests				
Tropical-subtropical lowland rainforests	T1.1	19,070	18,296	96.94
Tropical-subtropical dry forest and thickets	T1.2	11,960	12,248	102.41
Tropical-subtropical montane rainforests	T1.3	28,615	26,323	91.99
Shrublands & shrubby woodlands				
Seasonally dry tropical shrublands	T3.1	69,389	72,205	104.06
Savannas & grasslands				
Pyric tussock savannas	T4.2	5,685,737	5,603,698	98.56
Hummock savannas	T4.3	442,372	435,831	98.52
Temperate woodlands	T4.4	21,120	21,049	99.66
Deserts & semi-deserts				
Semi-desert steppes	T5.1	56,687	56,506	99.68
Freshwater–terrestrial				
Palustrine wetlands				
Subtropical-temperate forested wetlands	TF1.2	728,885	740,341	101.57
Seasonal floodplain marshes	TF1.4	44,414	25,233	56.81
Marine–terrestrial				
Supralittoral coastal systems				
Coastal shrublands and grasslands	MT2.1	5,960	5,962	100.03
Marine–freshwater–terrestrial				
Brackish tidal				
Intertidal forests and shrublands	MFT1.2	11,157	11,211	100.48
Coastal saltmarshes and reedbeds	MFT1.3	40,906	40,972	100.16
Broad Vegetation Groups of Queensland				
Non-remnant			91,612	
Water			4,785	
Estuary		5,947	5,947	100.00
Total		**7,172,218**	**7,172,218**	

Table 2. Ecosystem extent account for the Mitchell catchment. Change in extent is shown as the difference between pre-clearing and post-clearing areas. Area is reported in hectares. EFG refers to ecosystem functional group. Numbers in brackets are negative, i.e., indicate an overall reduction in area.

Realm	**Terrestrial**								
Biome	T1 Tropical-subtropical forests			T3 Shrublands & shrubby woodlands	T4 Savannas & grasslands			T5 Deserts & semi-deserts	Broad Vegetation Groups of Qld
EFG	T1.1 Tropical-subtropical lowland rainforests	T1.2 Tropical-subtropical dry forests and thickets	T1.3 Tropical-subtropical montane forests	T3.1 Seasonally dry tropical shrublands	T4.2 Pyric tussock savannas	T4.3 Hummock savannas	T4.4 Temperate woodlands	T5.1 Semi-desert steppes	Non-remnant
Opening extent	**19,070**	**11,960**	**28,615**	**69,389**	**5,685,737**	**442,372**	**21,120**	**56,687**	**0**
Additions to extent	0	288	0	2,816	0	0	0	0	91,611
Reductions in extent	774	0	2,292	0	82,039	6,541	71	181	0
Net change in extent	(774)	288	(2,292)	2,816	(82,039)	(6,541)	(71)	(181)	91,611
Closing extent	**18,296**	**12,248**	**26,323**	**72,205**	**5,603,698**	**435,831**	**21,049**	**56,506**	**91,611**

Realm	**Freshwater–terrestrial**		**Marine–terrestrial**	**Marine–freshwater–terrestrial**		Broad Vegetation Groups of Queensland	
Biome	TF1 Palustrine wetlands		MT2 Supralittoral coastal systems	MFT1 Brackish tidal			
EFG	TF1.2 Subtropical-temperate forested wetlands	TF1.4 Seasonal floodplain marshes	MT2.1 Coastal shrublands and grasslands	MFT1.2 Intertidal forests & shrublands	MFT1.3 Coastal saltmarshes & reedbeds	Water	Estuary
Opening extent	**728,885**	**44,414**	**5,960**	**11,157**	**40,906**	**0**	**5,947**
Additions to extent	11,456	0	2	54	66	4,785	0
Reductions in extent	0	19,181	0	0	0	0	0
Net change in extent	11,456	(19,181)	2	54	66	4,785	0
Closing extent	**740,341**	**25,233**	**5,962**	**11,211**	**40,972**	**4,785**	**5,947**

Table 3. Ecosystem type change matrix (in hectares). The top data row reports the number of hectares of each ecosystem type and the estuary broad vegetation group pre-clearing (~1750). The third column from the left reports the number of hectares of each ecosystem type and the estuary, non-remnant and water broad vegetation groups post-clearing (~2015). Cells in the body of the table report the number of hectares from the pre-clearing ecosystem type at the head of the column assigned to the relevant row's ecosystem type or broad vegetation group post-clearing.

Ecosystem Type nomenclature (using IUCN EFGs and Broad Vegetation Groups)													
Estuary	Intertidal forests and shrublands	Coastal saltmarshes and reedbeds	Coastal shrublands and grasslands	Tropical-subtropical lowland rainforests	Tropical-subtropical dry forest and thickets	Tropical-subtropical montane rainforests	Seasonally dry tropical shrublands	Pyric tussock savannas	Hummock savannas	Temperate woodlands	Semi-desert steppes	Subtropical-temperate forested wetlands	Seasonal floodplain marshes
Estuary	MFT1.2	MFT1.3	MT2.1	T1.1	T1.2	T1.3	T3.1	T4.2	T4.3	T4.4	T5.1	TF1.2	TF1.4

			Pre-clearing													
	IUCN EFG		Estuary	MFT1.2	MFT1.3	MT2.1	T1.1	T1.2	T1.3	T3.1	T4.2	T4.3	T4.4	T5.1	TF1.2	TF1.4
		Area (ha)	5,946.8	11,156.7	40,906.1	5,960.1	19,070.5	11,959.8	28,615.5	69,388.8	5,685,737.0	442,371.8	21,120.2	56,686.7	728,884.7	44,414.0
Post-clearing	Estuary	5,946.8	5,946.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	MFT1.2	11,210.8	0.0	11,136.2	73.8	0.0	0.0	0.0	0.0	0.0	0.7	0.0	0.0	0.0	0.0	0.0
	MFT1.3	40,972.4	0.0	20.4	40,631.2	4.0	0.0	0.0	0.0	0.0	316.7	0.0	0.0	0.0	0.0	0.0
	MT2.1	5,961.8	0.0	0.0	0.7	5,916.9	0.0	0.0	0.0	0.0	44.1	0.0	0.0	0.0	0.0	0.0
	Non-remnant	91,611.5	0.0	0.0	0.1	11.9	824.2	38.8	2,366.6	79.8	83,232.2	1531.8	182.1	175.4	2,515.1	653.6
	T1.1	18,296.0	0.0	0.0	0.0	0.0	18,215.1	0.0	1.4	0.0	79.5	0.0	0.0	0.0	0.0	0.0
	T1.2	12,248.4	0.0	0.0	0.0	0.0	10.9	9,661.5	271.8	179.1	2,099.6	7.9	3.6	0.0	13.9	0.0
	T1.3	26,322.9	0.0	0.0	0.0	0.0	17.3	0.0	25,700.6	141.2	463.9	0.0	0.0	0.0	0.0	0.0
	T3.1	72,205.0	0.0	0.0	0.0	0.0	0.0	187.9	76.9	67,501.8	4,388.3	0.6	0.0	0.0	49.5	0.0
	T4.2	5,603,698.0	0.0	0.0	48.0	24.9	0.2	1,986.2	196.2	1359.1	5,576,093.0	6,081.0	230.1	1.3	16,228.7	1,449.2
	T4.3	435,830.8	0.0	0.0	0.0	0.0	0.0	20.8	0.0	50.2	1,093.5	433,497.5	53.3	0.0	1115.1	0.2
	T4.4	21,048.7	0.0	0.0	0.0	0.0	0.0	29.3	0.0	1.3	222.0	74.1	20,566.0	0.0	156.0	0.0
	T5.1	56,506.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	56,506.2	0.0	0.0
	TF1.2	740,341.5	0.0	0.0	0.0	0.0	0.0	35.2	0.0	73.5	12,610.7	1125.7	83.1	0.0	708,551.9	17,861.4
	TF1.4	25,232.6	0.0	0.0	152.2	2.3	0.0	0.0	0.0	0.0	611.8	0.3	0.0	0.0	67.4	24,398.5
	Water	4,785.3	0.0	0.0	0.0	0.0	2.8	0.0	2.0	2.8	4,480.9	52.8	2.1	3.8	187.0	51.0

To exemplify how to read Table 3, consider the tropical/subtropical lowland rainforests ecosystem type (T1.1). From the data column headed ‘T1.1’, we see that 19,070.5 ha of this ecosystem type were reported in the pre-clearing (~1750) data. Looking down the T1.1. column, we see that 824.2 ha of pre-clearing tropical/subtropical lowland rainforests are now classified as being in the non-remnamt broad vegetation group, 18,215.1 ha are still classified as tropical/subtropical lowland rainforests, 10.9 ha are now classified as being tropical/subtropical dry forest and thickets (T1.2), 17.3 ha as tropical/subtropical montane rainforests, 0.2 ha as pyric tussock savannas, and 2.8ha as water. Cells on the leading diagonal report the number of hectares of each ecosystem type pre-clearing that remained assigned to that same ecosystem type post-clearing.

Following similar logic, cells along the row labelled ‘Non-remnant’, show from which pre-clearing ecosystem types land was taken to become the non-remnant broad vegetation group (principally, 83,232.2ha from pyric tussock savannas, 2,515.1ha from subtropical-temperate forested wetlands, and 2,366.6ha from tropical/subtropical montane rainforests).

Table 4 reports the same information in percentage terms. Thus, the T1.1 column in Table 4 reports that 95.5% of the area that was categorised as tropical/subtropical lowland rainforests pre-clearing (~1750) is still classified as that same ecosystem type post-clearing. However, 4.3% of the tropical/subtropical lowland rainforest area pre-clearing is classified as being in the non-remnant broad vegetation group post-clearing (~2015), 0.1% of what was classified as tropical/subtropical lowland rainforest pre-clearing is now classified as tropical/subtropical dry forest and thickets and as tropical/subtropical montane rainforest. Looking along the ‘non-remnant’ row in Table 4 shows that 8.3% of the pre-clearing area of tropical/subtropical montane rainforest and 4.3% of the pre-clearing tropical/subtropical lowland rainforest has been lost as a consequence of land conversion to the non-remnant broad vegetation group, whereas only small proportions of other ecosystem types have been lost to this process. Table 4 also reports two other major changes of ecosystem type classification pre-clearing to post-clearing; 40.2% of land that was seasonal floodplain marshes pre-clearing switched to subtropical-temperate forested wetlands post-clearing, and 16.6% of pre-clearing topical/subtropical dry forests and thickets became categorised as pyric tussock savanna post-clearling. The reasons for these changes in categorisation are not immediately evident from the data. This highlights an important use of the ecosystem type change matrix in focusing attention on (potentially) unexplained changes in ecosystem type between consecutive ecosystem extent accounts (here ‘post-clearing vs. ‘pre-clearing).

Table 4. Ecosystem type change matrix (reporting percentage change from pre-clearing areas). The top row of the table reports the number of hectares of each ecosystem type and the estuary broad vegetation group pre-clearing (~1750). The left-most column reports the number of hectares of each ecosystem type and the estuary, non-remnant and water broad vegetation groups post-clearing (~2015). Cells in the body of the table report the percentage of the area of the pre-clearing ecosystem type at the head of the column that was assigned to the relevant row's ecosystem type or broad vegetation group post-clearing.

Ecosystem Type nomenclature (using IUCN EFGs and Broad Vegetation Groups)													
Estuary	Intertidal forests and shrublands	Coastal saltmarshes and reedbeds	Coastal shrublands and grasslands	Tropical-subtropical lowland rainforests	Tropical-subtropical dry forest and thickets	Tropical-subtropical montane rainforests	Seasonally dry tropical shrublands	Pyric tussock savannas	Hummock savannas	Temperate woodlands	Semi-desert steppes	Subtropical-temperate forested wetlands	Seasonal floodplain marshes
Estuary	MFT1.2	MFT1.3	MT2.1	T1.1	T1.2	T1.3	T3.1	T4.2	T4.3	T4.4	T5.1	TF1.2	TF1.4

			Pre-clearing													
	IUCN EFG		Estuary	MFT1.2	MFT1.3	MT2.1	T1.1	T1.2	T1.3	T3.1	T4.2	T4.3	T4.4	T5.1	TF1.2	TF1.4
		Area (ha)	5,946.8	11,156.7	40,906.1	5,960.1	19,070.5	11,959.8	28,615.5	69,388.8	5,685,737.0	442,371.8	21,120.2	56,686.7	728,884.7	44,414.0
Post-clearing	Estuary	5,946.8	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	MFT1.2	11,210.8	0.0	99.8	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	MFT1.3	40,972.4	0.0	0.2	99.3	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	MT2.1	5,961.8	0.0	0.0	0.0	99.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Non-remnant	91,611.5	0.0	0.0	0.0	0.2	4.3	0.3	8.3	0.1	1.5	0.3	0.9	0.3	0.3	1.5
	T1.1	18,296.0	0.0	0.0	0.0	0.0	95.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	T1.2	12,248.4	0.0	0.0	0.0	0.0	0.1	80.8	0.9	0.3	0.0	0.0	0.0	0.0	0.0	0.0
	T1.3	26,322.9	0.0	0.0	0.0	0.0	0.1	0.0	89.8	0.2	0.0	0.0	0.0	0.0	0.0	0.0
	T3.1	72,205.0	0.0	0.0	0.0	0.0	0.0	1.6	0.3	97.3	0.1	0.0	0.0	0.0	0.0	0.0
	T4.2	5,603,698.0	0.0	0.0	0.1	0.4	0.0	16.6	0.7	2.0	98.1	1.4	1.1	0.0	2.2	3.3
	T4.3	435,830.8	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.1	0.0	98.0	0.3	0.0	0.2	0.0
	T4.4	21,048.7	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	97.4	0.0	0.0	0.0
	T5.1	56,506.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	99.7	0.0	0.0
	TF1.2	740,341.5	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.1	0.2	0.3	0.4	0.0	97.2	40.2
	TF1.4	25,232.6	0.0	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	54.9
	Water	4,785.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.1

2.3 Supplementary ecosystem extents for waterbodies and rivers

Supplementary extent accounts for waterbodies and rivers in the Mitchell catchment are summarised in in the following maps and tables:

Figure 9 shows watercourse areas (estuarine and freshwater). Watercourse areas are split between estuarine (8%) and freshwater (92%). A significant proportion of freshwater watercourse areas are non-perennial covering an area of 52,130 km^2 compared to perennial watercourse areas of 13,149 km^2.

Figure 10 shows major watercourse lines (perennial and non-perennial). Watercourse lines are described by the area covered by water (in km^2) and by their linear features, shown as length in kilometres, for the most recent year 2020. Perennial watercourse lines in the Mitchell catchment are much shorter (1,913 km) than non-perennial watercourse lines (6,852 km).

A supplementary extent accounts for waterbodies, dry-season wetlands and water observations from space across ecosystem types is shown in Table 5.

A supplementary extent account for watercourse lines (i.e., rivers) by ecosystem type is shown in Table 6.

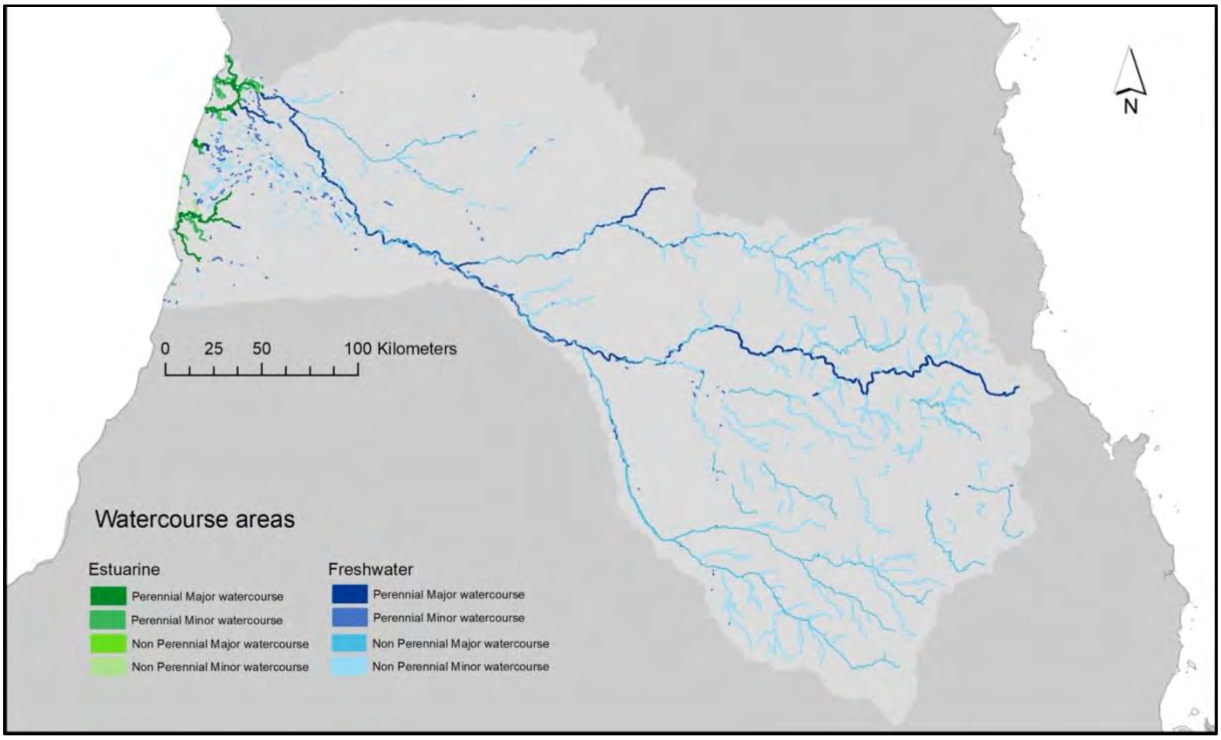


Figure 9. Watercourse areas (estuarine and freshwater) for the year 2020.

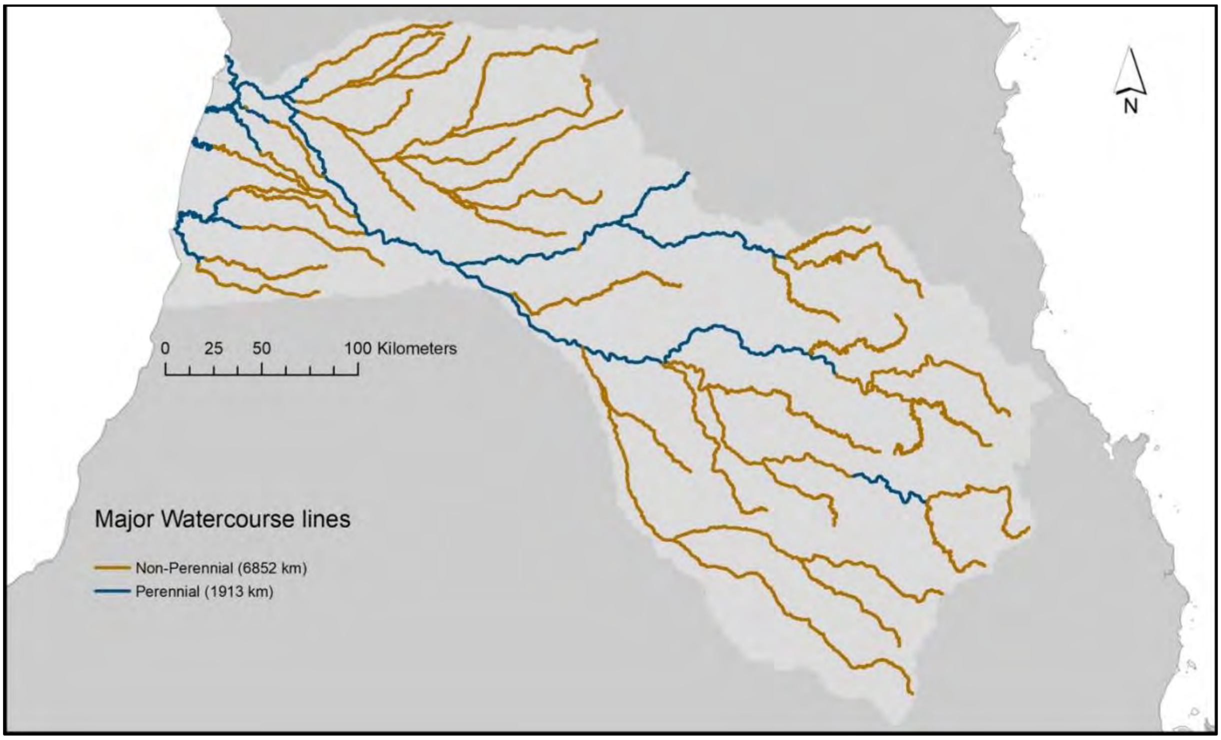


Figure 10. Major watercourse lines (perennial and non-perennial) for the year 2020.

Table 5. Supplementary extent account for waterbodies, dry-season wetlands and water observations from space by ecosystem types, presented in terms of area (hectares) and count, for the year 2020.

Realm	**Terrestrial**								
Biome	T1 Tropical-subtropical forests			T3 Shrublands & shrubby woodlands	T4 Savannas & grasslands			T5 Deserts & semi-deserts	Broad Vegetation Groups of Queensland
EFG	T1.1 Tropical-subtropical lowland rainforests	T1.2 Tropical-subtropical dry forests and thickets	T1.3 Tropical-subtropical montane forests	T3.1 Seasonally dry tropical shrublands	T4.2 Pyric tussock savannas	T4.3 Hummock savannas	T4.4 Temperate woodlands	T5.1 Semi-desert steppes	Non-remnant
Waterbodies (Digital Earth Australia)									
Mean extent of a waterbody (ha)	1.8	0.6	0	0.6	1.5	0.5	0.4	2.2	1.3
Number of waterbodies	135	1	0	12	5,850	23	3	141	391
Dry-season wetlands: waterholes persisting during dry season for 50 days or more (Landsat for NAWRA)									
Mean extent of a waterhole (ha)	1.15	0.31	0	0.37	0.43	0.27	0.3	0.38	0.67
Number of waterholes	142	1	0	11	2,680	33	2	78	460
Dry-season wetlands: waterholes persisting during dry season for 100 days or more (Landsat for NAWRA)									
Mean extent of a waterhole (ha)	0.84	0.3	0	0.35	0.33	0.32	0.19	0.36	0.65
Number of waterholes	129	1	0	5	999	19	1	42	217
Water observations from space (Geoscience Australia)									
Mean extent of a waterbody (ha)	0.6	0.25	0	0.33	0.37	0.2	0.26	0.35	0.48
Number of waterbodies	156	1	0	9	3,230	23	3	80	323

Table 5 (continued).

Realm	Freshwater–terrestrial		Marine–terrestrial	Marine–freshwater–terrestrial		Broad Vegetation Groups of Queensland	
Biome	TF1 Palustrine wetlands		MT2 Supralittoral coastal systems	MFT1 Brackish tidal			
EFG	TF1.2 Subtropical-temperate forested wetlands	TF1.4 Seasonal floodplain marshes	MT2.1 Coastal shrublands and grasslands	MFT1.2 Intertidal forests & shrublands	MFT1.3 Coastal saltmarshes & reedbeds	Water	Estuary
Waterbodies (Digital Earth Australia)							
Mean extent of a waterbody (ha)	4.3	6.4	0.3	0.8	6.8	20.5	2.1
Number of waterbodies	13,129	6,331	9	256	3,102	3,951	232
Dry-season wetlands: waterholes persisting during dry season for 50 days or more (Landsat for NAWRA)							
Mean extent of a waterhole (ha)	1.11	1.58	0.4	0.86	0.42	2.87	1.83
Number of waterholes	6,184	2,551	53	617	330	825	161
Dry-season wetlands: waterholes persisting during dry season for 100 days or more (Landsat for NAWRA)							
Total extent (ha)	1.2	1.07	1.26	1.8	0.43	12.11	23.63
Count (no.)	3,660	1,038	118	1,795	285	3,246	4,253
Water observations from space (Geoscience Australia)							
Mean extent of a waterbody (ha)	1.2	1.26	0.18	0.55	0.79	9.51	8.44
Number of waterbodies	11,496	3,574	16	784	1,310	3,728	5,273

Table 6. Supplementary extent account for rivers by ecosystem type. Rivers are described by the area covered by water (in ha) and by their linear features, shown as length in kilometres, for the year 2020. Cells shaded in grey indicate categories that are not relevant for the ecosystem types.

Realm	**Terrestrial**								
Biome	T1 Tropical-subtropical forests			T3 Shrublands & shrubby woodlands	T4 Savannas & grasslands			T5 Deserts & semi-deserts	Broad Vegetation Groups of Qld
EFG	T1.1 Tropical-subtropical lowland rainforests	T1.2 Tropical-subtropical dry forests and thickets	T1.3 Tropical-subtropical montane forests	T3.1 Seasonally dry tropical shrublands	T4.2 Pyric tussock savannas	T4.3 Hummock savannas	T4.4 Temperate woodlands	T5.1 Semi-desert steppes	Non-remnant
Major perennial									
Watercourse area - estuarine (ha)	12.2	0	0	0	170.9	0	0	0	0
Watercourse area – freshwater (ha)	34.6	0	0	0.5	1,141.3	44.6	0	3.5	19.7
Watercourse line (km)	0.2	0	0	0	36.1	0	0	0	6.8
Major non-perennial									
Watercourse area - estuarine (ha)	0	0	0	0	4.0	0	0	0	0
Watercourse area – freshwater (ha)	141.6	0.4	0	2.5	2,738.9	149.8	4.5	35.9	234.9
Watercourse line (km)	34.6	0.1	0	82.5	1,480.5	10.8	0	2.6	25.1
Minor perennial									
Watercourse area - estuarine (ha)	2.4	0	0	0	57.0	0	0	0	0
Watercourse area – freshwater (ha)	2.1	0	0	0	317.3	8.3	0	21.2	9.3
Watercourse line (km)	0	0	0	0	0.6	0	0	0	0
Minor non-perennial									
Watercourse area - estuarine (ha)	0	0	0	0	1.2	0	0	0	0
Watercourse area – freshwater (ha)	28.9	14.4	5.9	30.5	6,241.1	401.7	36.1	36.9	92.4
Watercourse line (km)	164.5	208.3	1,171.2	2,155.5	141,706	16,135.2	546.8	822.4	1,748.7

Table 6 (continued).

Realm	Freshwater–terrestrial		Marine–terrestrial	Marine–freshwater–terrestrial		Broad Vegetation Groups of Queensland	
Biome	TF1 Palustrine wetlands		MT2 Supralittoral coastal systems	MFT1 Brackish tidal			
EFG	TF1.2 Subtropical-temperate forested wetlands	TF1.4 Seasonal floodplain marshes	MT2.1 Coastal shrublands and grasslands	MFT1.2 Intertidal forests & shrublands	MFT1.3 Coastal saltmarshes & reedbeds	Water	Estuary
Major perennial							
Watercourse area - estuarine (ha)	74.8	0	7.4	153.2	72.7	0	3,910.8
Watercourse area – freshwater (ha)	10,594.5	0	0	31.5	0.4	0	38.1
Watercourse line (km)	811.3	1.6	0	19.4	3	2.3	216.9
Major non-perennial							
Watercourse area - estuarine (ha)	4.8	0	0	0	0	0	42.4
Watercourse area – freshwater (ha)	29,284.0	39.8	0	0	0	3.3	0
Watercourse line (km)	2,581.8	16.9	0	2.8	9.2	1.5	2.9
Minor perennial							
Watercourse area - estuarine (ha)	64.5	0.3	2.4	124.6	56.5	0	889.3
Watercourse area – freshwater (ha)	477.5	315.9	0.3	20.4	68.4	0	0
Watercourse line (km)	10.2	0	0	0.8	0	0	1.2
Minor non-perennial							
Watercourse area - estuarine (ha)	1.7	0	0	9.6	3.9	0	81.0
Watercourse area – freshwater (ha)	12,217.5	330.0	8.9	2.5	43.5	3.3	38.1
Watercourse line (km)	15,359.6	568.7	19.1	585.2	1,205.2	235.3	290.6

2.4 Land uses in the non-remnant Broad Vegetation Group of Queensland

A proportion of the catchment’s native vegetation was cleared between pre-clearing and post-clearing mapping, resulting in its categorisation into the BVG class ‘non-remnant’. This non-remant BVG class was delineated using the available land uses mapped under the Queensland Land Use Mapping Program (QLUMP) (Queensland Government, 2019). Land uses, as mapped by QLUMP, were then matched across (‘cross-walked’) with the IUCN Global Ecosystem Typology to produce another set of IUCN EFGs under the T7 Intensive land-use biome for non-remnant BVGs. This matching exercise produce QLUMP – IUCN EFG correspondences that covered 97% (89,029ha) and 96% (87,978ha) of non-remnant BVG extent in 1999 and 2015, respectively, and this is summarised in Table 7. The remainder of non-remnant BVG extent that was not matched to IUCN T7 Intensive land-use comprised:

QLUMP Class 1 Conservation and natural environments: 1.1.0 Nature conservation; 1.2.0 Managed resource protection; 1.3.0 Other minimal use [Total area in 1999: 1479 ha, Total area in 2015: 2377 ha]

QLUMP Class 6 Water: 6.1 Lake; 6.2 Reservoir/dam; 6.3 River; 6.4 Channel/aqueduct; 6.5 Marsh/wetland [Total area in 1999: 1103 ha, Total area in 2015: 1213 ha]

QLUMP Class 3 Plantation from dryland agriculture and plantations: 3.6.0 Land in transition [Total area in 1999: 0 ha, Total area in 2015: 44 ha]

Maps of land uses within the non-remnant BVG are shown in Figure 11, Figure 12, Figure 13, Figure 14, Figure 15, Figure 16).

Table 7. QLUMP–IUCN ecosystem functional group correspondence for the non-remnant class of Broad Vegetation Groups of Queensland and the corresponding land-use extents in the Mitchell catchment.

Non-remnant BVG (Total area: 91,583 ha)				IUCN
	QLUMP#	Land use extent in 1999	Land use extent in 2015	T7 Intensive land-use
Primary class	**Secondary class**	**(ha)**	**(ha)**	**EFG**
Class 2 Production from relatively natural environments	2.1 Grazing native vegetation	60,145	58,175	T7.5 Derived semi-natural pastures and old fields
	2.2 Production native forests	119	3	T7.3 Plantations
Class 3 Production from dryland agriculture and plantations	3.1 Plantation forests	74	77	T7.3 Plantations
	3.2 Grazing modified pastures	0	16	T7.5 Derived semi-natural pastures and old fields
	3.3 Cropping	2,099	2,132	T7.1 Annual croplands
Class 4 Production from irrigated agriculture and plantations	4.2 Grazing irrigated modified pasture	222	534	T7.2 Sown pastures and fields
	4.3 Irrigated cropping	17,385	15,334	T7.1 Annual croplands
	4.4 Irrigated perennial horticulture	3,888	5,768	T7.1 Annual croplands
	4.5 Irrigated seasonal horticulture	336	430	T7.1 Annual croplands
Class 5 Intensive uses	5.1 Intensive horticulture	6	10	T7.1 Annual croplands
	5.2 Intensive animal husbandry	112	260	T7.2 Sown pastures and fields
	5.3 Manufacturing and industrial	15	15	T7.4 Urban and industrial ecosystems
	5.4 Residential and farm infrastructure	2,948	3,222	T7.4 Urban and industrial ecosystems
	5.5 Services	410	499	T7.4 Urban and industrial ecosystems
	5.6 Utilities	5	5	T7.4 Urban and industrial ecosystems
	5.7 Transport and communication	343	343	T7.4 Urban and industrial ecosystems
	5.8 Mining	901	1,130	T7.4 Urban and industrial ecosystems
	5.9 Waste treatment and disposal	21	25	T7.4 Urban and industrial ecosystems

#The most recent QLUMP dataset, published by the Queensland Department of Environment and Science (Queensland Government, 2019) that covers the Mitchell catchment is based on the Australian Land Use and Management (ALUM) Classification version 7. ALUM Classification Version 8 was applied in the QLUMP mapping for other parts of Queensland, but – at the time of producing this Report – had not yet been applied for the Mitchell catchment.

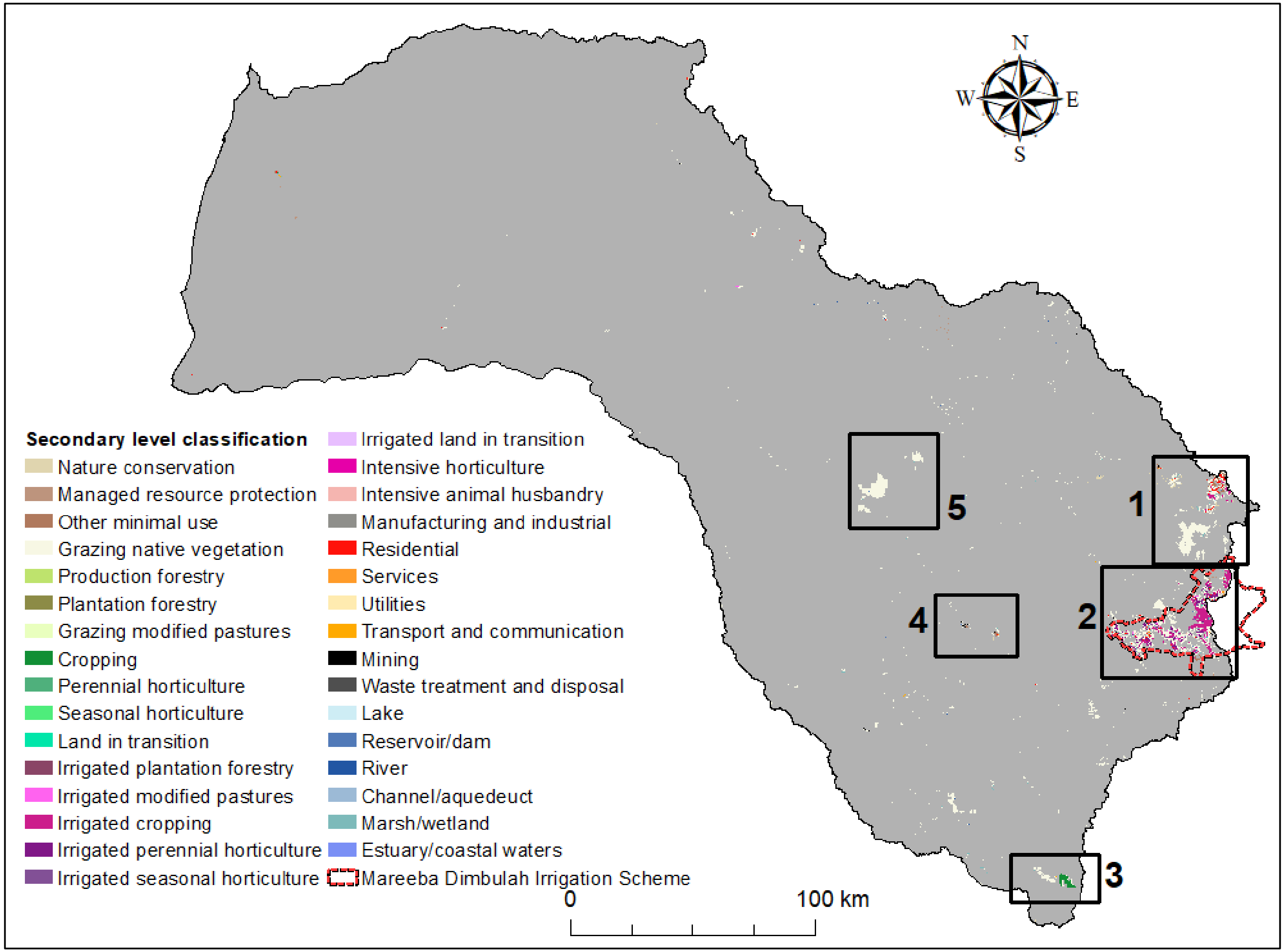


Figure 11. Land uses within the non-remnant Broad Vegetation Groups of Queensland in 2015. The non-remnant areas are split into five zones: 1, 2, 3, 4 and 5. Land uses for each zone is shown in the figures that follow. Data source: (Queensland Government, 2019).

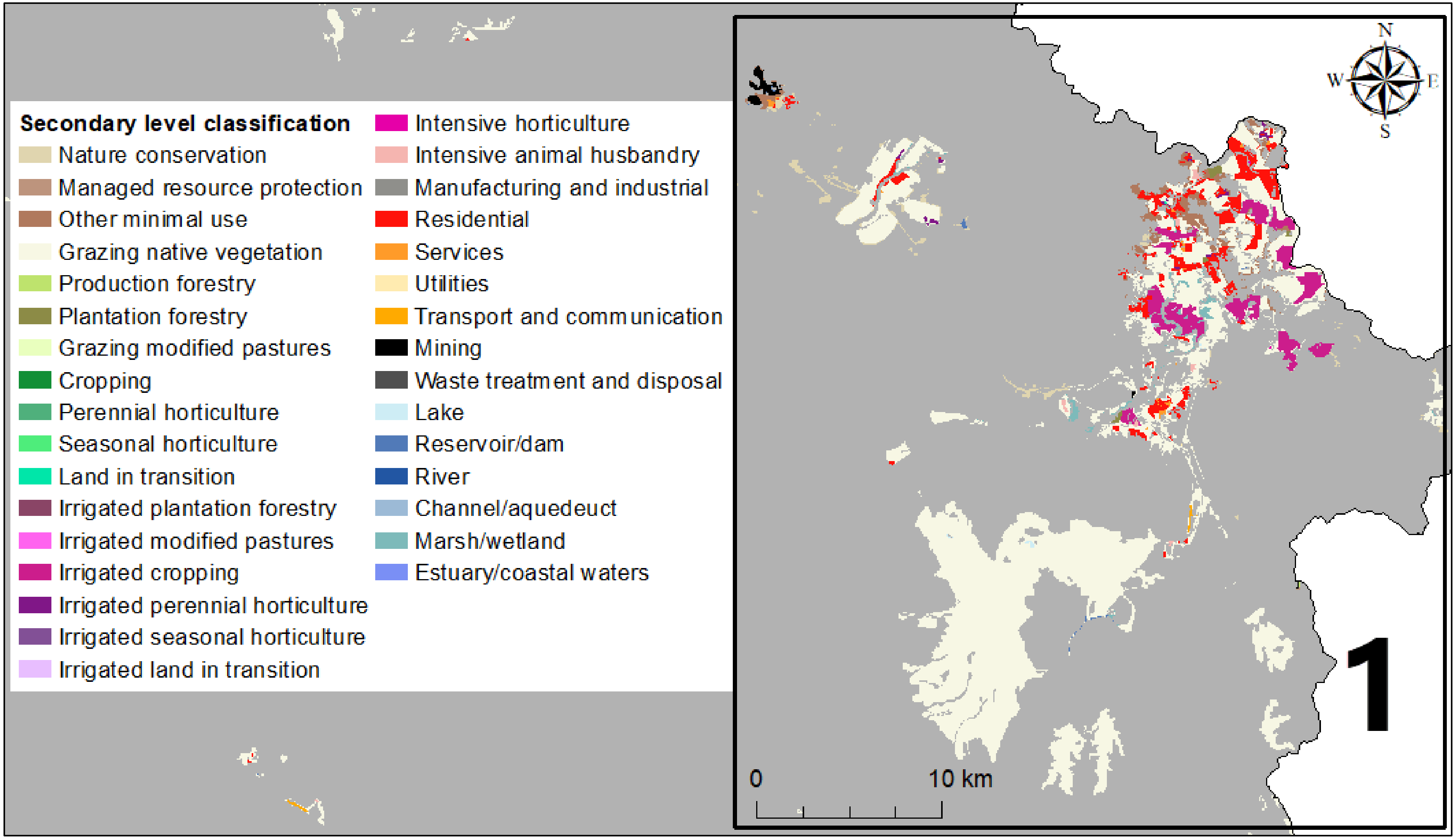


Figure 12. Land uses within Zone 1 of the non-remnant Broad Vegetation Groups of Queensland in 2015. Data source: (Queensland Government, 2019).

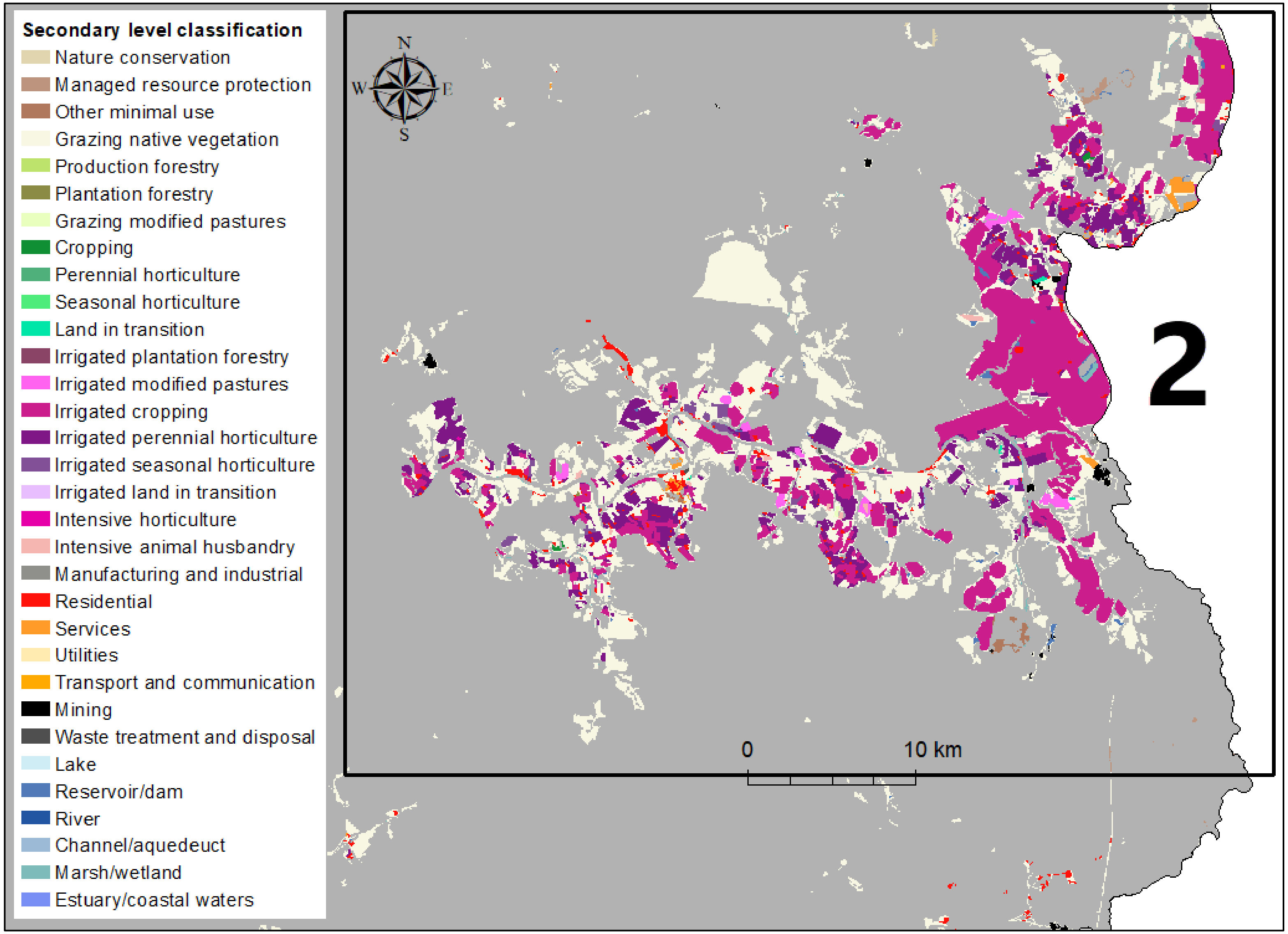


Figure 13. Land uses within Zone 2 of the non-remnant Broad Vegetation Groups of Queensland in 2015. Data source: (Queensland Government, 2019).

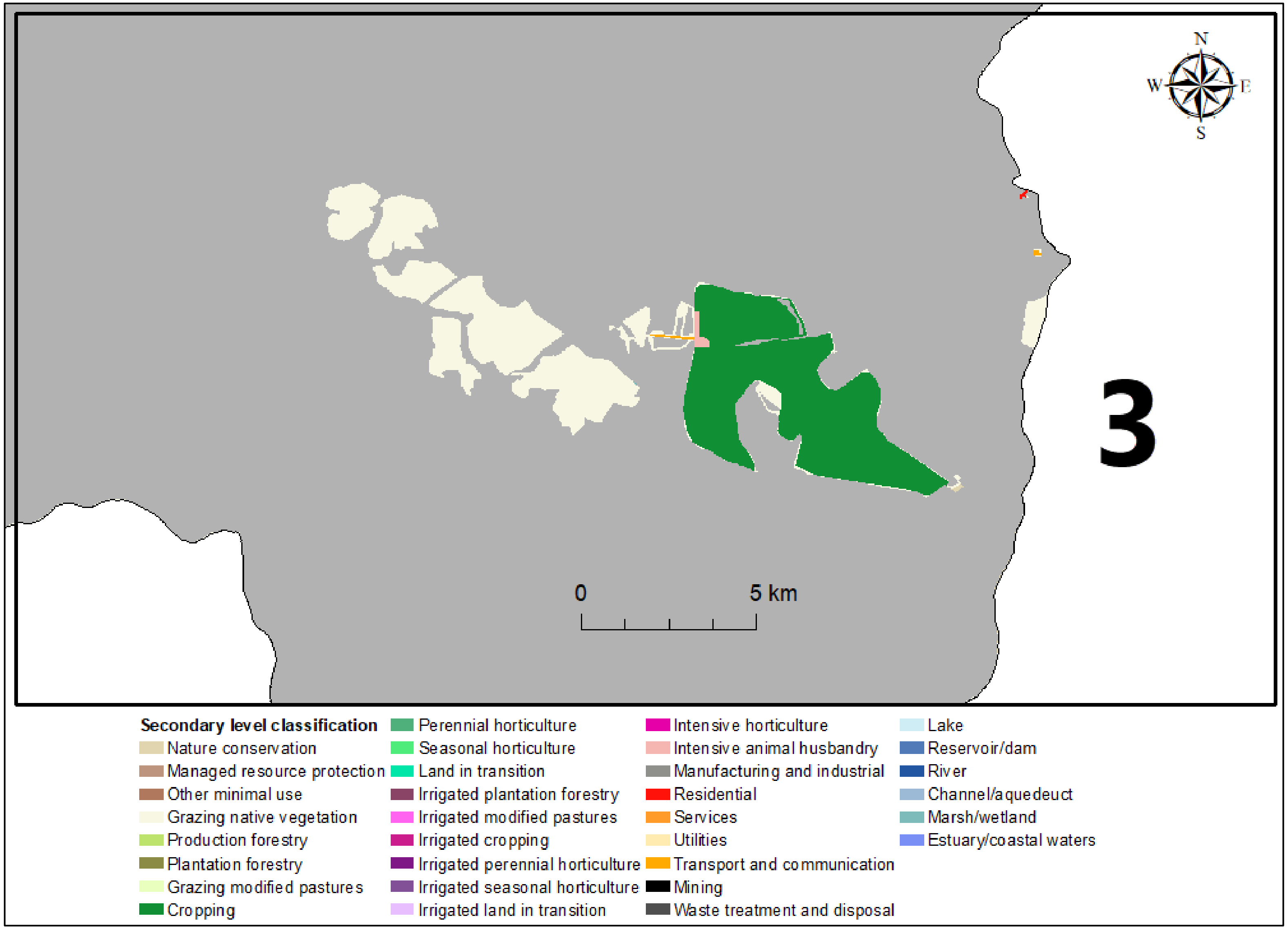


Figure 14. Land uses within Zone 3 of the non-remnant Broad Vegetation Groups of Queensland in 2015. Data source: (Queensland Government, 2019).

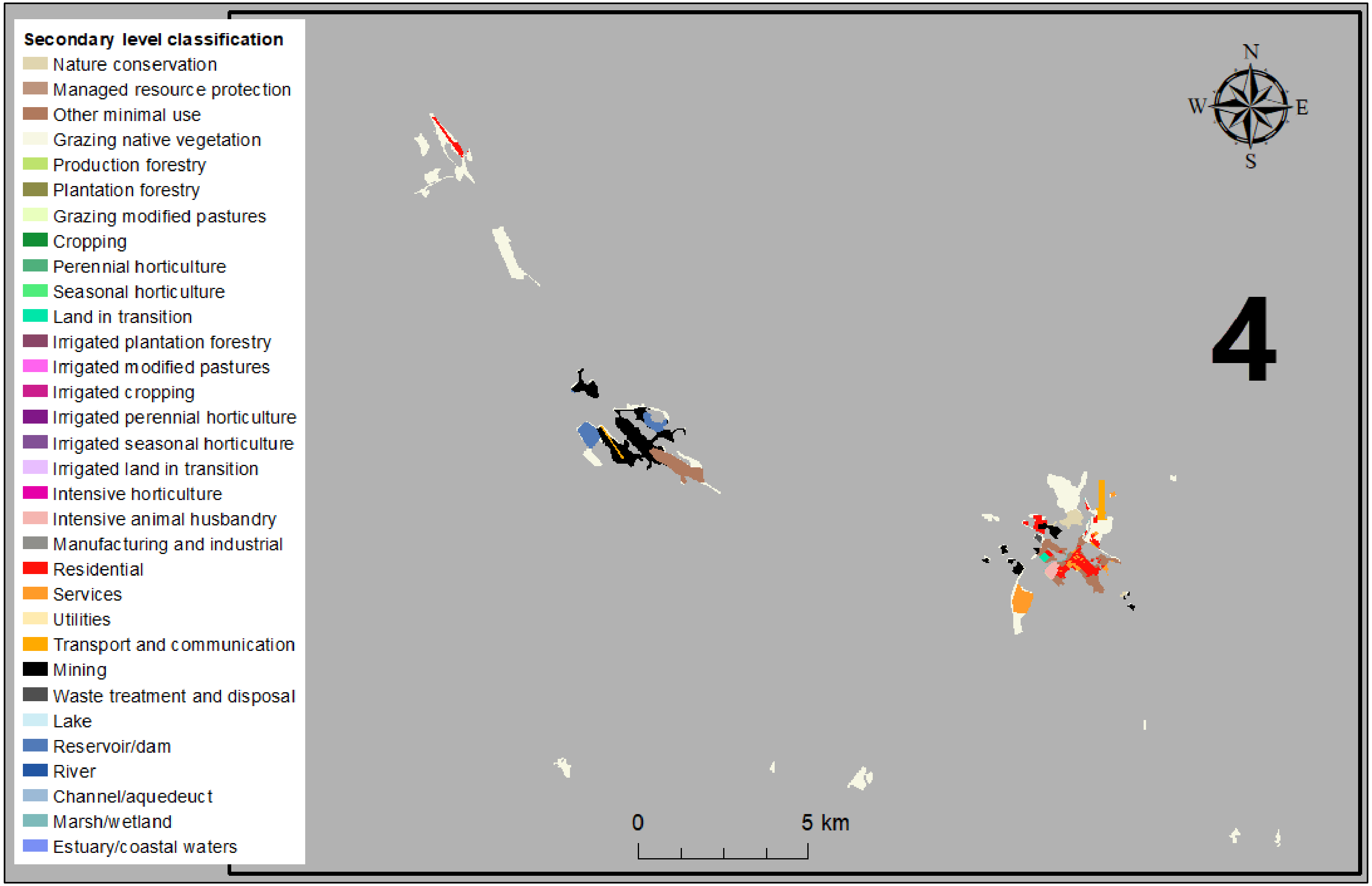


Figure 15. Land uses within Zone 4 of the non-remnant Broad Vegetation Groups of Queensland in 2015. Data source: (Queensland Government, 2019).

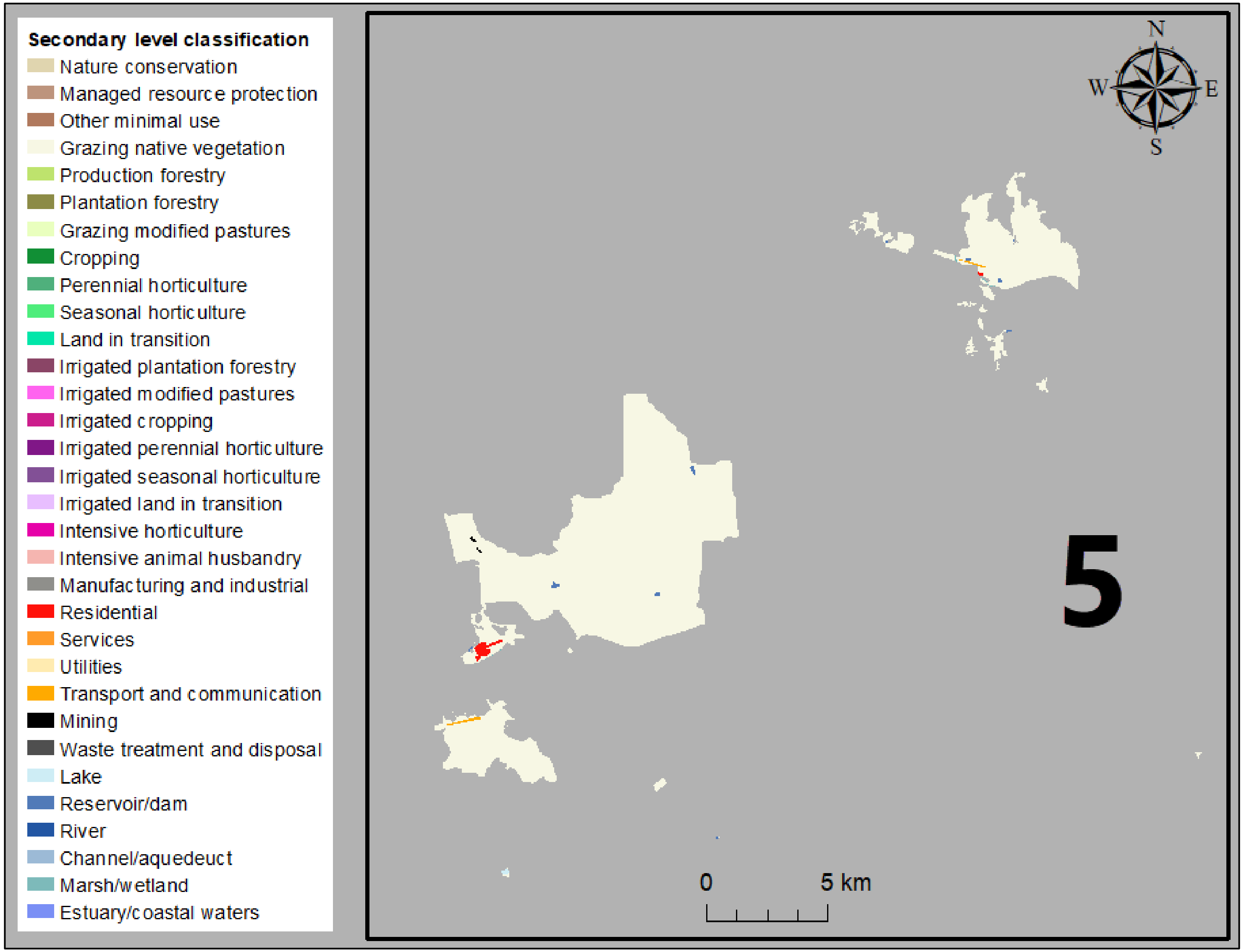


Figure 16. Land uses within Zone 5 of the non-remnant Broad Vegetation Groups of Queensland in 2015. Data source: (Queensland Government, 2019).

2.5 Land uses (QLUMP) by ecosystem type

To provide supplementary information to the ecosystem extent accounts, QLUMP land uses were further tabulated by ecosystem type for the Mitchell catchment for the most recent year available, 2015. This tabulation is shown in the following tables and maps:

- Table 8 summarises land use in the Mitchell catchment, based on the QLUMP primary classes mapping in 2015.
- Table 9 summarises land use in the Mitchell catchment, based on the QLUMP secondary classes mapping in 2015.
- The spatial extent of the grazing native vegetation land use in 2015, overlaid on IUCN Ecosystem Functional Groups (i.e., ecosystem types) is shown in Figure 17.
- Figure 18 shows the spatial extent of land uses in 2015, as mapped by QLUMP.

Grazing native vegetation is the dominant land use (~81% of the total catchment land area) with much of the remainder of the catchment area allocated for Conservation and Natural Environments (Managed resource protection and nature conservation) (15%) (Figure 17 and Figure 18).

80%, 9% and 7% of the grazing native vegetation areas are in pyric tussock savanna (~4.6 million ha), subtropical-temperate forested wetlands (~0.5 million ha) and hummock savannas (~ 0.4 million ha), respectively (Figure 17).

Managed resource protection and nature conservation together constitute 15% or just over 1 million ha within the catchment area (Figure 18).

Irrigated agricultural land uses, whilst only constituting a small proportion of the catchment area at 0.3% (22,211ha), remain important in economic terms, producing high valued crops such as mangoes, bananas, avocados, and sugarcane.

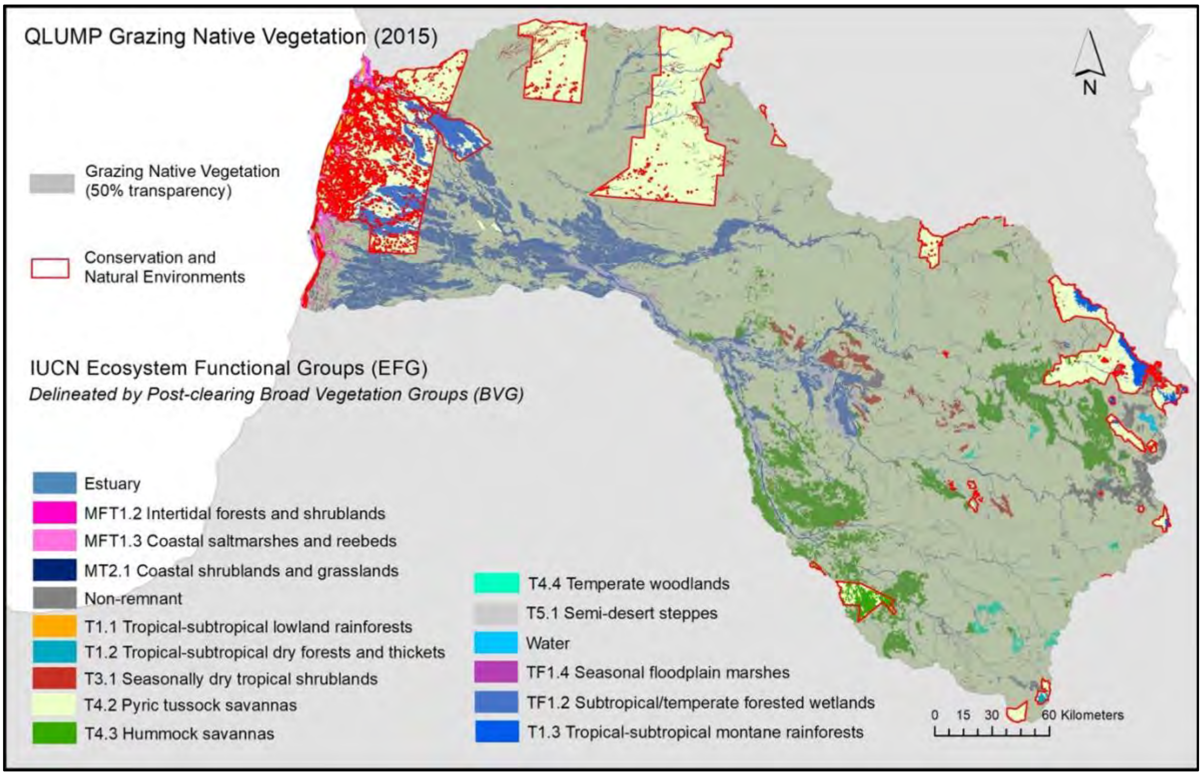


Figure 17. Spatial extent of grazing native vegetation land use in 2015, overlaid on IUCN Ecosystem Function Groups (i.e., ecosystem types) in the Mitchell catchment.

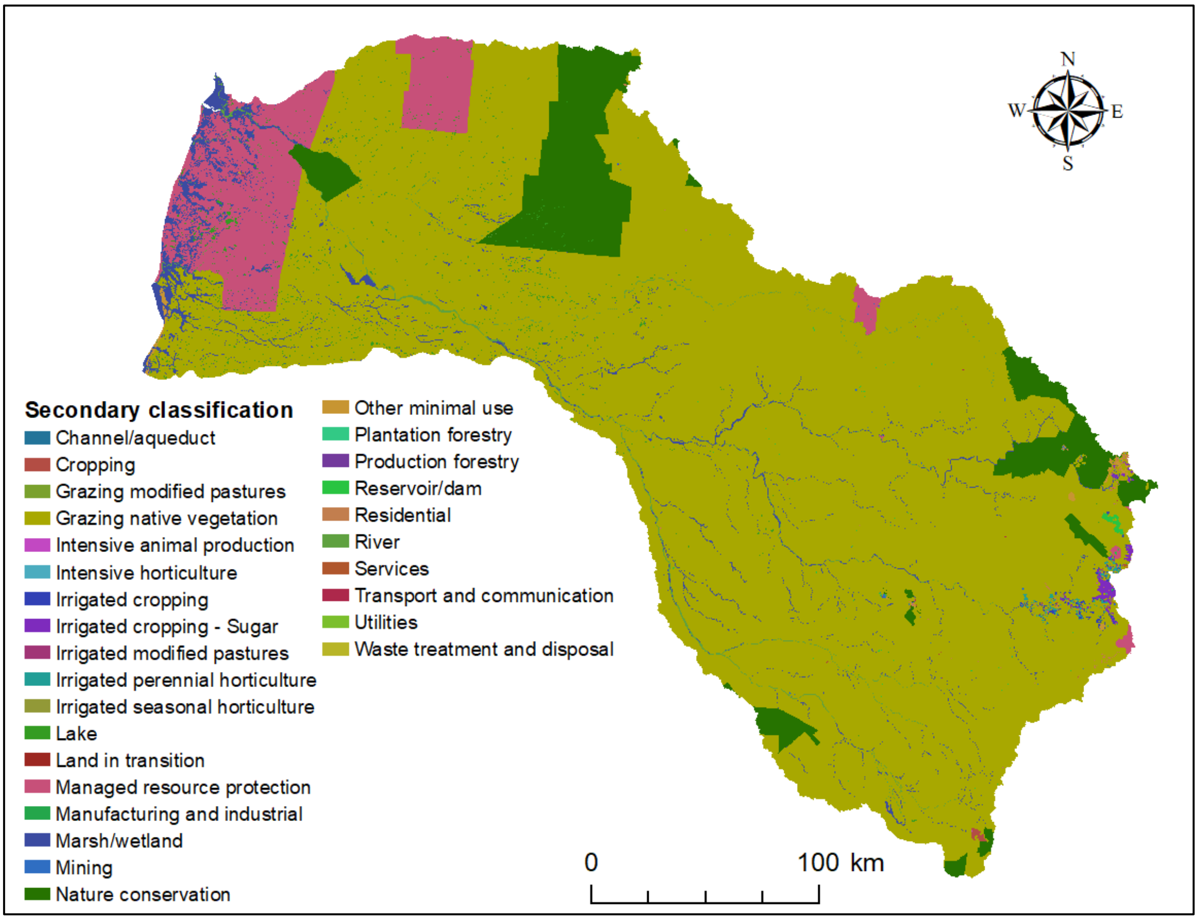


Figure 18. Spatial extent of land uses in 2015 for the Mitchell catchmentas mapped by QLUMP (DES 2020).

Table 8. Land use in the Mitchell catchment, based on QLUMP primary classes mapping in 2015.

Realm	**Terrestrial**								
Biome	T1 Tropical-subtropical forests			T3 Shrublands & shrubby woodlands	T4 Savannas & grasslands			T5 Deserts & semi-deserts	Broad Vegetation Groups of Qld
EFG	T1.1 Tropical-subtropical lowland rainforests	T1.2 Tropical-subtropical dry forests and thickets	T1.3 Tropical-subtropical montane forests	T3.1 Seasonally dry tropical shrublands	T4.2 Pyric tussock savannas	T4.3 Hummock savannas	T4.4 Temperate woodlands	T5.1 Semi-desert steppes	Non-remnant
Conservation and natural environments	12,074	3,423	25,387	11,467	879,627	23,200			2,377
Intensive uses	54	40	81	3	1,859	65	1	10	5,509
Production from dryland agriculture and plantations			1		63				2,269
Production from irrigated agriculture and plantation	5	0.133	2		334	3			22,066
Production from relatively natural environments	2,285	8,770	851	60,358	4,642,510	411,239	20,980	56,071	58,177
Water	3,826	15	1	378	79,291	1,325	68	425	1,213

Table 8 (continued).

Realm	**Freshwater–terrestrial**		**Marine–terrestrial**	**Marine–freshwater–terrestrial**		**Broad Vegetation Groups of Queensland**	
Biome	TF1 Palustrine wetlands		MT2 Supralittoral coastal systems	MFT1 Brackish tidal			
EFG	TF1.2 Subtropical-temperate forested wetlands	TF1.4 Seasonal floodplain marshes	MT2.1 Coastal shrublands and grasslands	MFT1.2 Intertidal forests & shrublands	MFT1.3 Coastal saltmarshes & reedbeds	Water	Estuary
Conservation and natural environments	119,689	2,563	2,312	130	508	26	33
Intensive uses	110	0.153	1		0.0321	21	
Production from dryland agriculture and plantations	1	2					
Production from irrigated agriculture and plantation	52	0.001				10	
Production from relatively natural environments	526,227	4,918	2,765	16	975	239	7
Water	94,263	17,750	824	10,850	39,433	4,490	5,186

Table 9. Land use in the Mitchell catchment, based on QLUMP secondary classes mapping in 2015.

Realm	**Terrestrial**								
Biome	T1 Tropical-subtropical forests			T3 Shrublands & shrubby woodlands	T4 Savannas & grasslands			T5 Deserts & semi-deserts	Broad Vegetation Groups of Qld
EFG	T1.1 Tropical-subtropical lowland rainforests	T1.2 Tropical-subtropical dry forests and thickets	T1.3 Tropical-subtropical montane forests	T3.1 Seasonally dry tropical shrublands	T4.2 Pyric tussock savannas	T4.3 Hummock savannas	T4.4 Temperate woodlands	T5.1 Semi-desert steppes	Non-remnant
Channel / aqueduct					3				8
Cropping					57				2,132
Grazing irrigated modified pastures					10				534
Grazing modified pastures									16
Grazing native vegetation	2,285	8,770	846	60,358	4,642,504	411,239	20,980	56,071	58,175
Intensive animal production	2		0.0004		10		0.055		260
Intensive horticulture			0.0041		0.117				10
Irrigated cropping	5	0.018	2		227	3			15,334
Irrigated perennial horticulture	0.448	0.115	0.39		93	0.163			5,768
Irrigated seasonal horticulture					3				430
Lake	42			67	14,921	25		122	51
Land in transition					1				44
Managed resource protection	9,537	9	1,137	6,468	419,500				507
Manufacturing and industrial					0.075				15

Table 9 (continued).

Realm	Terrestrial								
Biome	T1 Tropical-subtropical forests			T3 Shrublands & shrubby woodlands	T4 Savannas & grasslands			T5 Deserts & semi-deserts	Broad Vegetation Groups of Qld
EFG	T1.1 Tropical-subtropical lowland rainforests	T1.2 Tropical-subtropical dry forests and thickets	T1.3 Tropical-subtropical montane forests	T3.1 Seasonally dry tropical shrublands	T4.2 Pyric tussock savannas	T4.3 Hummock savannas	T4.4 Temperate woodlands	T5.1 Semi-desert steppes	Non-remnant
Marsh / wetland	3,627	11	1	292	60,521	1,216	66	277	490
Mining		21		0.192	600	25	1		1,130
Nature conservation	1,434	3,239	22,566	4,899	456,898	23,197			926
Other minimal use	1,103	175	6,684	100	3,229	3			944
Plantation forests			1		5				77
Production native forests			5		6				3
Reservoir / dam		2		19	521	9	2	8	497
Residential and farm infrastructure	52	14	81	2	1,091	16		8	3,222
River	157	2			3,325	74		19	167
Services	1	5	0.045		83	24			499
Transport and communication				0.077	65	0.341		2	343
Utilities		0.245			4				5
Waste treatment and disposal		0.19			7				25

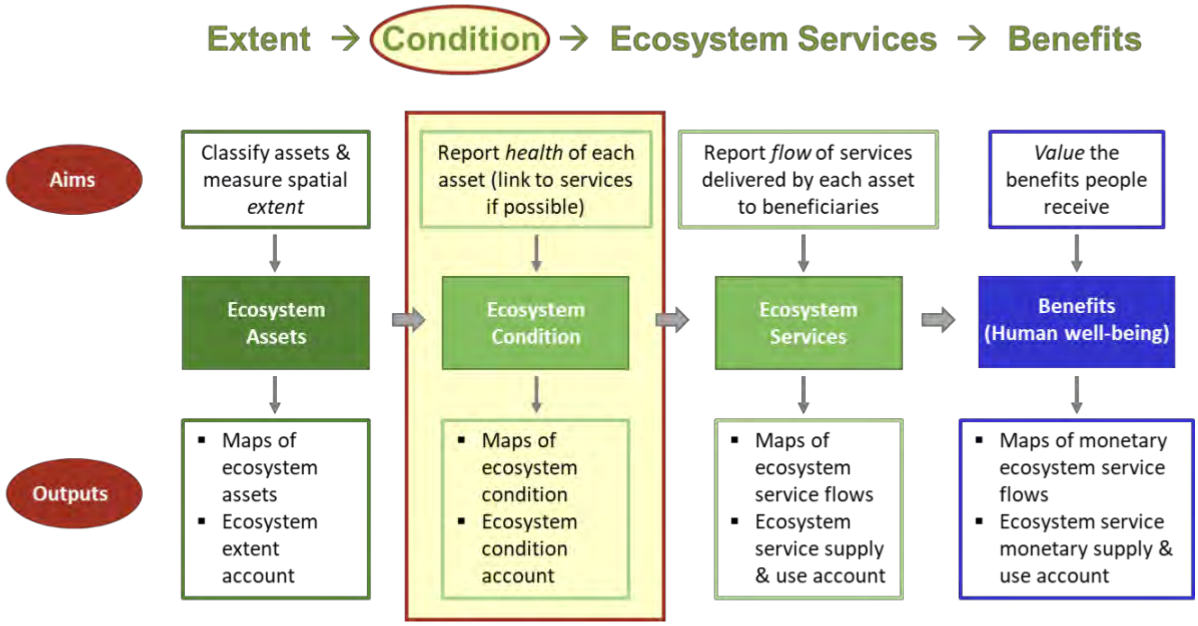
Table 9 (continued).

Realm	Freshwater–terrestrial		Marine–terrestrial	Marine–freshwater–terrestrial		Broad Vegetation Groups of Queensland	
Biome	TF1 Palustrine wetlands		MT2 Supralittoral coastal systems	MFT1 Brackish tidal			
EFG	TF1.2 Subtropical-temperate forested wetlands	TF1.4 Seasonal floodplain marshes	MT2.1 Coastal shrublands and grasslands	MFT1.2 Intertidal forests & shrublands	MFT1.3 Coastal saltmarshes & reedbeds	Water	Estuary
Channel / aqueduct							
Cropping	1	2					
Grazing irrigated modified pastures	1						
Grazing modified pastures							
Grazing native vegetation	526,227	4,918	1,603	16	975	239	7
Intensive animal production	2						
Intensive horticulture							
Irrigated cropping	36	0.001				10	
Irrigated perennial horticulture	12					0.094	
Irrigated seasonal horticulture	4						
Lake	11,425	8,133	16		22	41	
Land in transition							
Managed resource protection	80,404	1,956	2,112	127	368	10	33
Manufacturing and industrial							

Table 9 (continued).

Realm	Freshwater–terrestrial		Marine–terrestrial	Marine–freshwater–terrestrial		Broad Vegetation Groups of Queensland	
Biome	TF1 Palustrine wetlands		MT2 Supralittoral coastal systems	MFT1 Brackish tidal			
EFG	TF1.2 Subtropical-temperate forested wetlands	TF1.4 Seasonal floodplain marshes	MT2.1 Coastal shrublands and grasslands	MFT1.2 Intertidal forests & shrublands	MFT1.3 Coastal saltmarshes & reedbeds	Water	Estuary
Marsh / wetland	51,747	9,568	794	10,600	39,213	168	510
Mining	2					7	
Nature conservation	39,209	524				11	
Other minimal use	76	83	1,362	2	140	4	0.012
Plantation forests							
Production native forests							
Reservoir / dam	67	36				4,281	
Residential and farm infrastructure	99	0.153	1		0.032	4	
River	31,024	13	14	250	198		4,676
Services	2						
Transport and communication	2						
Utilities							
Waste treatment and disposal	4					9	

3. Condition accounts



3.1 Summary

- In SEEA-compliant ecosystem accounting, the quality of an ecosystem asset is assessed 'in terms of its abiotic and biotic characteristics' (United Nations et al., 2021, p.81)). SEEA-EA define a hierarchy for reporting condition that encompasses three groups of characteristics at the highest level (*abiotic*, *biotic*, and *landscape level* characteristics) and six classes of characteristics at a lower level (*abiotic physical state*; *abiotic chemical state*; *biotic compositional state*; *biotic structural state*; *biotic functional state*; and *landscape and seascape characteristics*) (Figure 16).
- Quantitative metrics that describe the state of an individual condition characteristic for an ecosystem asset(s) within an ecosystem type can be included as *ecosystem condition variables* in a *Stage 1 Ecosystem Condition Account* for the ecosystem accounting area (i.e., here, the Mitchell catchment) (Figure 17).
- If *reference levels* for 'best' and 'worst' condition of a characteristic can be defined for an ecosystem condition variable, that variable can be regarded as an *ecosystem condition indicator* for relevant ecosystem assets within an ecosystem type and included in a *Stage 2 Ecosystem Condition Account* (Figure 17).
- If appropriate, ecosystem condition indicators can be aggregated across ecosystem assets of the same ecosystem type to produce an overall *ecosystem condition index* for each ecosystem type. Where this is possible, condition indexes would be reported in a *Stage 3 Ecosystem Condition Account* (Figure 17).
- In Project 4.6 we collate data on *ecosystem condition variables* for ecosystem assets within the Mitchell catchment's ecosystem types and broad vegetation groups to produce a *Stage 1 Ecosystem Condition Account* for the catchment (Table 10, Table 11, Table 12).
- The intention in SEEA-EA is that all ecosystem condition variables in the Ecosystem Condition Variable Account would be recorded in the same year. The Account would subsequently be updated at regular intervals to enable changes in condition to be

tracked. In the Ecosystem Condition Variable Account compiled for the Mitchell catchment in Project 4.6 we have deliberately reported condition variables from *different* years – and have noted the year(s) in which data on each variable's were collected. This illustrates the types of condition variable that could contribute data to a Stage 1 Ecosystem Condition Account for the catchment. The intention is to promote discussion about how collection of (a subset of) the listed variables might be synchronised most cost-effectively, and whether or not Stage 2 and Stage 3 Ecosystem Condition Accounts could feasibly be produced.

- When compiled from data updated at regular intervals, the Stage 1 Ecosystem Condition Account for the Mitchell could help inform policy development by:
    - Providing quantitative information about the state of an ecosystem type and how this changes through time due to anthropogenic influences.
    - Enabling quantitative data on observed ecosystem condition variables to be compared against critical thresholds and management targets (e.g., invasive species counts, remaining woody vegetation cover).
- As part of the Stage 1 Ecosystem Condition Account, Table 10 reports data on 11 Abiotic physical state characteristics, 7 abiotic chemical state characteristics, 5 biotic compositional state characteristics, 8 biotic structural state characteristics, 6 biotic functional state characteristics, and 2 landscape characteristics. Condition variable data are recorded across a number of individual years ranging between 2003 and 2020, or as averages across multi-year periods (e.g., 1993–2012). Several condition variables are reported for multiple years.
- Raw data on many ecosystem condition variables in most characteristic groupings are derived via remote sensing (although this is not the case for pest presence).
- Updates of publicly accessible (processed) condition variables may still be infrequent, even when raw data are derived from remote sensing. This frustrates regular compilation of Ecosystem Condition Variable Accounts, although there is continual progress in this regard (e.g., via expansion and improvement of the Queensland Government's Open Data Portal data.qld.gov.au/).
- Overall, whilst an indicative SEEA-EA Stage 1 Ecosystem Condition Variable Account has been compiled for the Mitchell catchment, absence of defined reference levels for condition variables and a lack of consistency and repeatability in data collection currently limits the usefulness of this Account for informing policy development.

Key data and findings in the Stage 1 Ecosystem Condition Account for the Mitchell are:

Abiotic physical state

- *Water bodies* for 2020. Water bodies are dispersed throughout most ecosystem types in the catchment
- *Gully erosion*: Data on erosion volumes over the period 2000–04. Several ecosystem types are subject to *gully erosion*, with substantial median estimated annual erosion volumes and tonnages (2000–04) in *pyric tussock savannas* (1,398,504 m^3/r or 2,237,606 t/yr (assuming a soil bulk density of 1600 kg/m^3)), *subtropical-temperate forested wetlands* (1,153,934 m^3/yr or 1,846,294 t/yr), and semi-desert steppes (402,192 m^3/yr or 643,507 t/yr).

Abiotic chemical state

- *Above ground and below ground carbon biomass* and *organic carbon content in the top 30cm of the soil* by ecosystem type across the catchment. Data from 1993–2012, 2010, and 2019. Given the the relatively high tree cover in many of the catchment's ecosystem types, total carbon storage across the catchment is very substantial.

Biotic compositional state

- *Potential habitat extent for iconic faunal species* per ecosystem type for 2012 (Table 11 and Figure 19).
- *IUCN species richness* (all species and threatened species only) for 2020. Four *critically endangered* and 20 *endangered* animal species are resident in the catchment.
- *Presence of pest animals and weeds* (Figure 23 and Figure 24) for 2021. Pest animals and weeds are present throughout all ecosystem types in the catchment. Please refer to the Seciton 5: Environmental Pressures for further details.

Biotic structural state

- *Standing pasture biomass* for 2010, 2014 and 2019.
- *Mean tree cover* as percentage of ecosystem type area (Figure *21*) 2009, 2010, 2014 and 2017.
- *Vegetation height* for 2009.
- *Areas of woody, sparse woody and non-woody vegetation* (Figure 20) for 2009, 2010, 2014, 2017 and 2018. For *subtropical-temperate forested wetlands*, *seasonal floodplain marshes*, *tropical-subtropical dry forest and thickets*, *pyric tussock savannas*, and *hummock savannas*, reductions in areas of sparse woody vegetation since 2009 coincide with increases in non-woody vegetation; this may suggest land clearing. Please refer to Section 5: Environmental Pressures for further details.

Biotic functional state

- *Pasture growth.*
- *Fireburn intensity*: Percentage extent of low intensity or 'cool' fireburn as opposed to high intensity or 'hot' fireburn for each ecosystem type (Figure 22); data for 2003, 2006, 2009 and 2010. A higher percentage area of *tropical-subtropical lowland rainforests*, *pyric tussock savannas*, *subtropical-temperate forested wetlands*, *seasonal floodplain marshes*, and *coastal shrublands and grasslands* experienced high intensity burns than low intensity burns in all reported years. High intensity burns occurred across 30% of the catchment's *pyric tussock savannas* and 25% of *subtropical-temperate forested wetlands* in 2009.
- *Fireburn frequency*: over the period 2000–19, relative to burn frequency guidelines for the Regional Ecosystem(s) concerned; percentage of each ecosystem type burnt too often, not often enough, or within burn frequency guidelines. Please refer to Section 5: Environmental Pressures for further details.

Landscape characteristics

- *Fireburn extent*: area of fireburn scars in each ecosystem type (in ha and as percentage of ecosystem type area); data for 2010, 2014, 2018 and 2019. More than

20% of the area of *tropical-subtropical dry forest and thickets*, *seasonally dry tropical shrublands*, *pyric tussock savannas*, *hummock savannas*, *temperate woodlands*, *subtropical-temperate forested wetlands*, and *seasonal floodplain marshes* burnt in 2010, 2018 and 2019. More than 40% of *seasonally dry tropical shrublands* and *pyric tussock savannas* burnt in 2010. More than 40% of *subtropical-temperate forested wetlands* burnt in 2018 and again in 2019.

- *Fragmentation* (mean patch size post-clearing (~2015) vs. pre-clearing (~1750), by ecosystem type). Please refer to Section 5: Environmental Pressures for further details.

3.2 Background

In ecosystem accounting, the quality of an ecosystem asset is assessed 'in terms of its abiotic and biotic characteristics' (United Nations et al., 2021, p.81)). Ecosystem condition characteristics are organised in accordance with the SEEA ecosystem condition typology (Czúcz et al., 2021, Table 1 on p.5; United Nations et al., 2021, Table 5.1 on p.90), a hierarchical structure encompassing three groups of characteristics (abiotic, biotic, and landscape) at the higher level and six classes of characteristics at the next lower level (abiotic physical state; abiotic chemical state; biotic compositional state; biotic structural state; biotic functional state; and landscape and seascape), as shown in Figure 19.

Quantitative values or metrics that are used to describe these characteristics are referred to as *variables*, *indicators* and *indices;* each term comes with specific definitions (Czúcz et al., 2021). Any quantitative value or metric that can be used to describe the state of individual characteristics of an ecosystem asset is called an *ecosystem condition variable* (United Nations et al., 2021, p.93). Ecosystem condition variables with a 'strong direct normative interpretation (i.e., distinguishing 'good' from 'bad') for policy decisions' (Czúcz et al., 2021, p.2) are referred to as *ecosystem condition indicators*.

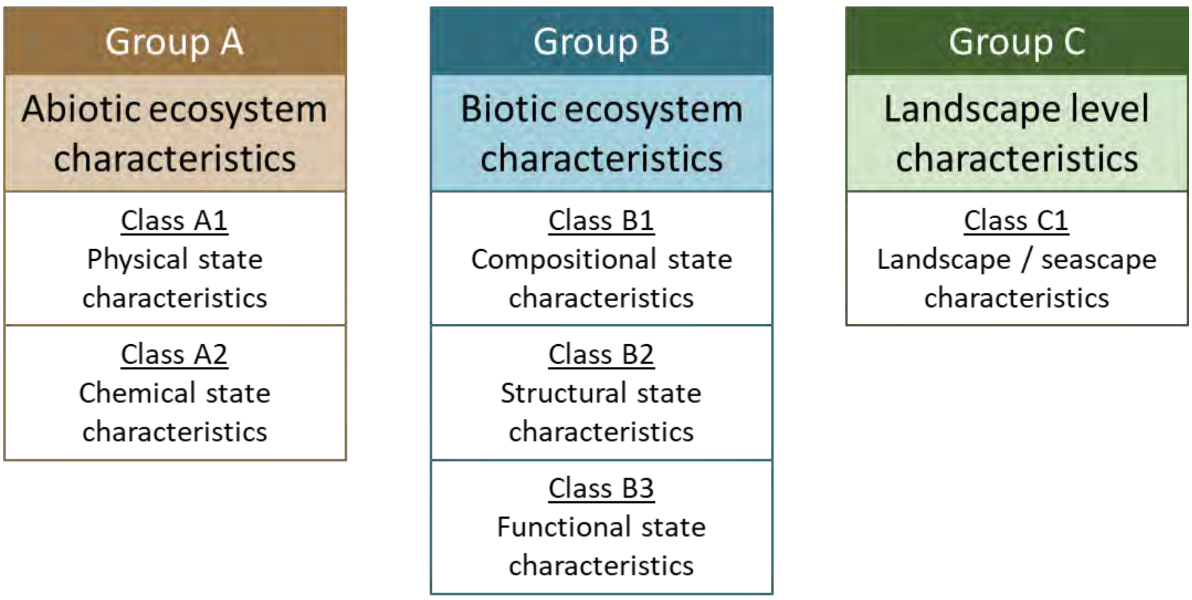


Figure 19. The SEEA-EA Ecosystem Condition Typology. Source: Czúcz et al. (2021, Table 1 on p.5); United Nations et al. (2021, Table 5.1 on p.90).

Ecosystem condition indicators are rescaled versions of ecosystem condition *variables*. Rescaling is typically to a common dimensionless scale ranging from 0 or 0% as the bottom ('worst') value to 1 or 100% as the top ('best') value (United Nations et al., 2021, p.95). Thus, ecosystem condition *variables* can only be used as ecosystem condition *indicators* if reference levels for the 'worst' and 'best' ends of the scale can be determined. Finally, it may be possible to derive an ecosystem condition *index* (per ecosystem type) from aggregation of ecosystem condition *indicators* (relating to that ecosystem type). This aggregation is typically undertaken to allow the index to provide a single quantitative summary of 'condition' per ecosystem type. The progression from *variables* to *indicators* and then to *indices* follows a three-stage process as described in H. Keith et al. (2020, p.15) and Keith et al. (2019, p.19), reproduced here as Figure 20.

In Project 4.6 we produce a Stage 1 *ecosystem condition variable account* (Figure 20). A Stage 1 ecosystem condition variable account is useful for the following purposes (United Nations et al., 2021; p.93–94):

- Providing quantitative information about the state of an ecosystem and how this state changes through time due to anthropogenic influences
- Enabling quantitative data on observed ecosystem condition variables to be compared against critical thresholds and management targets (e.g., invasive species counts, remaining woody vegetation cover).

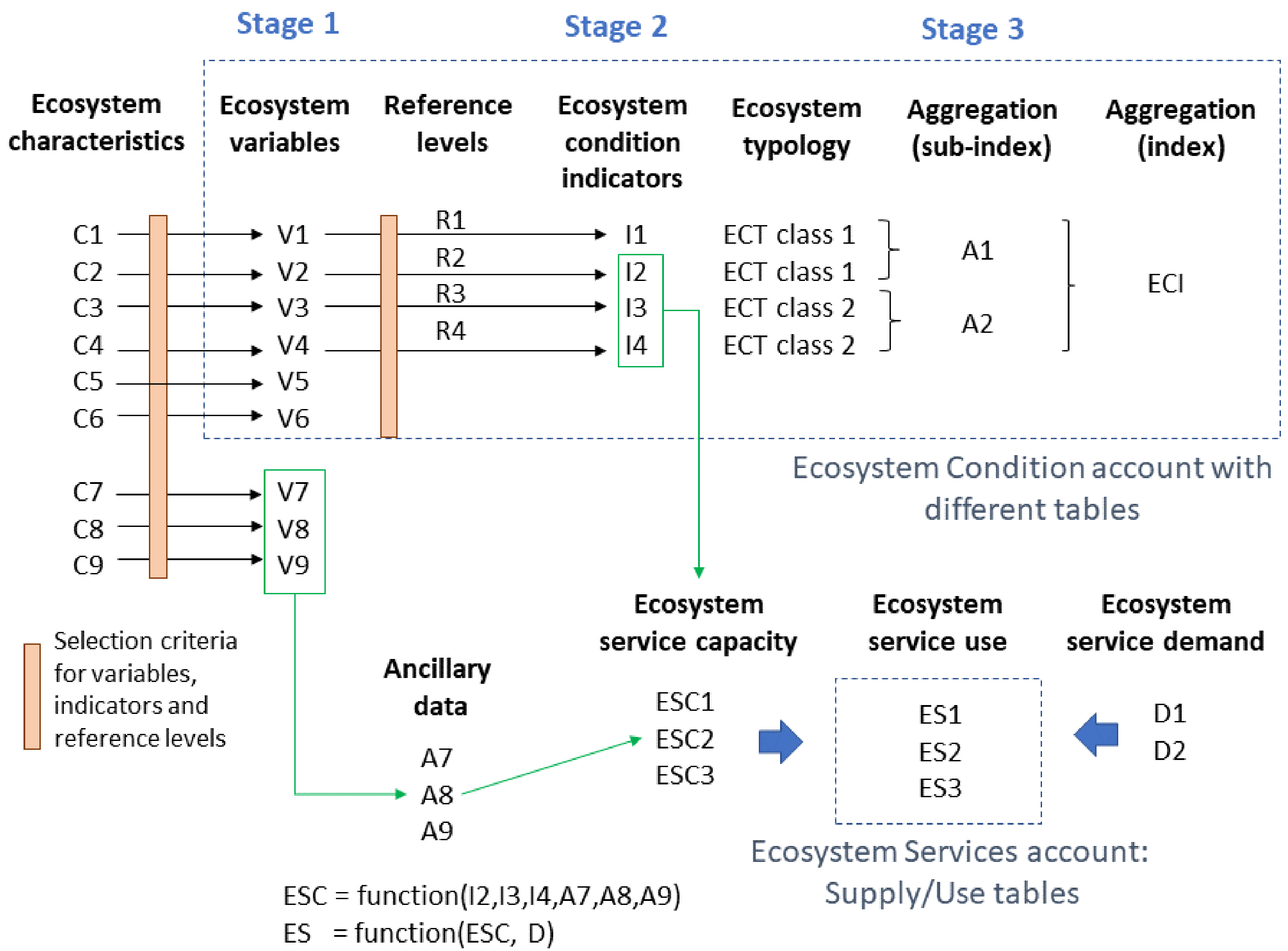


Figure 20. A framework proposed by Keith et al. (2020, p.15; 2019, p.19) for deriving an ecosystem condition index for reporting the health of the ecosystem, and for selecting variables, indicators and ancilliary data to inform the capacity of an ecosystem asset to supply particular ecosystem services.

3.3 Ecosystem condition variable account

The *Stage 1 ecosystem condition variable* account comprises *variables* (in rows) organised in accordance with SEEA EA's Ecosystem Condition Typology, with columns indicating the ecosystem types (i.e., IUCN EFGs & Qld BVGs) in the Mitchell catchment to which the condition variables refer. *Variables* are presented generically across the different ecosystem types and are broadly consistent with the examples of ecosystem condition *variables* for selected ecosystem types outlined in SEEA EA (United Nations et al., 2021, Table 5.1 on p.90 and Table 5.7 on p.106–107).

Complete presentation of the *Stage 1 ecosystem condition variable account* comprises a set of three condition tables:

- Table 10 contains *condition variables* that describe abiotic, biotic and landscape level characteristics of ecosystem assets.
- Table 11 details the area of modelled potential habitat extent for *critically endangered species* and *endangered species* as listed in Queensland Nature Conservation (Animals) Regulation 2020, presented by species and by ecosystem type.
- Table 12 and Table 13 summarise the area of weed and pest animal presence by species and by ecosystem type.

Maps of selected condition *variables* are provided in the following figures:

- Figure *21*: Median rates of gully erosion based on satellite imagery between the years 2000 and 2004, as described in Brooks et al. (2008).
- Figure 22: Modelled potential habitat extent of four critically endangered animal species in the Mitchell catchment, as listed in Queensland Nature Conservation (Animals) Regulation 2020.
- Figure 23: Spatial coverage of woody vegetation in 2018
- Figure 24: Mean tree cover expressed as percentages of ecosystem type extent
- Figure 25: Fire burn intensity (high vs. low intensity) for indicative years 2003 and 2008
- Figure 26: The number of priority weed species present
- Figure 27: The number of pest animal species present.

Table 10. Ecosystem condition variable account for the Mitchell catchment. Refer to table footnotes and the accompanying data inventory for data sources.

Realm		**Terrestrial**								
Biome		T1 Tropical-subtropical forests			T3 Shrublands & shrubby woodlands	T4 Savannas & grasslands			T5 Deserts & semi-deserts	Broad Vegetation Group of Qld
EFG		T1.1 Tropical-subtropical lowland rainforests	T1.2 Tropical-subtropical dry forests and thickets	T1.3 Tropical-subtropical montane forests	T3.1 Seasonally dry tropical shrublands	T4.2 Pyric tussock savannas	T4.3 Hummock savannas	T4.4 Temperate woodlands	T5.1 Semi-desert steppes	Non-remnant
Abiotic: physical state										
Waterbodies										
Mean extent of a waterbody (ha)	2020	1.8	0.6	0	0.6	1.5	0.5	0.4	2.2	1.3
Number of waterbodies (no)	2020	135	1	0	12	5,850	23	3	141	391
Dry-season wetlands: waterholes persisting during dry season for 50 days or more										
Mean extent of a waterhole (ha)	2020	1.15	0.31	0	0.37	0.43	0.27	0.3	0.38	0.67
Number of waterholes (no)	2020	142	1	0	11	2,680	33	2	78	460
Dry-season wetlands: waterholes persisting during dry season for 100 days or more										
Mean extent of a waterhole (ha)	2020	0.84	0.3	0	0.35	0.33	0.32	0.19	0.36	0.65
Number of waterholes (no)	2020	129	1	0	5	999	19	1	42	217
Water observations from space										
Mean extent of a waterbody (ha)	2020	0.6	0.25	0	0.33	0.37	0.2	0.26	0.35	0.48
Number of waterbodies (no)	2020	156	1	0	9	3,230	23	3	80	323
Gully erosion (estimated for the area of gullies modelled; erosion volume and rate are available as single values from satellite imagery from the years 2000 through to 2004)										
Area of gullies predicted (ha, % EFG)#	2000 - 2004	4.76 (0.03)	1.25 (0.01)		37.36 (0.05)	5,135 (0.09)	696 (0.16)		1,482 (2.62)	91.31 (0.1)
Median volume of erosion (m^3/yr)		794	201		16,954	1,398,504	161,135		402,192	21,271
Mean rate of head scarp retreat (m/yr)		0.34	0.34		0.34	0.34	0.34		0.34	0.34

Refers to total area of gullies (in ha) predicted by the model where the area of gullies from Aster imagery (15 m cell size) was adjusted by cross checking a subset against higher resolution using Quickbird imagery in Google earth (highest resolution was 0.61 m). Number in brackets indicate area of gullies as a percentage of EFG area.

Table 10 (continued).

Realm		**Terrestrial**								
Biome		T1 Tropical-subtropical forests			T3 Shrublands & shrubby woodlands	T4 Savannas & grasslands			T5 Deserts & semi-deserts	Broad Vegetation Group of Qld
EFG		T1.1 Tropical-subtropical lowland rainforests	T1.2 Tropical-subtropical dry forests and thickets	T1.3 Tropical-subtropical montane forests	T3.1 Seasonally dry tropical shrublands	T4.2 Pyric tussock savannas	T4.3 Hummock savannas	T4.4 Temperate woodlands	T5.1 Semi-desert steppes	Non-remnant
Abiotic: chemical state										
Above ground carbon (estimates from Liu et al. (2015), given as annual average values for the years 1993–2012)										
Mean carbon biomass (Mg/ha)	1993–2012	19.8	10.5	25.1	8.4	9.0	9.2	9.1	6.8	15.9
Above and below ground carbon (estimates from Spawn et al. (2020), given for the year 2010 only)										
Mean above ground carbon (Mg/ha)	2010	32.2	30.3	75.2	8.2	10.8	6.6	5.7	4.0	6.1
Mean below ground carbon (Mg/ha)	2010	19.2	23.3	19.2	14.3	17.4	11.0	9.8	6.6	7.5
Soil carbon (from baseline mapping of Australian soil organic carbon stocks by CSIRO in 2020, see Viscarra Rossel et al (2014))										
Soil carbon (Mg/ha)	2010	83.8	112.7	185.8	102.9	96.8	98.3	106.0	81.2	110.6
Coastal blue carbon (carbon stocks in Australian tidal marshes, mangrove forests and seagrass meadows, see O. Serrano et al. (2019); Oscar Serrano et al. (2019))										
Total burial (Mg/C/yr)	2019	117.8				23107.9				
Total stocks in soil (Mg)	2019	51276.6				1006251.9				
Total stocks in biomass (Mg)	2019	456				8949.2				
Total area of blue carbon ecosystems (ha)	2019	312				6104				

Table 10 (continued).

Realm		Terrestrial								
Biome		T1 Tropical-subtropical forests			T3 Shrublands & shrubby woodlands	T4 Savannas & grasslands			T5 Deserts & semi-deserts	Broad Vegetation Group of Qld
EFG		T1.1 Tropical-subtropical lowland rainforests	T1.2 Tropical-subtropical dry forests and thickets	T1.3 Tropical-subtropical montane forests	T3.1 Seasonally dry tropical shrublands	T4.2 Pyric tussock savannas	T4.3 Hummock savannas	T4.4 Temperate woodlands	T5.1 Semi-desert steppes	Non-remnant
Biotic: compositional state										
Iconic fauna species habitat extent (ha)	2012	Please refer to Table 11 for species-by-species modelled potential habitat extent								
IUCN Species richness (no. all species)[Ŧ]	2020	230.4	261.6	383.1	229.4	236.4	242.6	264.8	197.6	324.8
IUCN Species richness – (no. threatened species)[Ŧ]	2020	3.6	3.3	10.9	2.0	2.5	3.0	3.8	1.4	5.4
Pest animal presence (no. of species)[§]	Present day	6	7	6	7	7	6	7	6	7
Weed presence (no. of species)[§]	Present day	18	25	20	26	27	14	19	6	27
Biotic: structural state										
Pasture biomass (kgDM/ha)	2010	2889	2707	1906	2234	2201	2465	2468	2752	3493
Pasture biomass (kgDM/ha)	2014	2383	2432	1690	2279	2141	2729	2376	2689	3203
Pasture biomass (kgDM/ha)	2019	2275	2401	1424	2127	2077	2560	2376	2411	2987
Mean annual tree cover (% area)	2009	17	67	99	40	50	44	44	27	61
Mean annual tree cover (% area)	2010	17	68	98	40	52	49	52	27	63
Mean annual tree cover (% area)	2014	19	73	100	49	58	55	74	34	72
Mean annual tree cover (% area)	2017	16	68	99	42	52	47	53	23	69

Ŧ Includes all assessed species of amphibians, birds and mammals assessed under The IUCN Red List of Threatened Species™ (iucnredlist.org/resources/spatial-data-download).

§ Maximum number of pest animal species is seven comprising cane toad, feral deer, feral cat, feral horse, feral pig, rabbit and wild dog. Maximum number of weed species is 34. Details of the area in which each invasive species has been reported to be present within each EFG are shown separately in Table 12.

Table 10 (continued).

Realm		Terrestrial								
Biome		T1 Tropical-subtropical forests			T3 Shrublands & shrubby woodlands	T4 Savannas & grasslands			T5 Deserts & semi-deserts	Broad Vegetation Group of Qld
EFG		T1.1 Tropical-subtropical lowland rainforests	T1.2 Tropical-subtropical dry forests and thickets	T1.3 Tropical-subtropical montane forests	T3.1 Seasonally dry tropical shrublands	T4.2 Pyric tussock savannas	T4.3 Hummock savannas	T4.4 Temperate woodlands	T5.1 Semi-desert steppes	Non-remnant
Biotic: structural state (cont'd)										
Vegetation height										
No. of patches (polygons)	2009	210	762	370	615	18,487	1,776	69	144	1,042
Mean patch area (ha)	2009	87.1	16.1	71.1	117.4	303.1	245.4	305.1	392.4	89.5
Mean vegetation height in a patch (m)	2009	11.6	8.0	22.3	3.9	4.5	3.7	3.9	2.0	3.0
Woody vegetation (categorised into three classes: non-woody, sparse and woody (forests))										
Area of non-woody vegetation (ha,%)	2009	1143 (6%)	91 (1%)	62 (<1%)	16551 (23%)	588678 (11%)	81113 (19%)	797 (4%)	34756 (62%)	24803 (27%)
Area of non-woody vegetation (ha,%)	2010	1250 (7%)	99 (1%)	70 (<1%)	17167 (24%)	615683 (11%)	82712 (19%)	936 (4%)	35228 (62%)	26305 (29%)
Area of non-woody vegetation (ha,%)	2014	1099 (6%)	167 (1%)	103 (<1%)	22355 (31%)	766918 (14%)	84424 (19%)	1152(5%)	37537 (66%)	27847 (30%)
Area of non-woody vegetation (ha,%)	2017	1221 (7%)	302 (2%)	95 (<1%)	28260 (39%)	978852 (17%)	113693 (26%)	1588 (8%)	36859 (65%)	34489 (38%)
Area of non-woody vegetation (ha,%)	2018	1394 (8%)	314 (3%)	66 (<1%)	30149 (42%)	1075089(19%)	115426 (26%)	2009 (10%)	37794 (67%)	33972 (37%)
Area of sparse woody vegetation (ha,%)	2009	2018 (11%)	1819 (15%)	20 (<1%)	34838 (48%)	2133003(38%)	188268 (43%)	11160 (53%)	16892 (30%)	38343 (42%)
Area of sparse woody vegetation (ha,%)	2010	1915 (10%)	1683 (14%)	17 (<1%)	35870 (50%)	2120361(38%)	178476 (41%)	10735 (51%)	16399 (29%)	36169 (39%)
Area of sparse woody vegetation (ha,%)	2014	1676 (9%)	1519 (12%)	6 (<1%)	28641 (40%)	1797871(32%)	128840 (30%)	6790 (32%)	15689 (28%)	23254 (25%)
Area of sparse woody vegetation (ha,%)	2017	1554 (9%)	1385 (11%)	3 (<1%)	23523 (33%)	1599328(29%)	116305 (27%)	6919 (33%)	15208 (27%)	20125 (22%)
Area of sparse woody vegetation (ha,%)	2018	1661 (9%)	1379 (11%)	2 (<1%)	21999 (30%)	1563173(28%)	111488 (26%)	7009 (33%)	14352 (25%)	19582 (21%)
Area of woody vegetation (ha,%)	2009	15131 (83%)	10346 (84%)	26198 (100%)	20814 (29%)	2881590(51%)	166429 (38%)	9083 (43%)	4858 (9%)	28448 (31%)
Area of woody vegetation (ha,%)	2010	15127 (83%)	10474 (86%)	26192 (100%)	19166 (27%)	2867226(51%)	174623 (40%)	9369 (45%)	4880 (9%)	29117 (32%)
Area of woody vegetation (ha,%)	2014	15517 (85%)	10570 (86%)	26172 (99%)	21206 (29%)	3038481(54%)	222547 (51%)	13098 (62%)	3281 (6%)	40491 (44%)
Area of woody vegetation (ha,%)	2017	15517 (85%)	10568 (86%)	26182 (99%)	20419 (28%)	3025091(54%)	205813 (47%)	12533 (60%)	4439 (8%)	36978 (40%)
Area of woody vegetation (ha,%)	2018	15237 (84%)	10563 (86%)	26211 (100%)	20054 (28%)	2965009(53%)	208897 (48%)	12022 (57%)	4361 (8%)	38038 (42%)

Table 10 (continued).

Realm		**Terrestrial**								
Biome		T1 Tropical-subtropical forests			T3 Shrublands & shrubby woodlands	T4 Savannas & grasslands			T5 Deserts & semi-deserts	Broad Vegetation Group of Qld
EFG		T1.1 Tropical-subtropical lowland rainforests	T1.2 Tropical-subtropical dry forests and thickets	T1.3 Tropical-subtropical montane forests	T3.1 Seasonally dry tropical shrublands	T4.2 Pyric tussock savannas	T4.3 Hummock savannas	T4.4 Temperate woodlands	T5.1 Semi-desert steppes	Non-remnant
Biotic: functional state										
Pasture growth (kgDM/ha/yr)	2010	3630	5303	3235	4372	4639	5077	5368	5473	8021
Pasture growth (kgDM/ha/yr)	2014	2374	2856	1278	2198	2449	2796	3055	2858	3908
Pasture growth (kgDM/ha/yr)	2019	1866	2243	1243	2095	2144	2321	2146	2711	2679
High intensity fire (% area)	2003	6.73	7.70	0.05	12.67	18.04	2.86	0.91	11.19	4.39
High intensity fire (% area)	2006	6.85	2.46	0.04	21.55	18.74	2.22	9.81	9.75	4.02
High intensity fire (% area)	2009	3.07	7.69	0.09	21.26	29.63	13.05	4.23	7.56	5.86
High intensity fire (% area)	2010	3.09	2.91	0.15	6.45	7.66	2.90	5.00	4.62	4.32
Low intensity fire (% area)	2003	3.36	10.89	0.02	31.41	11.84	4.00	0.65	23.19	8.41
Low intensity fire (% area)	2006	3.03	3.23	0.06	20.15	9.77	2.35	1.92	12.24	3.36
Low intensity fire (% area)	2009	2.52	4.67	0.04	6.26	9.55	10.98	4.21	3.17	3.46
Low intensity fire (% area)	2010	1.06	3.47	0.02	19.94	6.78	3.35	5.66	13.51	5.78
Fire frequency (number of burns over a 20-year period categorised into three classes as percentage of observed area within each ecosystem type)										
Area observed	ha	4,128	12,162	26,267	72,037	4,943,887	432,733	21,040	56,047	
Burned too often (% area)		0.04	74.69	67.70	67.22	18.20	11.30	0.90	0.24	
Burned within guideline (% area)	2000–19	70.96	10.70	30.83	29.64	35.42	74.53	98.06	90.27	
Not burned often enough (% area)		29.00	14.61	1.47	3.14	46.38	14.17	1.04	9.49	

Table 10 (continued)

	Realm	**Terrestrial**								
	Biome	T1 Tropical-subtropical forests			T3 Shrublands & shrubby woodlands	T4 Savannas & grasslands			T5 Deserts & semi-deserts	Broad Vegetation Group of Qld
	EFG	T1.1 Tropical-subtropical lowland rainforests	T1.2 Tropical-subtropical dry forests and thickets	T1.3 Tropical-subtropical montane forests	T3.1 Seasonally dry tropical shrublands	T4.2 Pyric tussock savannas	T4.3 Hummock savannas	T4.4 Temperate woodlands	T5.1 Semi-desert steppes	Non-remnant
Landscape										
Fire scars (area burned each year)										
Area burned (ha)	2010	1,497	3,055	908	37,274	2,647,359	128,819	6,377	12,660	9,532
Area burned (% area)	2010	8.21	24.94	3.45	51.62	47.24	29.56	30.30	22.40	10.41
Area burned (ha)	2014	2,591	482	294	4,143	951,980	31,534	56	30	3,494
Area burned (% area)	2014	14.20	3.94	1.12	5.74	16.99	7.24	0.27	0.05	3.81
Area burned (ha)	2018	1,200	3,248	371	18,517	2,054,132	116,090	4,363	5,496	7,413
Area burned (% area)	2018	6.58	26.52	1.41	25.65	36.66	26.64	20.73	9.73	8.09
Area burned (ha)	2019	1,305	2,756	73	15,473	1,742,034	32,583	182	4,094	7,299
Area burned (% area)	2019	7.15	22.50	0.28	21.43	31.09	7.48	0.86	7.25	7.97
Fragmentation (measured as difference in mean patch size between pre- and post-clearing time periods).										
Mean patch size (ha)	Pre-clearing	103.07	28.23	158.97	176.11	3,665.86	487.20	364.18	429.46	
Mean patch size (ha)	Post-clearing	103.07	16.26	110.58	123.64	2220.17	457.33	363.88	406.53	80.98
Post-clearing mean patch size as a percentage of pre-clearing mean patch size (%)		100	57.60	69.56	70.20	60.56	93.87	99.64	94.66	

Table 10 (continued).

Realm		**Freshwater–terrestrial**		**Marine–terrestrial**	**Marine–freshwater–terrestrial**		**Broad Vegetation Groups of Queensland**	
Biome		TF1 Palustrine wetlands		MT2 Supralittoral coastal systems	MFT1 Brackish tidal			
EFG		TF1.2 Subtropical-temperate forested wetlands	TF1.4 Seasonal floodplain marshes	MT2.1 Coastal shrublands and grasslands	MFT1.2 Intertidal forests & shrublands	MFT1.3 Coastal saltmarshes & reedbeds	Water	Estuary
Abiotic: physical state								
Waterbodies								
Mean extent of a waterbody (ha)	2020	4.3	6.4	0.3	0.8	6.8	20.5	2.1
Number of waterbodies (no)	2020	13,129	6,331	9	256	3,102	3,951	232
Dry-season wetlands: waterholes persisting during dry season for 50 days or more								
Mean extent of a waterhole (ha)	2020	1.11	1.58	0.4	0.86	0.42	2.87	1.83
Number of waterholes (no)	2020	6,184	2,551	53	617	330	825	161
Dry-season wetlands: waterholes persisting during dry season for 100 days or more								
Mean extent of a waterhole (ha)	2020	1.2	1.07	1.26	1.8	0.43	12.11	23.63
Number of waterholes (no)	2020	3,660	1,038	118	1,795	285	3,246	4,253
Water observations from space								
Mean extent of a waterbody (ha)	2020	1.2	1.26	0.18	0.55	0.79	9.51	8.44
Number of waterbodies (no)	2020	11,496	3,574	16	784	1,310	3,728	5,273
Gully erosion (estimated for the area of gullies modelled; erosion volume and rate are available as single values from satellite imagery from the years 2000 through to 2004)								
Area of gullies predicted (ha, % EFG)#		5347 (0.72)	73.82 (0.29)			0.06 (0.0001)	2.3 (0.05)	0.58 (0.01)
Median volume of erosion (m^3/year)	2000–04	1153934	10949			19	889	118
Mean rate of head scarp retreat (m/yr)		0.34	0.34			0.34	0.34	0.34

Refers to total area of gullies predicted by the model where the area of gullies from Aster imagery (15 m cell size) was adjusted by cross checking a subset against higher resolution using Quickbird imagery in Google earth (highest resolution was 0.61 m). Numbers in brackets indicate the area of gullies as a percentage of EFG area.

Table 10 (continued).

Realm		Freshwater–terrestrial		Marine–terrestrial	Marine–freshwater–terrestrial		Broad Vegetation Groups of Queensland	
Biome		TF1 Palustrine wetlands		MT2 Supralittoral coastal systems	MFT1 Brackish tidal			
EFG		TF1.2 Subtropical-temperate forested wetlands	TF1.4 Seasonal floodplain marshes	MT2.1 Coastal shrublands and grasslands	MFT1.2 Intertidal forests & shrublands	MFT1.3 Coastal saltmarshes & reedbeds	Water	Estuary
Abiotic: chemical state								
Above ground carbon (estimates from Liu et al. (2015), given as annual average values for the years 1993–2012)								
Mean carbon biomass (tn/ha)	1993–2012	7.3	7.8	9.1	9.9	9.5	12.9	9.9
Above and below ground carbon (estimates from Spawn et al. (2020), given for the year 2010 only)								
Mean above ground carbon (Mg/ha)	2010	7.1	7.7	17.6	13.6	4.1	6.1	8.9
Mean below ground carbon (Mg/ha)	2010	10.6	10.6	16.5	7.1	4.5	7.8	5.5
Soil carbon (from baseline mapping of Australian soil organic carbon stocks by CSIRO in 2020, see Viscarra Rossel et al (2014))								
Soil organic carbon (Mg/ha)	2010	78.7	78.1	76.5	78.0	74.3	113.1	70.4
Coastal blue carbon (carbon stocks in Australian tidal marshes, mangrove forests and seagrass meadows, see O. Serrano et al. (2019); Oscar Serrano et al. (2019))								
Total burial (Mg/C/yr)	2019	81	137.6	43.2	444.5	8,973.1		43.05
Total stocks in soil (Mg)	2019	35,286.5	59,938.4	18,808	193,568	3,907,436		18,747
Total stocks in biomass (Mg)	2019	313.8	533.1	167.3	1,721.5	34,751		166
Total area of blue carbon ecosystems (ha)	2019	213	364	114	1,174	23,677		114

Table 10 (continued).

	Realm	Freshwater–terrestrial		Marine–terrestrial	Marine–freshwater–terrestrial		Broad Vegetation Groups of Queensland	
	Biome	TF1 Palustrine wetlands		MT2 Supralittoral coastal systems	MFT1 Brackish tidal			
	EFG	TF1.2 Subtropical-temperate forested wetlands	TF1.4 Seasonal floodplain marshes	MT2.1 Coastal shrublands and grasslands	MFT1.2 Intertidal forests & shrublands	MFT1.3 Coastal saltmarshes & reedbeds	Water	Estuary
Biotic: compositional state								
Iconic fauna species habitat extent (ha)[#]	2012	Please refer to Table 11 for species-by-species modelled potential habitat extent						
IUCN Species richness (no. <u>all</u> species)[ǂ]	2020	208.0	216.8	221.1	227.1	223.3	348.2	229.2
IUCN Species richness – (no. <u>threatened</u> species)[ǂ]	2020	1.6	2.3	3.3	3.5	3.3	5.9	3.7
Pest animal presence (no. of species)[§]	Present day	7	7	5	5	5		
Weed presence (no. of species)[§]	Present day	33	31	4	6	6	29	
Biotic: structural state								
Pasture biomass (kgDM/ha)	2010	2431	2822	2789	3081	2942	3065	3296
Pasture biomass (kgDM/ha)	2014	2276	2493	2676	2690	2654	2932	2750
Pasture biomass (kgDM/ha)	2019	2089	2292	2589	2490	2501	3035	2527
Mean annual tree cover (% area)	2009	24	24	5	22	16	60	22
Mean annual tree cover (% area)	2010	24	24	6	22	16	60	22
Mean annual tree cover (% area)	2014	31	27	6	23	18	69	24
Mean annual tree cover (% area)	2017	21	22	6	20	16	71	19

[#] Sum of modelled potential habitat extent for four critically endangered and 19 endangered animal species as listed in Queensland Nature Conservation (Animals) Regulation 2020. Information on modelled potential habitat for selected threatened and priority species in Queensland was downloaded as shapefiles from Queensland Government Open Data Portal (data.qld.gov.au/dataset/modelled-potential-habitat-for-selected-threatened-species-queensland, see Data Inventory). Maps showing habitat extent specific to a particular species are shown separately in Figure 22.

[ǂ] Include all assessed species of amphibians, birds and mammals assessed under The IUCN Red List of Threatened Species™.

[§] Maximum number of pest animal species is seven comprising cane toad, feral deer, feral cat, feral horse, feral pig, rabbit and wild dog. Maximum number of weed species is 34. Details of the area in which each invasive species has been reported to be present within each EFG are shown separately in Table 12.

Table 10 (continued).

Realm		Freshwater–terrestrial		Marine–terrestrial	Marine–freshwater–terrestrial		Broad Vegetation Groups of Queensland	
Biome		TF1 Palustrine wetlands		MT2 Supralittoral coastal systems	MFT1 Brackish tidal			
EFG		TF1.2 Subtropical-temperate forested wetlands	TF1.4 Seasonal floodplain marshes	MT2.1 Coastal shrublands and grasslands	MFT1.2 Intertidal forests & shrublands	MFT1.3 Coastal saltmarshes & reedbeds	Water	Estuary
Biotic: structural state (cont'd)								
Vegetation height								
No. of patches (polygons)	2009	3,638	1,944	100	372	330	229	14
Mean patch area (ha)	2009	203.5	13.0	59.6	30.1	124.2		425.8
Mean vegetation height in a patch (m)	2009	3.3	2.5	6.4	4.3	1.5	3.4	3.4
Woody vegetation (categorised into three classes: non-woody, sparse and woody (forests))								
Area of non-woody vegetation (ha, %)	2009	245,976 (33%)	13,923 (55%)	1,715 (29%)	1,617 (15%)	36,648 (90%)	3,031 (63%)	5,180 (99%)
Area of non-woody vegetation (ha, %)	2010	252,752 (34%)	13,475 (53%)	1,738 (29%)	1,809 (16%)	36,979 (90%)	3,102 (65%)	5,232 (100%)
Area of non-woody vegetation (ha, %)	2014	284,562 (38%)	14,651 (58%)	1,565 (27%)	1,775 (16%)	36,020 (88%)	3,452 (72%0	5,304 (101%)
Area of non-woody vegetation (ha, %)	2017	300,791 (41%)	16,379 (65%)	1,512 (26%)	1,946 (18%)	36,426 (89%)	3,539 (74%)	5,427 (104%)
Area of non-woody vegetation (ha, %)	2018	334,125 (45%)	17,209 (68%)	1,591 (27%)	2,055 (19%)	36,737 (90%)	3,487 (73%)	5,445 (104%)
Area of sparse woody vegetation (ha, %)	2009	338,887 (46%)	6,935 (27%)	1,277 (22%)	757 (7%)	2,377 (6%)	212 (4%)	223 (4%)
Area of sparse woody vegetation (ha, %)	2010	330,736 (45%)	6,909 (27%)	1,236 (21%)	704 (6%)	2,069 (5%)	191 (4%)	180 (3%)
Area of sparse woody vegetation (ha, %)	2014	298,672 (40%)	6,250 (25%)	1,181 (20%)	586 (5%)	2,630 (6%)	115 (2%)	83 (2%)
Area of sparse woody vegetation (ha, %)	2017	266,419 (36%)	4,930 (20%)	1,092 (19%)	506 (5%)	2,312 (6%)	112 (2%)	54 (1%)
Area of sparse woody vegetation (ha, %)	2018	240,577 (32%)	4,303 (17%)	1,102 (19%)	558 (5%)	2,201 (5%)	92 (2%)	52 (1%)
Area of woody vegetation (ha, %)	2009	155,418 (21%)	4,377 (17%)	2,950 (50%)	8,830 (80%)	1,936 (5%)	1,544 (32%)	553 (11%)
Area of woody vegetation (ha, %)	2010	156,792 (21%)	4,851 (19%)	2,968 (50%)	8,691 (79%)	1,913 (5%)	1,494 (31%)	544 (10%)
Area of woody vegetation (ha, %)	2014	157,046 (21%)	4,334 (17%)	3,196 (54%)	8,843 (80%)	2,311 (6%)	1,220 (25%)	569 (11%)
Area of woody vegetation (ha, %)	2017	173,071 (23%)	3,926 (16%)	3,338 (57%)	8,752 (80%)	2,222 (5%)	1,135 (24%)	475 (9%)
Area of woody vegetation (ha, %)	2018	165,579 (22%)	3,723 (15%)	3,249 (55%)	8,591 (78%)	2,022 (5%)	1,207 (25%)	459 (9%)

Table 10 (continued).

Realm		Freshwater–terrestrial		Marine–terrestrial	Marine–freshwater–terrestrial		Broad Vegetation Groups of Queensland	
Biome		TF1 Palustrine wetlands		MT2 Supralittoral coastal systems	MFT1 Brackish tidal			
EFG		TF1.2 Subtropical-temperate forested wetlands	TF1.4 Seasonal floodplain marshes	MT2.1 Coastal shrublands and grasslands	MFT1.2 Intertidal forests & shrublands	MFT1.3 Coastal saltmarshes & reedbeds	Water	Estuary
Biotic: functional state								
Pasture growth (kgDM/ha/yr)	2010	4930	4992	3234	3265	3381	4742	3825
Pasture growth (kgDM/ha/yr)	2014	2762	3025	2359	2104	2269	2956	2367
Pasture growth (kgDM/ha/yr)	2019	2382	2498	1773	1738	1816	2166	1988
High intensity fire (% area)	2003	18.81	13.28	6.88	7.56	8.01	3.42	17.57
High intensity fire (% area)	2006	20.99	17.92	7.50	6.05	8.54	1.60	14.17
High intensity fire (% area)	2009	24.89	12.00	4.07	4.83	3.98	3.98	15.15
High intensity fire (% area)	2010	13.84	13.12	13.24	3.56	5.14	1.48	12.17
Low intensity fire (% area)	2003	16.72	12.75	5.72	4.86	4.44	4.41	15.19
Low intensity fire (% area)	2006	10.70	9.80	5.65	3.86	5.40	1.75	11.30
Low intensity fire (% area)	2009	9.90	7.98	2.42	3.60	3.58	2.55	11.05
Low intensity fire (% area)	2010	9.50	6.63	7.60	1.96	3.47	1.09	6.87
Fire frequency (number of burns over a 20-year period categorised into three classes as percentage of observed area within each ecosystem type)								
Area observed	ha	724,786	21,500	2,035	10,367	513		717
Burned too often (% area)		18.21	7.51	0.012	8.37	3.84		11.97
Burned within guideline (% area)	2000–19	66.00	72.83	58.18	91.57	43.35		78.35
Not burned often enough (% area)		15.78	19.66	41.80	0.06	52.81		9.69

Table 10 (continued).

Realm		Freshwater–terrestrial		Marine–terrestrial	Marine–freshwater–terrestrial		Broad Vegetation Groups of Queensland	
Biome		TF1 Palustrine wetlands		MT2 Supralittoral coastal systems	MFT1 Brackish tidal			
EFG		TF1.2 Subtropical-temperate forested wetlands	TF1.4 Seasonal floodplain marshes	MT2.1 Coastal shrublands and grasslands	MFT1.2 Intertidal forests & shrublands	MFT1.3 Coastal saltmarshes & reedbeds	Water	Estuary
Landscape								
Fire scars (area burned each year)								
Area burned (ha)	2010	282,305	7,358	302	742	4,571	498	676
Area burned (% area)	2010	38.13	29.16	5.11	6.75	11.17	10.10	12.94
Area burned (ha)	2014	157,850	4,314	225	359	1,629	208	273
Area burned (% area)	2014	21.32	17.10	3.81	3.26	3.98	4.35	5.22
Area burned (ha)	2018	341,639	6,430	323	380	2,088	577	299
Area burned (% area)	2018	46.15	25.48	5.47	3.45	5.10	12.06	5.72
Area burned (ha)	2019	306,008	7,035	290	485	2,036	498	446
Area burned (% area)	2019	41.33	27.88	4.92	4.41	4.98	10.41	8.53
Fragmentation (measured as difference in mean patch size between pre- and post-clearing time periods).								
Mean patch size (ha)	Pre-clearing	964.08	13.00	39.20	33.40	136.80		73.42
Mean patch size (ha)	Post-clearing	434.71	13.16	36.35	33.56	137.48	20.72	62.75
Post-clearing mean patch size as a percentage of pre-clearing mean patch size (%)		45.09	101.28	92.72	100.50	100.49		85.47

Table 11. Area of modelled potential habitat extent for critically endangered species and endangered species as listed in Queensland Nature Conservation (Animals) Regulation 2020, presented by species and by ecosystem type. This table forms part of the ecosystem condition variable account.

Realm	**Terrestrial**								
Biome	T1 Tropical-subtropical forests			T3 Shrublands & shrubby woodlands	T4 Savannas & grasslands			T5 Deserts & semi-deserts	Broad Vegetation Group of Qld
EFG	T1.1 Tropical-subtropical lowland rainforests	T1.2 Tropical-subtropical dry forests and thickets	T1.3 Tropical-subtropical montane forests	T3.1 Seasonally dry tropical shrublands	T4.2 Pyric tussock savannas	T4.3 Hummock savannas	T4.4 Temperate woodlands	T5.1 Semi-desert steppes	Non-remnant
Habitat extent of *critically endangered* species (in ha)									
Mountain-top nursery frog (*Cophixalus monticola*)	0	104.1	4721.0	0	77.5	0	0	0	0
Armoured mist frog (*Litoria lorica*)	129.6	186.6	15585.0	159.0	27102.4	0	0	0	318.7
Kuranda tree frog (*Litoria myola*)	0	0	17.3	0	9.1	0	0	0	0
Mountain mist frog (*Litoria nyakalensis*)	259.1	199.9	17616.7	331.5	26324.0	0	0	0	450.5
Habitat extent of *endangered* species (in ha)									
Northern bettong (*Bettongia tropica*)	8.7	5.2	817.9	17.0	20086.1	0	0	0	299.0
Southern cassowary – southern population (*Casuarius johnsonii*)	2.3	212.6	17031.4	16.3	3462.8	0	0	0	432.0
Spotted-tailed quoll – northern subspecies (*Dasyurus maculatus gracilis*)	0	158.1	14985.1	10.4	6832.4	0	0	0	14.0
Red goshawk (*Erythrotriorchis radiatus*)	3516.4	5131.2	26054.7	5668.0	935763.2	77128.2	146.2	413.5	38558.8
Gouldian finch (*Erythrura gouldiae*)	143.8	7748.0	25.6	14760.0	1588686.2	278677.7	4713.4	9108.7	63133.6
Semon's leaf-nosed bat (*Hipposideros semoni*)	812.0	351.4	7922.5	1457.4	46761.5	5.4	62.2	0	5346.4

Table 11 (continued).

Realm	Terrestrial								
Biome	T1 Tropical-subtropical forests			T3 Shrublands & shrubby woodlands	T4 Savannas & grasslands			T5 Deserts & semi-deserts	Broad Vegetation Group of Qld
EFG	T1.1 Tropical-subtropical lowland rainforests	T1.2 Tropical-subtropical dry forests and thickets	T1.3 Tropical-subtropical montane forests	T3.1 Seasonally dry tropical shrublands	T4.2 Pyric tussock savannas	T4.3 Hummock savannas	T4.4 Temperate woodlands	T5.1 Semi-desert steppes	Non-remnant
Habitat extent of *endangered* species (in ha)									
Torrent treefrog (*Litoria nannotis*)	20.0	259.8	18509.1	448.4	30516.9	0	0	0	12.9
Common mist frog (*Litoria rheocola*)	3.6	175.6	15985.5	18.9	7861.8	0	0	0	2.6
Ghost bat (*Macroderma gigas*)	729.0	10709.4	11651.1	3579.6	1250363.6	78669.9	149.9	0	22355.7
Crimson finch – white-bellied subspecies (*Neochmia phaeton evangelinae*)	6744.8	0	0	0	11260.8	0	0	0	17.3
Yellow-bellied glider – northern subspecies (*Petaurus australis unnamed subsp.*)	0	150.4	10939.6	143.2	21074.7	0	0	0	41.6
Black-throated finch - white-rumped subspecies (*Poephila cincta*)	0	146.5	0	0	12101.5	51.3	0	0	1510.1
Golden-shouldered parrot (*Psephotus chrysopterygius*)	0	0	0	9884.9	769298.2	5242.8	0	33.5	963.3
Spectacled flying fox (*Pteropus conspicillatus*)	847.2	7019.6	19531.8	1564.2	93931.0	518.8	75.4	0	11636.6
Greater large-eared horseshoe bat (*Rhinolophus philippinensis*)	560.3	8530.1	21813.6	2032.9	134669.8	86.7	41.7	0	7462.9
Australian painted snipe (*Rostratula australis*)	145.9	516.6	375.6	263.8	301700.8	23717.0	118.3	60.1	48560.0
Bare-rumped sheathtail bat (*Saccolaimus nudicluniatus*)	753.7	73.0	5451.6	46.3	15191.5	3.7	0	0	4488.2

Table 11 (continued).

Realm	Terrestrial								
Biome	T1 Tropical-subtropical forests			T3 Shrublands & shrubby woodlands	T4 Savannas & grasslands			T5 Deserts & semi-deserts	Broad Vegetation Group of Qld
EFG	T1.1 Tropical-subtropical lowland rainforests	T1.2 Tropical-subtropical dry forests and thickets	T1.3 Tropical-subtropical montane forests	T3.1 Seasonally dry tropical shrublands	T4.2 Pyric tussock savannas	T4.3 Hummock savannas	T4.4 Temperate woodlands	T5.1 Semi-desert steppes	Non-remnant
Habitat extent of *endangered* species (in ha)									
Northern tinker frog (*Taudactylus rheophilus*)	0	165.8	15771.3	3.7	655.6	0	0	0	3.7
Buff-breasted button quail (*Turnix olivii*)	835.9	4777.8	5276.0	7523.9	1142514.8	129293.3	2162.0	1197.7	43545.8

Table 11 (continued).

Realm	Freshwater–terrestrial		Marine–terrestrial	Marine–freshwater–terrestrial		Broad Vegetation Groups of Queensland	
Biome	TF1 Palustrine wetlands		MT2 Supralittoral coastal systems	MFT1 Brackish tidal			
EFG	TF1.2 Subtropical-temperate forested wetlands	TF1.4 Seasonal floodplain marshes	MT2.1 Coastal shrublands and grasslands	MFT1.2 Intertidal forests & shrublands	MFT1.3 Coastal saltmarshes & reedbeds	Water	Estuary
Habitat extent of *critically endangered* species (in ha)							
Mountain-top nursery frog (*Cophixalus monticola*)	0	0	0	0	0	0	0
Armoured mist frog (*Litoria lorica*)	612.7	1.3	0	0	0	0.7	0
Kuranda tree frog (*Litoria myola*)	0	0	0	0	0	0	0
Mountain mist frog (*Litoria nyakalensis*)	64.1	8.1	0	0	0	0	0
Habitat extent of *endangered* species (in ha)							
Northern bettong (*Bettongia tropica*)	64.2	5.8	0	0	0	1.6	0
Southern cassowary – southern population (*Casuarius johnsonii*)	33.5	1.3	0	0	0	0	0
Spotted-tailed quoll – northern subspecies (*Dasyurus maculatus gracilis*)	1.2	1.9	0	0	0	0	0
Red goshawk (*Erythrotriorchis radiatus*)	82880.2	9918.5	138.7	20.7	94.5	3186.2	45.8
Gouldian finch (*Erythrura gouldiae*)	95946.2	929.4	0	0	0	2124.7	0
Semon's leaf-nosed bat (*Hipposideros semoni*)	319.3	8.6	0	0	0	11.0	0
Torrent treefrog (*Litoria nannotis*)	152.9	4.1	0	0	0	0	0
Common mist frog (*Litoria rheocola*)	27.2	0.9	0	0	0	0	0
Ghost bat (*Macroderma gigas*)	6989.8	35.3	0	0	0	3139.6	0

Table 11 (continued).

Realm	Freshwater–terrestrial		Marine–terrestrial	Marine–freshwater–terrestrial		Broad Vegetation Groups of Queensland	
Biome	TF1 Palustrine wetlands		MT2 Supralittoral coastal systems	MFT1 Brackish tidal			
EFG	TF1.2 Subtropical-temperate forested wetlands	TF1.4 Seasonal floodplain marshes	MT2.1 Coastal shrublands and grasslands	MFT1.2 Intertidal forests & shrublands	MFT1.3 Coastal saltmarshes & reedbeds	Water	Estuary
Habitat extent of *endangered* species (in ha)							
Crimson finch – white-bellied subspecies (*Neochmia phaeton evangelinae*)	15808.3	1996.5	864.7	4559.2	2860.4	1.0	1240.4
Yellow-bellied glider – northern subspecies (*Petaurus australis unnamed subsp.*)	39.0	8.1	0	0	0	0	0
Black-throated finch - white-rumped subspecies (*Poephila cincta*)	625.4	5.7	0	0	0	137.6	0
Golden-shouldered parrot (*Psephotus chrysopterygius*)	54148.1	1198.8	0.8	0	0	53.6	0
Spectacled flying fox (*Pteropus conspicillatus*)	4679.3	335.7	0	0	0	282.2	0
Greater large-eared horseshoe bat (*Rhinolophus philippinensis*)	593.4	28.6	0	0	0	80.2	0
Australian painted snipe (*Rostratula australis*)	40427.4	4332.0	0	0	0	3850.9	0
Bare-rumped sheathtail bat (*Saccolaimus nudicluniatus*)	4101.4	39.8	0	0	0	23.2	0
Northern tinker frog (*Taudactylus rheophilus*)	0	0	0	0	0	0	0
Buff-breasted button quail (*Turnix olivii*)	40224.7	403.1	0	0	0	4058.7	0

Table 12. Presence of priority invasive species in the Mitchell catchment, indicating the area (in hectares) in which each invasive species has been reported to be present within each Ecosystem Functional Group. Grey cells indicate unsuitable Ecosystem Functional Groups for each priority invasive species. This table forms part of the Ecosystem Condition Variable Account.

Weeds in the Mitchell catchment																
Ecosystem type	Estuary	Intertidal forests and shrublands	Coastal saltmarshes and reedbeds	Coastal shrublands and grasslands		Tropical-subtropical lowland rainforests	Tropical-subtropical dry forest and thickets	Tropical-subtropical montane rainforests	Seasonally dry tropical shrublands	Pyric tussock savannas	Hummock savannas	Temperate woodlands	Semi-desert steppes	Subtropical-temperate forested wetlands	Seasonal floodplain marshes	Water
IUCN EFG	Estuary	MFT1.2	MFT1.3	MT2.1	Non-remnant	T1.1	T1.2	T1.3	T3.1	T4.2	T4.3	T4.4	T5.1	TF1.2	TF1.4	Water
Area (ha)	5226	10996	40916	5902	91583	18244	12248	26323	72205	5603684	435831	21049	56506	740341	25233	4785
Asparagus fern		0	0	0	4519	53	265	10034	51	51831	0	824	0	1187	113	
Bellyache bush		0	0	0	15030	0	3519	0	8790	554729	21161	1695	10468	52656	521	
Broad leaf privet		0	0	0	1292	0	10	1122	265	15653	0	23	0	147	3	
Cabomba														1011	3	33
Camphor laurel		0	0	0	1292	0	10	1122	265	15653	0	23	0	147	3	
Cats claw creeper		0	0	0	1239	0	17	1310	39	25857	0	279	0	224	3	
Chinese apple		2034	6987	2153	11988	3743	4210	0	30477	1076513	29394	1011	13839	105189	5597	

Table 12 (continued).

Chinese privet		0	0	0	1191	0	10	1122	39	13101	0	23	0	117	3	
Fireweed		0	0	0	101	0	0	0	226	2552	0	0	0	30	0	
Gamba grass		0	0	0	49052	613	311	3431	2256	254142	54268	486	0	7025	1172	
Giant sensitive plant		0	0	0	5810	613	92	5260	5	10260	0	0	0	207	13	
Hymenachne														28742	4094	3678
Kosters curse		0	0	0	5809	613	85	1548	0	4784	0	0	0	166	13	
Lantana		0	0	0	70305	847	6274	25606	7179	989121	68812	6635	0	22942	1485	
Maderia vine		0	0	0	1191	0	10	1122	39	13101	0	23	0	117	3	
Miconia		0	0	0	10256	613	92	5260	27	18475	0	0	0	828	131	
Parkinsonia		6063	32458	5065	1931	10960	2444	0	16685	454141	10975	0	25423	190126	11670	
Parthenium		0	0	0	28276	794	2595	5792	61	116135	4567	509	0	2562	254	
Pond apple	0		0											0	0	0
Prickly acacia		117	3680	1286	2099	419	2444	0	16685	266886	10975	0	25423	74398	2169	
Prickly pear		0	0	0	31486	613	91	1822	54	67200	9819	486	0	2769	100	
Rat tail grass		0	0	0	67355	847	4082	24124	2814	626914	34962	509	11	26939	860	
Rubber vine		11211	40972	5962	79016	17502	12028	11355	72124	5545612	435831	21026	56506	737886	25099	
Sagittaria														11	0	67
Salvinia														2111	150	3552
Siam weed		0	0	0	11814	666	344	11393	51	139638	429	2387	0	2455	125	

Table 12 (continued).

Sicklepod		13	10	0	18284	766	1695	8322	16850	637529	16266	75	18256	73206	2526	
Singapore daisy		13	10	0	11856	613	103	6381	593	91028	30	23	0	6033	1908	
Thunbergia		0	0	0	12111	613	1156	2858	44	81016	0	824	0	925	135	
Tobacco weed		0	0	0	5810	613	86	5071	5	10259	0	0	0	207	13	
Water hyacinth														152546	10422	1006
Water lettuce														790	121	1042
Yellow oleander		0	0	0	10167	0	2392	0	3118	429785	12911	11193	0	9188	1111	

Table 13. Presence of pest animal species in the Mitchell catchment, indicating the area (in hectares) in which each invasive species has been reported to be present within each Ecosystem Functional Group. Grey cells indicate unsuitable ecosystem functional groups for each priority invasive species.

Pest animals in the Mitchell catchment																
Ecosystem type	Estuary	Intertidal forests and shrublands	Coastal saltmarshes and reedbeds	Coastal shrublands and grasslands	Non-remnant	Tropical-subtropical lowland rainforests	Tropical-subtropical dry forest and thickets	Tropical-subtropical montane rainforests	Seasonally dry tropical shrublands	Pyric tussock savannas	Hummock savannas	Temperate woodlands	Semi-desert steppes	Subtropical-temperate forested wetlands	Seasonal floodplain marshes	Water
IUCN EFG		MFT1.2	MFT1.3	MT2.1		T1.1	T1.2	T1.3	T3.1	T4.2	T4.3	T4.4	T5.1	TF1.2	TF1.4	
IUCN EFG Area (ha)	5226	10996	40916	5902	91612	18244	12248	26323	72205	5603684	435831	21049	56506	740341	25233	4785
Cane toad		960	8646	1401	58782	5416	6257	22337	9238	1350868	59301	1902	26	114619	9752	3922
Feral deer		0	0	0	5673	0	17	1310	61	53366	0	23	0	1306	133	
Feral cat		11211	40972	5962	91612	18296	12248	26323	72205	5601157	435831	21049	56506	739195	25233	
Feral horse		8906	32848	3648	3311	13025	3737	0	13152	1999827	193077	3895	17436	527619	19788	
Feral pig		11008	40533	5955	91612	18296	12248	26323	72205	5601523	435831	21049	56506	740341	25225	
Rabbit		0	0	0	78547	234	8201	14134	23111	1957421	358277	21049	1462	58831	1916	
Wild dog		11008	40533	5955	91612	18296	12248	26323	72205	5598981	435831	21049	56506	739195	25225	

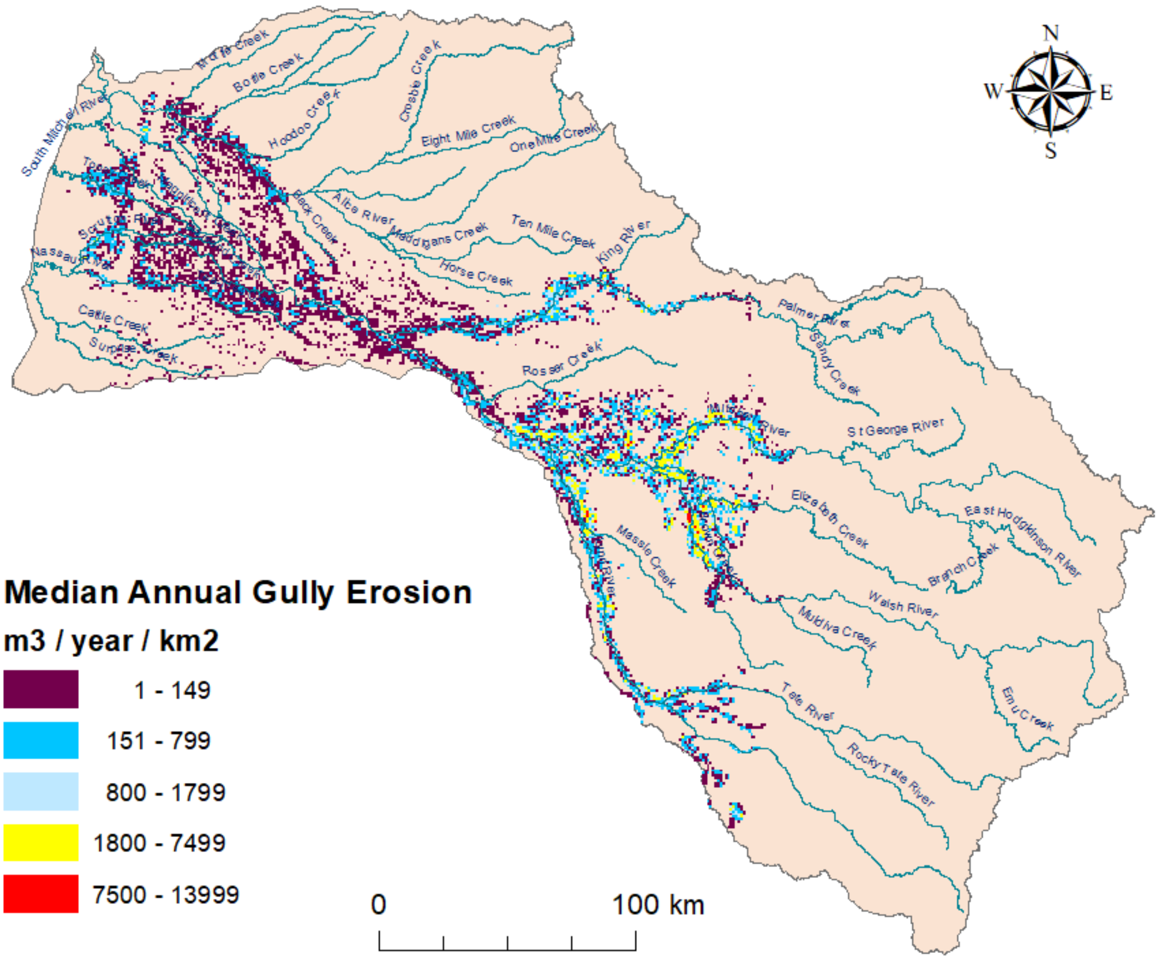
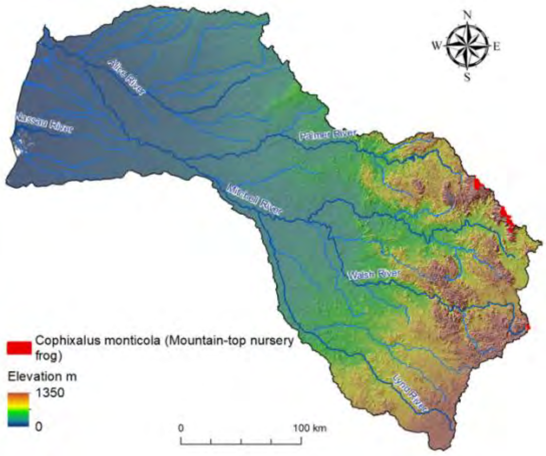
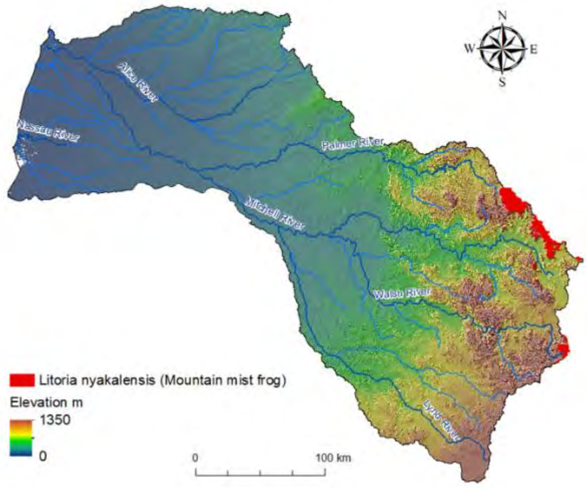


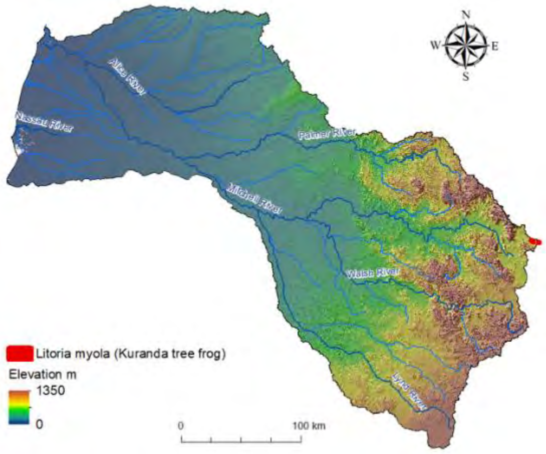
Figure 21. Median rates of gully erosion (m^3/km^2/year) in the Mitchell catchment, based on satellite imagery collected between the years 2000 and 2004, as described in Brooks et al. (2008). This map was re-constructed from Brooks et al. (2008).



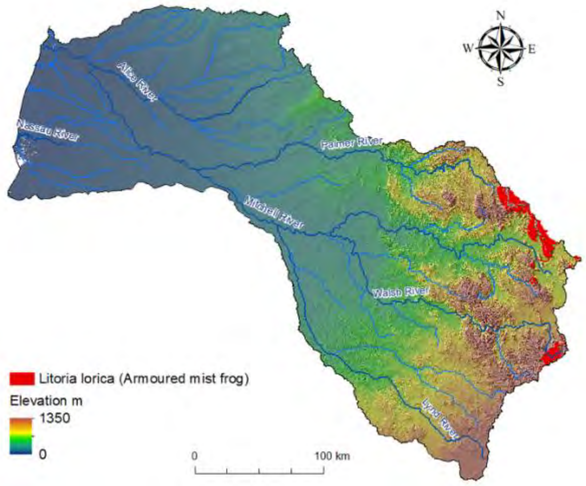
(a) Habitat distribution of *Cophixalus monticola* (mountain-top nursery frog)



(b) Habitat distribution of *Litoria nyakalensis* (mountain mist frog)



(c) Habitat distribution of *Litoria myola* (Kuranda tree frog)



(d) Habitat distribution of *Litoria lorica* (armoured mist frog)

Figure 22. Modelled potential habitat extent of four critically endangered animal species in the Mitchell catchment, as listed in Queensland Nature Conservation (Animals) Regulation 2020. Data sourced from Queensland Department of Environment and Science (data.qld.gov.au/dataset/modelled-potential-habitat-for-selected-threatened-species-queensland).

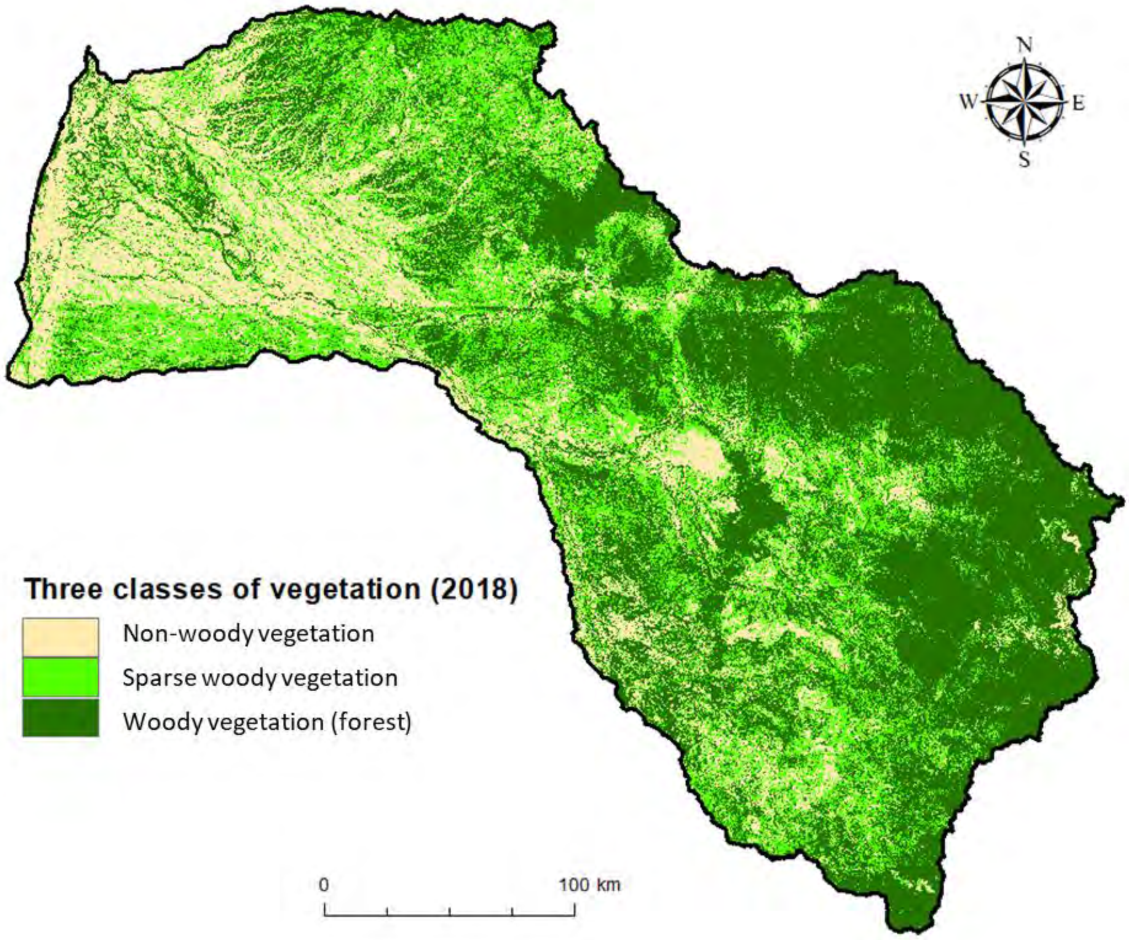


Figure 23. Spatial coverage of woody vegetation in 2018, categorised into three classes: non-woody vegetation, sparse woody vegetation and woody vegetation (forest).

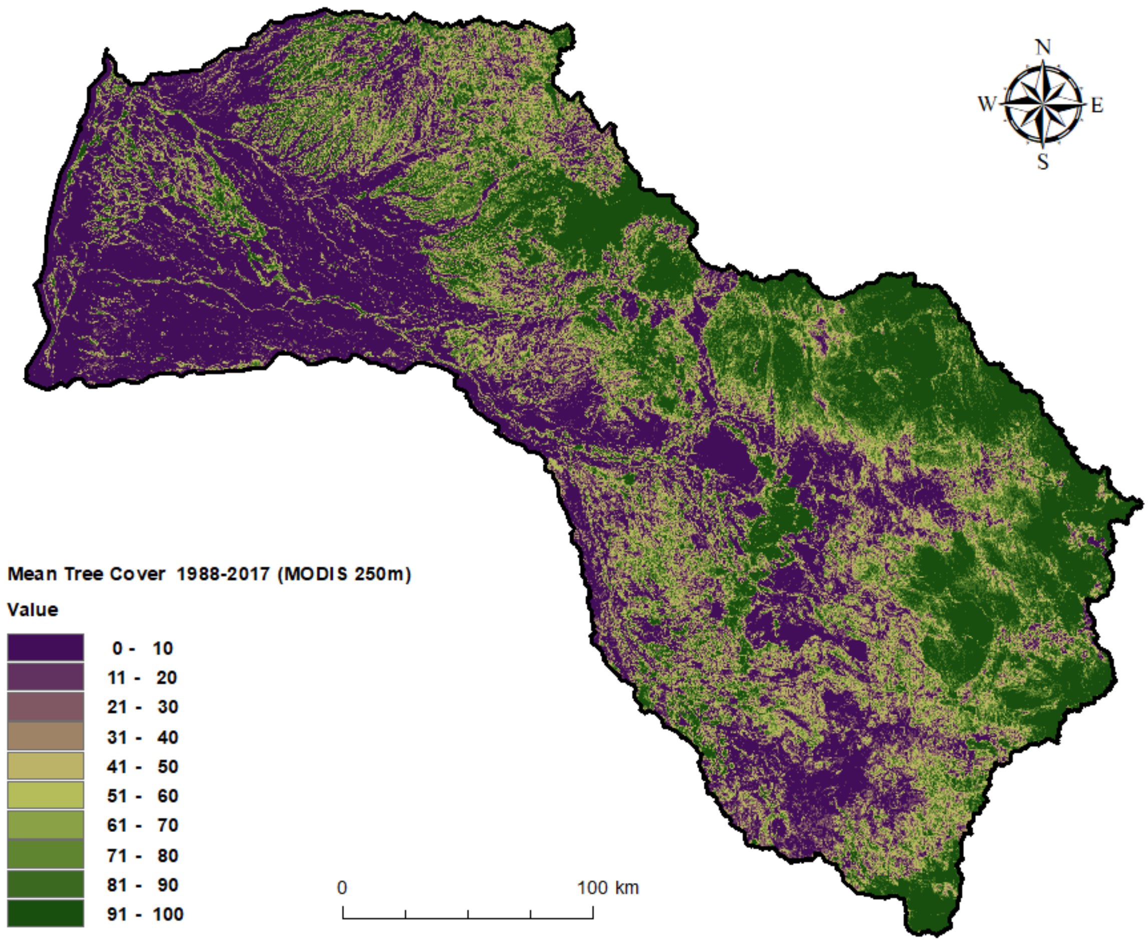


Figure 24. Mean tree cover expressed as percentages of ecosystem type extents over the period 1988–2017.

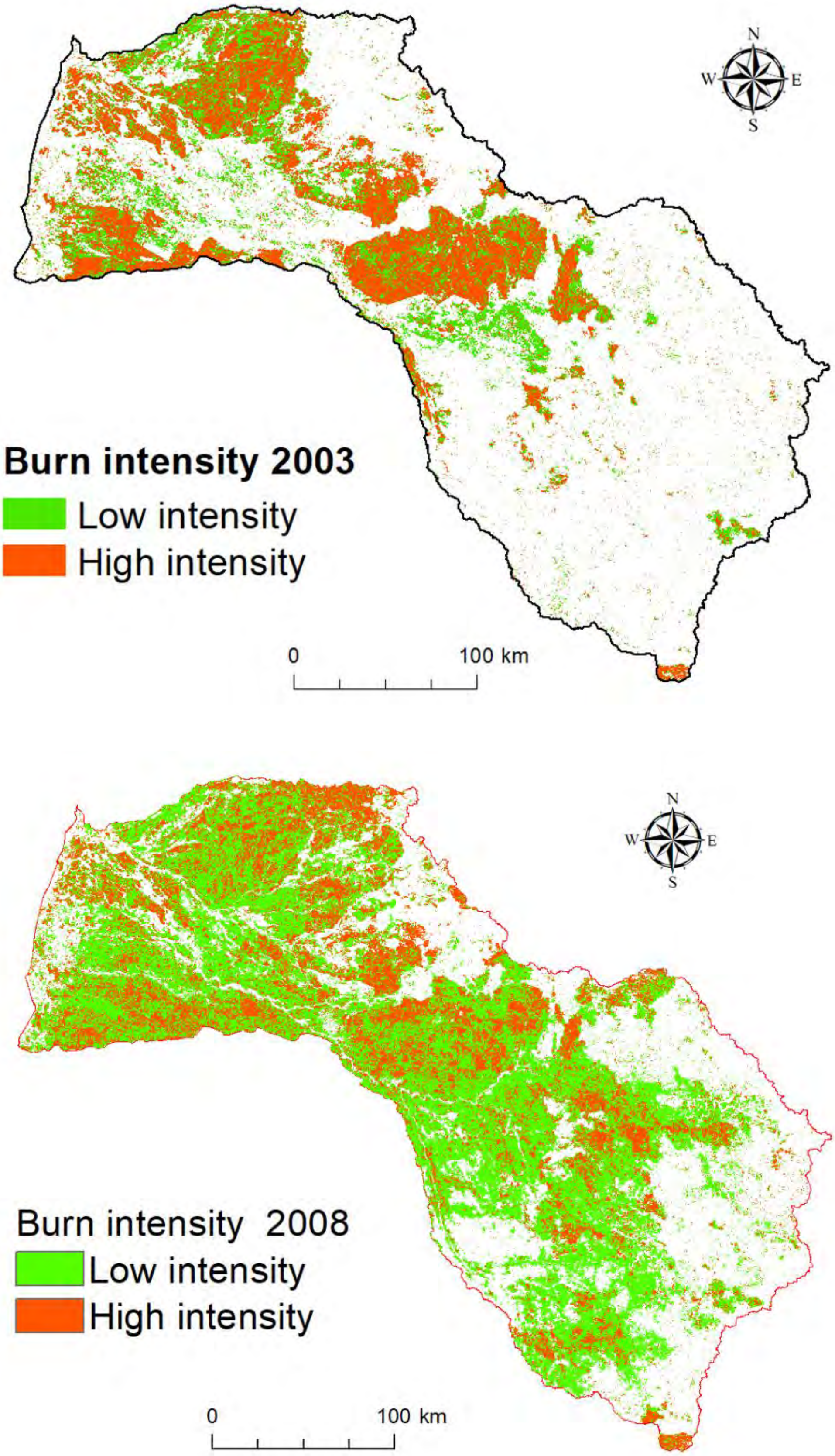


Figure 25. Fireburn intensity (high vs.low) for indicative years 2003 and 2008.

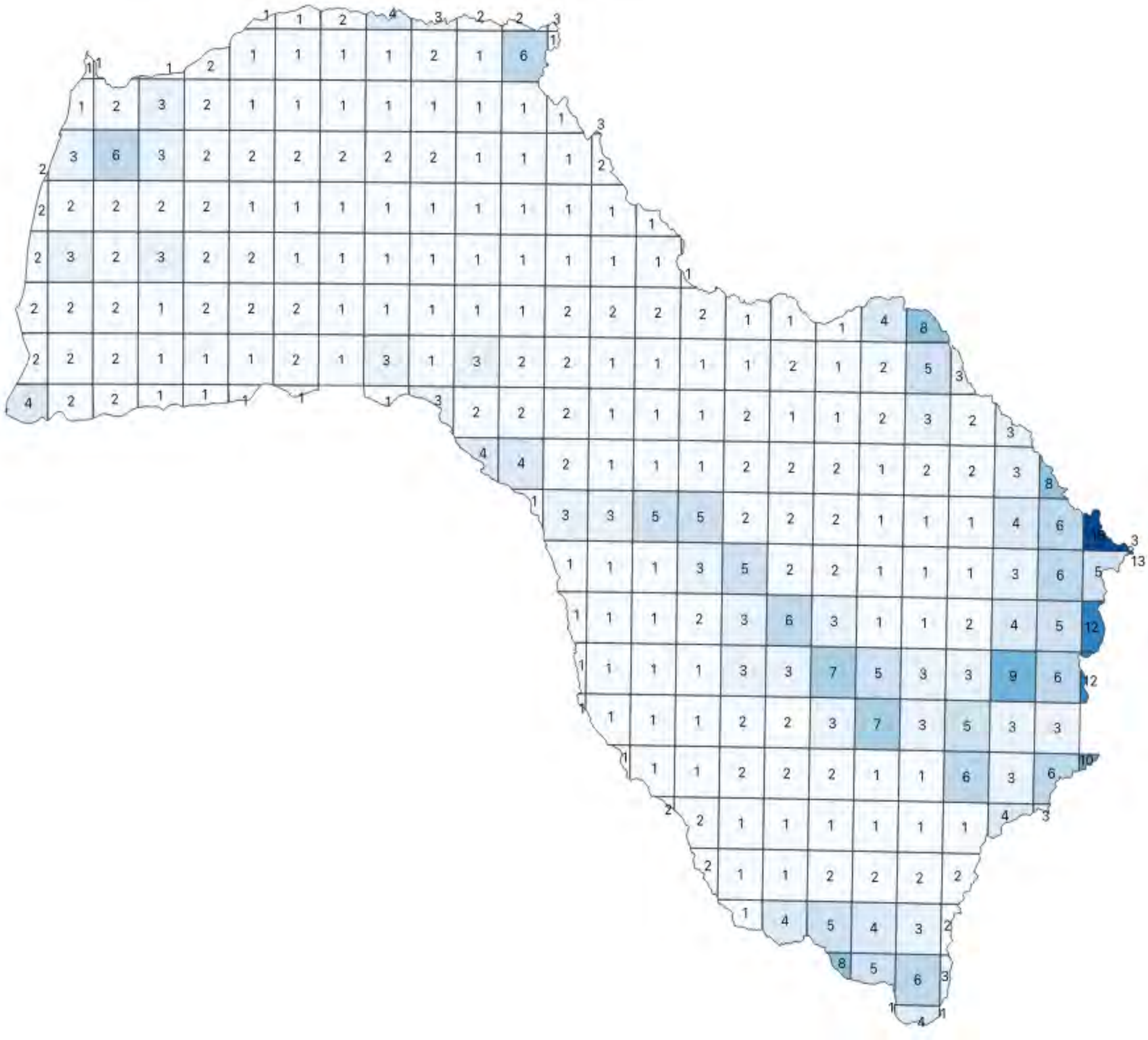


Figure 26. Number of priority weed species present per grid cell across the Mitchell River catchment. Maximum number of priority weed species calculated by Pest Central, Annual Pest Distribution Surveys, Queensland Weed Distribution Current, WildNet and Atlas of Living Australia datasets, available on QSpatial. Each grid cell is 18.5 km × 18.5 km = 342.25 km^2.

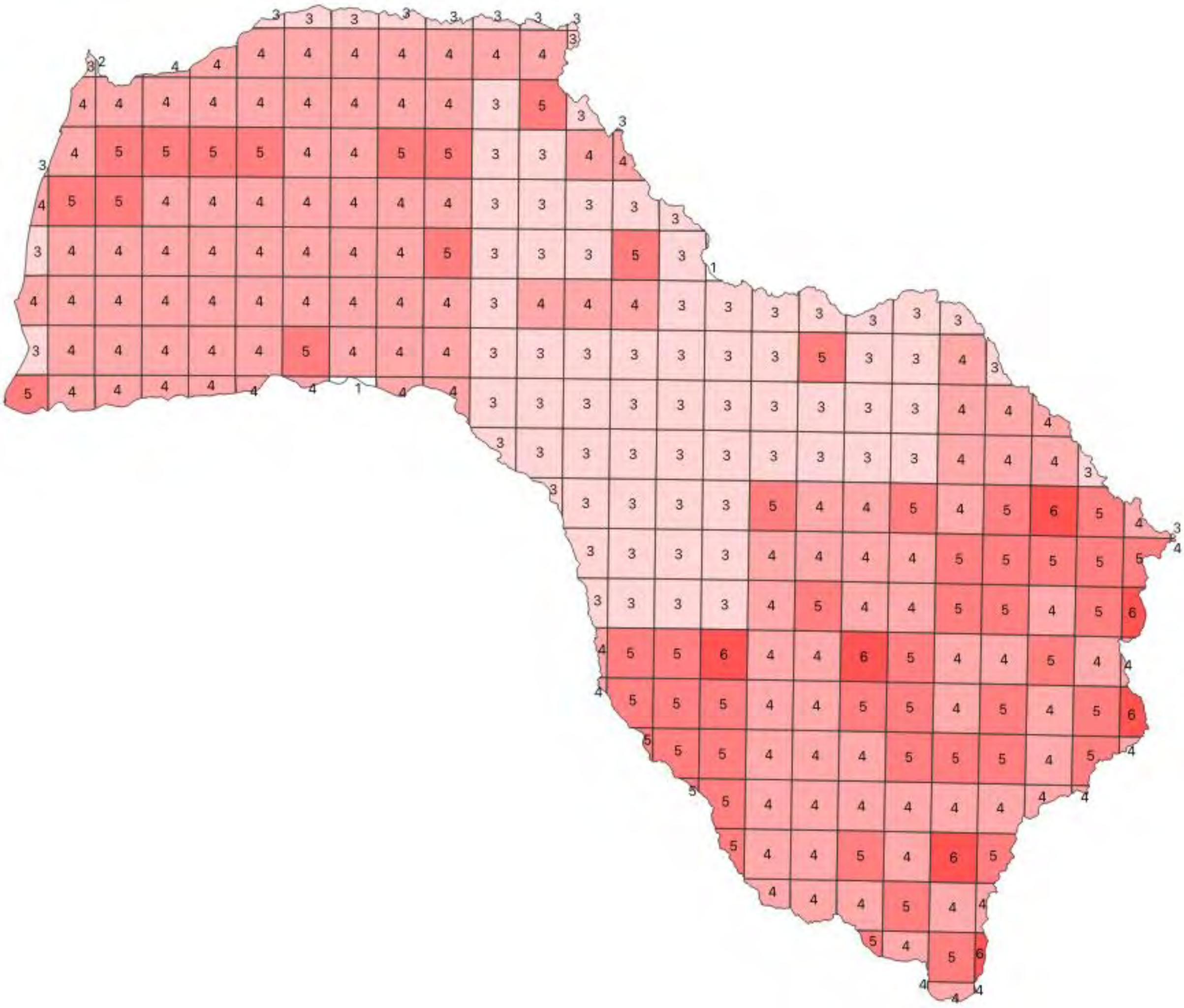


Figure 27. Number of priority pest animal species present per grid cell across the Mitchell River catchment. Maximum number of priority pest animal species calculated by Pest Central, Annual Pest Distribution Surveys, Queensland Weed Distribution Current, WildNet and Atlas of Living Australia datasets available on Qspatial. Each grid cell is 18.5 km × 18.5 km = 342.25 km^2.

4. Supporting information

4.1 Summary

Additional information to support the Stage 1 Ecosystem Condition Account in Section 3 are provided in this section. This comprises:

- Aquatic Conservation Assessment (ACA) scores for watercourse lines and watercourse areas derived for the Mitchell catchment in 2018 using the Aquatic Biodiversity Assessment Mapping Method (AquaBAMM) (Department of Environment and Science, 2018) that was developed for wetlands and made available by the Queensland Government Department of Environment and Science's Wetland*Info* team. The AquaBAMM methodology draws on indicators across eight different categories to produce its ACA scores. Some categories respond to intensity of agricultural and urban land use, others respond to presence of exotic plants, fish, invertebrates and/or vertebrates in either wetlands or their surrounding catchments.
- Extent of protected areas (tabulated by ecosystem type)
- Annual rainfall (spatially mapped)

In summary, across the Mitchell River catchment, approximately 94% (~67,091 ha) and 86% (~161,662 km) of all watercourse areas and watercourse lines, respectively, were assessed to be in very good condition (AquaBAMM's aquatic scores of 'very high' and 'high') when the most recent AquaBAMM assessment of the catchment was conducted in 2018. However, 1,900 km of minor non-perennial water course lines in the mid-Palmer catchment were assessed as being at very poor condition in the 2018 assessment.

Supporting information also indicates that a high percentage of the area of *tropical-subtropical montane rainforest* in the Mitchell catchment is under some form of protection designation (75% designated as National Park, 84% as Important Bird Area, and 85% as Essential Habitat). Additionally, 25% of *tropical-subtropical dry forests and thickets* are designated as National Park and Essential Habitat, and 81% of *tropical-subtropical lowland rainforest* is designated as Important Bird Area.

Important Bird Area designations also cover very substantial proportions of the catchment's estuarine and coastal ecosystems, with 99% of *intertidal forests and shrublands*, 96% of *coastal shrublands and grasslands*, and 94% of *coastal saltmarshes and reedbeds* falling under this designation.

4.2 Background

In addition to the ecosystem condition variables that were applicable across most of the catchment's ecosystem types, as listed in Table 10, Table 11 and Table 12, additional supporting information and findings from assessments of watercourse lines and watercourse areas were also compiled in this study, to provide additional supporting information. This supporting information comprised:

- Aquatic Conservation Assessment (ACA) scores for watercourse lines and watercourse areas derived in 2018 using the Aquatic Biodiversity Assessment Mapping Method (AquaBAMM) (Department of Environment and Science, 2018) and made available by the Queensland Government Department of Environment and

Science's Wetland*Info* team https://wetlandinfo.des.qld.gov.au/wetlands/assessment/assessment-methods/aca/ .The AquaBAMM methodology draws on indicators across eight different categories to produce its ACA scores. Some categories respond to intensity of agricultural and urban land use, others respond to presence of exotic plants, fish, invertebrates and/or vertebrates in either wetlands or their surrounding catchments.

- Extent of protected areas
- Annual rainfall

Figure 28 and Figure 29 show maps of AquaBAMM's Aquatic Conservation Assessment scores for major watercourse lines and minor watercourse lines, respectively.

Table 14 shows AquaBAMM aquatic scores categorised into major perennial and non-perennial, and minor perennial and non-perennial, watercourse lines.

AquaBAMM aquatic scores for watercourse areas are shown as maps of subsections of riverine catchments, river segments, palustrine wetlands and lacustrine wetlands in Figure 30, Figure 31, Figure 32, Figure 33, respectively. Table 15 shows AquaBAMM's aquatic scores for perennial and non-perennial freshwater, and perennial and non-perennial estuarine watercourse areas (in ha).

The extent and types of protected areas in the Mitchell catchment, based on Queensland-wide data collected from 2003 to 2021, are summarised in Table 16.

Mean annual rainfall for the period 1880 to 2020 is shown in Figure 34. Mean annual rainfall is highest (>300 mm per year) in areas adjacent to the Gulf of Carpentaria and generally declines moving further east.

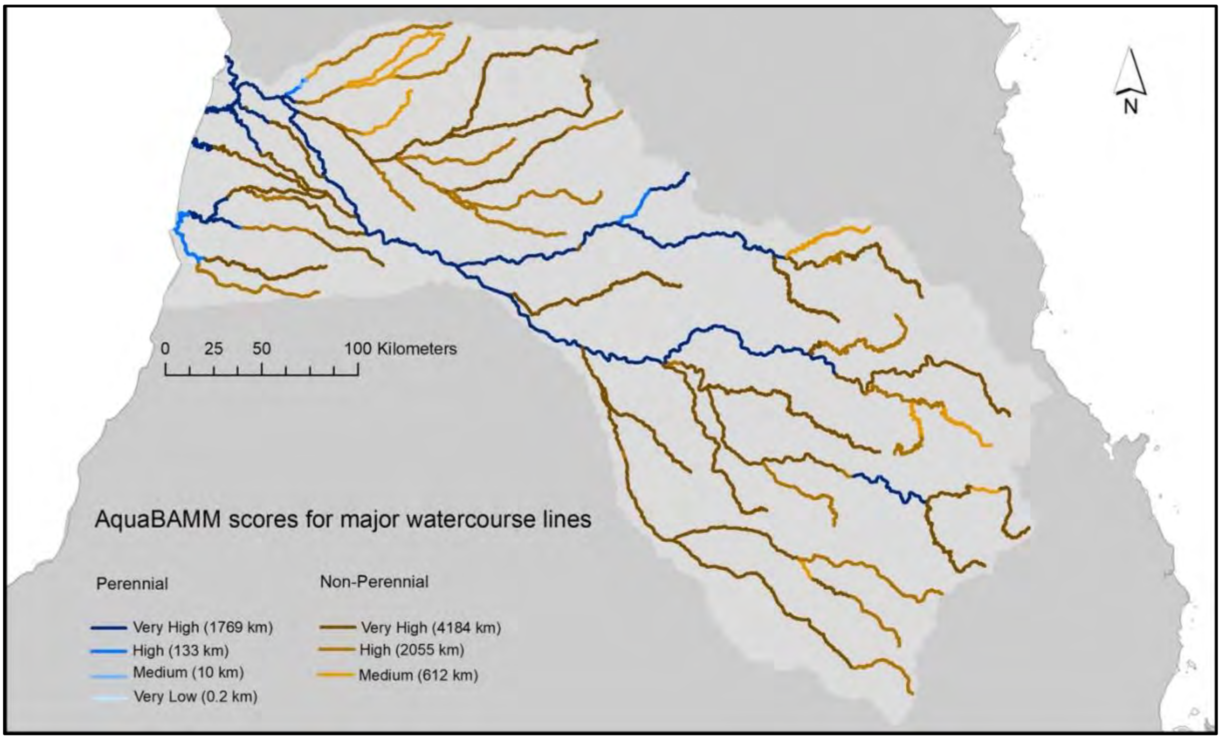


Figure 28. AquaBAMM's aquatic conservation assessment scores for major watercourse lines within the Mitchell catchment (Department of Environment and Science, 2018). Scores for the 'Low' category in AquaBAMM were missing from the data available for download.

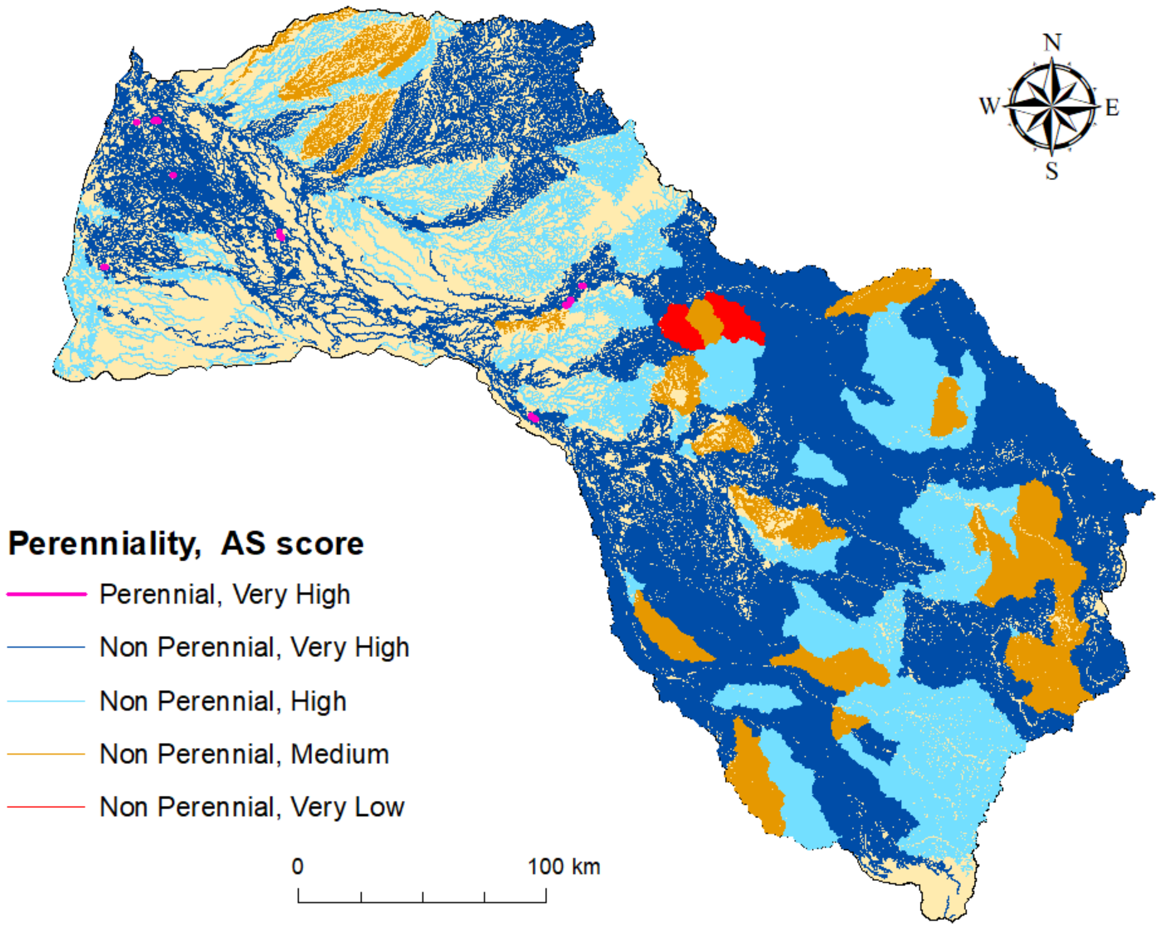


Figure 29. AquaBAMM's aquatic conservation assessment scores (AS) for minor watercourse lines within the Mitchell catchment (Department of Environment and Science, 2018). Scores for the 'Low' category in AquaBAMM were missing from the data available for download.

Table 14. AquaBAMM's aquatic conservation assessment score (Very High, High, Medium, Low and Very Low) for watercourse lines across all ecosystem types in the Mitchell catchment (Department of Environment and Science, 2018). Values indicate the length of watercourse lines in kilometres in each score category. The scores for the 'Low' category in AquaBAMM were missing from the data available for download. The 'Low' category is, however, included for completeness, indicated by cells coloured mid-blue.

Realm	**Terrestrial**								
Biome	T1 Tropical-subtropical forests			T3 Shrublands & shrubby woodlands	T4 Savannas & grasslands			T5 Deserts & semi-deserts	Broad Vegetation Group of Qld
EFG	T1.1 Tropical-subtropical lowland rainforests	T1.2 Tropical-subtropical dry forests and thickets	T1.3 Tropical-subtropical montane forests	T3.1 Seasonally dry tropical shrublands	T4.2 Pyric tussock savannas	T4.3 Hummock savannas	T4.4 Temperate woodlands	T5.1 Semi-desert steppes	Non-remnant
Major perennial									
Very high	0.18	0	0	0	21.55	0	0	0	6.55
High	0	0	0	0	4.29	0	0	0	0
Medium	0	0	0	0	10.30	0	0	0	0
Low									
Very low	0	0	0	0	0	0	0	0	0.20
Major non-perennial									
Very high	34.27	0.07	0	0.40	730.35	3.10	0	2.56	24.37
High	0.35	0	0	42.03	531.78	7.06	0	0	0.52
Medium	0	0	0	40.06	218.38	0.60	0	0	0.26
Low									
Very low	0	0	0	0	0	0	0	0	0

Table 14 (continued).

Realm	Terrestrial								
Biome	T1 Tropical-subtropical forests			T3 Shrublands & shrubby woodlands	T4 Savannas & grasslands			T5 Deserts & semi-deserts	Broad Vegetation Group of Qld
EFG	T1.1 Tropical-subtropical lowland rainforests	T1.2 Tropical-subtropical dry forests and thickets	T1.3 Tropical-subtropical montane forests	T3.1 Seasonally dry tropical shrublands	T4.2 Pyric tussock savannas	T4.3 Hummock savannas	T4.4 Temperate woodlands	T5.1 Semi-desert steppes	Non-remnant
Minor perennial									
Very high	0	0	0	0	0.59	0	0	0	0
High	0	0	0	0	0	0	0	0	0
Medium	0	0	0	0	0	0	0	0	0
Low									
Very low	0	0	0	0	0	0	0	0	0
Minor non-perennial									
Very high	152.96	171.37	1158.27	1075.03	79834.21	8381.20	119.02	732.03	1377.54
High	11.55	30.73	0	595.82	42428.79	3057.93	383.80	63.43	165.85
Medium	0	6.19	12.91	484.60	17544.73	4696.07	43.99	26.97	205.92
Low									
Very low	0	0	0	0	1898.22	0	0	0	0.29

Table 14 (continued).

Realm	Freshwater–terrestrial		Marine–terrestrial	Marine–freshwater–terrestrial		Broad Vegetation Groups of Queensland	
Biome	TF1 Palustrine wetlands		MT2 Supralittoral coastal systems	MFT1 Brackish tidal			
EFG	TF1.2 Subtropical-temperate forested wetlands	TF1.4 Seasonal floodplain marshes	MT2.1 Coastal shrublands and grasslands	MFT1.2 Intertidal forests & shrublands	MFT1.3 Coastal saltmarshes & reedbeds	Water	Estuary
Major perennial							
Very high	773.38	1.61	0	19.24	1.43	2.34	165.57
High	37.88	0	0	0.20	1.61	0	51.32
Medium	0	0	0	0	0	0	0
Low							
Very low	0	0	0	0	0	0	0
Major non-perennial							
Very high	1675.81	13.38	0	0.80	3.77	1.54	2.90
High	729.49	3.52	0	2.04	5.39	0	0.02
Medium	176.46	0	0	0	0	0	0
Low							
Very low	0	0	0	0	0	0	0

Table 14 (continued).

Realm	Freshwater–terrestrial		Marine–terrestrial	Marine–freshwater–terrestrial		Broad Vegetation Groups of Queensland	
Biome	TF1 Palustrine wetlands		MT2 Supralittoral coastal systems	MFT1 Brackish tidal			
EFG	TF1.2 Subtropical-temperate forested wetlands	TF1.4 Seasonal floodplain marshes	MT2.1 Coastal shrublands and grasslands	MFT1.2 Intertidal forests & shrublands	MFT1.3 Coastal saltmarshes & reedbeds	Water	Estuary
Minor perennial							
Very high	10.24	0	0	0.83	0	0	1.19
High	0	0	0	0	0	0	0
Medium	0	0	0	0	0	0	0
Low							
Very low	0	0	0	0	0	0	0
Minor non-perennial							
Very high	10555.36	471.90	0.14	352.94	580.98	181.54	201.32
High	3571.22	94.30	18.92	232.30	624.17	32.36	89.32
Medium	1148.61	2.47	0	0	0	21.44	0
Low							
Very low	84.40	0	0	0	0	0	0

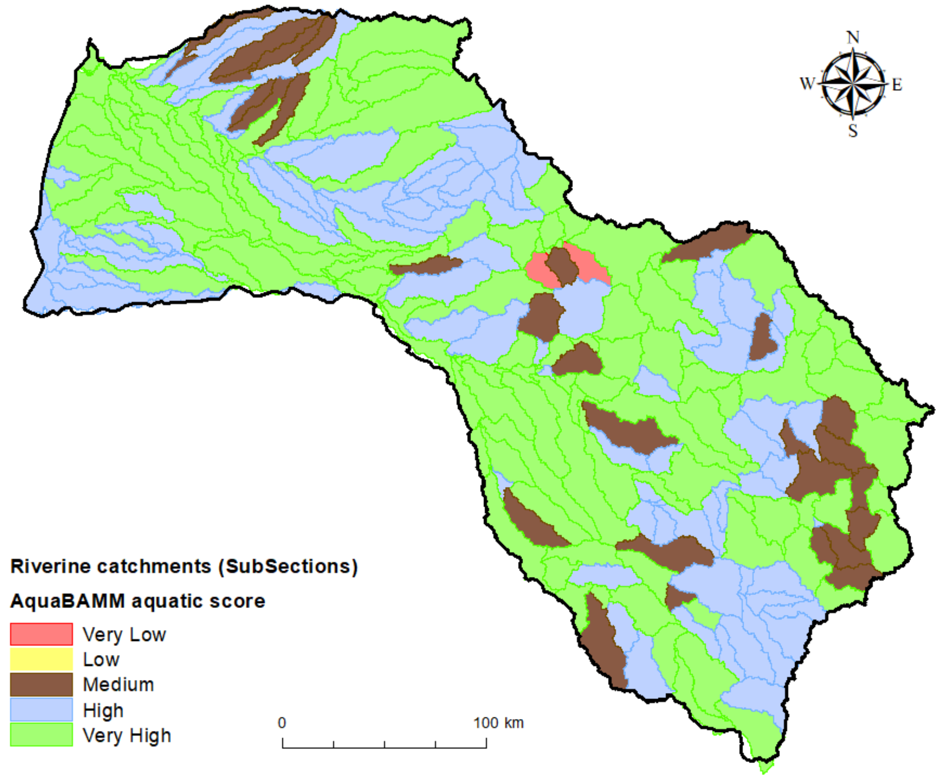


Figure 30. AquaBAMM's aquatic score for subsections of riverine catchments.

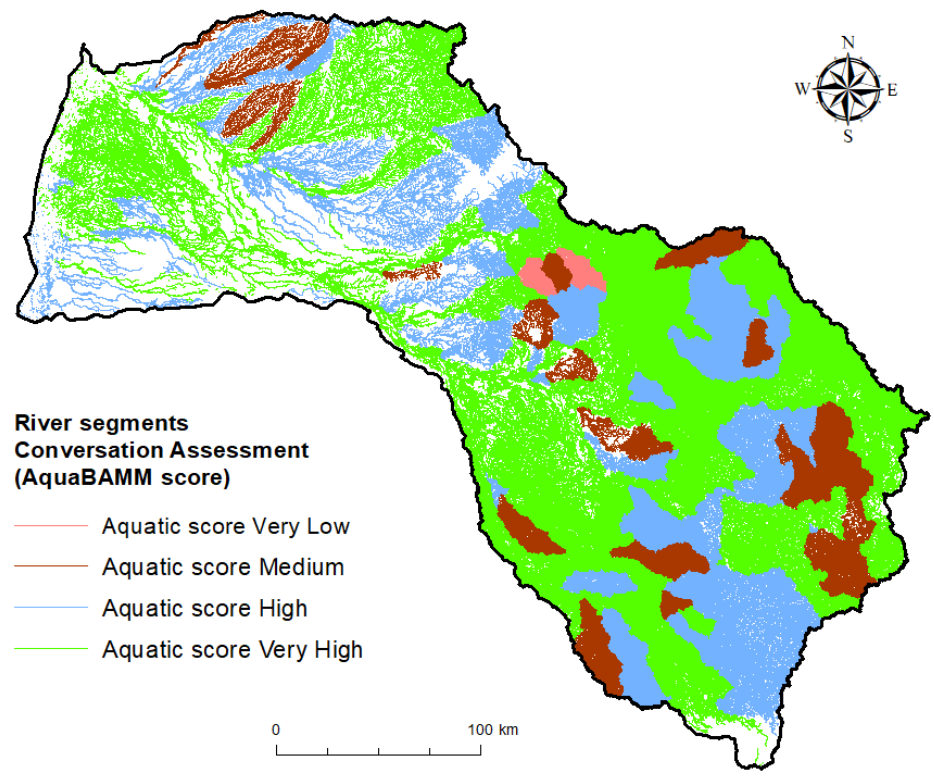


Figure 31. AquaBAMM's aquatic score for river segments.

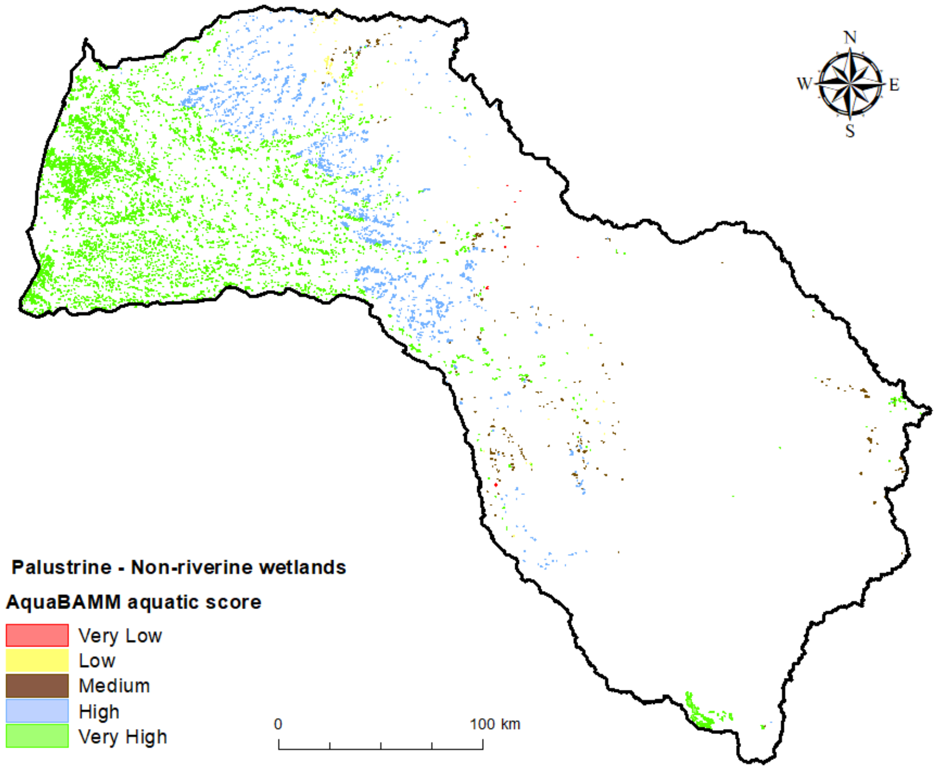


Figure 32. AquaBAMM's aquatic score for palustrine wetlands.

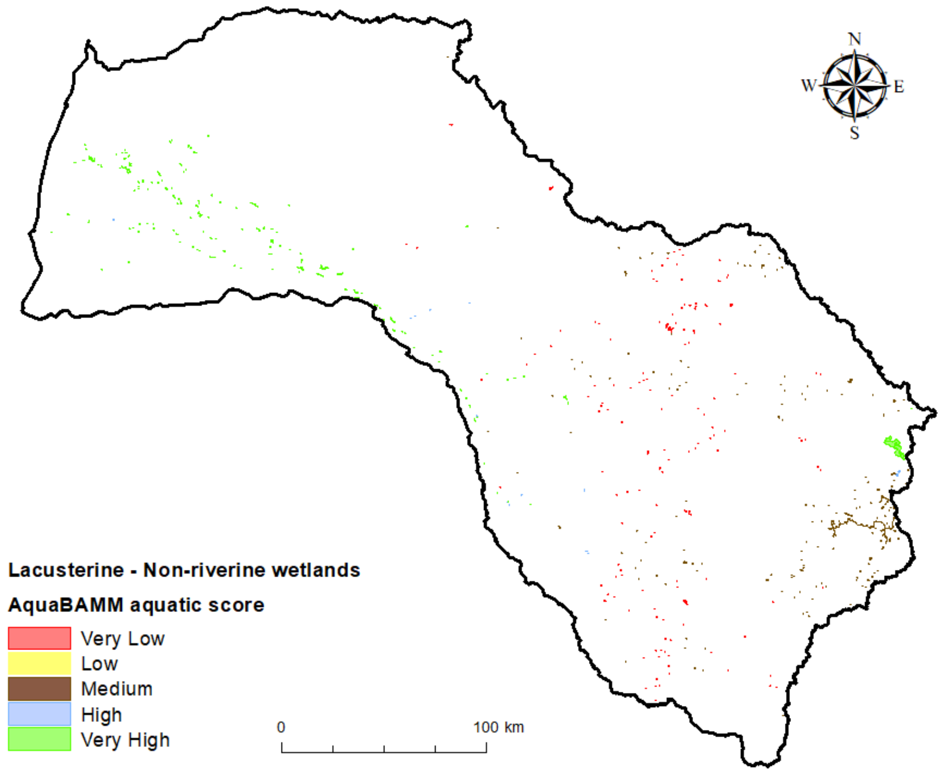


Figure 33. AquaBAMM's aquatic score for lacustrine wetlands.

Table 15. AquaBAMM's aquatic conservation assessment score (Very High, High, Medium, Low and Very Low) for watercourse areas across all ecosystem types in the Mitchell catchment. Values indicate the area of watercourse in hectares in each score category. Scores for the 'Low' category in AquaBAMM were missing from the data available for download. The 'Low' category is included in this table for completeness by cells coloured mid blue. Cells shaded in grey denote that AquaBAMM categories are not relevant for, or not provided for, those ecosystem types.

Realm	**Terrestrial**								
Biome	T1 Tropical-subtropical forests			T3 Shrublands & shrubby woodlands	T4 Savannas & grasslands			T5 Deserts & semi-deserts	Broad Vegetation Group of Qld
EFG	T1.1 Tropical-subtropical lowland rainforests	T1.2 Tropical-subtropical dry forests and thickets	T1.3 Tropical-subtropical montane forests	T3.1 Seasonally dry tropical shrublands	T4.2 Pyric tussock savannas	T4.3 Hummock savannas	T4.4 Temperate woodlands	T5.1 Semi-desert steppes	Non-remnant
Freshwater: major perennial									
Very high	34.58	0	0	0.54	1115.14	33.34	0	3.50	19.73
High	0	0	0	0.0001	26.14	11.22	0	0	0
Medium	0	0	0	0	0	0	0	0	0
Low									
Very low	0	0	0	0	0	0	0	0	0
Freshwater: major non-perennial									
Very high	141.55	0.42	0	2.54	2226.19	42.50	0	35.79	222.99
High	0	0	0	0	453.60	85.75	4.54	0.15	4.43
Medium	0	0	0	0	59.09	21.55	0	0	4.61
Low									
Very low	0	0	0	0	0	0	0	0	2.88

Table 15 (continued).

Realm	Terrestrial								
Biome	T1 Tropical-subtropical forests			T3 Shrublands & shrubby woodlands	T4 Savannas & grasslands			T5 Deserts & semi-deserts	Broad Vegetation Group of Qld
EFG	T1.1 Tropical-subtropical lowland rainforests	T1.2 Tropical-subtropical dry forests and thickets	T1.3 Tropical-subtropical montane forests	T3.1 Seasonally dry tropical shrublands	T4.2 Pyric tussock savannas	T4.3 Hummock savannas	T4.4 Temperate woodlands	T5.1 Semi-desert steppes	Non-remnant
Freshwater: minor perennial									
Very high	2.03	0	0	0	301.59	7.01	0	20.97	9.27
High	0.03	0	0	0	11.08	0.005	0	0.21	0
Medium	0	0	0	0	4.63	1.26	0	0.003	0
Low									
Very low	0	0	0	0	0	0	0	0	0
Freshwater: minor non-perennial									
Very high	28.93	4.36	5.86	15.69	3516.21	74.76	9.92	27.24	54.15
High	0	3.39	0	14.84	1952.44	119.60	26.13	8.51	35.30
Medium	0	6.61	0	0	748.69	207.33	0	1.17	1.87
Low									
Very low	0	0	0	0	23.79	0	0	0	1.08

Table 15 (continued).

Realm	Terrestrial								
Biome	T1 Tropical-subtropical forests			T3 Shrublands & shrubby woodlands	T4 Savannas & grasslands			T5 Deserts & semi-deserts	Broad Vegetation Group of Qld
EFG	T1.1 Tropical-subtropical lowland rainforests	T1.2 Tropical-subtropical dry forests and thickets	T1.3 Tropical-subtropical montane forests	T3.1 Seasonally dry tropical shrublands	T4.2 Pyric tussock savannas	T4.3 Hummock savannas	T4.4 Temperate woodlands	T5.1 Semi-desert steppes	Non-remnant
Estuarine: major perennial									
Very high	10.54	0	0	0	168.04	0	0	0	0
High	1.61	0	0	0	2.87	0	0	0	0
Medium	0	0	0	0	0	0	0	0	0
Low									
Very low	0	0	0	0	0	0	0	0	0
Estuarine: major non-perennial									
Very high	0	0	0	0	4.04	0	0	0	0
High	0	0	0	0	0	0	0	0	0
Medium	0	0	0	0	0	0	0	0	0
Low									
Very low	0	0	0	0	0	0	0	0	0

Table 15 (continued).

Realm	Terrestrial								
Biome	T1 Tropical-subtropical forests			T3 Shrublands & shrubby woodlands	T4 Savannas & grasslands			T5 Deserts & semi-deserts	Broad Vegetation Group of Qld
EFG	T1.1 Tropical-subtropical lowland rainforests	T1.2 Tropical-subtropical dry forests and thickets	T1.3 Tropical-subtropical montane forests	T3.1 Seasonally dry tropical shrublands	T4.2 Pyric tussock savannas	T4.3 Hummock savannas	T4.4 Temperate woodlands	T5.1 Semi-desert steppes	Non-remnant
Estuarine: minor perennial									
Very high	1.40	0	0	0	52.94	0	0	0	0
High	1.01	0	0	0	4.11	0	0	0	0
Medium	0	0	0	0	0	0	0	0	0
Low									
Very low	0	0	0	0	0	0	0	0	0
Estuarine: minor non-perennial									
Very high	0	0	0	0	1.20	0	0	0	0
High	0	0	0	0	0	0	0	0	0
Medium	0	0	0	0	0	0	0	0	0
Low									
Very low	0	0	0	0	0	0	0	0	0

Table 15 (continued).

Realm	Freshwater–terrestrial		Marine–terrestrial	Marine–freshwater–terrestrial		Broad Vegetation Groups of Queensland	
Biome	TF1 Palustrine wetlands		MT2 Supralittoral coastal systems	MFT1 Brackish tidal			
EFG	TF1.2 Subtropical-temperate forested wetlands	TF1.4 Seasonal floodplain marshes	MT2.1 Coastal shrublands and grasslands	MFT1.2 Intertidal forests & shrublands	MFT1.3 Coastal saltmarshes & reedbeds	Water	Estuary
Freshwater: major perennial							
Very high	10226.04	0	0	31.53	0.38	0	38.14
High	368.50	0	0	0	0	0	0
Medium	0	0	0	0	0	0	0
Low							
Very low	0	0	0	0	0	0	0
Freshwater: major non-perennial							
Very high	24148	39.76	0	0	0	3.32	0
High	4104.79	0	0	0	0	0	0
Medium	1030.93	0	0	0	0	0	0
Low							
Very low	0.40	0	0	0	0	0	0

Table 15 (continued).

Realm	Freshwater–terrestrial		Marine–terrestrial	Marine–freshwater–terrestrial		Broad Vegetation Groups of Queensland	
Biome	TF1 Palustrine wetlands		MT2 Supralittoral coastal systems	MFT1 Brackish tidal			
EFG	TF1.2 Subtropical-temperate forested wetlands	TF1.4 Seasonal floodplain marshes	MT2.1 Coastal shrublands and grasslands	MFT1.2 Intertidal forests & shrublands	MFT1.3 Coastal saltmarshes & reedbeds	Water	Estuary
Freshwater: minor perennial							
Very high	458.03	314.48	0	9.40	42.86	0	0
High	6.95	1.44	0.29	11.00	25.50	0	0
Medium	12.52	0	0	0	0	0	0
Low							
Very low	0	0	0	0	0	0	0
Freshwater: minor non-perennial							
Very high	5130.19	311.96	0	2.53	42.79	1.31	0
High	5280.37	18.08	8.93	0	0.67	1.96	0
Medium	1751.71	0	0	0	0	0	0
Low							
Very low	55.23	0	0	0	0	0	0

Table 15 (continued).

Realm	Freshwater–terrestrial		Marine–terrestrial	Marine–freshwater–terrestrial		Broad Vegetation Groups of Queensland	
Biome	TF1 Palustrine wetlands		MT2 Supralittoral coastal systems	MFT1 Brackish tidal			
EFG	TF1.2 Subtropical-temperate forested wetlands	TF1.4 Seasonal floodplain marshes	MT2.1 Coastal shrublands and grasslands	MFT1.2 Intertidal forests & shrublands	MFT1.3 Coastal saltmarshes & reedbeds	Water	Estuary
Estuarine: major perennial							
Very high	74.80	0	1.67	129.97	55.13	0	3184.97
High	0	0	5.76	23.19	17.59	0	725.82
Medium	0	0	0	0	0	0	0
Low							
Very low	0	0	0	0	0	0	0
Estuarine: major non-perennial							
Very high	4.80	0	0	0	0	0	42.41
High	0	0	0	0	0	0	0
Medium	0	0	0	0	0	0	0
Low							
Very low	0	0	0	0	0	0	0

Table 15 (continued).

Realm	Freshwater–terrestrial		Marine–terrestrial	Marine–freshwater–terrestrial		Broad Vegetation Groups of Queensland	
Biome	TF1 Palustrine wetlands		MT2 Supralittoral coastal systems	MFT1 Brackish tidal			
EFG	TF1.2 Subtropical-temperate forested wetlands	TF1.4 Seasonal floodplain marshes	MT2.1 Coastal shrublands and grasslands	MFT1.2 Intertidal forests & shrublands	MFT1.3 Coastal saltmarshes & reedbeds	Water	Estuary
Estuarine: minor perennial							
Very high	64.45	0	2.10	85.90	38.33	0	627.75
High	0	0	0.32	38.66	18.19	0	261.60
Medium	0	0	0	0	0	0	0
Low							
Very low	0	0	0	0	0	0	0
Estuarine: minor non-perennial							
Very high	1.66	0.03	0	9.58	3.92	0	80.98
High	0	0	0	0	0	0	0
Medium	0	0	0	0	0	0	0
Low							
Very low	0	0	0	0	0	0	0

Table 16. Protected areas within the Mitchell catchment classified as National Park, National Park – Cape York Aboriginal Land, State Forest, Forest Reserve, Resources Reserve, Nature Refuge, Important Bird Area and Essential Habitat managed by Queensland Parks and Wildlife Services under Nature Conservation Act 1992 and Forestry Act 1959.

	Realm	Terrestrial								
	Biome	T1 Tropical-subtropical forests			T3 Shrublands & shrubby woodlands	T4 Savannas & grasslands			T5 Deserts & semi-deserts	Broad Vegetation Group of Qld
	EFG	T1.1 Tropical-subtropical lowland rainforests	T1.2 Tropical-subtropical dry forests and thickets	T1.3 Tropical-subtropical montane forests	T3.1 Seasonally dry tropical shrublands	T4.2 Pyric tussock savannas	T4.3 Hummock savannas	T4.4 Temperate woodlands	T5.1 Semi-desert steppes	Non-remnant
National Park	ha	458	3118	19757	815	84684	18709	0	0	205
	%	2.51	25.46	75.06	1.13	1.51	4.29	0	0	0.22
National Park – Cape York Aboriginal Land	ha	950	0	0	4020	320944	2321	0	0	70
	%	5.21	0	0	5.57	5.73	0.53	0	0	0.08
State Forest	ha	0	0	5	0	7	0	0	0	7
	%	0	0	0.02	0	0.0001	0	0	0	0.01
Forest Reserve	ha	7	9	1110	12	4660	0	0	0	37
	%	0.04	0.07	4.22	0.02	0.08	0	0	0	0.04
Resources Reserve	ha	0	0	0	0	14984	0	0	0	326
	%	0	0	0	0	0.27	0	0	0	0.36
Nature Refuge	ha	3483	91	2774	6562	326317	2062	0	0	1225
	%	19.09	0.75	10.54	9.09	5.82	0.47	0	0	1.34
Important Bird Area	ha	14787	356	22115	2298	162778	188	0	0	167
	%	81.05	2.91	84.01	3.18	2.90	0.04	0	0	0.18
Essential Habitat	ha	2220	3052	22502	716	80276	1867	56	60	751
	%	12.17	24.92	85.48	0.99	1.43	0.43	0.26	0.11	0.82

Table 16 (continued).

Realm		Freshwater–terrestrial		Marine–terrestrial	Marine–freshwater–terrestrial		Broad Vegetation Groups of Queensland	
Biome		TF1 Palustrine wetlands		MT2 Supralittoral coastal systems	MFT1 Brackish tidal			
EFG		TF1.2 Subtropical-temperate forested wetlands	TF1.4 Seasonal floodplain marshes	MT2.1 Coastal shrublands and grasslands	MFT1.2 Intertidal forests & shrublands	MFT1.3 Coastal saltmarshes & reedbeds	Water	Estuary
National Park	ha	1231	6	0	0	0	0	0
	%	0.17	0.03	0	0	0	0	0
National Park – Cape York Aboriginal Land	ha	36110	366	0	0	0	5	0
	%	4.88	1.45	0	0	0	0.10	0
State Forest	ha	0	0	0	0	0	0	0
	%	0	0	0	0	0	0	0
Forest Reserve	ha	9	3	0	0	0	0	0
	%	0.001	0.01	0	0	0	0	0
Resources Reserve	ha	213	0	0	0	0	18	0
	%	0.03	0	0	0	0	0.38	0
Nature Refuge	ha	56393	9278	1161	1256	9754	119	249
	%	7.62	36.77	19.67	11.42	23.84	2.49	4.77
Important Bird Area	ha	2062	6677	5669	10900	38415	0	5082
	%	0.28	26.46	96.04	99.13	93.89	0	97.24
Essential Habitat	ha	2519	221	972	2379	1993	0	5
	%	0.34	0.88	16.46	21.63	4.87	0	0.09

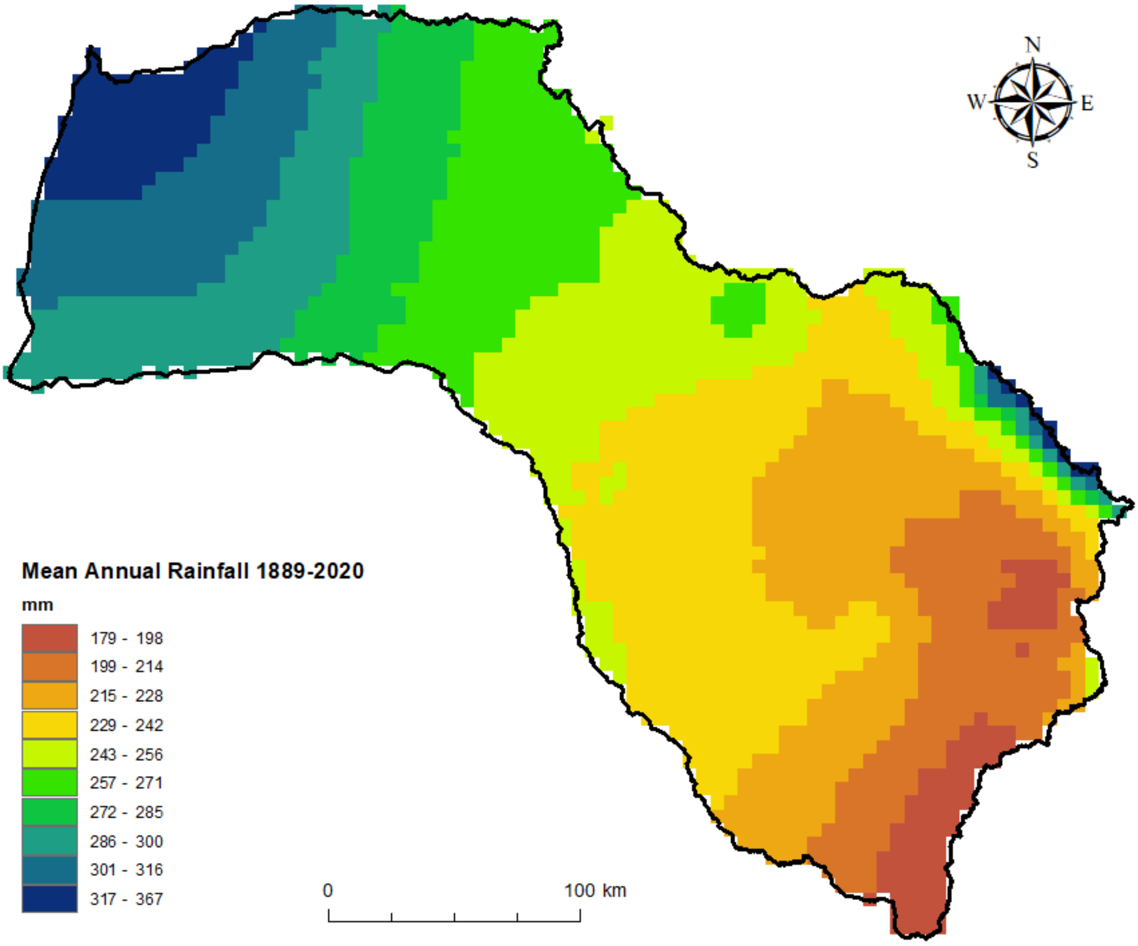


Figure 34. Mean annual rainfall (mm) across the Mitchell catchment for the period 1889–2020.

5. Environmental pressures

5.1 Summary

- Variables and indicators that report on anthropogenic **pressures** exerted on ecosystem types in the Mitchell catchment can provide valuable additional insights to help infrom policy development.
- This section presents variables or indicators on the following anthropogenic pressures acting in the Mitchell catchment:
  - **Fireburn frequency** over the period 2000–19 (relative to the frequency recommended for the Regional Ecosystem concerned) [variables (Table 17) and indicator (Table 18)]
  - **Fragmentation** [indicator (Table 18)]
  - **Ground cover disturbance** index as proxy for grazing pressure [variable Table 19 and Figure 35]
  - **Land clearing** [variable (Table 20, Table 21)]
  - **Pest animal and weed presence** [variable] – as presented previously in Section 3 (Table 12, Table 13, Figure 23, Figure 24)
  - **River disturbance** [variable (Table 22 and Figure 36)]
- **Fireburn frequencies** (Table 17) show that 67% or more of the area of *tropical-subtropical dry forest and thickets*, *tropical-subtropical montane rainforests*, and *seasonally dry tropical shrublands* in the catchment were burnt more frequently than the relevant Regional Ecosystems recommendations between 2000–19. Conversely, more than 40% of *pyric tussock savannas*, *coastal shrublands and grasslands*, and *coastal saltmarshes and reedbeds* were burnt less frequently than recommended over the same period. The fire pressure indicator (Table 18) reflects these findings.
- Moderate levels of **fragmentation** (with indicator values ranging between 58 and 70 (Table 18)) between pre-clearing (~1750) and post-clearing (~2015) have occurred in *tropical-subtropical dry forest and thickets*, *tropical-subtropical montane rainforests*, *seasonally dry tropical shrublands* and *pyric tussock savannas,* and *subtropical-temperate forested wetlands*. Fragmentation – as recorded by the fragmentation indicator – appears to be relatively minor across the remainder of the catchment.

- Variables and indicators that report on anthropogenic **pressures** exerted on ecosystem types in the Mitchell catchment can provide valuable additional insights to help infrom policy development.
- This section presents variables or indicators on the following anthropogenic pressures acting in the Mitchell catchment:
  - **Fireburn frequency** over the period 2000–19 (relative to the frequency recommended for the Regional Ecosystem concerned) [variables (Table 17) and indicator (Table 18)]
  - **Fragmentation** [indicator (Table 18)]
  - **Ground cover disturbance** index as proxy for grazing pressure [variable Table 19 and Figure 35]
  - **Land clearing** [variable (Table 20, Table 21)]

- **Pest animal and weed presence** [variable] – as presented previously in Section 3 (Table 12, Table 13, Figure 23, Figure 24)
- **River disturbance** [variable (Table 22 and Figure 36)]

- We regard the **ground cover disturbance index** (GCDI) as a loose proxy for grazing pressure. GCDI cannot be assessed for water, bare rock or where tree cover exceeds 20%. Of those ecosystem types for which GCDI could be assessed for more than 25% of their area, *hummock savannas*, *temperate woodlands* and *semi-desert steppes* were all experiencing high or very high levels of ground cover disturbance across more than 20% of their assessed area (Table 19). Figure 35 shows modest correspondence in some locations between high (proxy) grazing pressure and higher rates of gully erosion (Figure 18).
- Data from the Statewide Landcover and Trees Study (SLATS) were used to inform levels of **land clearing** in the Mitchell catchment. SLATS data report anthropogenically attributable change in woody vegetation (in ha) between successive mapping periods from 1988–91 through to the most recent annual mapping period available (2017–18) at the time when the Mitchell Ecosystem Accounts were compiled[3]. SLATS data (Table 20) indicate that woody vegetation clearing has occurred predominantly in *pyric tussock savannas*, *hummock savannas* and *subtropical-temperate forested wetlands*, and the *non-remant* BVG. Sustained high rates of clearing (600 ha or more) were recorded annually over the five-year period 2004–05 to 2008–09 in *pyric tussock savannas*. Generally, periods of relatively high annual rates of clearing were interspersed with periods of relatively low clearing rates in *hummock savannas* and *subtropical-temperate forested wetlands*.
- Woody vegetation cleared in *pyric tussock savanna* was predominantly used for pasture production (e.g., 98 ha in 2010–11, 202 ha in 2015–16, 170 ha in 2017–18) (Table 21). Woody vegetation cleared from *subtropical-temperate forested wetlands* was predominantly replaced by pasture and infrastructure, with *cropping* and *mining* land covers starting to appear in 2017–18. Woody vegetation cleared in the *non-remnant* BVG was generally replaced by *pasture*, *cropping*, *mining* and *infrastructure*.
- Priority **invasive species** are present across the entire Mitchell River catchment, with total invasive species richness per 18.5 km × 18.5 km grid cell ranging from 1 to 23, with a median of 6 and a mean of 6.3 (Figure 23, Figure 24).
- The most widespread priority **invasive species** are feral pig, feral cat, wild dog and rubber vine, each of which is reported to be present in 99% or more 18.5 km × 18.5 km grid cells across the catchment (Figure 23, Figure 24). Rubber vine, cane toad, feral cat, feral pig, and wild dog are present in all ecosystem types (Table 12, Table 13). The aquatic invasive weeds cabomba, hymenachne, salvinia, sagittaria, water hyacinth and water lettuce are present in all aquatic ecosystem types in the catchment (Table 12).
- Ecosystem types impacted by the greatest diversity of priority **invasive species** are *seasonal floodplain marshes*, *seasonally dry tropical shrublands*, the *non-remnant* BVG, *tropical-sub-tropical dry forests and thickets*, and *pyric tussock savannas* - with

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[3] SLATS methodology has been revised and improved since data were compiled for the Mitchell Account: see qld.gov.au/environment/land/management/mapping/statewide-monitoring/slats

a priority invasive species richness of 30, 26, 25 and 26, respectively (Table 12, Table 13, Figure 23, Figure 24).

- Invasive species in the lower Mitchell catchment and delta have significantly impacted multiple provisioning, regulating and cultural ecosystem services used by and supplied by Indigenous Traditional Owners in the Kowanyama community. As noted earlier, because of their relationship with Country and typically high level of utilisation of ecosystem services (e.g., Jackson, Finn, & Scheepers, (2014)), Indigenous communities are particularly vulnerable to adverse impacts when supply of ecosystem services is disrupted as the condition of ecosystem assets declines. Section 6.3.2 in the report and Section 7.8.2 and Appendix A in the accompanying Methodology Report provide detailed descriptions of the impacts that particular invasive species are having on supply of specific ecosystem services.
- Ecosystem types with the lowest priority invasive species richness are *coastal shrublands and grasslands*, *intertidal forests and shrublands*, *coastal saltmarshes and reedbeds*, and *semi-desert steppes*, which have a priority invasive species richness of between 4 and 6 (inclusive) (Table 12, Table 13, Figure 23, Figure 24).
- **River disturbance** due to anthropogenic processes (intensity and extent of human activities in the catchment, and modifications to the flow regime) is reported using the River Disturbance Index (RDI) values developed by Stein et al. (2002). RDI data for the Mitchell catchment were obtained from the Bureau of Metrology website for assessment year 1998 (see Data Inventory for further details). On a scale from 0 (‘wild’ or near-pristine) to 1 (severely degraded), all river segments in the Mitchell River catchment were found to have relatively low anthropogenic-induced disturbances, with the maximum RDI value reported at 0.595 (Table 22 and Figure 36).
- At the date of the RDI assessment (1998) at least 92% of river segments in all ecosystem types in the Mitchell except *intertidal forests and shrublands*, *coastal saltmarshes and reedbeds* and *seasonal floodplain marshes*, were assigned RDI values or 0.1 or below, indicating near-pristine river condition with respect to anthropogenic-induced disturbance (Table 22 and Figure 36).
- Approximately 83% of river segments in *intertidal forests and shrublands* and *coastal saltmarshes and reedbeds* were assigned RDI values of 0.1 or below, and only 68% of river segments in *coastal saltmarshes and reedbeds* were also assessed (in 1998) to be in near-pristine condition with respect to anthropogenic-induced disturbance.
- *Pyric tussock savannas* and *subtropical-temperate forested wetlands* were the only two ecosystem types for which some river segments had RDI values of 0.4 or higher. Whilst the majority of river segments in these two ecosystem types had RDI values 0.1 or below, approximately 14 km and 54 km of river segments in *pyric tussock savannas* and *subtropical-temperate forested wetlands*, respectively, were assigned relatively high RDI values of between 0.4 and 0.6, indicating moderately degraded aquatic ecosystems with respect to anthropogenic-induced disturbance.

5.2 Background

To provide an alternative or indirect assessment of ecosystem condition (European Commission, 2016, p.28) in the Mitchell River catchment’s ecosystem types, data on the following environmental pressures are reported in this section:

- Fire regimes – burn frequency relative to recommended for the Regional Ecosystem concerned (Table 17, Table 18, Figure 35, Figure 36) – also refer back to Table 10, Table 17 and Figure 25.
- Fragmentation (Figure 37) – also refer back to Table 10
- Ground cover disturbance index (Table 19 and Figure 38) – regarded as a proxy for grazing pressure
- Land clearing (Table 20 and Table 21)
- Pest animal and weed presence – refer back to Table 12, Table 13, Figure 26, Figure 27.
- River disturbance index (Table 22 and Figure 39).

Datasets and account tables for fire regimes, fragmentation and pest animals and weed presence have already been described under ecosystem condition variable accounts in Section 3. In Table 18 in this section, *variables* reporting on fire regimes and fragmentation are rescaled to convert them into *indicators*, with values ranging between 0 (lowest value, high pressure, indicating poor condition) and 100 (highest value, low pressure, indicating excellent condition).

Table 17. Fire pressures are assessed using three metrics of fire frequency

; expressed as percentages of current fire frequency that is within, below or above the recommended fire frequency guidelines

Realm		Terrestrial								
Biome		T1 Tropical-subtropical forests			T3 Shrublands & shrubby woodlands	T4 Savannas & grasslands			T5 Deserts & semi-deserts	Broad Vegetation Group of Qld
EFG		T1.1 Tropical-subtropical lowland rainforests	T1.2 Tropical-subtropical dry forests and thickets	T1.3 Tropical-subtropical montane forests	T3.1 Seasonally dry tropical shrublands	T4.2 Pyric tussock savannas	T4.3 Hummock savannas	T4.4 Temperate woodlands	T5.1 Semi-desert steppes	Non-remnant
Environmental pressure: fire frequency										
Number of burns observed from MODIS mapping 2000–19 compared against the Queensland Government's Regional Ecosystem Fire Guidelines										
Current fire frequency is above the *recommended fire frequency*	%	0.04	74.69	67.70	67.22	18.20	11.30	0.90	0.24	
Current fire frequency is within the *recommended fire frequency*	%	70.96	10.70	30.83	29.64	35.42	74.53	98.06	90.27	
Current fire frequency is below the *recommended fire frequency*	%	29.00	14.61	1.47	3.14	46.38	14.17	1.04	9.49	
Land area observed or covered by fire pressure assessment	ha	4,128	12,162	26,267	72,037	4,943,887	432,733	21,040	56,047	
Percentage of ecosystem type extent included in fire pressure assessment	%	22.63	99.30	99.79	99.77	88.23	99.29	99.96	99.19	

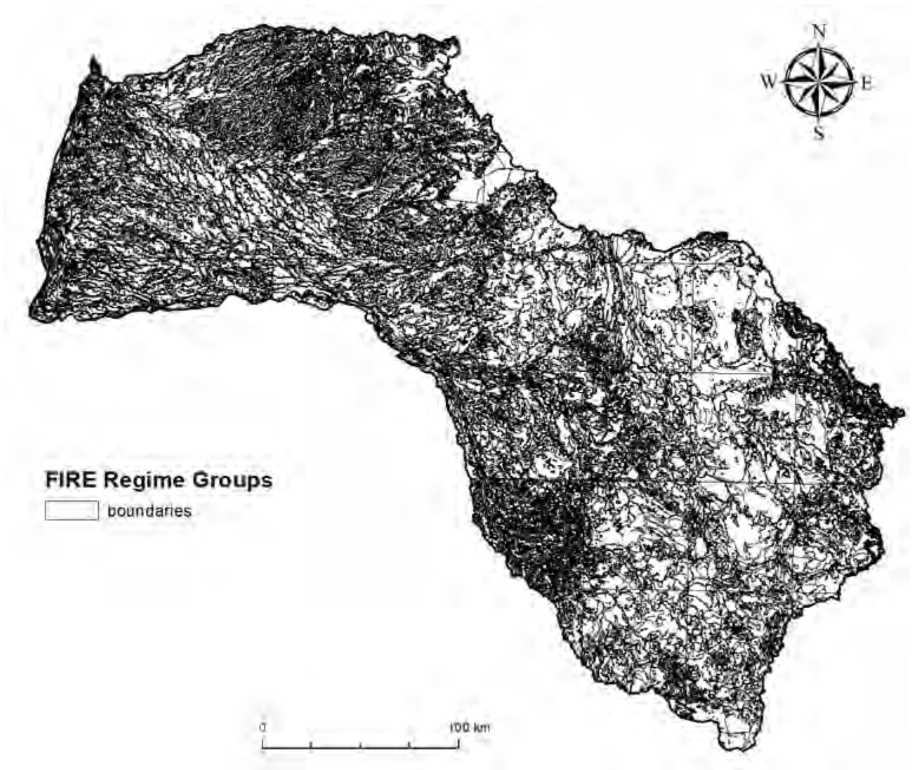
Table 17 (continued).

Realm		Freshwater–terrestrial		Marine–terrestrial	Marine–freshwater–terrestrial		Broad Vegetation Groups of Queensland	
Biome		TF1 Palustrine wetlands		MT2 Supralittoral coastal systems	MFT1 Brackish tidal			
EFG		TF1.2 Subtropical-temperate forested wetlands	TF1.4 Seasonal floodplain marshes	MT2.1 Coastal shrublands and grasslands	MFT1.2 Intertidal forests & shrublands	MFT1.3 Coastal saltmarshes & reedbeds	Water	Estuary
Environmental pressure: fire frequency								
Number of burns observed from MODIS mapping 2000–19 compared against the Queensland Government's Regional Ecosystem Fire Guidelines								
Current fire frequency is above the *recommended fire frequency*	%	18.21	7.51	0.01	8.37	3.84		11.97
Current fire frequency is within the *recommended fire frequency*	%	66.00	72.83	58.18	91.57	43.35		78.35
Current fire frequency is below the *recommended fire frequency*	%	15.78	19.66	41.80	0.06	52.81		9.69
Land area observed or covered by fire pressure assessment	ha	724786.21	21499.99	2035.10	10366.93	513.09		716.86
Percentage of ecosystem type extent included in fire pressure assessment	%	97.90	85.21	34.48	94.28	1.25		13.72

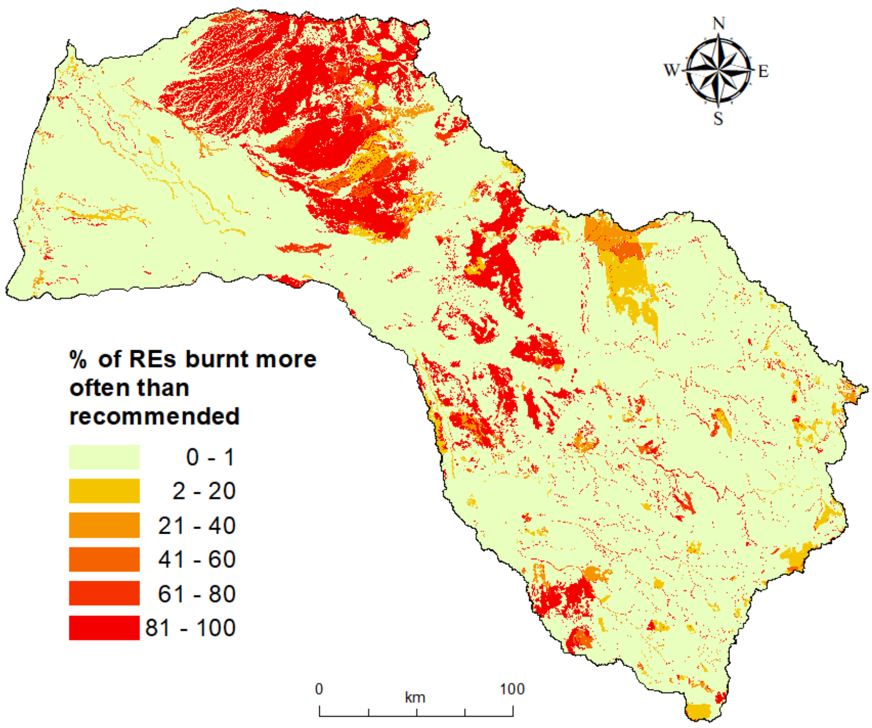
Table 18. Fire and fragmentation pressure indicator values by ecosystem types in the Mitchell catchment. The indicator value for fire pressure is rescaled from the fire pressure variable 'the percentage area indicating current fire frequency is within the recommended fire frequency' (see Table 17). The indicator value for fragmentation is taken fragmentation metric 'post-clearing mean patch size as a percentage of pre-clearing mean patch size' (see Table 10). Pressure indicator values for fire and fragmentation are dimensionless scale ranging between 0 (bottom value i.e., poor condition due to high pressure) and 100 (top value i.e., excellent condition due to absence of pressure).

Realm	**Terrestrial**								
Biome	T1 Tropical-subtropical forests			T3 Shrublands & shrubby woodlands	T4 Savannas & grasslands			T5 Deserts & semi-deserts	Broad Vegetation Group of Qld
EFG	T1.1 Tropical-subtropical lowland rainforests	T1.2 Tropical-subtropical dry forests and thickets	T1.3 Tropical-subtropical montane forests	T3.1 Seasonally dry tropical shrublands	T4.2 Pyric tussock savannas	T4.3 Hummock savannas	T4.4 Temperate woodlands	T5.1 Semi-desert steppes	Non-remnant
Fire pressure indicator	71	11	31	30	35	75	98	90	
Fragmentation pressure indicator	100	58	70	70	61	94	100	95	

Realm	**Freshwater–terrestrial**		**Marine–terrestrial**	**Marine–freshwater–terrestrial**		**Broad Vegetation Groups of Queensland**	
Biome	TF1 Palustrine wetlands		MT2 Supralittoral coastal systems	MFT1 Brackish tidal			
EFG	TF1.2 Subtropical-temperate forested wetlands	TF1.4 Seasonal floodplain marshes	MT2.1 Coastal shrublands and grasslands	MFT1.2 Intertidal forests & shrublands	MFT1.3 Coastal saltmarshes & reedbeds	Water	Estuary
Fire pressure indicator	66	73	58	92	43		78
Fragmentation pressure indicator	45	100	93	100	100		85

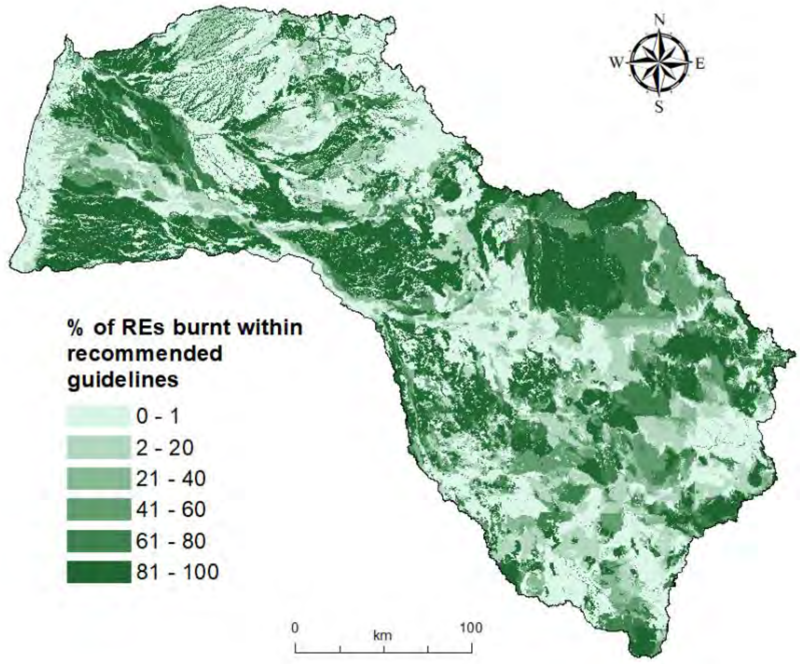


(a) Delineation of fire regime groups

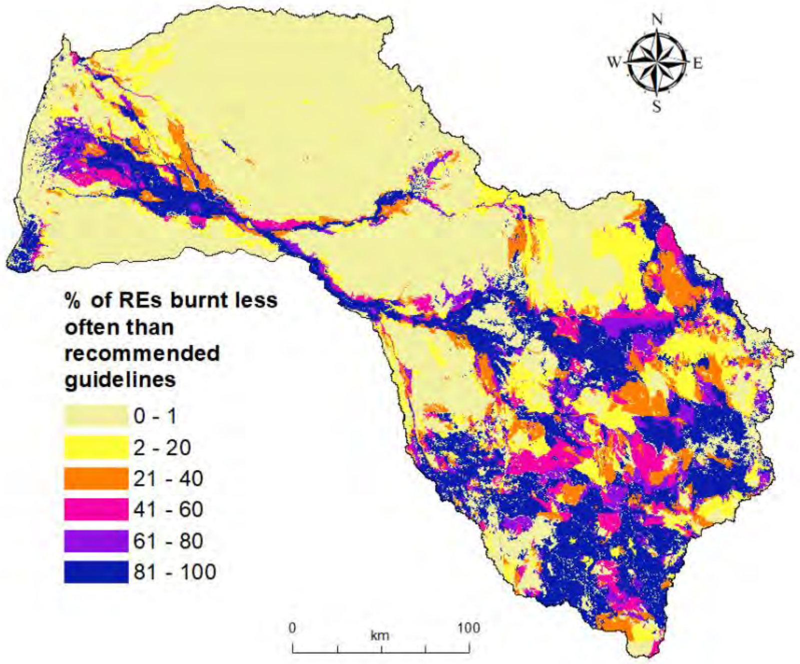


(b) Fireburn frequency exceeding recommended guidelines

Figure 35. Fire pressure expressed as a percentage of Regional Ecosystems (RE) areas experiencing fireburn frequencies 2000–19 above RE-specific frequency guidelines. Panel (a) shows the delineation of fire regime groups in the Mitchell catchment. Panel (b) shows the spatial distribution and percentage area of REs that were burned more often than the Queensland Government's Regional Ecosystem Fire Guidelines (Queensland Herbarium, 2021b).



(a) Fireburn frequency within recommended guidelines



(b) Fireburn frequency below recommended guidelines

Figure 36. Fire pressure expressed as a percentage of Regional Ecosystems (RE) areas experiencing fireburn frequencies 2000–19 within or below RE-specific frequency guidelines. Panel (a) shows the spatial distribution and percentage area of REs that were burned at a frequency within the Queensland Government's Regional Ecosystem Fire Guidelines (Queensland Herbarium, 2021b). Panel (b) shows the spatial distribution and percentage area of REs that were burned less often than the Queensland Government's Regional Ecosystem Fire Guidelines (Queensland Herbarium, 2021b).

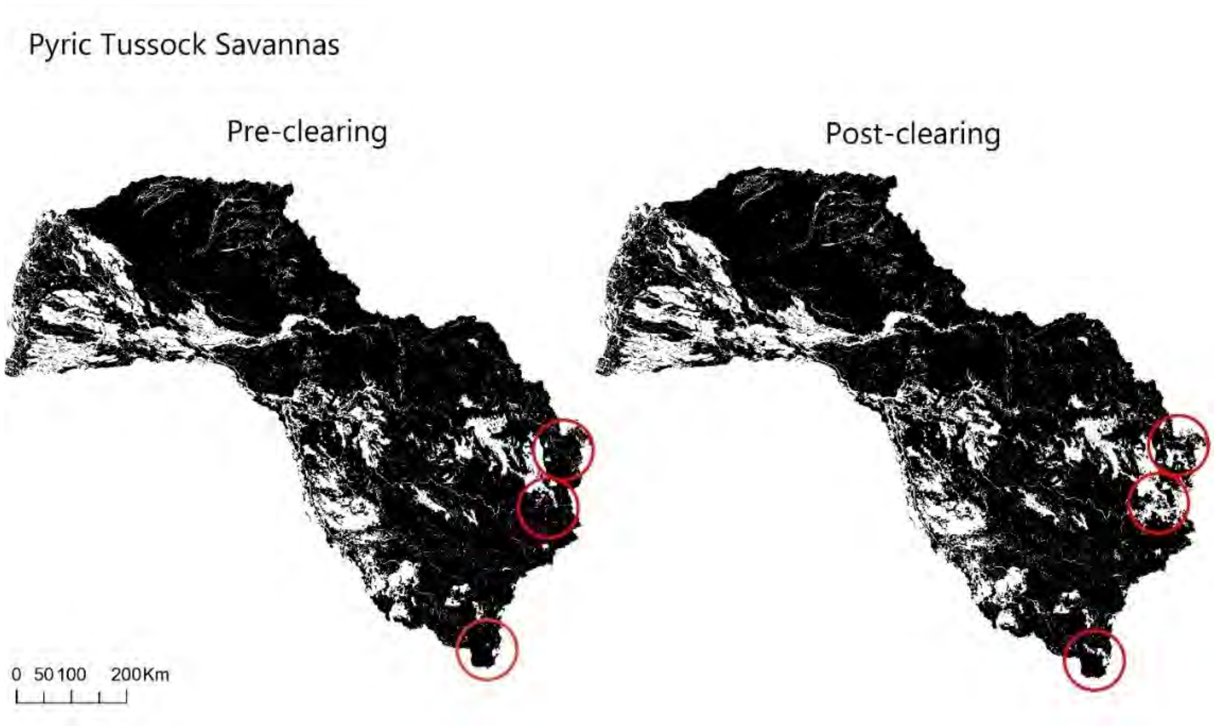


Figure 37. The extent of pyric tussock savannas pre-clearing (~1750) and post-clearing (~2015). Red circles indicate areas of high fragmentation or patch size decrease.

Table 19. Ground Cover Disturbance Index (GCDI), used as a proxy for grazing pressure, in the Mitchell catchment. Indicator values are a combination of mean ground cover (1988–2009) with ground cover trend over the same period to produce a GCDI score ranging from 1 (high ground cover and increasing trend) to 16 (low ground cover and decreasing trend). Values given for each ecosystem type represent the percentage of the ecosystem type area assigned to GCDI attribute category (excluding areas of water, bare rock, or with more than 20% foliage cover). GDCI values are only reported for ecosystem types that have grazing as predominant land use as mapped under QLUMP. Benchmark GCDI values for very low grazing pressure are 1 (high ground cover and increasing trend) and 2 (high ground cover and slight increase in trend).

Realm	**Terrestrial**								
Biome	T1 Tropical-subtropical forests			T3 Shrublands & shrubby woodlands	T4 Savannas & grasslands			T5 Deserts & semi-deserts	Broad Vegetation Group of Qld
EFG	T1.1 Tropical-subtropical lowland rainforests	T1.2 Tropical-subtropical dry forests and thickets	T1.3 Tropical-subtropical montane forests	T3.1 Seasonally dry tropical shrublands	T4.2 Pyric tussock savannas	T4.3 Hummock savannas	T4.4 Temperate woodlands	T5.1 Semi-desert steppes	Non-remnant
Ground Cover Disturbance score = 1 High Ground Cover – Increasing Trend – VERY LOW (BENCHMARK)	0.06	0.00	0.00	0.03	0.05	0.05	0.00	0.00	0.02
Ground Cover Disturbance score = 2 High Ground Cover – Slight Increase in Trend – VERY LOW (BENCHMARK)	0.05	0.06	0.00	0.18	0.21	0.30	0.02	0.07	0.09
Ground Cover Disturbance score = 3 High ground cover – Slight Decrease in Trend – LOW	0.13	0.32	0.00	0.84	0.96	1.55	0.34	0.90	0.27
Ground Cover Disturbance score = 4 High ground cover –Decreasing Trend – LOW	0.62	1.95	0.00	6.57	5.43	7.75	6.07	13.14	0.96

Table 19 (continued).

Realm	Terrestrial								
Biome	T1 Tropical-subtropical forests			T3 Shrublands & shrubby woodlands	T4 Savannas & grasslands			T5 Deserts & semi-deserts	Broad Vegetation Group of Qld
EFG	T1.1 Tropical-subtropical lowland rainforests	T1.2 Tropical-subtropical dry forests and thickets	T1.3 Tropical-subtropical montane forests	T3.1 Seasonally dry tropical shrublands	T4.2 Pyric tussock savannas	T4.3 Hummock savannas	T4.4 Temperate woodlands	T5.1 Semi-desert steppes	Non-remnant
Ground Cover Disturbance score = 5 Above Mean Ground Cover – Increasing Trend – LOW	0.94	0.94	0.04	2.52	2.93	2.68	2.60	6.78	0.53
Ground Cover Disturbance score = 6 Above Mean Ground Cover – Slight Increase in Trend – LOW	1.29	2.32	0.02	4.96	4.24	4.88	5.15	9.33	0.65
Ground Cover Disturbance score = 7 Above Mean Ground Cover – Slight Decrease in Trend – MEDIUM	2.76	4.19	0.02	13.53	7.08	9.13	9.50	11.54	0.97
Ground Cover Disturbance score = 8 Above Mean Ground Cover – Decreasing Trend – MEDIUM	3.38	3.37	0.01	19.89	8.97	11.90	11.75	17.42	1.52
Ground Cover Disturbance score = 9 Below Mean Ground Cover – Increasing Trend – MEDIUM	0.93	2.30	0.17	4.77	5.39	5.97	10.40	9.98	1.03
Ground Cover Disturbance score = 10 Below Mean Ground Cover – Slight Increase in Trend – MEDIUM	0.33	1.62	0.00	2.86	2.46	3.93	4.62	4.06	0.42

Table 19 (continued).

Realm	Terrestrial								
Biome	T1 Tropical-subtropical forests			T3 Shrublands & shrubby woodlands	T4 Savannas & grasslands			T5 Deserts & semi-deserts	Broad Vegetation Group of Qld
EFG	T1.1 Tropical-subtropical lowland rainforests	T1.2 Tropical-subtropical dry forests and thickets	T1.3 Tropical-subtropical montane forests	T3.1 Seasonally dry tropical shrublands	T4.2 Pyric tussock savannas	T4.3 Hummock savannas	T4.4 Temperate woodlands	T5.1 Semi-desert steppes	Non-remnant
Ground Cover Disturbance score = 11 Below Mean Ground Cover – Slight Decrease in Trend – High	0.24	1.10	0.00	2.66	1.87	3.88	3.24	2.92	0.32
Ground Cover Disturbance score = 12 Below Mean Ground Cover – Decreasing Trend – HIGH	0.25	0.54	0.00	1.81	1.45	3.66	2.16	3.05	0.43
Ground Cover Disturbance score = 13 Low Ground Cover – Increasing Trend – HIGH	0.76	1.94	0.06	3.04	4.00	5.30	10.75	6.89	1.69
Ground Cover Disturbance score = 14 Low Ground Cover – Slight Increase in Trend – HIGH	0.20	0.35	0.00	0.63	0.56	1.32	1.57	2.13	0.23
Ground Cover Disturbance score = 15 Low Ground Cover – Slight Decrease in Trend – VERY HIGH	0.14	0.19	0.00	0.47	0.37	1.00	1.12	1.94	0.17
Ground Cover Disturbance score = 16 Low Ground Cover – Decreasing Trend – VERY HIGH	0.18	0.18	0.00	0.47	0.46	1.18	1.43	3.55	0.42

Table 19 (continued).

Realm	Terrestrial								
Biome	T1 Tropical-subtropical forests			T3 Shrublands & shrubby woodlands	T4 Savannas & grasslands			T5 Deserts & semi-deserts	Broad Vegetation Group of Qld
EFG	T1.1 Tropical-subtropical lowland rainforests	T1.2 Tropical-subtropical dry forests and thickets	T1.3 Tropical-subtropical montane forests	T3.1 Seasonally dry tropical shrublands	T4.2 Pyric tussock savannas	T4.3 Hummock savannas	T4.4 Temperate woodlands	T5.1 Semi-desert steppes	Non-remnant
Percentage of ecosystem type area assessed for GCDI (%)	12.26	21.37	0.32	65.23	46.43	64.48	70.72	93.7	9.72
Areas of water	1.81	0.01	0.00	0.03	0.16	0.02	0.02	0.54	0.87
Low change areas (e.g., bare rock)	0.01	0.02	0.00	0.03	0.03	0.02	0.02	0.28	0.01
Areas with more than 20% foliage projective cover	86.22	78.68	99.65	34.71	53.37	35.48	29.23	5.49	89.41
Percentage of assessed area experiencing HIGH or VERY HIGH ground cover disturbance	14.4	20.1	18.8	13.9	18.8	25.3	28.7	21.9	33.5

Table 19 (continued).

Realm	Freshwater–terrestrial		Marine–terrestrial	Marine–freshwater–terrestrial		Broad Vegetation Groups of Queensland	
Biome	TF1 Palustrine wetlands		MT2 Supralittoral coastal systems	MFT1 Brackish tidal			
EFG	TF1.2 Subtropical-temperate forested wetlands	TF1.4 Seasonal floodplain marshes	MT2.1 Coastal shrublands and grasslands	MFT1.2 Intertidal forests & shrublands	MFT1.3 Coastal saltmarshes & reedbeds	Water	Estuary
Ground Cover Disturbance score = 1 High Ground Cover – Increasing Trend – VERY LOW (BENCHMARK)	0.02	0.12	0.88	1.91	23.02	0.00	0.03
Ground Cover Disturbance score = 2 High Ground Cover – Slight Increase in Trend – VERY LOW (BENCHMARK)	0.14	0.41	1.47	1.37	7.14	0.00	0.00
Ground Cover Disturbance score = 3 High ground cover – Slight Decrease in Trend – LOW	0.88	0.81	1.64	1.41	5.85	0.02	0.00
Ground Cover Disturbance score = 4 High ground cover –Decreasing Trend – LOW	6.49	4.02	0.91	2.33	7.50	0.13	0.01
Ground Cover Disturbance score = 5 Above Mean Ground Cover – Increasing Trend – LOW	4.61	3.66	5.77	1.02	14.75	0.04	0.03
Ground Cover Disturbance score = 6 Above Mean Ground Cover – Slight Increase in Trend – LOW	6.76	4.87	5.29	0.51	4.04	0.04	0.01
Ground Cover Disturbance score = 7 Above Mean Ground Cover – Slight Decrease in Trend – MEDIUM	10.01	7.74	6.42	0.45	2.44	0.10	0.01
Ground Cover Disturbance score = 8 Above Mean Ground Cover – Decreasing Trend – MEDIUM	14.29	13.68	2.94	0.77	2.65	0.13	0.05

Table 19 (continued).

Realm	Freshwater–terrestrial		Marine–terrestrial	Marine–freshwater–terrestrial		Broad Vegetation Groups of Queensland	
Biome	TF1 Palustrine wetlands		MT2 Supralittoral coastal systems	MFT1 Brackish tidal			
EFG	TF1.2 Subtropical-temperate forested wetlands	TF1.4 Seasonal floodplain marshes	MT2.1 Coastal shrublands and grasslands	MFT1.2 Intertidal forests & shrublands	MFT1.3 Coastal saltmarshes & reedbeds	Water	Estuary
Ground Cover Disturbance score = 9 Below Mean Ground Cover – Increasing Trend – MEDIUM	9.02	4.59	4.63	0.30	2.93	0.14	0.03
Ground Cover Disturbance score = 10 Below Mean Ground Cover – Slight Increase in Trend – MEDIUM	3.00	2.76	1.42	0.15	2.49	0.09	0.02
Ground Cover Disturbance score = 11 Below Mean Ground Cover – Slight Decrease in Trend – High	2.15	2.80	1.17	0.15	2.59	0.10	0.02
Ground Cover Disturbance score = 12 Below Mean Ground Cover – Decreasing Trend – HIGH	2.29	5.73	0.92	0.30	3.28	0.11	0.07
Ground Cover Disturbance score = 13 Low Ground Cover – Increasing Trend – HIGH	5.83	2.17	1.35	0.03	0.20	0.58	0.02
Ground Cover Disturbance score = 14 Low Ground Cover – Slight Increase in Trend – HIGH	1.13	0.79	0.38	0.02	0.12	0.07	0.02

Table 19 (continued).

Realm	Freshwater–terrestrial		Marine–terrestrial	Marine–freshwater–terrestrial		Broad Vegetation Groups of Queensland	
Biome	TF1 Palustrine wetlands		MT2 Supralittoral coastal systems	MFT1 Brackish tidal			
EFG	TF1.2 Subtropical-temperate forested wetlands	TF1.4 Seasonal floodplain marshes	MT2.1 Coastal shrublands and grasslands	MFT1.2 Intertidal forests & shrublands	MFT1.3 Coastal saltmarshes & reedbeds	Water	Estuary
Ground Cover Disturbance score = 15							
Low Ground Cover – Slight Decrease in Trend – VERY HIGH	0.99	0.82	0.37	0.02	0.29	0.08	0.03
Ground Cover Disturbance score = 16							
Low Ground Cover – Decreasing Trend – VERY HIGH	1.68	2.73	0.49	0.12	0.92	0.40	0.12
Percentage of ecosystem type area assessed for GCDI (%)	69.29	57.7	36.05	10.86	80.21	2.03	0.47
Areas of water	2.48	29.82	2.58	22.99	8.82	88.7	106.18
Low change areas (e.g., bare rock)	0.32	0.06	0.05	0.13	3.39	0.00	0.14
Areas with more than 20% foliage projective cover	27.89	12.43	62.31	67.98	7.69	9.31	7.27
Percentage of assessed area experiencing HIGH or VERY HIGH ground cover disturbance	20.3	26.1	13.0	5.9	9.2	NA	NA

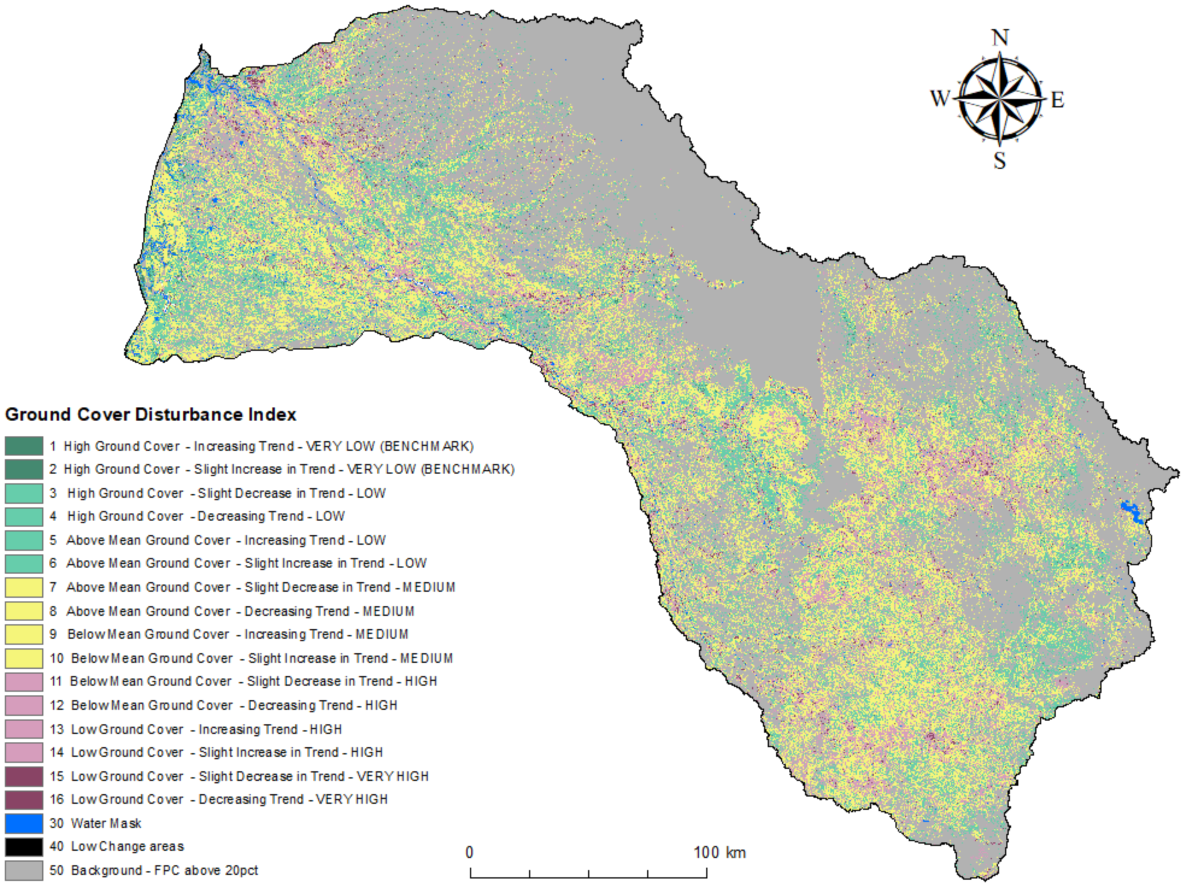


Figure 38. Spatial distribution of Ground Cover Disturbance Index (GCDI), used as a proxy for grazing pressure, in the Mitchell catchment. Indicator values are a combination of mean ground cover (1988–2009) with ground cover trend over the same period to produce a GCDI score ranging from 1 (high ground cover and increasing trend) to 16 (low ground cover and decreasing trend). Benchmark attribute values for very low GCDI are 1 (high ground cover and increasing trend) and 2 (high ground cover and slight increase in trend).

Table 20. Rate of woody vegetation clearing for the clearing periods 1998–91; 1991–95; 1995–97; 1997–99; and then annually from 1999–2000 through to 2017–18, from Statewide Landcover and Trees Study (SLATS). Rate of woody vegetation clearing is expressed in hectares over the stated period across all ecosystem types in the Mitchell catchment.

Realm	Terrestrial								
Biome	T1 Tropical-subtropical forests			T3 Shrublands & shrubby woodlands	T4 Savannas & grasslands			T5 Deserts & semi-deserts	Broad Vegetation Group of Qld
EFG	T1.1 Tropical-subtropical lowland rainforests	T1.2 Tropical-subtropical dry forests and thickets	T1.3 Tropical-subtropical montane forests	T3.1 Seasonally dry tropical shrublands	T4.2 Pyric tussock savannas	T4.3 Hummock savannas	T4.4 Temperate woodlands	T5.1 Semi-desert steppes	Non-remnant
1988–91	1.81	0	0.92	2.59	1004.7	43.59	5.69	20.22	5118
1991–95	0	17.49	0.54	0	448.69	24.60	0.02	0	1549.7
1995–97	0.18	1.39	5.24	1.32	1518.7	24.56	0	2.74	3557
1997–99	2.35	2.32	0.99	4.26	632.69	7.08	0	1.30	2174.1
1999–2000	0.06	0	0.002	5.74	480.24	2.32	0.69	6.58	1013.7
2000–01	0	0	0.04	0	85.23	4.18	0	0	69.3
2001–02	0	0	0.10	0.003	706.02	18.55	0.94	4.90	175.4
2002–03	0	0.15	0.63	0	199.50	15.75	3.63	0	304.8
2003–04	0	0.24	0	0.003	238.92	1.19	1.76	0.23	266.0
2004–05	0	2.86	0	1.39	599.79	28.88	0	0.0007	129.0
2005–06	0	0	1.60	1.27	1091.30	11.51	2.32	0	400.0
2006–07	0	1.18	0	37.08	769.63	8.06	2.42	1.925	1504.1
2007–08	0	0.98	0	0.55	735.71	48.05	0.38	1.518	164.5
2008–09	0.21	0.54	0.72	14.23	642.03	33.69	0.11	0.0002	273.4

Table 20 (continued).

Realm	Terrestrial								
Biome	T1 Tropical-subtropical forests			T3 Shrublands & shrubby woodlands	T4 Savannas & grasslands			T5 Deserts & semi-deserts	Broad Vegetation Group of Qld
EFG	T1.1 Tropical-subtropical lowland rainforests	T1.2 Tropical-subtropical dry forests and thickets	T1.3 Tropical-subtropical montane forests	T3.1 Seasonally dry tropical shrublands	T4.2 Pyric tussock savannas	T4.3 Hummock savannas	T4.4 Temperate woodlands	T5.1 Semi-desert steppes	Non-remnant
2009–10	0.12	0	0	5.86	385.85	6.41	0	2.88	170.9
2010–11	0	0	0	1.31	239.85	1.25	0.20	1.17	26.7
2011–12	0	0.64	0	2.65	348.65	15.72	0	9.83	144.9
2012–13	0.69	2.38	0.68	1.95	354.88	0.36	0.08	0.35	143.4
2013–14	0.07	0	0.53	1.78	191.48	4.63	0.29	1.62	271.7
2014–15	0	0	0.28	1.42	193.20	8.85	0	0	160.7
2015–16	5.80	0	0	0.01	240.21	8.07	0.96	0.52	2202.0
2016–17	0	0.01	0.17	3.01	305.70	25.32	1.31	0.75	1153.6
2017–18	0	0.06	0.07	0	202.33	8.33	1.68	3.99	251.2

Table 20 (continued).

Realm	Freshwater–terrestrial		Marine–terrestrial	Marine–freshwater–terrestrial		Broad Vegetation Groups of Queensland	
Biome	TF1 Palustrine wetlands		MT2 Supralittoral coastal systems	MFT1 Brackish tidal			
EFG	TF1.2 Subtropical-temperate forested wetlands	TF1.4 Seasonal floodplain marshes	MT2.1 Coastal shrublands and grasslands	MFT1.2 Intertidal forests & shrublands	MFT1.3 Coastal saltmarshes & reedbeds	Water	Estuary
1988–91	121.47	0.31	0	0	0	144.97	0
1991–95	10.04	0	0	0	0	9.49	0
1995–97	170.55	34.95	0.59	0	0	36.08	0
1997–99	46.33	0.005	0.23	0	0	16.21	0
1999–2000	143.77	0.13	0	0	0	5.28	0
2000–01	2.07	0	0	0	0	0.22	0
2001–02	41.72	0.29	0	0	0	0	0
2002–03	9.52	0	0	0	0	0	0
2003–04	33.78	0	0	0	0.037	0.03	0.056
2004–05	58.81	0	0	0	0	0.03	0
2005–06	19.25	0.07	0	0	0	0.006	0
2006–07	50.41	0.17	0	0	0	0	0
2007–08	29.65	0	0	0	0	0.0006	0
2008–09	20.05	0.03	0	0	0	0.44	0
2009–10	32.49	0.04	0	0	0	0.64	0
2010–11	123.60	0	0	0	0	0.17	0
2011–12	61.94	0	0	0	0	0	0
2012–13	9.51	0.26	0.427	0	0	0.38	0
2013–14	21.42	0	0	0	0	3.91	0
2014–15	30.75	0	0	0	0	1.52	0
2015–16	20.50	4.18	0.001	182.58	11.44	1.71	7.089
2016–17	17.36	0	0	0	0	4.85	0
2017–18	38.52	0.56	0	0	0	1.25	0

Table 21. Rate of vegetation clearing reported by replacement land cover for the selected clearing periods: 2010–11, 2015–16 and 2017–18, from Statewide Landcover and Trees Study (SLATS). The rate of vegetation clearing by replacement land cover is expressed in hectares over the stated on-year period for each relevant ecosystem type in the Mitchell catchment.

Realm	**Terrestrial**								
Biome	T1 Tropical-subtropical forests			T3 Shrublands & shrubby woodlands	T4 Savannas & grasslands			T5 Deserts & semi-deserts	Broad Vegetation Group of Qld
EFG	T1.1 Tropical-subtropical lowland rainforests	T1.2 Tropical-subtropical dry forests and thickets	T1.3 Tropical-subtropical montane forests	T3.1 Seasonally dry tropical shrublands	T4.2 Pyric tussock savannas	T4.3 Hummock savannas	T4.4 Temperate woodlands	T5.1 Semi-desert steppes	Non-remnant
Clearing period: 2010–11									
Pasture	0	0	0	0.64	97.52	0.94	0.20	0	21.28
Crops	0	0	0	0	0	0	0	0	0
Timber plantation	0	0	0	0	0	0	0	0	0
Mining	0	0	0	0	0	0	0	0	0.19
Infrastructure	0	0	0	0	115.74	0.31	0	0	2.13
Settlement	0	0	0	0	0	0	0	0	0
Sub-total	0	0	0	1.31	213.26	1.25	0.20	0	23.60
Missed clearing in previous era	0	0	0	0	1.75	0	0	0	3.08
Natural disaster damage	0	0	0	0	24.84	0	0	1.17	0
Natural tree death	0	0	0	0	0	0	0	0	0
Re-allocated class	0	0	0	0	0	0	0	0	0
Thinning	0	0	0	0	0	0	0	0	0
Total	**0**	**0**	**0**	**1.31**	**239.85**	**1.25**	**0.20**	**1.17**	**26.68**

Table 21 (continued).

Realm	Terrestrial								
Biome	T1 Tropical-subtropical forests			T3 Shrublands & shrubby woodlands	T4 Savannas & grasslands			T5 Deserts & semi-deserts	Broad Vegetation Group of Qld
EFG	T1.1 Tropical-subtropical lowland rainforests	T1.2 Tropical-subtropical dry forests and thickets	T1.3 Tropical-subtropical montane forests	T3.1 Seasonally dry tropical shrublands	T4.2 Pyric tussock savannas	T4.3 Hummock savannas	T4.4 Temperate woodlands	T5.1 Semi-desert steppes	Non-remnant
Clearing period: 2015–16									
Pasture	0	0	0	0	201.58	8.06	0.96	0	2117.60
Crops	0	0	0	0	0.69	0	0	0	49.27
Timber plantation	0	0	0	0	0	0	0	0	0
Mining	0	0	0	0	1.22	0	0	0	10.41
Infrastructure	0	0	0	0.01	8.35	0	0	0.52	12.52
Settlement	0	0	0	0	0	0	0	0	0
Sub-total	0	0	0	0.01	211.84	8.06	0.96	0.52	2189.80
Missed clearing in previous era	0	0	0	0	0.59	0	0	0	1.42
Natural disaster damage	0	0	0	0	0	0	0	0	0
Natural tree death	5.80	0	0	0	23.98	0	0	0	0
Re-allocated class	0	0	0	0	0	0	0	0	0
Thinning	0	0	0	0	3.80	0	0	0	10.75
Total	**5.80**	**0**	**0**	**0.01**	**240.21**	**8.06**	**0.96**	**0.52**	**2201.97**

Table 21 (continued).

Realm	Terrestrial								
Biome	T1 Tropical-subtropical forests			T3 Shrublands & shrubby woodlands	T4 Savannas & grasslands			T5 Deserts & semi-deserts	Broad Vegetation Group of Qld
EFG	T1.1 Tropical-subtropical lowland rainforests	T1.2 Tropical-subtropical dry forests and thickets	T1.3 Tropical-subtropical montane forests	T3.1 Seasonally dry tropical shrublands	T4.2 Pyric tussock savannas	T4.3 Hummock savannas	T4.4 Temperate woodlands	T5.1 Semi-desert steppes	Non-remnant
Clearing period: 2017–18									
Pasture	0	0.05	0.07	0	170.30	8.32	1.68	3.99	63.91
Crops	0	0	0	0	15.41	0	0	0	165.89
Timber plantation	0	0	0	0	0	0	0	0	0
Mining	0	0	0	0	5.20	0	0	0	11.38
Infrastructure	0	0	0	0	4.59	0	0	0	8.03
Settlement	0	0	0	0	0	0	0	0	0
Sub-total	0	0.05	0.07	0	195.50	8.32	1.68	3.99	249.21
Missed clearing in previous era	0	0	0	0	0	0	0	0	0
Natural disaster damage	0	0	0	0	0	0	0	0	0
Natural tree death	0	0	0	0	0	0	0	0	0
Re-allocated class	0	0	0	0	0	0	0	0	0
Thinning	0	0	0	0	6.84	0	0	0	1.97
Total	**0**	**0.05**	**0.07**	**0**	**202.33**	**8.32**	**1.68**	**3.99**	**251.18**

Table 21 (continued).

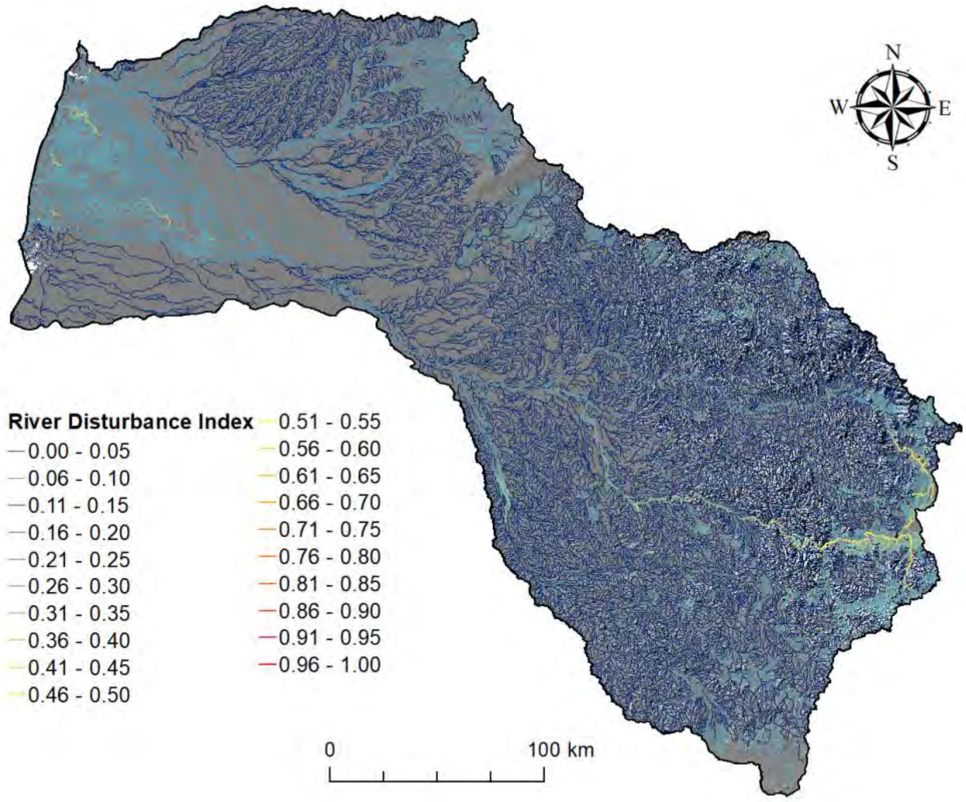
Realm	Freshwater–terrestrial		Marine–terrestrial	Marine–freshwater–terrestrial		Broad Vegetation Groups of Queensland	
Biome	TF1 Palustrine wetlands		MT2 Supralittoral coastal systems	MFT1 Brackish tidal			
EFG	TF1.2 Subtropical-temperate forested wetlands	TF1.4 Seasonal floodplain marshes	MT2.1 Coastal shrublands and grasslands	MFT1.2 Intertidal forests & shrublands	MFT1.3 Coastal saltmarshes & reedbeds	Water	Estuary
Clearing period: 2010–11							
Pasture	0.98	0	0	0	0	0.17	0
Crops	0	0	0	0	0	0	0
Timber plantation	0	0	0	0	0	0	0
Mining	0	0	0	0	0	0	0
Infrastructure	8.81	0	0	0	0	0	0
Settlement	0	0	0	0	0	0	0
Sub-total	9.79	0	0	0	0	0.17	0
Missed clearing in previous era	0	0	0	0	0	0	0
Natural disaster damage	113.81	0	0	0	0	0	0
Natural tree death	0	0	0	0	0	0	0
Re-allocated class	0	0	0	0	0	0	0
Thinning	0	0	0	0	0	0	0
Total	**123.60**	**0**	**0**	**0**	**0**	**0.17**	**0**

Table 21 (continued).

Realm	Freshwater–terrestrial		Marine–terrestrial	Marine–freshwater–terrestrial		Broad Vegetation Groups of Queensland	
Biome	TF1 Palustrine wetlands		MT2 Supralittoral coastal systems	MFT1 Brackish tidal			
EFG	TF1.2 Subtropical-temperate forested wetlands	TF1.4 Seasonal floodplain marshes	MT2.1 Coastal shrublands and grasslands	MFT1.2 Intertidal forests & shrublands	MFT1.3 Coastal saltmarshes & reedbeds	Water	Estuary
Clearing period: 2015–16							
Pasture	17.18	0	0	0	0	1.71	0
Crops	0	0	0	0	0	0	0
Timber plantation	0	0	0	0	0	0	0
Mining	0	0	0	0	0	0	0
Infrastructure	2.86	0	0	0	0	0	0
Settlement	0	0	0	0	0	0	0
Sub-total	20.04	0	0	0	0	1.71	0
Missed clearing in previous era	0	0	0	0	0	0	0
Natural disaster damage	0	0	0	0	0	0	0
Natural tree death	0	4.18	0	182.58	11.43	0	7.09
Re-allocated class	0	0	0	0	0	0	0
Thinning	0.46	0	0	0	0	0	0
Total	20.50	4.18	0	182.58	11.43	1.71	7.09

Table 21 (continued).

Realm	Freshwater–terrestrial		Marine–terrestrial	Marine–freshwater–terrestrial		Broad Vegetation Groups of Queensland	
Biome	TF1 Palustrine wetlands		MT2 Supralittoral coastal systems	MFT1 Brackish tidal			
EFG	TF1.2 Subtropical-temperate forested wetlands	TF1.4 Seasonal floodplain marshes	MT2.1 Coastal shrublands and grasslands	MFT1.2 Intertidal forests & shrublands	MFT1.3 Coastal saltmarshes & reedbeds	Water	Estuary
Clearing period: 2017–18							
Pasture	36.78	0.56	0	0	0	0	0
Crops	0.61	0	0	0	0	0	0
Timber plantation	0	0	0	0	0	0	0
Mining	0.46	0	0	0	0	0	0
Infrastructure	0.36	0	0	0	0	1.25	0
Settlement	0	0	0	0	0	0	0
Sub-total	38.21	0.56	0	0	0	1.25	0
Missed clearing in previous era	0	0	0	0	0	0	0
Natural disaster damage	0	0	0	0	0	0	0
Natural tree death	0	0	0	0	0	0	0
Re-allocated class	0	0	0	0	0	0	0
Thinning	0.31	0	0	0	0	0	0
Total	**38.52**	**0.56**	**0**	**0**	**0**	**1.25**	**0**



Comparison of River Disturbance Index values between Mitchell catchment and Australia.

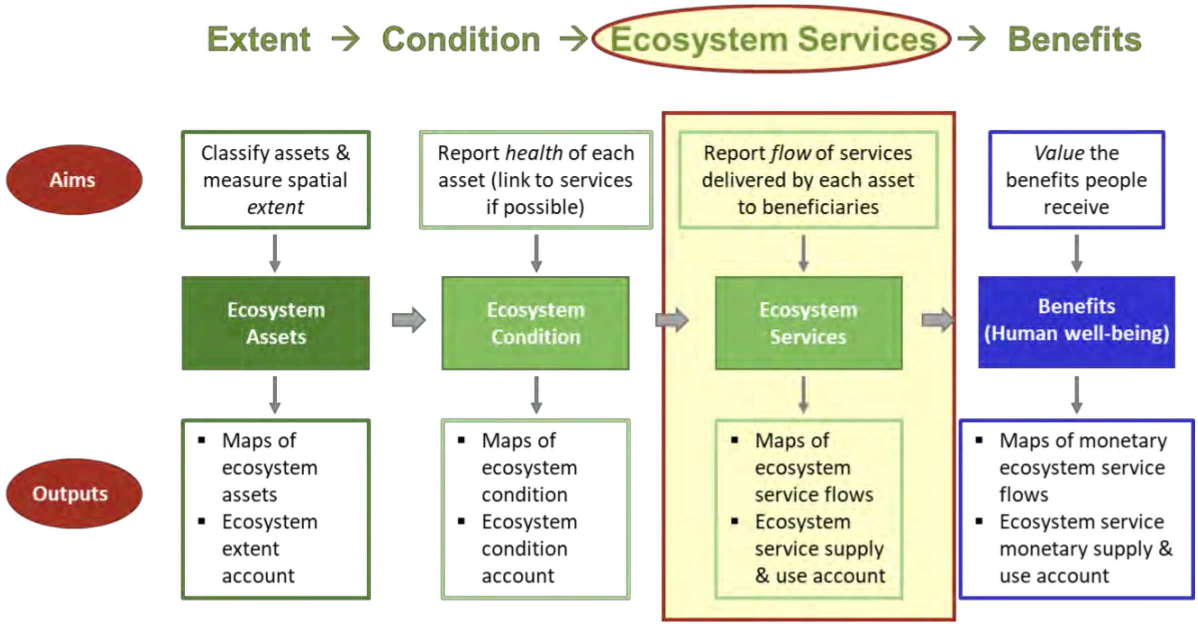
RDI statistics	Mitchell catchment	Australia
No. of polylines	27,614	1,396,648
Minimum	0	0
Maximum	0.595	0.941
Mean	0.040	0.102
Standard deviation	0.049	0.120

Figure 39. River Disturbance Index (RDI) values within the Mitchell catchment. RDI values in the Mitchell catchment range between 0 and 0.595. Values on the lowest RDI class, 0.00–0.05, are shown in dark blue to indicate that the majority of the rivers in the catchment as having low anthropogenic-induced disturbances. The table below the map shows a comparison between RDI statistics for the Mitchell catchment and across Australia as a whole. RDI values form a continuum from severely degraded (value at or near 1) to near-pristine or 'wild' (value at or near zero) (Stein, Stein, & Nix, 2002).

Table 22. River Disturbance Index value assigned to the length of rivers (in km) within ecosystem types in the Mitchell catchment.

Ecosystem type	IUCN EFG	IUCN EFG Area (ha)	River Disturbance Index						
			0–0.1	0.1–0.2	0.2–0.3	0.3–0.4	0.4–0.5	0.5–0.6	Total length (km)
Estuary	Estuary	5226	148.3	30.6	0.7	0.0	0.0	0.0	179.6
Intertidal forests and shrublands	MFT1.2	10996	203.9	35.1	5.6	0.0	0.0	0.0	244.6
Coastal saltmarshes and reedbeds	MFT1.3	40916	393.1	94.2	11.4	4.6	0.0	0.0	503.4
Coastal shrublands and grasslands	MT2.1	5902	10.9	0.1	0.0	0.0	0.0	0.0	11.0
Non-remnant	Non-remnant	91612	488.2	158.8	97.4	33.2	12.8	11.2	801.6
Tropical-subtropical lowland rainforests	T1.1	18244	111.2	6.4	0.2	0.0	0.0	0.0	117.9
Tropical-subtropical dry forest and thickets	T1.2	12248	54.6	2.6	0.1	0.0	0.0	0.0	57.3
Tropical-subtropical montane rainforests	T1.3	26323	232.0	13.3	0.2	0.0	0.0	0.0	245.5
Seasonally dry tropical shrublands	T3.1	72205	861.7	5.3	0.0	0.0	0.0	0.0	866.9
Pyric tussock savannas	T4.2	5603684	43306.8	1723.6	183.6	37.9	9.2	4.8	45265.9
Hummock savannas	T4.3	435831	3597.2	29.2	1.2	0.0	0.7	0.0	3628.3
Temperate woodlands	T4.4	21049	167.6	10.9	0.0	0.0	0.0	0.0	178.6
Semi-desert steppes	T5.1	56506	324.2	1.9	14.4	0.0	0.0	0.0	340.5
Subtropical-temperate forested wetlands	TF1.2	740342	7706.0	415.9	127.2	45.4	33.9	20.4	8348.8
Seasonal floodplain marshes	TF1.4	25233	141.7	64.6	2.4	0.3	0.0	0.0	208.9
Water	Water	4785	28.6	3.9	16.2	7.2	8.1	11.3	75.3

6. Ecosystem services – supply and use accounts in biophysical terms



6.1 Summary

- Biophysical supply and use tables in the Mitchell catchment Ecosystem accounts record which ecosystem types in the catchment supply which final ecosystem services to which users (businesses, households and government).
- Where possible, supply and use are quantified in biophysical terms (e.g., tonnes of grazing fodder, ML of water, tonnes of CO_2 sequestered, number of visitor nights).
- Biophysical supply and use of the following final ecosystem services is reported:
  - Provisioning ecosystem services
    - Crop provisioning services into irrigated agriculture (e.g., naturally occurring soil nutrients, trace minerals, soil water etc. that production of cultivated crops).
    - Grazed biomass provisioning services into cattle rearing on cattle stations.
    - Wild fish provisioning services into the commercial barramundi fishery in the Mitchell Delta and coastal zone.
- Biophysical supply and use of the following final ecosystem services is reported:
  - Provisioning ecosystem services (continued)
    - The supply of juvenile banana prawns from the Mitchell estuary that can subsequently be caught by vessels of the Northern Prawn Fishery operating in the Gulf of Carpaentaria is **not** detailed in the Mitchell supply and use accounts because (i) this is an intermediate service, rather than a final service, and (ii) the service is 'used' outside the boundary defined as the ecosystem accounting area for the Mitchell catchment Ecosystem Accounts.
    - Biomass provisioning of other animals and plants is acknowledged, but not quantified due to lack of data.

        - Water supply services (from surface water and groundwater) into irrigated agriculture
        - Water supply services (from surface water and groundwater) for household consumption (after subsequent treatment)
    - Regulating ecosystem services
        - Global climate regulation services via:
            - Carbon storage in above- and below-ground biomass
            - Carbon storage in the top 30cm of soils
            - Carbon sequestration (in the form of avoided carbon release) through manged early-seasonsavanna fireburn
        - Soil and sediment retention services are acknowledged, but not quantified. However, drawing on prior research, an estimate of the increase in soil erosion pre-clearing (~1750) to post-clearing (~2015) is provided
    - Cultural ecsosytem services
        - Recreation services supplied to domestic and international visitors
        - A suite of other cultural services is ackowledged, but not quantified due to lack of data: *Visual amenity services*; *Education, scientific & research services*; *Spiritual, artistic and symbolic servic*es; *Other cultural services*
        - We note that co-production under the reciprocal relationship between Traditional Owners and Country gives rise to several different categories of cultural ecosystem services – when using SEEA-EA concepts and terminology. These services can potentially be accommodated within SEEA EA, either via a link to cultural identity, or by introducing *caring for Country*, *knowing that Country is being cared for*, and *knowing that Country will continue to be cared for*, as cultural ecosystem services in their own right in the 'other cultural services' category

- For tens of thousands of years prior to appropriation and settlement by Europeans, the ancestors of today's Traditional Owners of the Mitchell catchment socialised the landscapes of the region as they managed land and water, fulfilled custodial responsibilities under customary law and maintained an economic arrangement that sustained their way of life. This active management by Traditional Owners continues in many localities today, albeit under constrained conditions.
- Due to Covid-19 access restrictions, only a modest amount of on-site research could be undertaken to investigate use and supply of ecosystem services from an Indigenous perspective in the Mitchell catchment. Consequently, our research centred on the township of Kowanyama and drew on data collected by Project 4.6 research associate Viv Sinnamon with the support of Kowanyama Aboriginal Land and Natural Resource Management Office, Abm Elgoring Ambung RNTBC, and Kowanyama Aboriginal Council. These data were collected in accordance with Griffith University Human Research Ethics Approval No. 2019/850. This section summarises these findings; more detailed descriptions are provided in the accompanying Technical Report
- We note that there are fundamental misalignments between SEEA-EA conceptualisations of anthropogenic interactions with ecosystems and those of

proposed for Indigenous Traditional Owners. SEEA-EA's conceptualisation is fundamentally 'linear' and 'transactional'. In contrast, Indigenous Traditional Owners' conceptualisation has been portrayed as being 'reciprocal' and 'relational'; Custodians have responsibilities to care for Country in order for Country to continue to contribute benefits to Custodians. The values arising from these reciprocal interactions are grounded in the fundamental *relationship* between Custodians and Country.

- The SEEA-EA White Cover version clearly states that *non-use value* and *relational value* fall <u>*outside*</u> the remit of SEEA Ecosystem Accounts. Notwithstanding these fundamental conceptual misalignments, Project 4.6 investigated how Indigenous Traditional Owners' activities and interactions with Country in the vicinity of Kowanyama in the Mitchell Delta could potentially be represented in SEEA Ecosystem Accounts.
- Drawing on several decades of interaction with the Kowanyama community, Viv Sinnamon's data collection reported that the Indigenous Traditional Owners in Kowanyama both benefit from provisioning and cultural ecosystem services and facilitate supply of regulating and cultural ecosystem services. However, Traditional Owners' ability to benefit from and supply ecosystem services is being compromised by the declining condition of ecosystems in the lower Mitchell catchment and Delta. The primary pressures reported as causing these declines are invasive weeds and feral animals.

6.2 Background

In the SEEA-EA framing, humans derive benefits from ecosystem assets (grouped into ecosystem types) through their utilisation of the ecosystem services those assets supply. Ecosystem services are thus regarded as the *contributions* that ecosystems make to benefits in the form of goods and services that contribute to human well-being (United Nations et al., 2021; Section 6.2, p.121). These benefits can be delivered as goods and services that are purchased in markets (e.g., food, water, energy, shelter, recreation etc.) and are thus included *within* the 'production boundary' of the United Nations' System of National Accounts (SNA) (European Commission, International Monetary Fund, Organisation for Economic Co-operation and Development, United Nations, & The World Bank, 2009). These types of benefits are termed 'SNA benefits' in SEEA-EA terminology (United Nations et al., 2021; paragraph 6.17, p.122). However, ecosystems can also contribute to supply benefits in the form of goods and services that sit *outside* the production boundary of SNA (i.e., outside the production economy) and are thus not reported in the SNA (e.g., global climate regulation, flood protection, water quality filtration) (Eigenraam & Obst, 2018; Obst & Eigenraam, 2017; Obst, Hein, & Edens, 2016). These are termed 'non-SNA benefits' in SEEA-EA terminology (United Nations et al., 2021; paragraph 6.18, p.123). Ecosystems' contributions to supply of SNA benefits and non-SNA benefits should <u>*both*</u> be reported in supply and use tables in ecosystem accounts.

Viewing ecosystem services as ecosystems' contributions to SNA benefits and non-SNA benefits, the ecosystem services that should be reported in supply and use tables in ecosystem accounts are those that have the most direct link between ecosystem assets and the benefits provided to human beneficiaries (i.e., businesses, governments and households – collectively termed 'economic units'). Consequently, only <u>*final*</u> *ecosystem service flows* are reported in SEEA-EA supply and use tables i.e., those services from ecosystem assets that contribute to SNA or non-SNA benefits that are *delivered* to economic units (United Nations et al., 2021; paragraph 6.24, p.124). In appropriate contexts, *provisioning*, *regulating*, and *cultural* ecosystem services can generally be regarded as final services, whereas *supporting* services cannot.

It is important to note that irrespesctive of whether the benefits to which ecosystem services contribute are reported in SNA (or not), *ecosystem services* as defined above and reported in ecosystem accounts are themselves necessarily *outside the production boundary* of SNA (United Nations et al., 2021; paragraph 619, p.123). This is the case even though ecosystem services *can contribute* to the production of SNA benefits[4] (which by definition will be represented within the production boundary of SNA). The positioning of ecosystem accounts and the SNA is quite distinct. Ecosystem accounts report supply and use of ecosystem services (in both biophysical and monetary terms) as 'ecosystems' contributions to delivery of SNA benefits and non-SNA benefits'. These ecosystem services are, by definition, *outside* the production boundary of the SNA. They may, however, represent ecosystems' *contributions* to *benefits* that *are* reported in SNA ('SNA benefits') (i.e., although the *benefits* may be reported within SNA, ecosystems' *contributions* to those benefits are not). The SNA reports these SNA-*benefits,* in monetary terms ($).

As described in Section 2, the ecosystem accounting area for the Mitchell catchment SEEA Ecosystem Accounts was defined as the watershed of the Mitchell River catchment, extending seven nautical miles from the shoreline into the Gulf of Carpentaria. This includes part of the operating area of the commercial barramundi in the Gulf of Carpentaria (State of Queensland Department of Agriculture and Fisheries, 2019; Appendix B)). However, this definition excludes the operating area of the Northern Prawn Fishery (https://www.afma.gov.au/fisheries/northern-prawn-fishery).

In SEEA-EA accounting, *final* ecosystem services are accounted at the location of their *use*. Hence supply of harvestable fish to the commercial barramundi fishery is reported as a provisioning ecosystem service in the Mitchell ecosystem accounts, and supply of this service is attributed to the Mitchell estuary and its coastal zone. Supply of juvenile banana prawns by the Mitchell estuary is noted as an *intermediate* service, but the subsequent harvest of prawns by the Northern Prawn Fishery (the corresponding final provisioning service) is not reported in the Mitchell ecosystem accounts because this final provisioning service is 'used' outside the Mitchell ecosystem accounting area. Further examples of *intermediate* services that the Mitchell River supplies to the coastal zone and Gulf of Carpentaria include juvenile biomass of other fish species such as king threadfin (*Polydactylus macrochir*) (Moore et al., 2012) and blue threadfin (*Eleutheronema tetradactylum*) (Horne, Momigliano, Welch, Newman, & Van Herwerden, 2011), and nutrients that enhance the productivity of these marine environments and the fisheries they support (Broadley, Stewart-Koster, Burford, & Brown, 2022; Burford & Faggotter, 2021).

Following the same principle regarding the locations of 'supply' and 'use', supply of raw water to irrigated agriculture in the Mitchell catchment's section of the Mareeba Dimbulah Irrigation

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[4] Typically, this will be the case for provisioning ecosystem services which contribute as inputs to joint production processes in primary industries such as farming, fishing, and forestry, or for businesses that offer recreation services in natural landscapes (e.g., guided nature tours, recreational fishing charters etc.)

Area, and – after treatment – for residential use by households in Dimbulah and Mutchilba is reported as a final provisioning service within the Mitchell ecosystem accounts. However, supply of those water services is reported as an 'import', rather than being attributed to an ecosystem type within the Mitchell catchment, because the water supply for the Mareeba Dimbulah Irrigation Area that supplies these uses is obtained from Lake Tinaroo in the neighbouring Barron catchment and conveyed into the Mitchell catchment by irrigation infrastructure.

Figure 40 clarifies these concepts, using the example of catches in the commercial barramundi fishery operating in the Mitchell estuary. The $ value of commercial barramundi catch revenues will be reported in SNA as an 'SNA benefit' from the commercial fishery[5]. Aquatic and estuarine ecosystems in the Mitchell catchment contribute to the reported SNA benefit by supplying a stock of barramundi from which the commercial harvest is taken. The harvested barramundi from this stock *are* the biophysical *contribution* (i.e., the ecosystem service) that the ecosystem[6] supplies as an input to the *joint production process*[7] of the commercial barramundi fishery. In *biophysical* terms, this ecosystem service would be reported in the ecosystem account's *biophysical* supply and use tables as the commercial tonnage of barramundi caught in the Mitchell estuary and coastal zone in a particular year.

When reported in the ecosystem account's supply and use tables in *monetary* terms (for further details see Section 7), the *monetary value* of the *ecosystem's contribution* to the joint production process that generates the SNA benefit has to be *separated out* from the monetary value of contributions to joint production from other inputs i.e., from produced assets (e.g., fishing boats and fishing gear), intermediate inputs (e.g., diesel), and labour. This needs to be done carefully and consistently if the monetary value of the ecosystem contribution (i.e., the monetary value of the ecosystem service) is to be determined clearly.

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[5] Albeit aggregated into the total sales revenues of the wild capture fisheries sector.

[6] In the supply and use tables in Ecosystem Accounts, supply of an ecosystem service is assigned to the ecosystem type in which the ecosystem service *delivers* its contribution to the relevant household, business or government. In this example this is the Mitchell estuary and its coastal zone.

[7] The term *joint production process* indicates that the production process that produces a benefit (e.g., the harvest of barramundi from the Mitchell estuary by the commercial barramundi fishery) uses inputs supplied by ecosystem assets (provision of natural fish biomass as an ecosystem service from the estuary), *jointly* with inputs sourced as produced assets from the manufactured capital stock (fishing boats and fishing gear), intermediate inputs for other economic sectors (e.g., diesel) and labour (fishers – and their knowledge) as an input from stocks of human and intellectual capital (as illustrated in Figure 40).

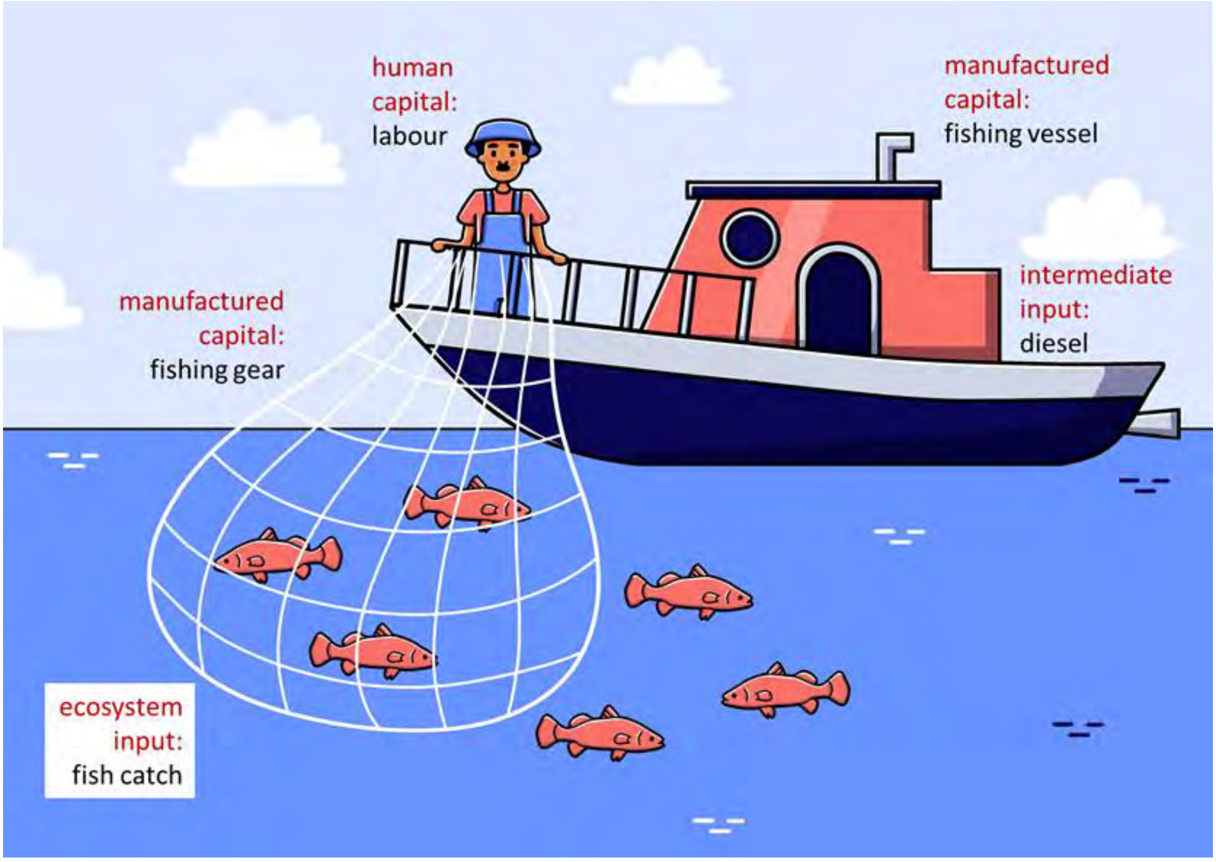

Figure 40. Biophysical inputs to the joint production process in a commercial fishery. Inputs are contributed from natural capital (the catch of harvestable fish), manufactured capital (fishing boat and fishing gear), intermediate inputs (diesel etc. from other industrial sectors), and human and intellectual capital (fishers' labour and knowledge).

Where final ecosystem services are inputs to a joint production process (as will typically be the case with provisioning ecosystem services that contribute to agriculture, forestry or fisheries), the value attributed to those ecosystem services in monetary supply and use tables will necessarily be *less than* the overall monetary value of the benefit provided to society – to acknowledge the value contributions from other inputs to the joint production process (United Nations et al., 2021; paragraph 7.21, p.163).

This would *not* be the case, however, if the benefit to society is delivered via a natural 'production process' that requires *no* inputs other than those from natural capital stocks in the form of ecosystem assets, e.g., the global climate regulation service provided by sequestration and storage of carbon in natural forests, woodlands and soils[8]. In such cases it is highly likely that the societal benefit concerned is a non-SNA benefit i.e., the value of that benefit is *not* recorded in the SNA. Monetary valuation of ecosystem services for inclusion in monetary supply and use tables for the Mitchell catchment ecosystem account is described briefly in Section 7, following. Full methodological details are provided in the accompanying Final Technical Report for Project 4.6.

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[8] We note that this conceptualisation is *not* consistent with the *co-production* that follows from Indigenous Traditional Owners' relationship *with* Country. Co-production recognises that responsibilities under customary law require that custodians care for Country appropriately in order for Country to continue to provide ecosystem services.

By accounting separately and distinctly for ecosystem services (in both biophysical and monetary terms), as ecosystems' contributions to SNA benefits and non-SNA benefits, an important intention and outcome of ecosystem accounting is to make the contributions of ecosystem assets to human well-being more explicit (Remme, Edens, Schröter, & Hein, 2015). Before the advent of ecosystem accounting the contributions of ecosystem assets to human well-being were absent, or at best opaque, in national accounts.

Two additional points are important here, regarding whether ecosystem services should be included in an ecosystem account's supply and use tables:

- The quantity of the ecosystem service *supplied* can be influenced by ecological factors (e.g., the biotic, abiotic and/or landscape condition of the ecosystem asset(s) supplying the service) and by societal factors. Relevant societal factors could include availability of produced assets (e.g., fishing boats or tractors) and labour to contribute alongside the ecosystem service as inputs to a *joint production process*, as if often the case for provisioning ecosystem service flows. For regulating ecosystem service flows, societal factors such as pollutant concentrations can affect ecosystem service supply. Thus, if the air contains negligible concentrations of the pollutants that could be filtered out by forests and woodlands then these ecosystem assets will would not be considered to supply air filtration services.
- The quantity of the ecosystem service *used* will be influenced by how individuals and economic units (households, businesses, government) engage with the ecosystem service flow. If the *use* of the ecosystem service flow *cannot be described and quantified* then it should *not* be reported in the supply and use tables in ecosystem accounts. Thus, if no households or businesses are located down-wind of forests and woodlands that filter out PM10 particulates then there are no 'users' of the air filtration ecosystem service and no supply or use of the service will be reported in the supply and use tables in ecosystem accounts. This has important consequences for reporting the supply and use of ecosystem services from a sparsely populated region like the Mitchell catchment; where no (or very few) users are present, no ecosystem service flows (or only very minor ecosystem service flows) will be reported – unless the service flow concerned delivers a public good benefit from collective use (e.g., the global climate regulation service).

6.3 Ecosystem service supply and use accounts in biophysical terms

6.3.1 Introduction

The SEEA-EA (White cover version) (United Nations et al., 2021; Table 6.3, p.131) provides a reference list of selected ecosystem services grouped into *provisioning*, *regulating* and *cultural* ecosystem service categories. In this study we address supply and use of the following ecosystem services from the SEEA-EA (White cover version) reference list from ecosystem types in the Mitchell: *(supply of services in italics is acknowledged by not quantified)*

- Provisioning services
    - Biomass provisioning services
        - Crop provisioning services

        - Grazed biomass provisioning services
        - Wild fish biomass provisioning services
        - *Wild animals, plants and other biomass provisioning services*
    - Water supply services
        - Water for irrigation: from surface water and groundwater
        - Water for household usage: from surface water and groundwater
- Regulating and maintenance services
    - Global climate regulation services
        - Carbon storage in above- and below-ground biomass
        - Carbon storage as organic carbon in the top 30cm of soils
        - Carbon sequestration via savanna fireburn management
    - Soil and sediment retention services
        - Soil erosion control services
- Cultural services
    - Recreation-related services
    - *Visual amenity services*
    - *Education, scientific & research services*
    - *Spiritual, artistic and symbolic services*
    - *Other cultural services (caring for Country, knowing that Country is being cared for, passing on knowledge of how to care for Country to younger generations)*

The Final Technical Report for Project 4.6 details the specific methodologies used to quantify biophysical supply and use of these ecosystem services in the Mitchell catchment. Footnotes to the supply and use tables provide abbreviated methodological descriptions.

The ecosystem service *supply* account shown in Table 23 and Table 25 reports the quantities of these provisioning, regulating and cultural services *supplied* by ecosystem types in the Mitchell catchment in selected years.

The ecosystem service *use* account in biophysical terms (Table 26 and Table 28) reports the biophysical quantities of ecsosystem services from ecosystem types in the Mitchell catchment *used* by economic entities (sectors of the production economy, households or government) in selected years.

On subsequent pages, Figure 41, Figure 42, Figure 43 and Figure 44 illustrate the spatial distribution of supply of global climate regulation services between and within ecosystem types across the catchment.

Figure 45 illustrates locations in the vicinity of Kowanyama (by ecosystem type) at which Indigenous hunters obtain provisioning ecosystem services during the wet and dry seasons[9].

[9] Note that traditional gatherers gather and hunt enroute to places indicated in those figures that may engage a range of ecosystem types. For example, goannas or bustards might be taken on grasslands enroute to a fresh or saltwater fishing spot. Equally a goose egg gathering trip to a wetland/s may result in the taking of a wallaby in grassland or woodland. Equally timber for spears might be taken from a vine thicket. Many resources are thus likely to be harvested on the way to the sites indicated in the figure.

Aboriginal and Torres Strait Islander people should be aware that this Section contains the names of deceased persons who are cited as authoritative sources for land management practices and ecosystem extent and condition.

6.3.2 Ecosystem services used and supplied by Indigenous Traditional Owners at Kowanyama in the Mitchell Delta

As Project 4.6 had a limited budget for fieldwork, only a modest amount of on-site research could be undertaken to investigate use and supply of ecosystem services from an Indigenous perspective in the Mitchell catchment. Consequently, this aspect of research in Project 4.6 focused on the Mitchell Delta, centred on the township of Kowanyama (Figure 5). This decision was taken because Project 4.6 researchers had collaborated successfully with the local, predominantly Indigenous, community in Kowanyama previously, and the community indicated that they were willing to collaborate with project researchers in this research. Data collected in Kowanyama by Project 4.6 research associate Viv Sinnamon with the support of Kowanyama Aboriginal Land and Natural Resource Management Office, Abm Elgoring Ambung RNTBC, and Kowanyama Aboriginal Council, provide important insights into the supply of multiple provisioning, regulating and cultural ecosystem services by and to the Indigenous community in Kowanyama. These data were collected in accordance with Griffith University Human Research Ethics Approval No. 2019/850. Full details of the findings are provided in the Project 4.6 Technical Report; a brief summary is provided in the paragraphs that follow.

For tens of thousands of years prior to appropriation and settlement by Europeans, the ancestors of today's Traditional Owners of the Mitchell catchment socialised the landscapes of the region as they managed land and water, fulfilled custodial responsibilities under customary law and maintained an economic arrangement that sustained their way of life (Jackson, Finn, & Scheepers, 2014; Strang, 2000). As explained earlier in this Report, we use the term 'pre-clearing' to refer to the historical reference condition for the ecosystems in our ecosystem accounts for the Mitchell Catchment. We consider that this definition respectfully acknowledges that 'pre-clearing', the land and water ecosystems in the Mitchell catchment were actively managed as socialised landscapes by the ancestors of today's Traditional Owners in fulfilment of their custodial responsibilities. This active management by Traditional Owners continues in many localities today, albeit under constrained conditions - particularly where Aboriginal Land Tenure is not held.

The Mitchell River landscape is anything but an empty, inert wilderness, as Strang explains in the following quote:

> *'… ancestral tracks … reflect a cosmological vision of the land as having been created by ancestral beings in the 'Dreamtime', or 'Story Time' as it is called in North Queensland. Having acted upon and formed the landscape, the ancestral beings went back into the land, bequeathing it to totemic clans in perpetuity, and conferring upon them inalienable rights of ownership and responsibility for caring for its well-being. They remained in the land 'for all time', creating a sentient landscape which watches and responds to human action.'*
>
> *'The male and female ancestral forces within the land are generative, providing wells of human spirituality which tie each individual to a spiritual conception site on or near their clan land. Human cycles of birth, growth and death are further bound into the land by a series of ceremonial interactions reaffirming these 'ancestral connections' … The clan's own land is said to 'give' resources to it, for example allowing people to catch fish, or find what they need, whilst withholding these from strangers. The relationship is presented as reciprocal: clans take care of their land through managing it properly, keeping it 'clean', and through ritual activities which manifest the presence of the ancestral beings; the land 'knows' and takes care of them by providing resources and refraining from being malevolent towards them.'* (Strang, 2000; p.282)

The system of land and natural resource management practised by Aboriginal clans of this region was severely disrupted by colonisation, particularly the removal of people from their homelands, the establishment of missions and reserves, and the introduction of pastoralism and mining. In addition to bringing about great social change, these land uses affected the condition of the catchment (e.g., Brooks et al., 2009; Shellberg et al., 2016 – and examples of adverse consequences from invasive weeds and feral animals reported in the paragraphs below). Yet, Aboriginal people continued to hunt and gather and to maintain connections with and manage their land as best they could alongside these introduced modes of production (Strang, 2000). Barber et al. (2014) reveal the significance of consistent Indigenous residence to ecological management of some of the former pastoral lands and how Aboriginal stockmen of the region were able to retain and adapt their knowledge and traditional familiarity as they worked pastoral leases.

As discussed at more length in the Project 4.6 Technical Report, there are fundamental misalignments between the SEEA-EA conceptualisations of anthropogenic interactions with ecosystems and those of Indigenous Traditional Owners. SEEA-EA's conceptualisation is fundamentally 'linear' and 'transactional' (as exemplified in the *linear* sequence of contributions *from* ecosystems delivering benefits *to* society (Figure 4), and an emphasis on *transactional use* values within ecosystem accounts (United Nations et al., 2021; Section 6.3.4 and particularly paragraph 6.72, p.137)). In contrast, Indigenous Traditional Owners' conceptualisation has been portrayed as 'reciprocal' and 'relational', with reciprocal responsibilities between custodians and Country; Custodians have responsibilities to care for Country in order for Country to continue to contribute benefits to custodians (e.g., Jackson et al., 2014; Strang, 2000). The values arising from those reciprocal interactions are grounded in the fundamental *relationship* between custodians and Country (e.g., Chan et al., 2016). Earlier conceptualisations of ecosystem services in the Millennium Ecosystem Assessment recognised that reciprocal relationships can be important components of societal interactions with ecosystems (e.g., MEA, 2005; Box 2.1, p.120), and the SEEA-EA White Cover version recognises that there are situations in which relational values are relevant and important; however, the SEEA-EA White Cover version clearly states that *non-use value* and *relational value* fall *outside* the remit of SEEA Ecosystem Accounts (United Nations et al., 2021; Section 6.3.4 and particularly paragraph 6.72, p.137).

In this preliminary report we do not attempt to comprehensively describe how Indigenous peoples of the Mitchell River catchment measure and value the contributions that ecosystem services supply to their society. Given our understanding of the ways in which Indigenous peoples conceptualise socio-ecological relations (Jackson & Palmer, 2015), we acknowledge that Indigenous perspectives cannot be incorporated into SEEA EA in any straightforward way. The ontological category of 'nature' cannot be taken for granted as a source of ecological stocks and flows. Instead, Indigenous peoples *co-produce* with Country and the ecosystem services flow from that relation. The concept of *co-production* recognises that responsibilities under customary law require that custodians care for Country appropriately in order for Country to continue to provide ecosystem services. Comberti *et al.* (2015) consider that the standard linear conceptualisation of ecosystem services is flawed in framing ecosystems services as *'a one-way flow of benefits from ecosystems to humans'* (Comberti *et al.*, 2015; p.247). They argue that local and Indigenous communities often play an important role in providing 'Services to Ecosystems' (S2E), which they define as:

> *'Actions humans have taken in the past and currently that modify ecosystems to enhance the quality or quantity of the services they provide, whilst maintaining the general health of the cognised*[10] *ecosystem over time'* (Comberti *et al.*, 2015; p.247)

Comberti *et al.* argue that the conventional linear, unidirectional ecosystem services paradigm should be extended to become an *'ecosystem services and services-to-ecosystems loop of reciprocity'* (Comberti *et al.*, 2015; p.257).

Environmental accounts necessarily promote standardisation and equivalence, where complex socio-ecological processes are made amenable to assessment that can be used and compared across wider landscapes, different policy actors, and multiple stakeholders (McElwee, 2017). In the Mitchell River catchment there are many groups (Indigenous and non-Indigenous) with interests in the environment and varied forms of attachment and connection. Concepts and metrics common to the methodologies of ecosystem accounting are likely to be unfamiliar to some if not many and may well be contested. The 'tools' that ecologists and economists use to enumerate the living and life-giving processes of the Mitchell River catchment delineate a 'natural' world that does not align with Indigenous ways of knowing Country. The selection of which ecosystem services to enumerate, the objectification of phenomena (into 'catch', for example) and the choice of spatial and temporal scales will generate forms of knowledge that are contestable (McElwee, 2017) and therefore warrant more focused attention and discussion with Indigenous people of the study locality. Our team did not discuss which new things (the indicators, statistics, maps, or economic values reported here) should be created to stand in for the actual ecosystem processes, functions, and products that are considered beneficial or valuable. The Traditional Owners, elders and rangers of the Kowanyama community did, however, share Indigenous knowledge of the following topics:

- interactions with Country that support supply of provisioning, regulating and cultural ecosystem services, (where these terms are used in their SEEA-EA sense)
- how interactions with Country for multiple purposes are adversely affected by declining ecosystem condition – particularly by invasive weeds and feral animals

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[10] The term 'cognised' here recognises that local or Indigenous understandings of what constitutes the 'ecosystem' that is being managed may differ from those held by western science.

- cataloguing of on-Country activities as a potential starting point for developing SEEA EA-compliant valuations of some cultural ecosystem services (as conceptualised by SEEA EA) – recognising that any valuations that might be produced will only provide a very limited, partial representation of the full value that Traditional Owners and the Kowanyama community derive from the associated cultural and custodianship practices.

Notwithstanding these fundamental conceptual misalignments, and operating within the limitations of the field work budget and regional and organisational travel restrictions during a global pandemic, Project 4.6 investigated how Indigenous Traditional Owners' activities and interactions with Country could potentially be represented in SEEA Ecosystem Accounts for the Mitchell catchment – adopting SEEA-EAs standard categorisation of provisioning, regulating and cultural ecosystem services.

Drawing on several decades of interaction with the Kowanyama community, Viv Sinnamon's research reported that the Indigenous Traditional Owners in Kowanyama both benefit from a range of provisioning and cultural ecosystem services, and facilitate supply of a range of regulating and cultural ecosystem services.

As noted in Section 6.2, the Indigenous community in Kowanyama recognise the importance of the healthy array of fish species in the delta and coastal zone, many of which are traditionally used by Kowanyama people as well as by commercial and recreational fishers. The Indigenous community is very aware of the importance of healthy ecosystem assets within the delta and flood plain wetlands that provide (in SEEA-EA terminology) multiple intermediate services (such as nutrient supply) to support provision of harvested species in the estuary and the Gulf of Carpentaria (e.g., Broadley et al., 2022; Burford & Faggotter, 2021). From an Indigenous perspective, all things are connected; healthy habitat supporting healthy fisheries, locally and regionally, for the benefit of multiple service users. The successful growth of juvenile stock is highly dependent upon delta and floodplain wetlands and the growth of fish larvae and juvenile finfish is driven by healthy algae stocks and other small fish within these wetlands (Jardine et al., 2012).

Kowanyama's concerns regarding degradation of the river system and its ecosystem services have led to vocal opposition to increased pressures from upstream developments such as mining that will increase sediment load and potentially lead to loss of significant permanent instream lagoons. Since the late 1980s the Kowanyama community has engaged in ongoing opposition against at least five instances of exploration proposals for mineral sands and gold on both nearshore and onshore parts of the lower delta. On their own initiative, Kowanyama hosted a Northern Fisheries Conference (1988), a Mitchell River Watershed Conference (1990) and was instrumental in the designation of the Nassau River Fisheries Habitat Reserve (1990) over a conflicting proposed Mineral Exploration Permit over the same area. Additionally, because of concern about fishing pressure in the delta, the Kowanyama community negotiated a river closure on the delta with Gulf Commercial and State fisheries interests, committing to buyout two inshore gillnet and mud crab fisheries entitlements to effectively remove them from these limited entry Gulf of Carpentaria fisheries. The buyout was affected in 1989 using Kowanyama Aboriginal Council enterprise funds.

All the above illustrate that the Kowanyama community's concerns for ecosystems are expressed via caring for Country in the context of contemporary Indigenous management that incorporates both traditional and non-Indigenous knowledge systems.

Viv's research describes how Traditional Owners' ability to benefit from and supply provisioning, regulating and cultural ecosystem services is being compromised by declining condition of ecosystems in the lower Mitchell catchment and Delta. The primary pressures reported as causing these problems are invasive weeds and feral animals. Prominent provisioning, regulating and cultural ecosystem services used by and supplied by Traditional Owners the lower Mitchell catchment and the Mitchell Delta are:

- Provisioning services
  - Woody biomass provisioning service - *Phragmites australis* (Common reed) stems used for production of spears. Service now lost due to local extinction of what were previously extensive *Phragmites* stands at Long Swamp on the edge of Topsy Creek marine plains and Kowanyumal wetlands due to earlier grazing pressure from domestic and feral animals (cattle and feral pigs) (pers. comm. Jerry Mission, Jack Bruno and Patrick Eric, all deceased, 1980s).
  - Wild plant provisioning services - *Nymphaea gigantea (*'seed lily' the traditional source of grain for ground lily seed dampers) and bulgaruw (*Eliocharis spp.* – including *Eliocharis dulcis*, *E. spacelata* and ors.). Grazing pressure from feral animals (horses and feral pigs) has reduced supply of these wild plant provisioning services to the Kowanyama community.
  - Wild aquatic species biomass provisioning services (Jackson et al., 2014) – opportunities to harvest long necked turtles (*Chelodina*), freshwater crabs (*Austrothelphusa*) and shellfish (*Velesunio*) from wetland margins is impaired due to structural disturbance ('pugging') of wetland margins by hard-hoofed animals (principally cattle and feral pigs) (J. Shellberg et al., 2017) and through direct competitive predation by feral pigs.
  - Wild animal biomass provisioning services – harvesting of multiple species during the dry and wet seasons (Figure 45). Ability to hunt wallabies (Macropus agilis) – an important traditional food – and presence of the Plains wallaby (Northern nail-tailed wallaby: *Onychogalea ungifera*) (which has spiritual association to country and is not hunted) and the seasonally migrating kangaroo (Eastern Grey Kangaroo: Macropus giganteus) are decreasing due to loss of open grazing space and native food grasses following invasion by grader grass (*Themeda quadrivulvis*).

- Regulating services
  - Habitat maintenance regulating ecosystem service through early dry-season burning (providing protection for fire-vulnerable species and also generating Australian Carbon Credit Units under the Federal Government's Emissions Reduction Fund[11]). Floral markers provided Traditional Owners' cues for implementing burning on different components within the Delta complex. Many of these key marker species have now been displaced due to loss of the diversity in the floral mosaic following introduction and invasion of weeds, pastoral grasses and legumes. This significantly impairs Traditional Owners'

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[11] Spatial locations of ERF Savanna Fire Burn projects in the Mitchell obtained via download from cleanenergyregulator.gov.au/maps/Pages/erf-projects/index.html.

    - ability to supply habitat maintenance services through cultural burning and also reduces the opportunity to obtain revenue through sale of ACCUs to the Emissions Reduction Fund[12].
- Cultural services
    - Caring for Country
    - Knowing that Country is being cared for
- Passing on knowledge of caring for Country to younger generations
    - Traditional Owners' impaired ability to supply habitat maintenance services through early dry-seaons cultural burning has led to consequent reductions in the cultural ecosystem service benefits that Traditional Owners derive from caring for Country, knowing that country is being cared for, and the opportunity to pass on knowledge of how to care for Country to younger generations. This reduces wellbeing benefits to Traditional Owners and the Indigenous community in Kowanyama as a whole.
    - It is suspected that the changes in grass diversity following invasion by grader grass (*Themeda quadrivulvis*) and subsequent loss of other preferred grass species have resulted in the diminishment of the Northern nail tailed wallaby (*Onychogalea ungifera*) population and its habitat. The 'Plain's wallaby' was the ancestral creator of *TuaR,* (Racecourse Swamp), a significant wetland of the region. Reductions in populations of these species therefore reduce community wellbeing by evidencing that Country is not being as well cared for as its Traditional Owners would wish.

Two invasive weed species are noted as particularly problematic for supply of multiple provisioning, regulating and cultural ecosystem services to and by Traditional Owners in the Mitchell Delta:

Grader grass (*Themeda quadrivulvis*)

Grader grass, an aggressive, competitive pastoral weed, was first transported to Kowanyama 30 years ago on road building machinery. Growing over 2 m tall, thick stands of grader grass physically impede access and visibility, and fuel high-intensity fires later in the dry season. Grader grass is now present across many areas of savanna woodlands and grassland in the Delta. Consequences include:

- Loss of native softwoods in open woodland: leading to
    - Loss of woody biomass provisioning services (through loss of less fire-resistant woody species)
    - Loss of wild plant provisioning services (through physical barriers to access)
- Loss of riparian and vine thicket species: leading to:
    - Loss of woody biomass provisioning services (through loss of less fire-resistant woody species)
- Loss of native ground plants
    - Loss of wild plant provisioning services – for food and medicinal uses (due to out competition of native floral plants by grader grass).

[12] A Savanna Fire Burn ERF project is currently operating on Oriners Station through the Aboriginal Carbon Foundation (https://www.abcfoundation.org.au).

    - Inability to supply habitat maintenance regulating service due to loss of floral markers required to cue traditional early dry-seaon burns (due to out competition of native floral plants by grader grass).
- Loss of established soft grass wetland margins
    - Loss of nursery services provided by grass wetland margins (through grader grass competition) and stands of hollow trees that provide habitat for reptiles, marsupials, insects and hollow-tree-nesting birds (through loss of less fire-resistant woody species).
- Loss of open grazing space and native food grasses
    - Loss of wild animal provisioning services – reduced ability to hunt wallabies (through reduced visibility), and reduction in the size of the wallaby population (through out-competition of native food grasses by grader grass).

Olive hymenachne (*Hymenachne amplexicaulis*)

Hymenachne is a semi-aquatic perennial grass that has become a major weed of northern Australia invading freshwater wetlands, flood plains and stream banks. Hymenachne is a Weed of National Significance and a declared weed throughout Australia.

Hymenachne was intentionally introduced into Delta wetlands in the mid to late 1980s by a pastoralist at Kowanyama who was familiar with the concept of ponded pasture in south-eastern Queensland (pers. comm. The late Philip Yam, Olkola stock worker and Ranger KALNRMO). Four of the Delta's iconic wetlands are now reported to have varying levels of infestation: *Thabvlang wvtaR* (Kokoberra Swamp), *Worpo* (Ten Mile Swamp), *TuaR* (Racecourse Swamp) and *May Yel* (Red Lily).

There is concern that, similar to Grader Grass, Hymenachne is an aggressive competitor in native plant communities. It has the potential to dominate and replace native species of water plants. Its dense growth and deep roots assist in its ability to colonise open water areas that are critical for the habitat needs of many species of plants and animals. North Australian wetlands are iconic key habitat for pied geese (*Anseranas semipamata*) and other waterbirds.

Concerns in relation to future impacts include:

- Density of growth will out compete other species of water plants, leading to their replacement, with the loss of significant resources and ecosystem services.
- Density of growth of the pest grass will restrict access of pied geese hatchlings to food sources at distance from nests and other refuge areas.
- Displacement of *Oryza* and *Eleocharis* beds will diminish key food resources for adult geese during nesting time.
- Loss of refuge and open water landing areas for ducks and other water birds.

Table 23. Provisioning ecosystem services supply table in biophysical terms for selected years.

		Realm	Terrestrial									Freshwater–terrestrial		Marine–terrestrial	Marine–freshwater–terrestrial		Water		**TOTAL SUPPLY**
		Biome	T1			T3	T4			T5	BVGs	TF1		MT2	MFT1		BVGs		
		EFG	Tropical-subtropical lowland rainforests	Tropical-subtropical dry forests and thickets	Tropical-subtropical montane forests	Seasonally dry tropical shrublands	Pyric tussock savannas	Hummock savannas	Temperate woodlands	Semi-desert steppes	Non-remnant	Subtropical-temperate forested wetlands	Seasonal floodplain marshes	Coastal shrublands and grasslands	Intertidal forests and shrublands	Coastal saltmarshes and reedbeds	Water	Estuary	
Supply: Biophysical	Units of measure	Year	T1.1	T1.2	T1.3	T3.1	T4.2	T4.3	T4.4	T5.1		TF1.2	TF1.4	MT2.1	MFT1.2	MFT1.3			
Provisioning services																			
Biomass provisioning																			
Crop provisioning[1]: sugarcane	tonnes	2019									861,649								861,649
Crop provisioning[1]: mango	tonnes	2019									19,646								19,646
Crop provisioning[1]: avocado	tonnes	2019									17,392								17,392
Crop provisioning[1]: citrus	tonnes	2019									9,109								9,109
Crop provisioning[1]: banana	tonnes	2019									4,481								4,481
Grazed biomass provisioning[2]	tonnes dry matter	Avg 2010–19	165	639	63	4,408	338,885	30,018	1,531	4,095	4,247	38,411	360	118	0	72	17	0	423,030
Wild fish provisioning[3]	tonnes	Avg 2010–17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	143	143

Grey cells indicate that an ecosystem type is known to, or likely to, supply the nominated biomass provisioning service, but the quantity of supply cannot be established.

[1] As recommended in the SEEA EA (White Cover version) (United Nations et al., 2021; paragraph 6.89, p.140), supply of crop provisioning services to irrigated agriculture in the Non-remnant Broad Vegetation Group is proxied by harvested biomass. The supply account reports harvested biomass for the five main crops (by area) grown on irrigated land in the Mitchell catchment (State of Queensland Department of Agriculture and Fisheries, 2019b; University of New England: Applied Agricultural Remote Sensing Centre, 2022).

[2] Grazing biomass provision estimated via average cattle numbers in the Mitchell catchment 2010–19 (data for the Northern Gulf NRM Region from Meat and Livestock Australia beefcentral.com; cattle numbers in the Mitchell catchment estimated in proportion to the area of the Northern Gulf NRM Region in the catchment). Bowen, et. al. (2019; Table 7, p.33) providea link between cattle numbers and adult equivalents (AEs) for a representative cattle property in the region. A representative grazing intake per AE for Northern Australia (8.5 kg DM/AE/day) from McLennan et al. (2020) is then used to determine the total annual grazing biomass offtake requirement for the Mitchell's cattle herd. This offtake requirement is apportioned to ecosystem types within the 'Grazing Native Vegetation' QLUMP land use in proportion to area of cover.

[3] Average annual barramundi catch in the Southern Gulf commercial barramundi fishery between 2010 and 2017 from Mitchell-relevant fishing zones AB12, AB13 and AC14. Data from the Queensland Department of Agriculture and Fisheries QFISH database (qfish.fisheries.qld.gov.au/).

Table 23 (continued).

		Realm	Terrestrial									Freshwater–terrestrial		Marine–terrestrial	Marine–freshwater–terrestrial		Water					
		Biome	T1			T3	T4			T5	BVGs	TF1		MT2	MFT1		BVGs					
		EFG	Tropical-subtropical lowland rainforests	Tropical-subtropical dry forests and thickets	Tropical-subtropical montane forests	Seasonally dry tropical shrublands	Pyric tussock savannas	Hummock savannas	Temperate woodlands	Semi-desert steppes	Non-remnant	Subtropical-temperate forested wetlands	Seasonal floodplain marshes	Coastal shrublands and grasslands	Intertidal forests and shrublands	Coastal saltmarshes and reedbeds	Surface water[3]	Estuary	Groundwater[4]	Total supply from resident ecosystem assets	IMPORTS: Supply from non-resident assets[5]	**TOTAL SUPPLY**
Supply: Biophysical	Units of measure	Year	T1.1	T1.2	T1.3	T3.1	T4.2	T4.3	T4.4	T5.1		TF1.2	TF1.4	MT2.1	MFT1.2	MFT1.3						
Provisioning services																						
Biomass provisioning																						
Wild animals, plants and other biomass provisioning																						
Water supply[2]: irrigation	ML	2019	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	572	572	65,833	66,455
Water supply[2]: households	ML	2019	0	0	0	0	0	0	0	0	0	0	0	0	0	0	64	0	390	454	113	567

[1] Average annual barramundi catch in the Southern Gulf commercial barramundi fishery between 2010 and 2017 from Mitchell-relevant fishing zones AB12, AB13 and AC14. Data from the Queensland Department of Agriculture and Fisheries QFISH database (qfish.fisheries.qld.gov.au).

[2] SEEA-EA (White Cover version) recommends that in situations where the individual contributions of services such as water flow regulation and water purification from ecosystem assets cannot be determined separately, a combined ecosystem service termed 'water supply' can be reported as a proxy (United Nations et al., 2021; paragraph 6.57 and Section 6.4.2). In these circumstances, the volume of water abstracted can be regarded as a final ecosystem service and reported as a proxy for the ecosystem contributions (United Nations et al., 2021; Section 6.4.2, paragraph 6.103, p.143).

[3] A reticulated non-potable water supply for 97 residential properties in Mt Molloy is abstracted from Hunter Creek. Mareeba Shire Council (2020) report that the volume extracted for domestic use in 2020 was 64 ML.

[4] Water supply for irrigated cropping around Julatten, Leadingham Creek, Petford and Watsonville is supplied from groundwater bores. Raw water input to the household drinking water supply for Chillagoe and Kowanyama is extracted from ground water aquifers. The volume of groundwater supplied for irrigation is estimated knowing the areas of citrus, mango and banana cropping at each location from remote sensing imagery supplied by the Applied Agricultural Remote Sensing Centre, University of New England (sunwater.com.au/water-data/report-statistics), together with the median irrigation water requirements (ML/ha) quoted by Ash et al. (2018; Table 5–8, p.79) for citrus (lime), mango and banana cropping in the vicinity of Mareeba. The resulting estimated total volume of groundwater supplied is 572 ML. Mareeba Shire Council (2020) report that the volume extracted for domestic use in Chillagoe in 2020 was 62 ML. Kowanyama Aboriginal Shire Council (2012) report that the volume extracted for domestic use in Kowanyama in 2012 was 329 ML.

[5] Surface water supplied from the Mareeba-Dimbulah irrigation system for agricultural irrigation or as the raw water input to household drinking water supply to the townships of Dimbulah and Mutchilba is sourced from Lake Tinaroo in the neighbouring Barron catchment. These water supply services are thus listed as 'imports' in Table 23 because they are not supplied by ecosystems in the Mitchell catchment. The water supply volume imported from the Barron catchment to service irrigated cropping in the Mitchell catchment's portion of the Mareeba-Dimbulah Irrigation Area is estimated to be in direct proportion to the percentage of the Mareeba-Dimbulah Irrigation Area's tree cropping that falls within the Mitchell catchment (52.4%) (determined from QLUMP 2015 spatial mapping). Using Sunwater's FY2019–20 data on the total volume of irrigation water delivered to the Mareeba-Dimbulah Irrigation Area (125,530 ML) (sunwater.com.au/water-data/report-statistics), the estimated water volume imported from the Barron catchment to service irrigated cropping in the Mitchell catchment portion of the Mareeba-Dimbulah Irrigation Area is 65,833 ML.

Table 24. Regulating ecosystem services supply table in biophysical terms for selected years.

		Realm	Terrestrial									Freshwater–terrestrial		Marine–terrestrial	Marine–freshwater–terrestrial		Water		
		Biome	T1			T3	T4			T5	BVGs	TF1		MT2	MFT1		BVGs		
		EFG	Tropical-subtropical lowland rainforests	Tropical-subtropical dry forests and thickets	Tropical-subtropical montane forests	Seasonally dry tropical shrublands	Pyric tussock savannas	Hummock savannas	Temperate woodlands	Semi-desert steppes	Non-remnant	Subtropical-temperate forested wetlands	Seasonal floodplain marshes	Coastal shrublands and grasslands	Intertidal forests and shrublands	Coastal saltmarshes and reedbeds	Water	Estuary	**TOTAL SUPPLY**
Supply: Biophysical	Units of measure	Year	T1.1	T1.2	T1.3	T3.1	T4.2	T4.3	T4.4	T5.1		TF1.2	TF1.4	MT2.1	MFT1.2	MFT1.3			
Regulating & maintenance services																			
Global climate regulation services: carbon storage in above & below ground biomass[1]	million tonnes carbon stored[2]	2010	0.937	0.651	2.507	1.630	161.070	8.085	0.332	0.571	1.251	12.84	0.462	0.202	0.228	0.339	0	0	191.109
Global climate regulation services: carbon storage as organic carbon in soils[3]	million tonnes carbon stored[2]	2010	1.529	1.384	4.867	7.425	539.234	42.950	2.224	4.566	10.120	58.50	1.969	0.450	0.858	3.054	0	0	679.139
Global climate regulation services: carbon sequestration[4]	ACCUs[5]	Total FY14–15 to FY20–21	258	549	82	9,229	746,238	3,726	0	7,485	286	47,838	549	0	0	0	0	0	816,253
Global climate regulation services: carbon sequestration[4]	ACCUs[5]	Avg per year FY14–15 to FY20–21	37	78	12	1,319	106,605	532	0	1,069	41	6,834	79	0	0	0	0	0	116,608

Grey cells indicate that an ecosystem type is known to, or likely to, supply the nominated regulating and maintenance provisioning service, but the quantity of supply cannot be established.

[1] Total carbon storage in above-ground biomass and below-ground biomass from Spawn et al., (2020).

[2] Multiplying by the ratio 44/12 converts tonnes of carbon to tonnes of CO_2-e (and thus converts tonnes of carbon stored to ACCUs) (Frydenberg, 2018; p.45).

[3] Organic carbon in the top 30cm of soil from Viscarra Rossel et al., (2014).

[4] Carbon sequestration from Savanna Fire Burn projects in the Mitchell. Data on ACCUs issued from the Australian Federal Government's Emissions Reduction Fund (ERF) (cleanenergyregulator.gov.au/ERF). Spatial locations of ERF Savanna Fire Burn projects in the Mitchell obtained via download from cleanenergyregulator.gov.au/maps/Pages/erf-projects/index.html. Shape files for projects used to apportion project ACCUs to ecosystem types in proportion to area of overlap.

[5] One ACCU corresponds to one tonne of CO_2-e removed from the atmosphere.

Table 24 (continued).

<table>
<tr><th colspan="3">Realm</th><th colspan="9">Terrestrial</th><th colspan="2">Freshwater–terrestrial</th><th>Marine–terrestrial</th><th colspan="2">Marine–freshwater–terrestrial</th><th colspan="2">Water</th><th rowspan="3">TOTAL SUPPLY</th></tr>
<tr><th colspan="3">Biome</th><th colspan="3">T1</th><th>T3</th><th colspan="3">T4</th><th>T5</th><th>BVGs</th><th colspan="2">TF1</th><th>MT2</th><th colspan="2">MFT1</th><th colspan="2">BVGs</th></tr>
<tr><th colspan="3">EFG</th><th>Tropical-subtropical lowland rainforests</th><th>Tropical-subtropical dry forests and thickets</th><th>Tropical-subtropical montane forests</th><th>Seasonally dry tropical shrublands</th><th>Pyric tussock savannas</th><th>Hummock savannas</th><th>Temperate woodlands</th><th>Semi-desert steppes</th><th>Non-remnant</th><th>Subtropical-temperate forested wetlands</th><th>Seasonal floodplain marshes</th><th>Coastal shrublands and grasslands</th><th>Intertidal forests and shrublands</th><th>Coastal saltmarshes and reedbeds</th><th>Water</th><th>Estuary</th></tr>
<tr><th>Supply: Biophysical</th><th>Units of measure</th><th>Year</th><th>T1.1</th><th>T1.2</th><th>T1.3</th><th>T3.1</th><th>T4.2</th><th>T4.3</th><th>T4.4</th><th>T5.1</th><th></th><th>TF1.2</th><th>TF1.4</th><th>MT2.1</th><th>MFT1.2</th><th>MFT1.3</th><th></th><th></th><th></th></tr>
<tr><td colspan="20">Regulating & maintenance services</td></tr>
<tr><td>Soil & sediment retention services</td><td></td><td></td><td colspan="14"></td><td></td><td></td><td></td></tr>
<tr><td>Soil erosion: pre-clearing</td><td>ktonnes/year</td><td>c.1750</td><td colspan="16">1053</td><td>1053</td></tr>
<tr><td>Soil erosion: post-clearing</td><td>ktonnes/year</td><td>c.2015</td><td colspan="16">5036</td><td>5036</td></tr>
<tr><td>Reduction in soil and sediment retention service</td><td>ktonnes/year</td><td>1750–2015</td><td colspan="16">3983</td><td>3983</td></tr>
</table>

Soil erosion estimates (pre- and post- clearing) are produced as described in the McMahon et al (2021) pre-print referred to in the Project 4.6 Technical Report (see biorxiv.org/content/10.1101/2021.08.06.455476v4)

Table 25. Cultural ecosystem services supply table in biophysical terms for selected years.

Realm			Terrestrial									Freshwater–terrestrial		Marine–terrestrial	Marine–freshwater–terrestrial		Water		
Biome			T1			T3	T4			T5	BVGs	TF1		MT2	MFT1		BVGs		
EFG			Tropical-subtropical lowland rainforests	Tropical-subtropical dry forests and thickets	Tropical-subtropical montane forests	Seasonally dry tropical shrublands	Pyric tussock savannas	Hummock savannas	Temperate woodlands	Semi-desert steppes	Non-remnant	Subtropical-temperate forested wetlands	Seasonal floodplain marshes	Coastal shrublands and grasslands	Intertidal forests and shrublands	Coastal saltmarshes and reedbeds	Water	Estuary	**TOTAL SUPPLY**
Supply: Biophysical	Units of measure	Year	T1.1	T1.2	T1.3	T3.1	T4.2	T4.3	T4.4	T5.1		TF1.2	TF1.4	MT2.1	MFT1.2	MFT1.3			
Cultural services																			
Recreation-related services	Visitor nights[1]	FY18–19	0	0	0	0	183,124	66,591	16,648	0	266,362	33,295	0	0	0	0	0	0	566,020
Visual amenity services																			
Education, scientific & research serv.																			
Spiritual, artistic & symbolic serv.																			
Other cultural services																			

Grey cells indicate that an ecosystem type is known to, or likely to, supply the nominated cultural service, but the quantity of supply cannot be established.

[1] Visitor nights (international and domestic visitors combined) for FY2018–19 by Local Government Area (LGA) from Tourism Research Australia (tra.gov.au/regional/local-government-area-profiles/local-government-area-profiles). Visitor numbers for the following LGAs apportioned to the Mitchell catchment in proportion to the area of the LGA in the catchment: Carpentaria Shire, Cook Shire, Kowanyama Aboriginal Shire, Mareeba Shire [no visitor data available for Kowanyama Aboriginal Shire]. Total visitor numbers apportioned across ecosystem types in proportion to the number of caravan parks and camping sited listed on WikiCamps (wikicamps.com.au) in each ecosystem type. (See the Project 4.6 Technical Report for a more detailed description).

Table 26. Provisioning ecosystem services use table in biophysical terms for selected years.

			Economic units											Ecosystem Types Water		
			Selected Industries													
			Citrus fruit growing	Other fruit and tree nut growing	Sugarcane growing	Beef cattle farming	Fish trawling, seining and netting	Accommodation	Other industries							
Use: Biophysical	Units of measure	Year	A0136[1]	A0139	A0151	A0142	A0414	H4400		**Total industry**	Government consumption	Household consumption	**Total use by economic units**	Estuary	Exports – intermediate services[2]	**Total use**
Provisioning services																
Biomass provisioning																
Crop provisioning (biomass as proxy)	tonnes	2019	9,109	41,519	861,649					915,277[3]			915,277[3]			915,277[3]
Grazed biomass provisioning	tonnes dry matter	Avg 2010–19				423,030				423,030			423,030			423,030
Wild fish provisioning	tonnes	Avg 2010–17					143			143			143			143
Wild animals, plants and other biomass provisioning																
Water supply: irrigation	ML	2020								66,455[4]			66,455[4]			66,455[4]
Water supply: households	ML	2020										567	567			567

Orange cells in the body of the table indicate that ecosystem services from ecosystems in the Mitchell are being used, or are likely to be used, by the nominated economic entities, but the biophysical quantities of services used cannot be estimated.

[1] Group and class codes for industrial sectors from ANZSIC 2006 definitions (Australian and New Zealand Standard Industrial Classification (ANZSIC), 2006 (Revision 2.0), last updated 10/07/2013).

[2] An unknown quantity of banana prawns from the Mitchell estuary will be harvested by vessels of the Northern Prawn Fishery outside coastal waters. These are regarded as an intermediate ecosystem service, exported from the catchment.

[3] The total tonnage reported here is the combined tonnage of citrus, avocado, banana, mango and sugarcane biomass production.

[4] The total volume of irrigation water used is the total for all irrigated agricultural usages in the Mareeba Dimbulah Irrigation Area, plus localised usages in the vicinities of Julatten, Leadingham Creek, Petford and Watsonvill

Table 27. Regulating ecosystem services use table in biophysical terms for selected years.

			Economic units											Ecosystem Types Water		
			Selected Industries													
Use: Biophysical	Units of measure	Year	Citrus fruit growing A0136[1]	Other fruit and tree nut growing A0139	Sugarcane growing A0151	Beef cattle farming A0142	Fish trawling, seining and netting A0414	Accommodation H4400	Other industries	**Total industry**	Government consumption	Household consumption	**Total use by economic units**	Estuary	Exports – intermediate services[2]	**Total use**
Regulating & maintenance services																
Global climate regulation services: carbon storage in above & below ground biomass[1]	million tonnes carbon stored	2010									191.109		191.109			191.109
Global climate regulation services: carbon storage as organic carbon in top 30cm of soil[1]	million tonnes carbon stored	2010									679.139		679.139			679.139
Global climate regulation services: carbon sequestration[2]	ACCUs	Avg per yr FY14–15 to FY20–21									116,608		116,608			116,608
Soil & sediment retention services																

Orange cells in the body of the table indicate that ecosystem services from ecosystems in the Mitchell are being used, or are likely to be used, by the nominated economic entities, but the biophysical quantities of services used cannot be estimated.

[1]The SEEA EA (White Cover Version) recommends that the Government should be assigned as the user of global climate regulation services, in recognition of the 'collective benefit' from this regulating ecosystem service (United Nations et al., 2021; p.155)

Table 28. Cultural ecosystem services use table in biophysical terms for selected years.

			Economic units											Ecosystem Types		
			Selected Industries											Water		
			Citrus fruit growing	Other fruit and tree nut growing	Sugarcane growing	Beef cattle farming	Fish trawling, seining and netting	Accommodation	Other industries		Government consumption	Household consumption		Estuary	Exports – intermediate services	
Use: Biophysical	Units of measure	Year	A0136	A0139	A0151	A0142	A0414	H4400		**Total industry**			**Total use by economic units**			**Total use**
Cultural services																
Recreation-related services[1]	Visitor nights	FY18–19										566,020	566,020			566,020
Visual amenity services																
Education, scientific & research serv.																
Spiritual, artistic & symbolic serv.																
Other cultural services																
Supplementary Information																
Recreation-related services used by businesses[1]	Visitor nights	FY18—19						566,020		566,020						

Orange cells in the body of the table indicate that ecosystem services from ecosystems in the Mitchell are being used, or are likely to be used, by the nominated economic entities, but the quantities of services supplied cannot be estimated.

1 The SEEA EA (White Cover Version) recommends that households should be recorded as the user of recreation services (United Nations et al., 2021; para 7.52, p.170). The SEEA EA (White Cover Version) also recommends that the same quantity of service usage by relevant businesses (here the Accommodation sector ANZSIC06 code H4400) should be recorded as supplementary information (United Nations et al., 2021; para 7.53, p.170).

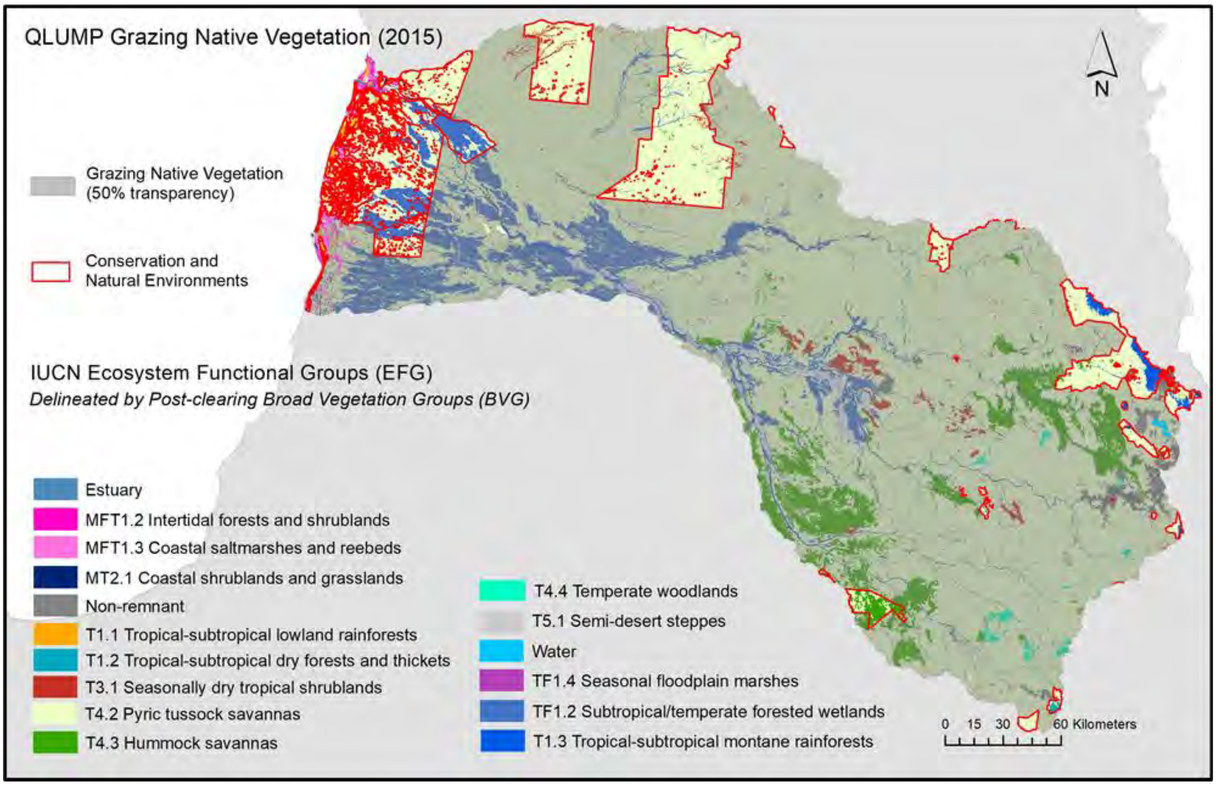


Figure 41. QLUMP Grazing Native Vegetation land use in the Mitchell catchment in 2015 overlaid on IUCN Global Ecosystem Typology ecosystem types, illustrating the spatial distribution of supply of grazed biomass provisioning services from catchment ecosystems to beef cattle farming businesses.

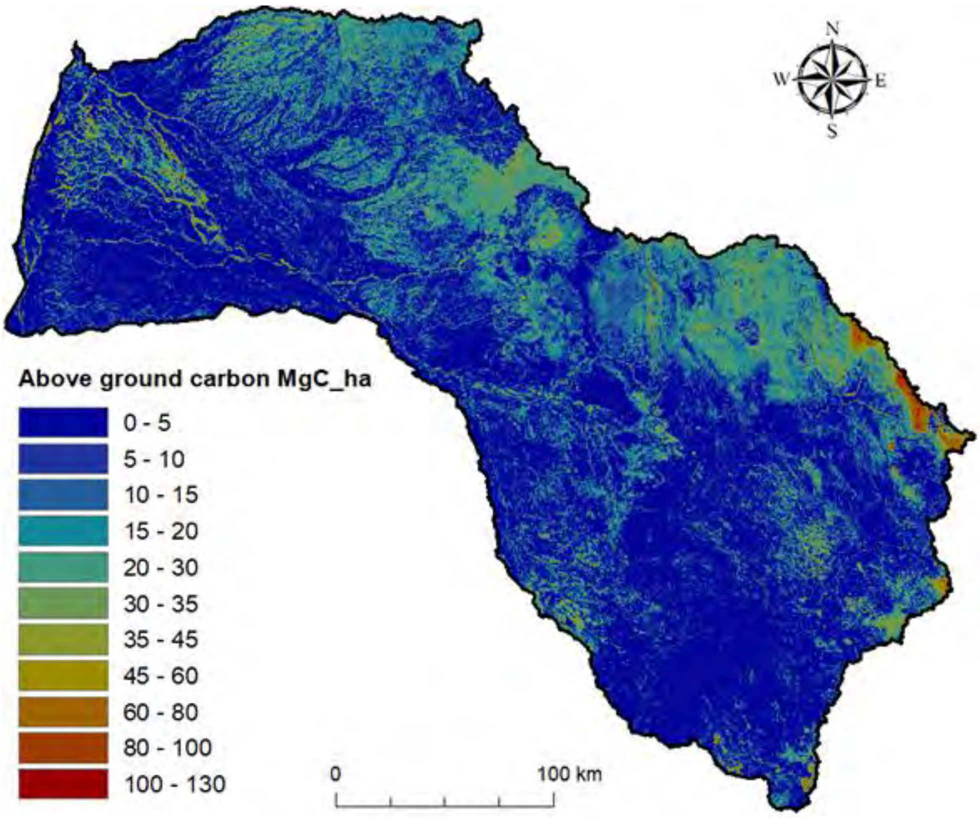


Figure 42. Spatial distribution of estimated above-ground carbon density in the Mitchell catchment in 2010. Data from Spawn et al. (2020).

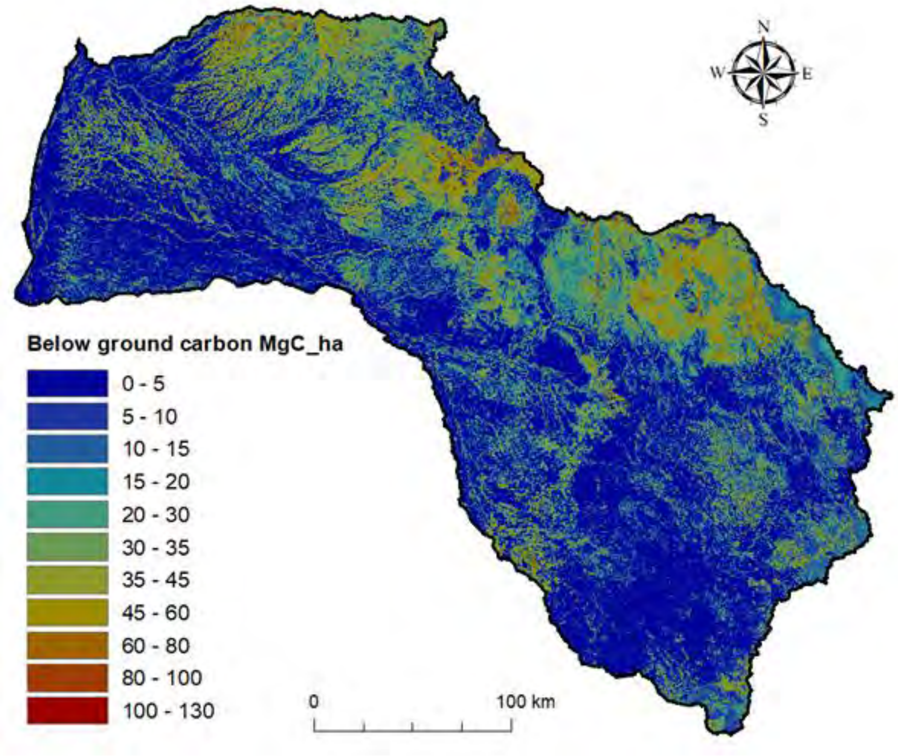


Figure 43. Spatial distribution of estimated below-ground carbon density in the Mitchell catchment in 2010. Data. from Spawn et al. (2020).

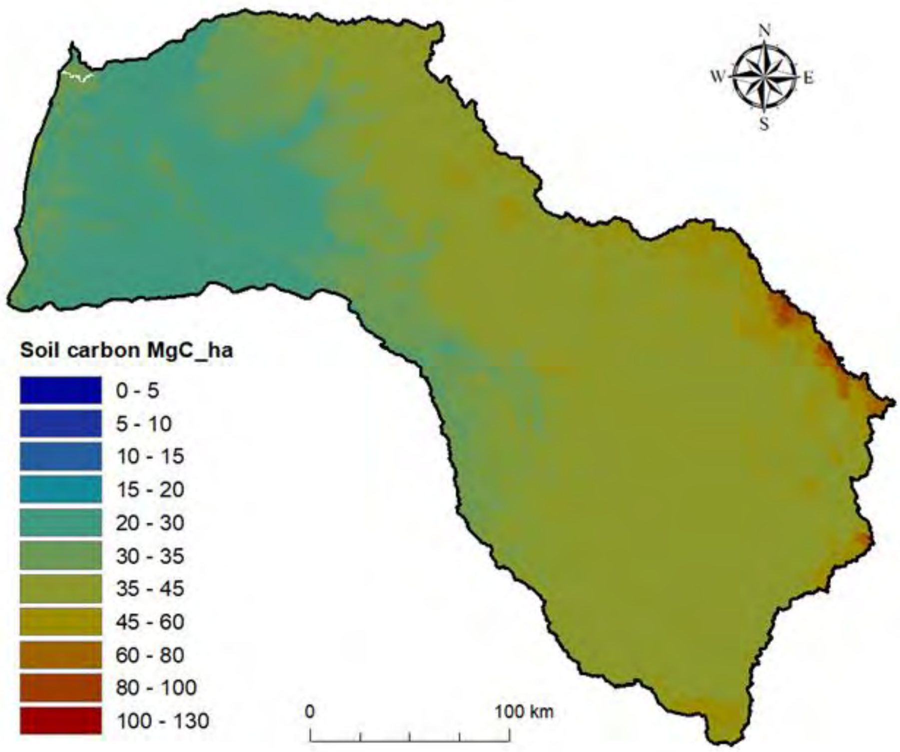
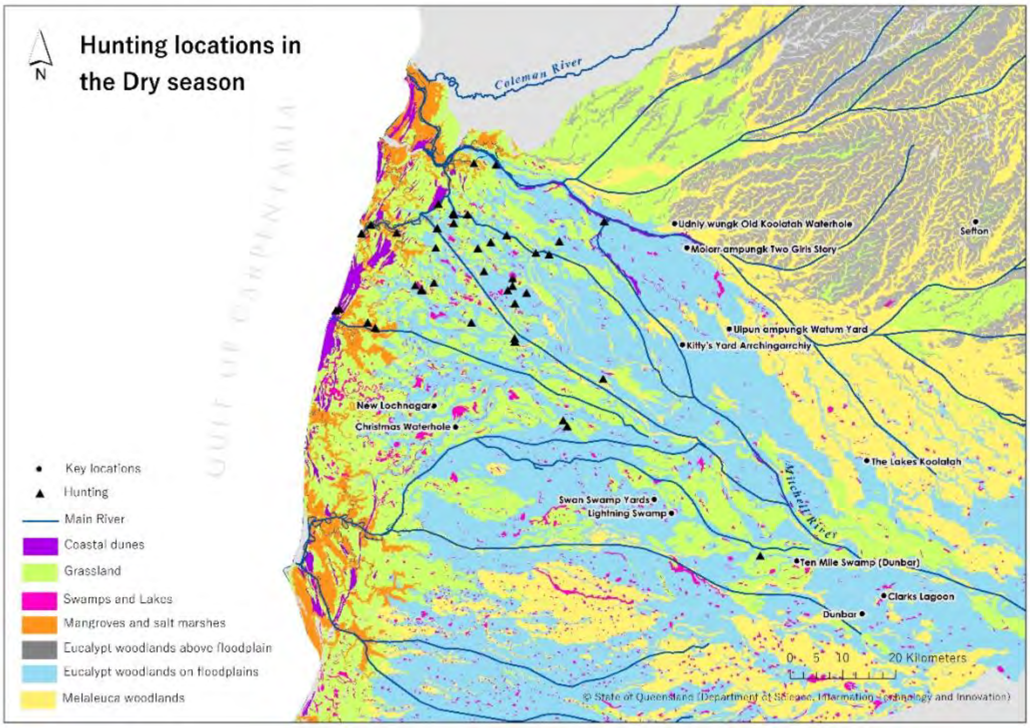


Figure 44. Spatial distribution of estimates of organic carbon content in the top 30 cm of soils across the Mitchell catchment. Data from Viscarra Rossel et al. (2014).



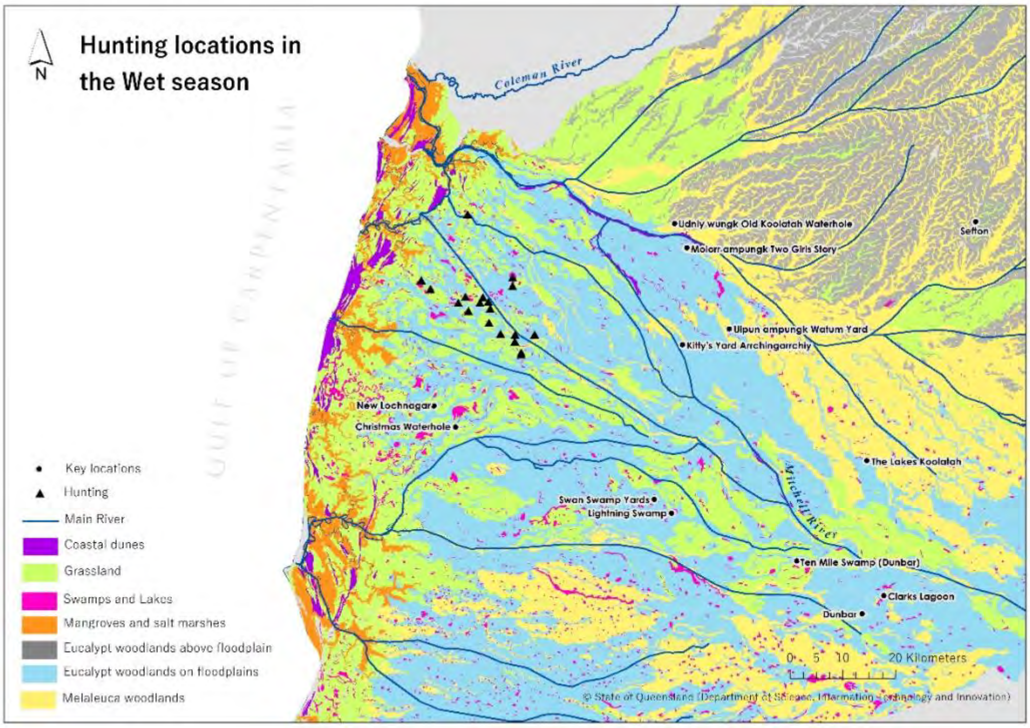
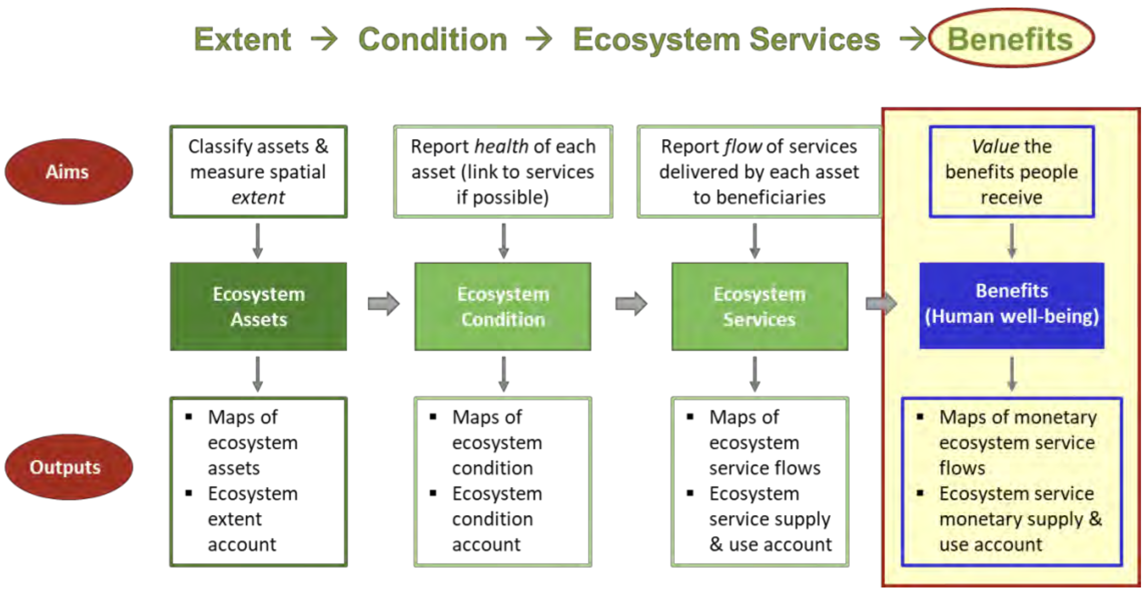


Figure 45. Hunting locations by ecosystem type in the lower Mitchell delta used by a sample of Indigenous hunters from Kowanyama during the wet and dry seasons. Data collected by Viv Sinnamon using information from Indigenous Traditional Owners in Kowanyama and surrounding areas. Due to time constraints, mapping of usages should not be considered complete. Information and data presented in these maps remain the property of the Traditional Owners (or of their families in circumstances where they are deceased). Information and data from these maps must not be reproduced, nor should data be extracted and re-analysed in any way, without obtaining prior informed consent from the Traditional Owners through the Kowanyama Aboriginal Land and Natural Resource Management Office and Abm Elgoring Ambung RNTBC.

7. Ecosystem services – supply and use accounts in monetary terms



7.1 Summary

- For consistency with SNA globally, ecosystem accounting is based on the concept of exchange value. Biophysical quantities in the biophysical supply and use tables are multiplied by their respective market or 'exchange' prices to calculate the exchange values for supply of ecosystem services that are reported in monetary supply and use tables.
- The intention in using exchange (or exchange-equivalent) based valuations in Ecosystem Accounts is to acknowledge and record the contributions of ecosystem services (and, by implication, the ecosystem assets that supply those services) to human wellbeing more explicitly. Before the advent of Ecosystem Accounting these contributions were absent from, or at best opaque in, national accounts.
- It is important to recognise that the $ values reported in monetary supply and use tables in Ecosystem Accounts should not be used to estimate the 'gains' and 'losses' that affected parties in society would realise from different developments at specific locations (e.g., development of a new irrigation area, or issuing permits for timber extraction from a particular forest).This is because the $ values reported in monetary supply and use tables are not appropriate for calculating changes in welfare or the gains from trade.
- In contrast, social cost benefit analysis would be an appropriate method for quantifying the 'gains' and 'losses' that affected parties in society would realise from different potential courses of action at specific locations. Monetary supply and use tables in Ecosystem Accounts are not intended to inform 'cost benefit' comparisons around specific options for development or future management.
- SEEA-EA (White cover edition) describes a suite of exchange-based or exchange-equivalent valuation methods for deriving the exchange value or exchange-equivalent value of ecosystem services, when relevant data are available.

- The following methods were used to produce valuations of the different categories of ecosystem services supplied by ecosystem types in the Mitchell catchment:
    - Provisioning services: the residual value method was used to estimate exchange-equivalent values for:
        - Crop provisioning services to agriculture
        - Grazing biomass provisioning services to cattle rearing
        - Wild fish biomass provisioning service to the commercial barramundi fishery
        - Water supply services to irrigated agriculture (bundled with crop provisioning services)
    - Regulating services:
        - Global climate regulating services supplied via:
            - Carbon sequestration (via avoided carbon release) through savanna fireburn management: valued via the Austalian carbon market price for the carbon credits generated.
            - Carbon storage in above- and below-ground biomass and the top 30cm of soils: valued via the avoided damage cost approach using the social cost of carbon for Australia
    - Cultural services:
        - Recreational services used by domestic and overseas visitors: valued via expenditures on overnight stays
- Careful consideration was given to possible incorporation of Indigenous-related cultural ecosystem services into monetary supply and use tables in SEEA Ecosystem Accounts. However, we concluded that the significant challenges arising from contrasts between SEEA-EA's 'linear, transactional use value-based' paradigm and Traditional Owners' 'reciprocal, relational value-based' paradigm could not be resolved without careful collaboration and full consultation with Traditional Owners. Covid-19-related access issues prevented such consultations from taking place. Consequently, although potential approaches for representing Indigenous-related cultural ecosystem services in SEEA Ecosystems Accounts in monetary terms were considered, monetary valuations of Indigenous-related cultural ecosystem services were not produced in Project 4.6.
- The following valuation results were obtained for those ecosystem services for which monetary value could be estimated:
    - Mitchell ecosystems' contributions to global climate regulating services via carbon storage totalled 504 M$/year from carbon storage (110 M$/year from carbon storage in above- and below-ground biomass, and 391 M$/year from carbon storage in the top 30cm of soils), and an average of $3.5 M$/year from carbon sequestration (via avoided carbon release) from savanna fireburn management that utilises Indigenous Traditional Owners' expertise.
    - The next most valuable ecosystem services evaluated were the crop provisioning services to irrigated production of avocado, bananas, mango and sugarcane, totalling 79 M$/year. Recreation-related services contributed $48 M$/year and grazing biomass provisioning services to the cattle rearing industry contributed $18 M/year.
    - Accounting for those ecosystem services that could be valued, *pyric tussock savannas* were the most valuable source of ecosystem service supply (436

M$/year) in the Mitchell catchment, followed by the non-remnant broad vegetation group (108 M$/year).

- The *non-remnant broad vegetation group* supplied considerably higher ecosystem service value annually per hectare than all other ecosystem types ($1,175/ha/year), followed by *tropical-subtropical montane forests* ($162/ha/year), *temperate woodlands* ($140/ha/year), *tropical-subtropical dry forests and thickets* ($98/ha/year) and *hummock savannas* ($83/ha/year). Across the Mitchell catchment's ecosystems overall, the average ecosystem service value contributed annually per hectare is $90/ha/year.
- An indicative *total aggregate gross ecosystem product* (GEP) for the Mitchell catchment was calculated by summing the estimate exchange value of those ecosystem services in the Mitchell whose supply and use could be quantified in monetary terms. This **total aggregate GEP is $649 million per year** in FY2020/21 AUD$. (For comparison, the total farm gate revenue generated from irrigated cropping of avocado, banana, citrus and mango (the top four crops by revenue) in the Mitchell catchment section of the Mareeba-Dimbulah Irrigation Area was reported to be $201 million (in FY2020/21 AUD$) in 2019.

A spatial plot of the average ecosystem service value supplied annually per hectare from ecosystem types in the Mitchell is shown in Figure 43 following (repeated as Figure 45 later in the text).

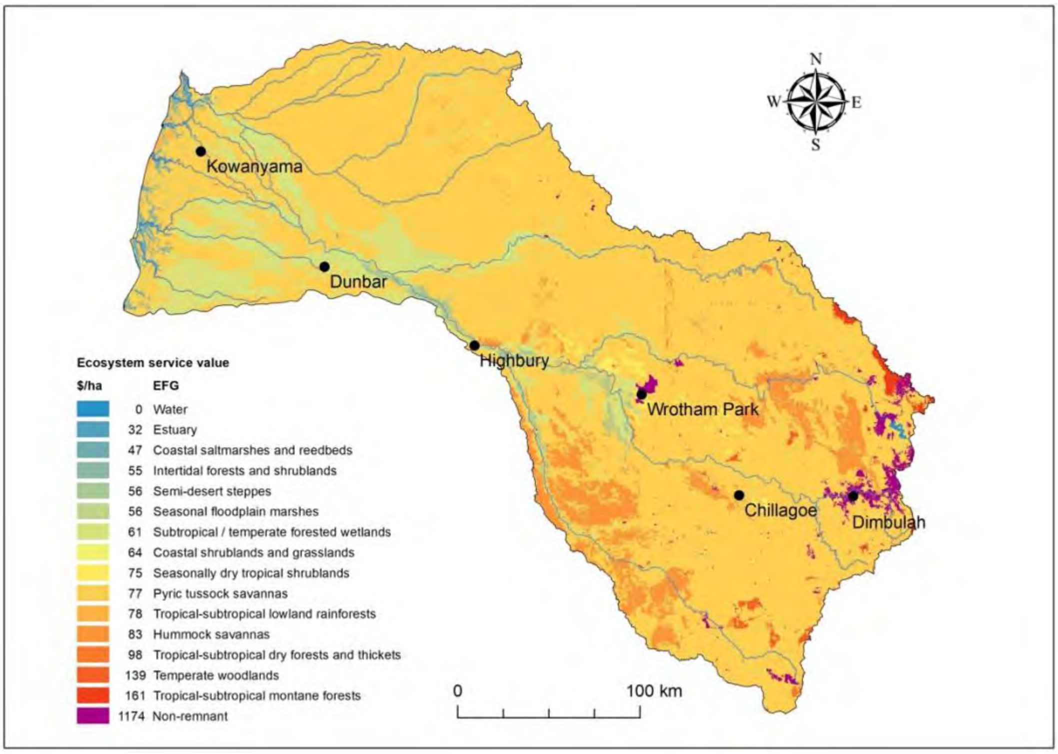


Figure 46. Total monetary value per hectare ($/ha) of selected ecosystem services from ecosystem types in the Mitchell catchment. Monetary valuations expressed in exchange value or exchange-equivalent value. Table 29, Table 30 and Table 31 report which ecosystem services are valued for each ecosystem type.

7.2 Background

7.2.1 Instrumental value and exchange value in SEEA-EA

Economics generally adopts an anthropocentric, instrumental value paradigm[13]. Within this paradigm, the suite of values that human society derives from and associates with the natural environment can be conceptualised using the Total Economic Value (TEV) framework (Pearce & Turner, 1990). TEV distinguishes between two main categories of value: *use values* and *non-use values*. Within the TEV framework, *use values* arise when benefits to human society are generated through direct (e.g., harvesting food and resources, hiking in a forest, breathing clean air) or indirect (e.g., flood mitigation provided by water regulation in ecosystems) interactions between people and the environment. These *use values* (direct and indirect) are the focus for ecosystem services in SEEA-EA, as '*ecosystems' contributions to societal benefits*' (United Nations et al., 2021; paragraph 6.69, p.136). In contrast, *non-use values* arise when people ascribe value to particular ecosystems even though they do not receive any benefits *from interactions* (either directly or indirectly) with those ecosystems. Examples of non-use values include the benefit that an individual may ascribe to the continued existence of a wetland ecosystem in good ecological condition, perhaps because they consider it important to pass that ecosystem on in good condition to future generations ('bequest value'), or because they consider it important that such pristine ecosystems continue to exist amidst multiple pressures and threats ('existence value').

These non-use values may be of considerable importance and the benefits associated with them may be of considerable value to society (e.g., Ahtiainen et al., 2014; Carson, 2000; He et al., 2017; Lindhjem et al., 2015). However, because non-use values arise in the absence of any *interactions* (direct or indirect) between economic units and the ecosystems concerned, SEEA-EA does not consider that a *transaction* has taken place to generate the resulting benefit. Consequently, since 'transaction' or 'exchange' is the basis for recording supply and use of ecosystem services in SEEA-EA, non-use values are *not* recorded in the supply and use tables in SEEA Environmental Accounts (United Nations et al., 2021; paragraph 6.72, p.137).

Focusing solely on exchange value from a transaction perspective ensures that $ valuations in the monetary supply and use tables in SEEA Environmental Accounts are consistent and compatible with $ valuations in SNA globally (Obst et al., 2016; United Nations, 2017; United Nations, European Union, Food and Agriculture Organization of the United, Organisation for Economic Co-operation and Development, & World Bank Group, 2014). To produce the ecosystem service monetary supply and use tables in ecosystem accounts, the biophysical quantities in the biophysical supply and use tables are multiplied by their respective *market or 'exchange' prices* to produce *exchange values*. For a transacted good or service that is included in national accounts, the exchange value represents the 'SNA benefit' i.e., the total revenue received by the producers for supplying a given quantity of the good (or service).

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[13] Economics adopts an anthropocentric perspective and an instrumental value paradigm in which ecosystems and the environment are valued because of the multiple benefits they supply to human society. These benefits can be categorised using Pearce and Turners' Total Economic Value Framework (Pearce & Turner, 1990). Alternative paradigms for valuing ecosystems and the environment include the intrinsic value paradigm (in which environment has value irrespective of whether or not it delivers benefits to human society – see Batavia and Nelson (2017) for a recent review) and the relational value paradigm (in which values emerge from relationships and responsibilities between entities – here 'environment' and human society – see Chan et al. (2016)).

Total revenue received matches the total expenditure paid by the consumers (or users) for purchasing that same quantity of the good (or service), thus satisfying the 'double entry' requirement of accounting. Applying this double entry accounting convention to ecosystem accounting requires finding an appropriate *exchange price* that can be applied to an '*imputed exchange of (or transaction in) ecosystem services between a given ecosystem asset (e.g., a forest) and an economic unit (e.g., a forestry company) or individual (e.g., visitor to a forest)*' (United Nations, 2017, p.98). The price estimated for the imputed exchange could be termed an '*exchange-equivalent price*', which then enables the value of the imputed transaction to be termed the '*exchange-equivalent value*'.

Expressing ecosystem services in monetary terms using SNA-aligned exchange-equivalent values allows SNA-compatible accounts to incorporate ecosystem services that are not normally freely exchanged in markets, i.e., this facilitates inclusion of 'non-SNA benefits' into ecosystem accounts. Augmentation of SNA with the non-SNA benefits supplied by ecosystems provides a more complete picture of the value of the basket of final goods and services supplied and produced in a country or region over a given period of time. Viewed through the lens of SNA, ecosystem accounts thus report the 'exchange-equivalent' value of the basket of ecosystem services that are actually utilised by people i.e., at the point at which the ecosystem service flows enter either the utility function of individuals directly as a non-SNA benefit, or the production function of economic agents as ecosystems' inputs to the production of an SNA benefit (Schröter, Barton, Remme, & Hein, 2014). The intention in using exchange (or exchange-equivalent) based valuations in ecosystem accounts is to acknowledge and record the contributions of ecosystem services (and, by implication, the ecosystem assets that supply those services) to human wellbeing more explicitly (Remme et al., 2015). Before the advent of ecosystem accounting these contributions were absent from, or at best opaque in, national accounts.

7.2.2 Estimating economic gains and losses

Noting the transactional use-value basis for valuing supply of ecosystem services in SEEA-EA, it is important to recognise that the monetary supply and use tables in ecosystem accounts should ***not*** be used to predict in advance the economic gains and losses that would accrue to affected parties from particular courses of action e.g., development of a new irrigation area, or leasing out a new logging concession. There are several reasons for this:

- Monetary supply and use tables only report the value of the ecosystem services supplied by ecosystem assets, grouped into ecosystem types, within a specified ecosystem accounting area (here the Mitchell catchment). Thus:
    - Economic impacts due to effects *other than* changes in ecosystem service flows (e.g., changes in employment, economic activity associated with business startups etc.) are **not** reported in the monetary supply and use tables in ecosystem accounts.
    - Economic impacts that arise from changes in the *export of intermediate ecosystem services* from the ecosystem accounting area would **not** appear in that area's monetary supply and use tables. For example, the impact on the Northern Prawn Fishery of a change in the export of juvenile banana prawns (an *intermediate* ecosystem service) from the Mitchell estuary would **not** be recorded in the Mitchell catchment's monetary supply and use tables.

- SEEA-EA's focus on transacted use values (estimated as exchange values or exchange-equivalent values via a 'price x quantity' product) as the basis for valuing supply of ecosystem services **cannot** capture the net benefit that the consumers or users ecosystem services derive from their usage[14] of those services. This component – the consumers' 'net gain' from consuming ecosystem goods or using ecosystem services – is thus *absent* from the valuations reported in ecosystem accounts' monetary supply and use tables.
- As described in the preceding section, for compatibility with SNA, *non-use values* associated with ecosystems and/or ecosystem services are **not** recorded in monetary supply and use tables in ecosystem accounts. These components of Total Economic Value are thus *absent* from the valuations reported in ecosystem accounts' monetary supply and use tables. Relational values are also *absent*, as they sit outside economics' instrumental value paradigm.

As a consequence of these limitations (which have been imposed to ensure that ecosystem accounts are compatible with SNA), monetary valuations from ecosystem accounts can provide only a very incomplete picture of the economic gains and losses that would accrue to affected parties from particular courses of action; thus, they should **not** be used for this purpose.

In contrast, *social cost benefit analysis* is specifically designed to estimate (in monetary terms, within an instrumental value paradigm) the full suite of gains and losses that would accrue to all affected parties in society following a particular course of action. Thus, in relevant circumstances, social benefit cost analysis **can** be an appropriate tool for evaluating the economic consequences from alternative courses of action e.g., alternative development pathways for particular locations. This is because, in contrast to the monetary supply and use tables in SEEA-EA:

- Social benefit cost analysis can include economic impacts due to effects *other than* changes in ecosystem service flows (e.g., changes in employment, economic activity associated with business startups etc.)
- Evaluations in social benefit cost analysis can extend beyond geographical and administrative boundaries[15] to encompass all relevant economic impacts.
- Social benefit cost analysis evaluates the net gains and net losses (monetised as $ values) predicted to accrue to all affected entities in society (Boardman, Greenberg, Vining, & Weimer, 2001). These *welfare values*[16] constrast with the exchange values reported in SEEA-EA and the SNA. By estimating welfare values within the TEV framework, social benefit cost analysis can capture anticipated net benefits to consumers as well as to producers (i.e., it will include $-based estimates of consumer surplus *and* producer surplus). Furthermore, the TEV framework is capable of

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[14] This 'net benefit to consumers' is termed *consumer surplus* in economics. It reports the gain in value that consumers realise from their consumption of the good or use of a service, net of the expenditure they incur in securing the use of that good or service.
[15] The boundary within which a social benefit cost analysis will estimate economic impacts must be defined as part of the specification for the work. This could be within a local LGA, within a state, within a nation, or globally (e.g., Stern, 2007).
[16] The term *welfare* is used an economic sense here. *Changes in welfare* are the changes in net benefits (i.e., 'net gains' and 'net losses') that would arise to all affected parties in society from implementing a particular course of action e.g., setting up an irrigated agriculture development.

accommodating *non-use values* alongside use values (although considerable care has to be exercised to avoid 'double counting'). However, in practice, the requirement to monetise net gains and net losses for inclusion in cost benefit analysis becomes increaringly problematic as focus shifts from use values to non-use values[17]. Multiple concerns undoubtedly remain regarding the appropriateness, or otherwise, of attempting to represent Indigenous and local communities' connections to ecosystems and the natural environment via monetised representations in benefit cost analysis (e.g., Chan et al., 2016; Comberti et al., 2015; Jackson and Palmer, 2015; Larson et al., 2019; Sangha et al., 2019, 2018; Stoeckl et al., 2018).

Thus, whilst social benefit cost analysis is by no means an ideal solution for quantifying the full suite of gains and losses that would accrue to all affected parties in society following a particular course of action, we suggest that it is somewhat better suited to this task than evaluations that only draw on the monetary supply and use tables in SEEA Ecosystem Accounts.

7.2.3 Valuation approaches for ecosystem services in SEEA-EA

SEEA-EA (White cover edition) describes a suite of exchange-based or exchange-equivalent valuation methods, appropriate for deriving the exchange value or exchange-equivalent value of ecosystem services, when the necessary data are available (United Nations et al., 2021; Section 9.3).The valuation methods and data used to produce the exchange-based or exchange-equivalent valuations shown in the monetary supply and use tables for ecosystem services from the Mitchell catchment are described in detail in the Final Technical Report for Project 4.6. In summary, the following methods are used to produce valuations of the following categories of ecosystem services:

7.2.3.1 Provisioning services

Following SEEA-EA (White Cover version) (United Nations et al., 2021; Section 9.3 generally, and paragraph 9.36, p.195 specifically) the *residual value method* is used to estimate the exchange value of provisioning services, i.e., ecosystems' contributions as inputs to joint production processes that generate SNA benefits such as fish catches, livestock growth or crop outputs. The residual value method subtracts the cost of all other inputs to these joint production processes from the SNA benefit generated (i.e., it subtracts the cost of all other inputs from the revenues obtained from the sale of the produced output); what remains – 'the residual' – is then used as a valuation of ecosystems' contributions to that production. Figure 47 illustrates the method applied in the residual value calculation.

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[17] Additional challenges would be encountered if relational values (Chan et al., 2016) were to be included in decision support assessments (Grubert, 2018).

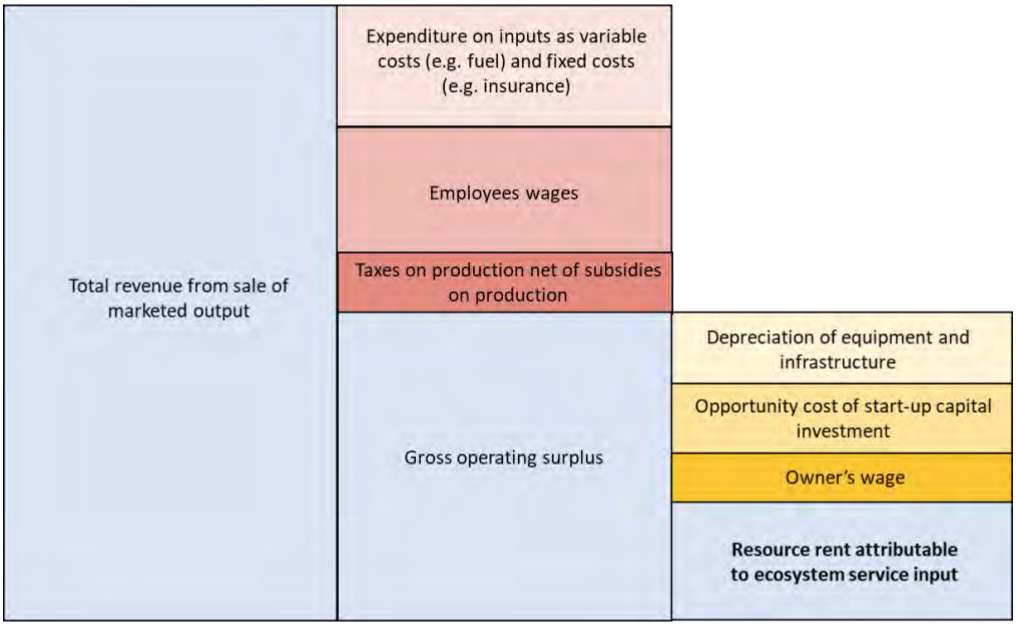

Figure 47. The residual value method for calculating the value of provisioning ecosystem services as inputs to a joint production process.

Note that in following the residual value method (Figure 47), if the total revenue from sales is equal to the sum of expenditures on variable costs and fixed costs, employees wages, taxes on production (net of subsidies on production), depreciation of capital assets, the opportunity cost of start-up capital[18], and the owners wage then the residual value attributable to the ecosystem service input will be zero. It is entirely feasible that a residual value of $0 will be reported under less favourable production conditions e.g., years in which crop yields or fish catches are particularly low, or years in which the market price for the produced output slumps, or the cost of a key input spikes. In practice, in such circumstances the business owner receives a lower wage than they would have liked.

Sufficient data were available to apply the residual value method to calculate the monetary value of the following provisioning ecosystem services in the Mitchell catchment (see Table 29):

- Crop provisioning services for irrigated production of avocado, banana, mango and sugarcane in the Mitchell catchment section of the Mareeba-Dimbulah Irrigation Area (also see below re: water irrigation water supply services).
- Grazing biomass provisioning service (supplied to the cattle rearing industry).
- Wild fish biomass provisioning service (supplied to the commercial barramundi fishery operating in the Mitchell estuary and coastal zone).

Water supply services for agricultural irrigation could not be valued successfully via the residual value method. This is because, if the residual value method is to produce a non-zero residual, the gross revenue generated through sale of the output of the joint production

[18] Consistent with the approach taken in the Australian SNA, capital assets that are financed through a long-term lease (e.g., agricultural land, fishing vessels, fruit packing sheds, major items of agicultral equipment) are treated as capital owned by the lessee (i.e., the farm or fishing business) (Australian Bureau of Statistics, 2021; paragraph 19.95, p.508). Hence, the interest paid on these long-term loans is not subtracted from total revenue in the residual value calculation.

system (in this instance, irrigation water sold as the output of the Mareeba-Dimbulah Water Supply Scheme) must exceed the costs incurred in producing that output. A recent review by the Queensland water pricing regulator found that irrigation water pricing in the Mareeba-Dimbulah irrigation scheme has been too low to cover the total operating, maintenance and capital renewal costs of the scheme, and that 'The shortfall is currently funded by a subsidy, paid by the Queensland taxpayer' (Queensland Competition Authority, 2020; p.1). This will persist under the price trajectory announced for the Mareeba-Dimbulah Water Supply Scheme over the period FY2019/20 to FY2023/24 (Queensland Competition Authority, 2020). In this situation, the subsidy is transferred through to the irrigation farmer and appears as part of the residual value attributed to 'crop provisioning services'. Thus, when irrigation water pricing is insufficient to recover the total operating, maintenance and capital renewal costs of the water supply scheme, a portion of the residual value attributed to 'crop provisioning services' in irrigated agriculture could potentially be attributed to irrigation water supply services. It was not possible to separate out these two components of provisioning ecosystem service value using available data.

A similar situation may also apply to water supply services for domestic use as it was not possible to determine whether current domestic water pricing in Dimbulah, Mutchilba, Mt Molloy, Chillagoe or Kowanyama is sufficient to cover the total operating, maintenance and capital renewal costs of these towns' water supply schemes. Consequently, whilst water supply services to irrigated agriculture and households in the Mitchell catchment are undoubtedly valuable, it was not possible to produce valuations for these services in the supply and use tables in the Mitchell's ecosystem accounts.

The Final Technical Report for Project 4.6 provides full details of how the residual value method was applied to produce exchange-equivalent valuations for each of these provisioning ecosystem services from ecosystems in the Mitchell. The valuations produced are reported in Table 29.

7.2.3.2 Regulating services: global climate regulation

Carbon sequestration generated via managed savanna fireburn is recorded in biophysical terms as tonnes of CO_2-e sequestered (or, equivalently, as tonnes of CO_2-e release avoided). Savanna fireburn management generates carbon sequestration credits in the form of Australian Carbon Credit Units (ACCUs) that can be purchased for carbon offsetting purposes on the national carbon market operated by the Clean Energy Regulator on behalf of the Emissions Reduction Fund (cleanenergyregulator.gov.au/Infohub/Markets/Pages/About-Carbon-Markets.aspx). One ACCU equates to one tonne of CO_2-e sequestered. One ACCU can thus be purchased to *offset* one tonne of CO_2-e emissions, with the purchase occurring at the market price ($/ACCU, i.e., $/tonne of CO_2-e sequestered). A representative ACCU price of $30/tonne (current at October 2021: accus.com.au/) is used to derive an exchange value for carbon sequestration directly, knowing the quantity of ACCUs generated from savanna fireburn management across the Mitchell catchment, and the ecosystem types in which those ACCUs were generated. This valuation approach is consistent with SEEA-EA (White cover version) recommendations (United Nations et al., 2021; paragraph 9.3.2, p.193).

The contribution of carbon storage in ecosystems' above- and below-ground biomass and in the organic carbon stock in the top 30cm of soils to global climate regulation is valued using the *avoided damage cost* approach. This approach values an ecosystem service by estimating the additional expenditures or reduced incomes that would result for businesses, households and governments if that ecosystem service were no longer to be supplied (United Nations et al., 2021; Section 9.3.6); i.e., the method calculates the 'avoided cost' that arises because the carbon storage service *is* supplied and uses this as a valuation for supply of that service. If carbon was not stored in the woody biomass and soils of the Mitchell's ecosystems, CO_2-e concentrations in the atmosphere would be higher than they are now and *additional* damage costs would be incurred by households, businesses and goverments in Australia (and elsewhere in the world). Burke et al. (2015) estimated these damages costs by quantifying the relationship between increasing temperature and economic productivity (at the whole-of-economy scale) for each national economy separately. Knowing the reduction in economic productivity that would be expected in a particular national economy from a given temperature rise, and knowing how CO_2-e emissions are predicted to affect temperature, the additional damage cost that follows from releasing one more tonne of CO_2-e can be estimated. The additional damage cost that follows (at whole-of-economy scale) from releasing one *more* tonne of CO_2-e, or, equivalently, the additional damage cost that would result from one *less* tonne of CO_2-e storage, is termed the 'social cost of carbon' (Ricke, Drouet, Caldeira, & Tavoni, 2018).

The social cost of carbon can be estimated at global or country-specific level, with Ricke et al. (2018) providing a comprehensive set of estimates, under a wide range of well justified scenarios. Here, consistent with the avoided damage cost method described in SEEA-EA (White cover edition) (United Nations et al., 2021; Paragraph 9.52, p.198) and prior practice (e.g., Mikhailova et al. (2019)), we use Ricke et al.'s social cost of carbon for Australia (equivalent to $5.24/tonne CO_2-e in AUD$ 2020) to value (in $) the carbon stored in above- and below-ground biomass and the organic carbon stored in the top 30cm of soils in the Mitchell's ecosystems.

An *annual* valuation for the carbon storage service supplied by the Mitchell's ecosystems is produced as an annuity ($/year) derived from the value of the total stock of carbon stored by applying the standard annualisation formula (Boardman et al., 2001; p.144), assuming a social discount rate of 3% per annum[19] over an infinite timeframe. The corresponding annuity value ($/year) is thus 3% of the value of the total stock of carbon stored, where the stock value is determined using Ricke et al's social cost of carbon for Australia, escalated to 2020 AUD$. Valuations of the contribution that annual supply of carbon storage services in the biomass and soils of ecosystem types in the Mitchell make to global climate regulation are produced by this method and reported in Table 30.

7.2.3.3 Cultural services: recreation-related services

In the absence of data on estimated visitation demand functions and direct expenditure on travel costs, SEEA-EA (White Cover version) recommends that the exchange value of recreation-related services can be calculated by summing relevant consumption expenditures (United Nations et al., 2021; para. 9.48, p.197). This is the approach adopted here, using the visitor numbers reported in the biophysical supply and use tables together with per-night LGA-specific expenditures for domestic and overseas visitors provided by Tourism Research Australia for the 2019 season (https://www.tra.gov.au/Regional/local-

[19] A 3% per annum discount rate is the central discount rate used by Ricke et al. in their suite of scenarios to evaluate the social cost of carbon (Ricke et al. 2018).

government-area-profiles) for the Carpentaria, Cook and Mareeba Shire LGAs, escalated to to FY20/21 AUD$ using the RBA inflation calculator (https://www.rba.gov.au/calculator/).

7.2.4 Monetary valuation of ecosystem services used and supplied by Indigenous Traditional Owners at Kowanyama in the Mitchell delta

In Project 4.6, we do not attempt to comprehensively describe how Indigenous peoples of the Mitchell River catchment measure and value the contribution made by ecosystem services to their society. Given our understanding of the ways in which Indigenous peoples conceptualise socio-ecological relations (Jackson & Palmer, 2015), we acknowledge that Indigenous perspectives cannot be incorporated into SEEA EA in any straightforward way. Sections 6.3.2 and 7.2.1 describe SEEA-EA's conceptualisation of ecosystem services as fundamentally 'instrumental', 'transactional' and 'linear'. This contrasts starkly with Indigenous peoples' conceptualisations of nature-society relations as 'relational' and 'reciprocal', with the relationship between Custodians and Country giving rise to reciprocal responsibilities and generating value (Chan et al., 2016; Comberti et al., 2015). Custodians have responsibilities to care for Country in order for Country to continue to contribute benefits to Custodians (e.g., Jackson et al., 2017), and in caring for Country the relationship between Custodians and Country is maintained and this is recognised as delivering considerable value to society (Chan et al., 2016).

Extending the value boundary through the loop of reciprocity

The Millennium Ecosystem Assessment (MEA) defines cultural ecosystem services as:

> *'… the nonmaterial benefits people obtain from ecosystems through spiritual enrichment, cognitive development, reflection, recreation and aesthetic experiences'* (MEA, 2005; *Box 2.1, p.40*).

The MEA assesses six main categories of cultural ecosystem services: cultural diversity and identity; cultural landscapes and heritage values; spiritual services; inspiration (such as for arts and folklore); aesthetics; and recreation and tourism. The underlying concept of 'services to ecosystems' was acknowledged to some extent in the MEA:

> *'At the same time, humankind has influenced and shaped its environment to enhance the availability of certain valued services.'* (MEA, 2005; *Box 2.1, p.120*)

but subsequent development of a unidirectional ecosystem services paradigm '*from* ecosystems *to* people' failed to retain this important reciprocity.

Drawing on the heritage of the MEA, the March 2021 specification of SEEA EA defines cultural ecosystem services as:

> *'Cultural services are the experiential and intangible services related to the perceived or actual qualities of ecosystems whose existence and functioning contributes to a range of cultural benefits.'* (SEEA EA, 2021; Section 6.51, p.126)

and further notes that:

> *'The label 'cultural services' is a pragmatic choice and reflects its longstanding use in the ecosystem services measurement community. It is not implied that culture itself is a service, rather it is a summary label intended to capture the variety of ways in which*

people connect to, and identify with, nature and the variety of motivations for these connections.' (SEEA EA, 2021; Footnote 58, p.126)

The SEEA EA (White cover version) provides a reference list of 'selected ecosystem services' (United Nations et al., 2021; Table 6.3; p.133–134). Five categories of cultural ecosystem services are included:

- recreation-related services
- visual amenity services
- education, scientific and research services
- spiritual, artistic and symbolic services
- other cultural services

The accompanying descriptions for each category are somewhat broader and more flexible than the naming of the services initially suggests. For example, recreation-related services can include 'experiential interactions with the environment'; education, scientific and research services can include 'biophysical characteristics and qualities of ecosystems, that enable people to use the environment through intellectual interactions with the environment'; spiritual, artistic and symbolic services can include 'services [that] may underpin people's cultural identity'; and 'other cultural services' remains a broad catch-all.

The SEEA EA (White cover version) Table 6.3 description of 'services [that] may underpin people's cultural identity' can accommodate the value (in the sense of an increase in wellbeing) that Traditional Owners derive from fulfilling their custodial responsibilities by caring for Country in ways that align with the 'services to ecosystems' concept in Comberti et al's loop of reciprocity (Comberti et al., 2015; p.257). Survey-based research by Larson et al. (2019) with the Ewamian people (Traditional Owners of land in the Gilbert and upper Mitchell catchments), found that 'Knowing that country is being looked after' (Larson et al., 2019; p.89) can also be an important source of wellbeing for Indigenous people – beyond just those custodians who are involved on-ground in caring for Country. Thus, 'knowing that Country is being cared for' could be viewed as a cultural ecosystem service in its own right. The wellbeing that Indigenous people derive from knowing that Country is being cared for can be further enhanced by knowing that Country will *continue* to be cared for into the future. This is evidenced by the importance that Traditional Owners place on passing on knowledge of how to care for Country to younger generations. These conceptualisations of cultural ecosystem service value facilitated by Comberti et al's 'loop of reciprocity' can all be accommodated within SEEA EA's descriptions of cultural ecosystem services, either via the link to cultural identity, or by introducing *caring for Country*, *knowing that Country is being cared for*, and *knowing that Country will continue to be cared for*, as cultural ecosystem services in their own right in the 'other cultural services' category. This latter approach is preferred as it makes 'services to ecosystems' explicit as a value delivery mechanism within SEEA-EA, and thus evidences the importance of the 'loop of reciprocity' to Traditional Owners. The activism of the Kowanyama Land Office and Dhimurru Aboriginal Corporation in East Arnhem Land (https://www.dhimurru.com.au) from the 1990s onwards, evidenced by negotiation of river closures and active engagement in fisheries management are examples of contemporary Indigenous management strategies by Indigenous land management agencies in Northern Australia that have since been mirrored across the country. These provide very tangible evidence of Indigenous communities delivering (in Comberti et al's terminology) 'services to ecosystems' through caring for Country.

Valuation approaches for Indigenous cultural ecosystem services within SEEA-EA

Although it has long been recognised that cultural ecosystem services make important contributions to human wellbeing, cultural ecosystem services have featured much less frequently in economic valuation assessments than provisioning and regulating services (recreation-related services are the exception here) (see, for example, de Groot et al., 2012). This likely reflects the difficulty in quantifying their value in monetary terms (cultural ecosystem service values supplied through recreation and tourism are again the exception).

This challenge is more acute when attempting to place a value on the cultural services that Indigenous people derive from ecosystems and their custodianship of Country. Stoeckl et al. (2018) show that the economics toolkit for valuing simple individual goods is much more developed than the toolkit for valuing complex social goods. They argue that this has led to a focus on valuation of simple individual goods as the basis for informing policy making. An unintended consequence may be that the institutions and behaviours required to produce complex, socially-constructed ecosystem service values are at risk of being 'crowded out' through lack of policy awareness (Stoeckl et al., 2018). Sangha, Russell-Smith and Costanza (2019) relate similar concerns and advocate that decision-making around sustainable development practices must recognise and understand that nature underpins the wellbeing of Indigenous and local communities in ways that go far beyond merely livelihood opportunities.

Hirons, Comberti and Dunford (2016) provide a comprehensive review of methods that have been used to value cultural ecosystem services. They document 24 different methods spanning quantitative and qualitative, monetary and non-monetary, spatial and non-spatial, deliberative and non-deliberative dimensions, that have been implemented with or without stakeholder involvement. This breadth of assessment methods reflects the plurality of values associated with cultural ecosystem services (Hirons, Comberti and Dunford, 2016; Section 4, p.556–558), and further emphasises the challenge inherent in attempting to produce monetary valuations of cultural ecosystem services that comply with the exchange value-based principles of SEEA-EA. This challenge is particularly acute for cultural ecosystem services supplied to and by Indigenous communities.

The importance of concepts akin to cultural ecosystem services and Comberti et al's *loop of reciprocity*, and *relational value* more generally, in supporting and enabling the cultural, spiritual and socio-economic livelihoods and wellbeing of Indigenous communities in northern Australia has been well documented in the literature (e.g., Altman and Jackson, 2014; Barber and Jackson, 2017; Russell-Smith et al., 2013; Sangha et al., 2019; Scheepers and Jackson, 2012). The particular challenges in producing appropriate valuations of the suite of ecosystem services – including cultural ecosystem services and 'services to ecosystems' that arise from custodianship of Country – supplied by and delivered on Indigenous-managed land in northern Australia have been highlighted recently by Sangha et al. (2017).

As noted in the preceding sections, Indigenous management of natural and cultural resources is crucial to the future sustainability of Australian landscapes. In the Mitchell River catchment, Traditional Owners undertake a range of activities to manage land and water, fulfil custodial responsibilities under customary law and sustain their way of life (M. Barber, 2015; Scheepers & Jackson, 2012; Strang, 1999). In this light, SEEA Ecosystem Accounts can potentially play a role in drawing the importance of Traditional Ownership of Country to the attention of decision makers by including (albeit partial and incomplete) estimates of the value generated by custodianship-related activities on Country.

Research from other parts of the world on *relational values* is challenging the uni-directional, individualistic and instrumental/utilitarian premise of the ecosystem services framework (Chan et al., 2016; Comberti et al., 2015; Díaz et al., 2018; Kenter, 2016). With respect to Indigenous Australia, the labour and practices of Indigenous communities have been framed as the means by which some Australian Indigenous communities *co-produce* ecosystem services (Jackson & Palmer, 2015). The concept of co-production recognises that responsibilities under customary law require that custodians care for Country appropriately in order for Country to continue to care for custodian communities by supplying ecosystem services. This *bi-directional* nature of the *relationship* between custodians and Country forms the basis for a reconceptualising of the interdependencies between custodians, Country and ecosystem service flows. To the best of the authors' knowledge, this bi-directional perspective has not yet been applied to a local/regional Indigenous context in which evidence exists both for such co-production and for the significance of catchment ecosystem service flows and interdependencies.

The original intention of Project 4.6, before Covid-19 travel restrictions emerged as a constraint, was to seek to quantify and, if possible, estimate a value metric for the contributions that Traditional Owners of the Kowanyama area make by maintaining the condition of ecosystems and thus ensuring sustainable delivery of ecosystem service flows. We intended to do this by obtaining an understanding of how the Kowanyama community, households and family groups chose to allocate their scarce community and household resources (e.g., personnel, time, effort, knowledge, vehicles and equipment) to produce beneficial provisioning, regulating and cultural ecosystem service outcomes through custodianship of Country via on-Country activities. Beneficial outcomes from on-Country activities could include, for example, harvesting of barramundi, turtles, and magpie goose eggs; enhanced individual wellbeing through time spent on-Country; management actions to maintain or improve the condition of Country – for example, managing feral animals and weeds, savanna burning to reduce fuel load for late-season wildfires; and enhancing sustainable management into the future by passing on knowledge about caring for Country to the next generation.

These different outcomes are valued by the local community because they are recognised as making positive contributions to individual and societal wellbeing (Larson et al., 2019). In a SEEA-EA framing, these contributions to wellbeing can be categorised as provisioning (e.g., resource harvesting), regulating (e.g., savanna fire burn), or cultural ecosystem services (e.g., time spent on Country, enhanced wellbeing because community know that Country is being cared for and that knowledge of how to care for Country is being passed on to the next generation), and as investments that enhance the long-term capacity of ecosystems to deliver ecosystem service flows (e.g., caring for Country; passing on of knowledge).

Two approaches for producing SEEA-EA compliant estimates that could potentially reflect *some portion of* the values arising from these interactions between custodians and Country were considered, as described in the following sub-sections.

The 'cost of inputs' approach

The Australian SNA recognises that 'social transfers in kind' deliver substantial value to households and individuals in society. Social transfers in kind are defined as follows:

> *'….. goods and services provided to individual households by general government units and non-profit institutions serving households. The goods and services may be produced by the government units and NPISHs or purchased by them from market providers. They are provided to households for free or at prices that are not economically significant*[20]*.'* (Australian Bureau of Statistics, 2021; paragraph 13.88, p.410)

Education and health services are typically regarded as this type of 'social transfer in kind' and would usually be classified as 'non-market outputs' in SNA (Australian Bureau of Statistics, 2021; paragraph 9.12, p.126). In these circumstances, market prices are unlikely to exist for the services delivered, so a valuation for the services provided is calculated in SNA by summing *'the costs of producing the outputs, comprising compensation of employees, the cost of purchased goods and services used in production (intermediate consumption), other taxes (less subsidies) on production and consumption of fixed capital'* (Australian Bureau of Statistics, 2021; paragraph 9.13, p.126) i.e., summing the 'cost of inputs' required to supply the service as an output.

This 'cost of inputs' approach that SNA uses to value 'caring for people', i.e., delivering health services, could also potentially be applied to 'caring for Country'. Were a 'cost of inputs' approach to be followed, however, stark contrasts would immediately be apparent. Government expenditures on 'caring for people' comprise a very high wage bill for a large workforce (many of whom have extremely high levels of knowledge and expertise), very considerable expenditures on produced inputs (medicines, high technology equipment, vehicles, surgical implants etc.), and very substantial capital investments in built infrastructure (hospitals, operating rooms, clinics etc.). In contrast, although Traditional Owners' caring for Country also relies on individuals with extremely high levels of knowledge and expertise, this is unlikely to be reflected in wage rates, and only very modest expenditures on produced inputs and built infrastructure are likely to be incurred. Consequently, an SNA and SEEA-EA-compliant 'cost of inputs' approach for valuing Traditional Owners' caring for Country would produce a very low valuation, grossly under-representing the value that Indigenous communities place on caring for Country, knowing that Country is being cared for, and passing on knowledge of how to care for Country to future generations. For these reasons, the 'cost of inputs' approach was not pursued in Project 4.6.

The 'opportunity cost of outputs' approach

An 'opportunity cost of outputs' approach could also potentially be used to provide a SEEA-EA-compliant, estimate *<u>of part of the value</u>* that Traditional Owners derive from caring for

[20] When prices are 'not economically significant', the price of the good or service is sufficiently low that it does not affect demand for that good or service, i.e., in the context of 'social transfers in kind' the government heavily subsidies the cost of providing the goods or services concerned with the intention that all households should be able to access them.

Country, knowing that Country is being cared for, and passing on knowledge of how to care for Country to future generations. The basis for this approach is as follows.

An indication of how the Kowanyama community, families and households value the positive contributions that these cultural ecosystem services make to individual and societal wellbeing is the extent to which they *voluntarily* commit *scarce resources* (e.g., personnel, time, effort, knowledge, vehicles and equipment) to on-Country activities that care for Country and pass on knowledge of caring for Country to future generations. The underlying principle is that resources that are 'scarce' are valuable. 'Scarcity' applies when there is not enough of a resource to allow it to be used in all possible 'value generation pathways'. Consequently, decisions have to be made regarding to which 'value generation pathway(s)' the available amount of resource should be committed. After acknowledging relevant constraints, these resource allocation decisions can be used to infer the *relative* value that families and communities place on outputs from the different 'value generation pathways'.

For example, previous analyses of active Indigenous hunters and land managers (M. Barber, 2015) suggest that this portion of the population is usually time poor; thus, demand for these individuals' time exceeds supply and their time is therefore a scarce resource. Demand for other resources such as effort, knowledge, vehicles and equipment is also likely to exceed available supply, thus ensuring that these resources are also 'scarce' – and therefore valuable – in an economic sense. The way in which family groups and community choose to allocate these scare resources to different on-Country activities can tell us a lot about the *relative values* that families and community attach to the *outcomes* of those activities.

An initial intention in Project 4.6 was to explore, through workshop discussions with Traditional Owners and households in Kowanyama, how people chose to configure combinations of scarce household and community resources to deliver particular outcomes from time spent on Country. In an economic framing, this information could be used to define the *'bundles' of inputs* required to produce particular levels of different ecosystem service *outputs* by undertaking particular activities at specific locations. A dataset could then be assembled of the input resource bundles (e.g., personnel, time, effort, knowledge, vehicles and equipment etc.) required to produce particular levels of outputs (e.g., barramundi catch, magpie goose egg harvest, control of invasive weeds or feral animals, on-Country activities and ceremony). If a sufficiently large dataset could be assembled, distance-function approaches (after Vaughn Aiken, 2006) could be used within a household production framework, to parameterise the output tradeoffs that would follow from committing particular bundles of resource inputs to different on-Country activities. This would establish the opportunity cost (in terms of the foregone output of one on-Country activity e.g., the catch from barramundi fishing) that would follow from committing a particular bundle of scare resources (personnel, time, effort, knowledge, vehicles and equipment) to another on-Country activity (e.g., sharing on-Country traditional knowledge with emerging elders)

Previous TRaCK research with Kowanyama households established (quasi-) market valuations for some provisioning ecosystem service outputs from on-Country activity: harvested barramundi, turtles, goose eggs etc. (Jackson, Finn, & Scheepers, 2014). This enables an exchange value to be established for barramundi catch. It would also enable a SEEA-EA-compliant exchange value to be placed on the barramundi catch *foregone* when a particular bundle of scarce resources is committed to another on-Country activity. In this way a SEEA-EA-compliant exchange value can be determined for the activity to which that bundle of scarce resources had been committed.

Unfortunately, the intended workshops could not be held in Kowanyama due to Covid-19 access restrictions, although some data on on-Country resource harvesting activities, locations and the bundle of resources required to harvest the relevant resources (e.g., barramundi, turtles, magpie goose eggs) were collected by Project 4.6 research associate Viv Sinnamon located in Kowanyama (see Figure 45). These data enabled resource harvesting patterns for particular species across ecosystem types to be established for the wet and dry seasons, and informed further data collection regarding the extent to which resource harvesting and value generation from other on-Country ecosystem services was impaired by weed infestations and feral animals.

As we were unable to conduct workshops and discussions with the Kowanyama community, we do not know whether an 'opportunity cost of outputs' valuation approach – and the *partial* representations of the value of on-Country activities that it would produce – would be acceptable to Traditional Owners and the Kowamyama community. Lacking the necessary dataset, and without an endorsement of the appropriateness (or otherwise) of the proposed methodology from the Kowanyama community, we did not pursue this valuation approach further in Project 4.6.

7.3 Ecosystem services supply and use accounts in monetary terms

The **ecosystem service supply** account in monetary terms (Table 29, Table 30, Table 31) reports the **exchange value** (or exchange value-equivalent) of the quantities **of ecosystem services supplied by ecosystem types** in the Mitchell catchment in selected years. The final rows of Table 31 report – for those services whose monetary value could be estimated – the total value of ecosystem services supplied annually (M$/year), and the total annual ecosystem service value supplied per hectare ($/ha/year), by each ecosystem type in the Mitchell catchment. The monetary ecosystem service supply tables report that – of the services whose monetary value could be estimated – the most valuable services supplied by ecoystems in the Mitchell catchment were the contributions that carbon storage in biomass and soil make to the global climate regulating service. Together, the Mitchell's contributions to global climate regulating services via carbon storage totalled 502 M$/year (110 M$/year from carbon storage in above- and below-ground biomass, and 391 M$/year from carbon storage in the top 30cm of soils). The next most valuable ecosystem services evaluated were the crop provisioning services to irrigated agriculture production of avocado, bananas and sugarcane, totalling 79 M$/year[21], with the largest contribution coming from crop provisioning services to avocado production at 74 M$/year. Supply of two other ecosystem services from the Mitchell's ecosystems contributed more than $10 M$/year: recreation-related services at $48 M$/year and grazing biomass provisioning services to the cattle rearing industry at $18 M/year.

For those ecosystem services that could be valued, the final rows of Table 31 show that *pyric tussock savannas* are the most valuable source of ecosystem service supply in the catchment ($436 million/yr), followed by the non-remnant broad vegetation group ($108

[21] As noted earlier, it is likely that some portion of this value is attributable to water supply services from irrigation, but the split of value between crop provisioning services and water supply services cannot be determined from the available data.

million/yr). When ranked by value of ecsosytem services supplied annually *per hectare*, the *non-remnant broad vegetation group* supplied considerably higher ecosystem service value per hectare than all other ecosystem types ($1,175/ha/yr,), followed by *tropical-subtropical montane forests* ($162/ha/yr), *temperate woodlands* ($140/ha/yr), *tropical-subtropical dry forests and thickets* ($98/ha/yr) and *hummock savannas* ($83/ha/yr).

Across the Mitchell catchment's ecosystems overall, the average ecosystem service value contributed annually is $90/ha/yr. Figure 48 shows the spatial location of the total monetary value per hectare ($/ha/yr), averaged per ecosystem type,[22] for the ecosystem services reported in the monetary ecosystem service supply tables for the Mitchell catchment (Table 29, Table 30, Table 31).

The ecosystem service use account in monetary terms (Table 32, Table 33) reports the exchange value (or exchange value-equivalent) of ecosystem services from ecosystem types in the Mitchell catchment used by economic entities (sectors of the production economy, households or government) in selected years.

The final rows of Table 33 report the indicative gross ecosystem products ($M/year) that ecosystems in the Mitchell catchment supply to industry, to governments and to households. An indicative *total aggregate gross ecosystem product* (GEP) is calculated by summing the estimate exchange value of those ecosystem services in the Mitchell whose supply and use could be quantified in monetary terms. This **total aggregate GEP** is **$649 million per year** in FY2020/21 AUD**$** (Table 33)[23].

[22] Spatial variation in the value of some ecosystem services is available at finer spatial resolution (e.g., global climate regulating services supplied via carbon sequestration and carbon storage (see Figure 39, Figure 40, Figure 41)). However, finer resolution of the spatial supply of ecosystem service value is not available for all ecosystem services. Consequently, Figure 44 shows overall ***average supply value per hectare per ecosystem type***.

[23] For comparison, the total farm gate revenue generated from irrigated cropping of avocado, banana, citrus and mango (the top four crops by revenue) in the Mitchell catchment section of the Mareeba-Dimbulah Irrigation Area was reported to be 201 $M (in FY20/21 AUD$) in 2019 (State of Queensland Department of Agriculture and Fisheries, 2019).

Table 29. Provisioning ecosystem services supply table in monetary terms for selected years. Monetary values are quoted in FY20–21 AUD$, escalated appropriately using the RBA online inflation calculator (rba.gov.au/calculator/financialYearDecimal.html).

		Realm	Terrestrial									Freshwater–terrestrial		Marine–terrestrial	Marine–freshwater–terrestrial		Water		TOTAL SUPPLY
		Biome	T1			T3	T4			T5	BVGs	TF1		MT2	MFT1		BVGs		
		EFG	Tropical-subtropical lowland rainforests	Tropical-subtropical dry forests and thickets	Tropical-subtropical montane forests	Seasonally dry tropical shrublands	Pyric tussock savannas	Hummock savannas	Temperate woodlands	Semi-desert steppes	Non-remnant	Subtropical-temperate forested wetlands	Seasonal floodplain marshes	Coastal shrublands and grasslands	Intertidal forests and shrublands	Coastal saltmarshes and reedbeds	Water	Estuary	
Supply: Monetary	Units of measure	Year	T1.1	T1.2	T1.3	T3.1	T4.2	T4.3	T4.4	T5.1		TF1.2	TF1.4	MT2.1	MFT1.2	MFT1.3			
Provisioning services																			
Biomass provisioning																			
Crop provisioning[1,2] sugarcane	M$/year	2018–19									1.030								1.030
Crop provisioning[1,2] mango	M$/year	2018–19									0								0
Crop provisioning[1,2] avocado	M$/year	2018–19									73.741								73.741
Crop provisioning[1,2] banana	M$/year	2018–19									3.760								3.760
Grazed biomass provisioning[3]	M$/year	Avg 2010–19	0.007	0.027	0.003	0.183	14.063	1.246	0.064	0.170	0.176	1.594	0.015	0.005	0	0.003	0	0	17.555

[1] Indicative valuation estimated by the residual value method using unit price and yield from FY2018/19 production data (for avocado, banana, mango) (State of Queensland Department of Agriculture and Fisheries, 2019) and FY2015/16 production data (for sugarcane) (State of Queensland Department of Agriculture and Fisheries, 2015), and costs derived from AgBiz spreadsheets (avocado, banana, sugarcane) (publications.qld.gov.au/dataset/agbiz-tools-plants-fruits-and-nuts) and Ngo and Owen (2002) (mango), escalated appropriately using ABARES indexes for the cost of agricultural inputs (for components of variable and fixed costs) (Australian Bureau of Agricultural and Resource Economics and Sciences, 2021). Capital investment requirement is escalated from AgBiz spreadsheets and Ngo and Owen (2002) using ABS indexes of the output costs of construction and manufacturing (Australian Bureau of Statistics, 2021). User cost of capital is derived from capital investment using (i) straight-line depreciation at the rates and lifetimes specified in AgBiz spreadsheets, and (ii) an opportunity cost of capital derived from the 1.75% coupon rate of return on an 11-year Federal Government bond GSBU32 issued in 2021 (australiangovernmentbonds.gov.au/bond-types/exchange-traded-treasury-bonds/list-etbs). Monetary values are then further escalated from FY2018/19 to FY2020/21 using the RBA online inflation calculator.

[2] Residual value provides an indication of the value attributed to the crop provisioning ecosystem service **and** the water supply ecosystem service for the crop concerned. With the information available, it is not possible to allocate this estimated valuation between crop provisioning services and water supply service. To avoid double counting, this valuation is entered in the supply and use tables only once: under 'crop provisioning services'.

[3] Indicative valuation estimated by equating resource rent to the earnings before interest and tax ($/AE) calculated for representative Mitchell cattle enterprises at Highbury and Dunbar (Ash et al., 2018; Table 2.3, p.15). The resource rent i.e., earnings before interest and tax per AE is $128.75/AE (in FY2020/21 AUD$). AE numbers across the Mitchell (and per ecosystem type) are estimated as described in the footnote to Table 23.

Table 29 (continued).

Realm			Terrestrial									Freshwater–terrestrial		Marine–terrestrial	Marine–freshwater–terrestrial		Water					
Biome			T1			T3	T4			T5	BVGs	TF1		MT2	MFT1		BVGs					
EFG			Tropical-subtropical lowland rainforests	Tropical-subtropical dry forests and thickets	Tropical-subtropical montane forests	Seasonally dry tropical shrublands	Pyric tussock savannas	Hummock savannas	Temperate woodlands	Semi-desert steppes	Non-remnant	Subtropical-temperate forested wetlands	Seasonal floodplain marshes	Coastal shrublands and grasslands	Intertidal forests and shrublands	Coastal saltmarshes and reedbeds	Surface water	Estuary	Groundwater	Total supply from resident ecosystem assets	**IMPORTS**: Supply from non-resident assets[2]	**TOTAL SUPPLY**
Supply: Monetary	Units of measure	Year	T1.1	T1.2	T1.3	T3.1	T4.2	T4.3	T4.4	T5.1		TF1.2	TF1.4	MT2.1	MFT1.2	MFT1.3						
Provisioning services																						
Biomass provisioning																						
Wild fish provisioning[1]	M$/year	Average 2010–17	0	0	0	0	0	0	0	0	0	0	0	0	0	0		0	0.194	0.194	0	0.194
Wild animals, plants and other biomass provisioning																						
Water supply: irrigation	M$/year	2020																				
Water supply: households	M$/year	2020																				

Grey cells indicate that an ecosystem type is known to, or likely to, supply the nominated biomass provisioning service, but the value of the service suppliedy cannot be established

[1] Indicative valuation estimated assuming resource rent is 20% of the gross margin per tonne harvested. Gross margin from McMahon et al. (2021; Table 2, p.22).

[2] Surface water supplied from the Mareeba-Dimbulah irrigation system for agricultural irrigation or as the raw water input to household drinking water supply to the townships of Dimbulah and Mutchilba is sourced from Lake Tinaroo in the neighbouring Barron catchment. These water supply services are thus listed as 'imports' in Table 29 because they are not supplied by ecosystems in the Mitchell catchment.

Table 30. Regulating ecosystem services supply table in monetary terms for selected years. Monetary values are quoted in FY20/21 AUD$, escalated appropriately using the RBA online inflation calculator (rba.gov.au/calculator/financialYearDecimal.html).

		Realm	Terrestrial									Freshwater–terrestrial		Marine–terrestrial	Marine–freshwater–terrestrial		Water		
		Biome	T1			T3	T4			T5	BVGs	TF1		MT2	MFT1		BVGs		
		EFG	Tropical-subtropical lowland rainforests	Tropical-subtropical dry forests and thickets	Tropical-subtropical montane forests	Seasonally dry tropical shrublands	Pyric tussock savannas	Hummock savannas	Temperate woodlands	Semi-desert steppes	Non-remnant	Subtropical-temperate forested wetlands	Seasonal floodplain marshes	Coastal shrublands and grasslands	Intertidal forests and shrublands	Coastal saltmarshes and reedbeds	Water	Estuary	**TOTAL SUPPLY**
Supply: Monetary	Units of measure	Year	T1.1	T1.2	T1.3	T3.1	T4.2	T4.3	T4.4	T5.1		TF1.2	TF1.4	MT2.1	MFT1.2	MFT1.3			
Regulating & maintenance services																			
Global climate regulation services: carbon storage in above & below ground biomass	M$/year[1]	2010	0.540	0.375	1.445	0.940	92.841	4.660	0.192	0.329	0.721	7.403	0.266	0.117	0.131	0.196	0	0	110.155
Global climate regulation services: carbon storage in top 30cm of soil	M$/year[1]	2010	0.881	0.798	2.806	4.280	310.815	24.757	1.282	2.632	5.833	33.724	1.135	0.260	0.495	1.760	0	0	391.458
Global climate regulation services: carbon sequestration	M$/year[2]	Average FY14/15 to FY20/21	0.001	0.002	0	0.040	3.198	0.016	0	0.032	0.001	0.205	0.002	0	0	0	0	0	3.498

Grey cells in the body of the table indicate that an ecosystem type is known to, or likely to, supply the nominated regulaing service, but the monetary value of supply cannot be established.

[1]Carbon storage service is valued as an annuity derived from the value of the stored carbon mass using a discount rate of 3% per annum and assuming storage continues in perpetuity. The value of stored carbon is determined using Ricke et al’s estimated social cost of carbon for Australia (Ricke et al. 2018), escalated to 2020 AUD$: $5.24/tonne CO2-e. Multiplying stored carbon mass by the ratio 44/12 converts tonnes of carbon stored to tonnes of CO_2-e and thus enables valuation of the total mass of carbon stored via the social cost of carbon (Frydenberg, 2018; p.45)*). A* 3% discount rate is used to value the annuity from the value of the stored carbon mass, consistent with findings of the Interagency Working Group on the Social Cost of Greenhouse Gases (IWG) *(National Academies of Sciences Engineering and Medicine, 2017; Chapter 6, p.168)* and prior applications of this valuation methodology under the United Nations SEEA Natural Capital Accounting and Valuation of Ecosystem Services Project (NCAVEs) e.g., *(Government of India, 2021;* Section 4.5.2, p.73*)*).

[2]Average annual supply of ACCUs from Savanna Burn carbon sequestration projects via the Australian Government’s Emissions Regulation Fund valued via the October 2021 ACCU price of $30/tonne CO_2-e. (One ACCU corresponds to one tonne of CO_2-e removed from the atmosphere, or one tonne of CO_2 release avoided).

Table 30 (continued).

		Realm	Terrestrial									Freshwater–terrestrial		Marine–terrestrial	Marine–freshwater–terrestrial		Water		Total Supply
		Biome	T1			T3	T4			T5	BVGs	TF1		MT2	MFT1		BVGs		
		EFG	Tropical-subtropical lowland rainforests	Tropical-subtropical dry forests and thickets	Tropical-subtropical montane forests	Seasonally dry tropical shrublands	Pyric tussock savannas	Hummock savannas	Temperate woodlands	Semi-desert steppes	Non-remnant	Subtropical-temperate forested wetlands	Seasonal floodplain marshes	Coastal shrublands and grasslands	Intertidal forests and shrublands	Coastal saltmarshes and reedbeds	Water	Estuary	
Supply: Monetary	Units of measure	Year	T1.1	T1.2	T1.3	T3.1	T4.2	T4.3	T4.4	T5.1		TF1.2	TF1.4	MT2.1	MFT1.2	MFT1.3			
Regulating & maintenance services																			
Soil & sediment retention services	M$/year																		
Soil erosion: pre-clearing	M$/year	c.1750																	
Soil erosion: post-clearing	M$/year	c.2015																	
Reduction in soil and sediment retention service	M$/year	1750 to 2015																	

Grey cells in the body of the table indicate that an ecosystem type is known to, or likely to, supply the nominated regulaing service, but the monetary value of supply cannot be established.

Table 31. Cultural ecosystem services supply table in monetary terms for selected years. Monetary values are quoted in FY20–21 AUD$, escalated appropriately using the RBA online inflation calculator (rba.gov.au/calculator/financialYearDecimal.html).

		Realm	Terrestrial									Freshwater–terrestrial		Marine–terrestrial	Marine–freshwater–terrestrial		Water		TOTAL SUPPLY
		Biome	T1			T3	T4			T5	BVGs	TF1		MT2	MFT1		BVGs		
		EFG	Tropical-subtropical lowland rainforests	Tropical-subtropical dry forests and thickets	Tropical-subtropical montane forests	Seasonally dry tropical shrublands	Pyric tussock savannas	Hummock savannas	Temperate woodlands	Semi-desert steppes	Non-remnant	Subtropical-temperate forested wetlands	Seasonal floodplain marshes	Coastal shrublands and grasslands	Intertidal forests and shrublands	Coastal saltmarshes and reedbeds	Water	Estuary	
Supply: Monetary	Units of measure	Year	T1.1	T1.2	T1.3	T3.1	T4.2	T4.3	T4.4	T5.1		TF1.2	TF1.4	MT2.1	MFT1.2	MFT1.3			
Cultural services																			
Recreation-related services[1]	M$/year	FY18–19	0	0	0	0	15.37	5.59	1.40	0	22.36	2.80	0	0	0	0	0	0	47.52
Visual amenity services																			
Education, scientific & research serv.																			
Spiritual, artistic & symbolic serv.																			
Other cultural services																			
Totals																			
By EFG	M$/year	as above	1.43	1.20	4.26	5.44	436.29	36.27	2.94	3.163	107.62	45.72	1.42	0.38	0.63	1.96	0	0.19	648.91
By EFG	$/ha/year	as above	78.1	98.1	161.6	75.4	77.9	83.2	139.5	56.0	1174.8	61.8	56.2	64.1	55.8	47.8	0	32.6	

Grey cells in the body of the table indicate that an ecosystem type is known to, or likely to, supply the nominated cultural service, but the monetary value of supply cannot be established.

[1] Visitor nights (domestic and international) derived from LGA-specific data from Tourism Research Australia as described in Table 25. LGA-specific expenditure per night for domestic and international visitors derived from LGA-specific data from Tourism Research Australia for the 2019 season, escalated to FY20/21 AUD$ using the RBA inflation calculator. In the absence of data on estimated visitation demand functions and direct expenditure on travel costs, SEEA-EA (White Cover version) recommends that the exchange value of recreation-related services can be calculated by summing relevant consumption expenditures (United Nations et al., 2021; para. 9.48, p.197).

Table 32. Provisioning and regulating ecosystem services use table in monetary terms for selected years. Monetary values are quoted in FY20/21 AUD$, escalated appropriately using the RBA online inflation calculator (rba.gov.au/calculator/financialYearDecimal.html).

			Economic units											Ecosystem Types Water		
			Selected Industries													
			Citrus fruit growing	Other fruit and tree nut growing	Sugarcane growing	Beef cattle farming	Fish trawling, seining and netting	Accommodation	Other industries	**Total industry**	Government consumption	Household consumption	**Total use by economic units**	Estuary	Exports – intermediate services[1b]	**Total use**
Use: Biophysical	Units of measure	Year	A0136	A0139	A0151	A0142	A0414	H4400								
Provisioning services																
Biomass provisioning																
Crop provisioning	M$/year	2018–19		77.501	1.030					78.531						78.531
Grazed biomass provisioning	M$/year	Avg 2010–19				17.555				17.555			17.555			17.555
Wild fish provisioning	M$/year	Avg 2010–17					0.194			0.194			0.194			0.194
Wild animals, plants and other biomass provisioning[1a,b]																
Regulating & maintenance services																
Global climate regulation services: carbon storage in above & below ground biomass[2]	M$/year	2010									110.155		110.155			110.155
Global climate regulation services: carbon storage in top 30cm of soil[2]	M$/year	2010									391.458		391.458			391.458
Global climate regulation services: carbon sequestration[2]	M$/year	Avg per ye FY14—5 to FY20–21									3.498		3.498			3.498
Soil & sediment retention services																

Orange cells in the body of the table indicate that ecosystem services from ecosystems in the Mitchell are being used, or are likely to be used, by the nominated economic entities, but the monetary value of services used cannot be estimated.

1a We assume that wild animals and plants harvested from ecosystems in the catchment are used for household consumption.

1b Some of the banana prawns from the Mitchell estuary will subsequently be harvested by vessels of the Northern Prawn Fishery outside coastal waters. These are regarded as an intermediate ecosystem service, exported from the catchment.

2 The SEEA EA (White Cover Version) recommends that the Government should be assigned as the user of global climate regulation services, in recognition of the 'collective benefit' from this regulating ecosystem service (United Nations et al., 2021; p.155).

Table 33. Cultural ecosystem services use table in monetary terms for selected years. Monetary values are quoted in FY20–21 AUD$, escalated appropriately using the RBA online inflation calculator (rba.gov.au/calculator/financialYearDecimal.html).

			Economic units											Ecosystem Types Water		
			Selected Industries													
			Citrus fruit growing	Other fruit and tree nut growing	Sugarcane growing	Beef cattle farming	Fish trawling, seining and netting	Accommodation	Other industries	**Total industry**	Government consumption	Household consumption	**Total use by economic units**	Estuary	Exports – intermediate services	**Total use**
Use: Biophysical	Units of measure	Year	A0136	A0139	A0151	A0142	A0414	H4400								
Cultural services																
Recreation-related services[1]	M$/year	FY18–19										47.519	47.519			47.519
Visual amenity services																
Education, scientific & research serv.																
Spiritual, artistic & symbolic serv.																
Other cultural services																
Totals																
Gross Ecosystem Product used by Industry (M$/year)										96.280						
Gross Ecosystem Product used by Government (M$/year)											505.111					
Gross Ecosystem Product used by Households (M$/year)												47.519				
Gross Ecosystem Product from the Mitchell catchment (M$/year)																**648.910**
Supplementary Information																
Recreation-related services used by businesses[1]	M$/year	FY18–19						47.519		47.519						

Orange cells in the body of the table indicate that ecosystem services from ecosystems in the Mitchell are being used, or are likely to be used, by the nominated economic entities, but the monetary value of services used cannot be estimated.

1 The SEEA EA (White Cover Version) recommends that households should be recorded as the user of recreation services (United Nations et al., 2021; para 7.52, p.170). The SEEA EA (White Cover Version) also recommends that the same monetary value of service usage by relevant businesses (here the Accommodation sector ANZSIC06 code H4400) should be recorded as supplementary information (United Nations et al., 2021; para 7.53, p.170).

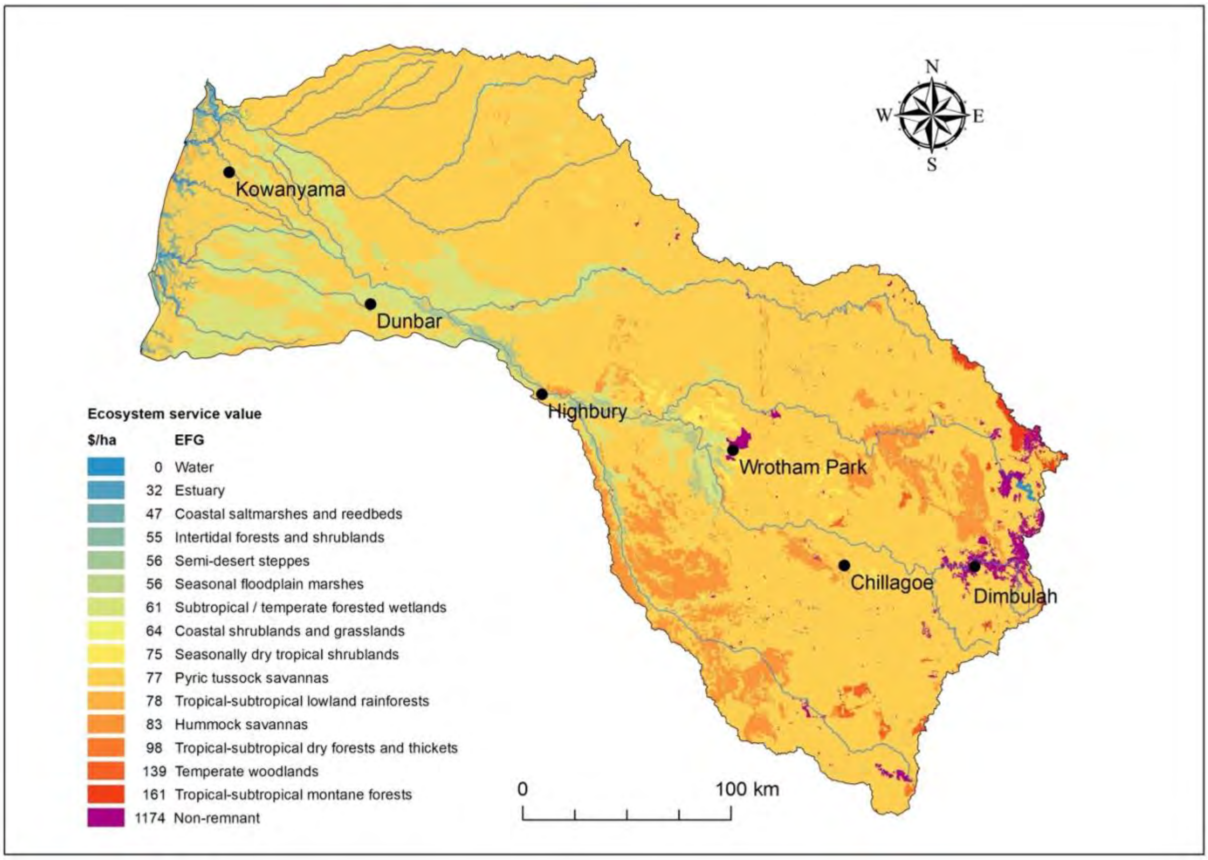

Figure 48: Total monetary value per hectare ($/ha) of selected ecosystem services from ecosystem types in the Mitchell catchment. Monetary valuations expressed in exchange value or exchange-equivalent value. Table 29, Table 30 and Table 31 report which ecosystem services are valued for each ecosystem type.

8. Learnings and reflections

8.1 Learnings on construction of SEEA Ecosystem Accounts

The process of compiling a pilot set of (largely) SEEA-EA compliant Ecsoystem Accounts for the Mitchell River catchment has been informative. In order for ecosystem accounts to be as useful as possible for informing policy direction (see Section 8.2 following), they should be sufficiently comprehensive to provide a clear picture of the current extent and condition of ecosystems in the ecosystem accounting area, provide an indication of the levels of anthropogenic pressures affecting ecosystems, and report on the supply and use of ecosystem services from those ecosystems in biophysical and monetary terms. However, to provide timely information to help inform policy direction, it is also important that ecosystem accounts can be updated consistently and regularly. The dual requirements for Accounts to provide a comprehensive representation of the ecosystem accounting area and yet also be amenable to frequent, consistent updating (at relatively low cost) is challenging. The following paragraphs reflect on these requirements for each component of the Accounts in turn.

8.1.1 Extent accounts

In principle, it should be relatively straightforward to compile an Extent Account for an ecosystem accounting area. For ecosystem accounting areas in Queensland, the starting point is publicly available spatial data on Remnant Regional Ecosystems (Queensland Herbarium, 2021a) (qld.gov.au/environment/plants-animals/plants/ecosystems/about). However, as SEEA-EA recommend that Ecosystem Functional Groups within the IUCN's Global Ecosystem Typology (D. A. Keith et al., 2020) should be used to delineate ecosystem types in SEEA Ecosystem Accounts, a 'cross-walk' – informed by relevant experts – may be required between the different ecosystem classifcations (e.g., between Remnant Regional Ecosystems and Ecosystem Functional Groups within the IUCN's Global Ecosystem Typology).

Thereafter, the frequency with which the SEEA-EA Extent Account can be updated will be determined by how frequently spatial data on Remnant Regional Ecosystems are updated. Given the level of effort required for updating, it may be unrealistic to expect that the Extent Account could be updated annually. Regular updating of the Extent Account (at a feasible frequency) adds considerably to its usefulness for informing policy direction. In the pilot example for the Mitchell, changes in ecosystem extents between the opening (pre-clearing ~ 1750) extent account and the closing (post-clearing ~ 2015) extent account were very informative – for example, by indicating that not all changes in the extent of ecosystem types over that period appeared to be due to the direct effect of anthropogenic changes in land use.

8.1.2 Condition accounts

In many respects, compiling the Stage 1 (Variables) Condition Account of ecosystem variables was the most challenging task in assembling the suite of ecosystem accounts for the Mitchell catchment. Ideally, it would have been preferable to produce a Stage 2 (Indicators) Condition Account, but the absence of reference levels to determine 'best' and 'worst' condition of the different variables proved problematic, so we did not convert condition variables (without reference levels) to their corresponding condition indicators (with reference levels).

SEEA-EA recommend that Condition Accounts should include variables (and/or indicators) that conform with the SEEA-EA Ecosystem Condition Typology (ECT). SEEA-EA's ECT comprises six characteristics that cover different aspects of ecosystem condition: abiotic physical state, abiotic chemical state, biotic compositional state, biotic structural state, biotic functional state, and landscape and seascape characteristics. Ideally, variables (and/or indicators) included in the Condition Account should be useful for informing an ecosystem type's capacity to supply individual ecosystem services as well as informing on ecosystem condition. Alongside the requirement to conform with SEEA-EA's ECT, this makes selection of variables (and/or indicators) for inclusion in the Condition Account particularly challenging.

A further requirement, if the Condition Account is to be useful for informing policy direction, is that the condition variables (and/or indicators) should be amenable to frequent updating at relatively low cost. Variables and indicators derived from remote sensing could, potentially, be updated relatively frequently – but this may depend on the amount of post-processing that has to be applied to the remotely-sensed data. Remote sensing may also be better suited to producing variables and indicators in some SEEA-EA ECT categories than others; for example, variables that reflect biotic structural and functional state, or landscape characteristics, rather than variables that reflect abiotic physical state or biotic compositional state.

For all these reasons, it will be advantageous to consult with experts in the state science departments who manage and monitor ecosystem condition when considering which particular condition variables and/or indicators to include in Condition Accounts. Iterative consultations as the Accounts take shape will likely be particularly useful.

8.1.3 Supplementary information on pressures

Supplementary Information on anthropogenic pressures affecting ecosystem extent, condition and/or supply of ecosystem services can be useful for informing policy direction. It is likely that the agencies who manage ecosystem condition will monitor relevant pressures (e.g., tree clearing, water extractions for irrigation, land use conversions). These data should therefore be relatively easy to obtain and are likely to be updated relatively frequently.

Ready-made composite indices of pressures or condition may also be available (e.g., ground cover disturbance index, river disturbance index, AquaBAMM Aquatic Condition Assessment). It may be useful to include these indices as Supplementary Information in Ecsoystem Accounts. However, the various components used to construct a given indicator should be clearly understood and this information should be conveyed to potential Account users to ensure that the indicators are not misinterpreted. For example, the river disturbance index does not respond to the presence of invasive species and weeds, whereas AquaBAMM's Aquatic Condition Assessment does. Some indicators may also include a trend term within their pressure assessment (e.g., the ground cover disturbance index incorporates a trend term). This is useful for the purposes for which the index was devised, but is contrary to the underlying philosophy of SEEA-EA (and the SNA) that Accounts should respond rapidly to changes in circumstances (e.g., revenues from iron ore sales in Australia's SNA will track volatility in iron ore pricing). For all these reasons, considerable care should be taken when selecting which pressures to include as Supplementary Information in ecosystem accounts. Here again, iterative consultation with the experts who devised the recording metrics for pressures to inform particular aspects of ecosystem management is likely to be very useful.

8.1.4 Supply and use tables

Tables that report supply and use of ecosystem services in biophysical and monetary terms are a key element of ecosystem accounts. The data required to compile biophysical supply and use tables varies depending on the category of ecosystem service concerned.

Biophysical supply of *provisioning ecosystem services* as inputs to joint production processes operated by primary industries can usually be quantified at whole-of-accounting area scale from industrial production data (e.g., commercial fish catches, farm crop outputs, livestock sales etc.). Biophysical outputs can then be attributed back to separate ecosystem types either directly (e.g., the commercial barramundi fish catch from the Mitchell ecosystem accounting area must have been taken from the estuary and its immediate coastal zone), or by overlaying relevant land use type(s) on mapped ecosystem extents (e.g., overlaying the QLUMP 'grazing native vegetation' land use on the Mitchell's ecosystem types to allocate supply of grazing biomass provisioning services to cattle rearing businesses across ecosystem types). Similar approaches can be adopted for biophysical supply of *recreation-related cultural ecosystem services* based on estimates of visitor numbers to particular localities (e.g., Local Government Areas) with tourist attractions and accommodation facilities overlaid on ecosystem types.

Determining biophysical supply of regulating ecosystem services can be particularly challenging, and is likely to rely, at least to some extent, on biophysical modelling of service delivery based on aspects of ecosystem condition and features that determine society's demand for the regulating service being modelled. For example, modelling delivery of flood regulation services will likely require knowledge of the underlying physical processes that affect surface water runoff, together with physical (e.g., slope, soil type) and biotic (e.g., vegetation cover) conditions of a catchment's ecosystems, and geographical and societal factors that affect demand for flood regulation (locations of towns and cities in the lower catchment, the types of property and infrastructure at risk, and presence of flood mitigation measures such as levees).

Where regulating services are supplied to markets – for example, carbon sequestration credits that can be sold as carbon offsets – verification methodologies should already exist. If relevant archives can be accessed, these methodologies will generate direct data on service supply.

Monetary valuation of ecosystem service supply should follow the methodologies recommended in SEEA-EA White Cover version (United Nations et al., 2021; Sections 9.3, 9.4 and 9.5). As discussed in Section 7, valuations in SEEA-EA monetary supply and use tables should reflect only *use values* and should be derived from the biophysical quantities of services supplied using *exchange prices* or *exchange-equivalent prices* constructed appropriately for this purpose.

In the ecosystem accounts for the Mitchell, we used the residual value method to estimate the value of provisioning ecosystem services supplied to primary industries. This method values the provisioning ecosystem service input via the residual that remains once the cost of all other inputs (including the user cost of capital) have been subtracted from the gross revenue obtained from selling the produced output (e.g., farm crop, fish catch, livestock). An (almost) inevitable consequence of this approach is that the 'residual value' assigned to the provisioning ecosystem service input will be higher for production processes with higher value intensity (i.e., where higher gross revenues are generated per hectare: irrigated production of avocado compared with rangeland cattle rearing).

How helpful biophysical and monetary supply and use tables in ecosystem accounts are for informing policy direction will likely depend on how many of the ecosystem accounting area's ecosystem services can be included. It is extremely likely that – with the levels of information currently available – it will only be possible to quantify biophysical and monetary supply of a modest *subset* of ecosystem services from an accounting area. An equivalent circumstance in National Accounting would be for the SNA to report a gross domestic product (GDP) metric that included value contributions from, for example, the manufacturing sector whilst omitting value contributions from, for example, the services sector. Consequently, the supply and use tables in the pilot Mitchell ecosystem accounts should be regarded as a work in progress.

8.2 Reflections on using SEEA-EA to inform policy direction

This section reflects on how SEEA Ecosystem Accounts might be used to help inform policy direction. The choice of wording here is deliberate. For the reasons explained in Sections 7.2.1 and 7.2.2, SEEA Ecosystem Accounts are **not** well suited to 'informing decision making' when the 'decision' entails choosing between alternative proposals for specific activities at a specific location. However, carefully and consistently constructed SEEA Ecosystem Accounts that are regularly updated can potentially be very useful for 'informing policy direction' as explained below.

The role of National Accounts (Australia's SNA) in 'informing policy direction' (as opposed to 'informing decision making') is instructive here. The SNA is compiled carefully and consistently and is updated regularly (quarterly). Accounts in the SNA report on supply of 'outputs' by the different sectors of the economy and use of these outputs by businesses, households and government[24]. Other accounts in the SNA report on the stock of manufactured capital (e.g., machine tools, construction equipment, Information Technology) retained within production sectors so that they can continue to produce their output into the future. The parallels with SEEA-EA's extent and condition accounts for ecosystem types, and supply and use tables for ecosystem services are clear.

The SNA provides a consistent, regularly updated source of information on the performance of the national economy. Information is provided on the economy's current production of output, by industrial sector, and the trajectory of that production through time – over multiple decades to the current year. This information shows the relative scale of value generated by different sectors in the economy and reveals expansion or contraction of the different sectors through time. This type of information can 'inform policy direction' by, for example, making it evident that a particular sector of the economy (e.g., coal extraction) has been contracting over a number of years and thus suggesting that policies to mitigate the impacts of this contraction on employment and household income should be considered for regions where

[24] Taking due account of imports and exports.

this sector is a significant component in the local economy. In this simplified example, the SNA 'informed policy direction' by making it evident that policies to mitigate the adverse impacts of the sector's contraction should be considered. For example, the government might decide that a reconstruction fund should be set up for the region to stimulate new industries and employment opportunities. However, the SNA would **not** be used to inform detailed decision making about which investments or interventions at particular locations would receive grants from the reconstruction fund (e.g., startup grants for renewable energy businesses, financial assistance for on-going professional education). This would be a task for cost benefit analysis as it could draw on separately collected project-level data to evaluate the gains and losses that would likely accrue to affected parties in society at those locations under specific implementations of the alternative solutions.

Turning back to SEEA Ecosystem Accounts, the information provided by consistently compiled and regularly updated ecosystem accounts for an ecosystem accounting area could, for example, help inform the following aspects of policy direction[25]:

- By observing 'past to present' trajectories of ecosystem extent or condition, and the biophysical or monetary supply and use of ecosystem services, ecosystem accounts could help to:
  - Identify the emergence of a problem affecting ecosystem extent, condition or ecosystem service supply – or the escalation of a pressure (e.g., reduction in the area of an ecosystem type that supports an endangered species, a steady increase in water extraction for irrigation, an increase in the prevalence of an invasive species, a reduction in catch per unit effort in a commercial fishery)
  - (Assuming a suitably lengthy and consistent time series of accounts are available) Identify correlations between the emerging problem and escalating pressures, and then use this information to inform possible policy levers for addressing the problem.
- By observing trajectories of ecosystem extent or condition, and the biophysical or monetary supply and use of ecosystem services, from the current point in time forwards ecosystem accounts could help to:
  - Assess the performance of interventions or policy levers relative to defined targets in terms of extent, condition or biophysical service supply (e.g., monitor progress towards a restoration target for habitat extent; track progress towards slowing the expansion of an invasive species; track progress towards a pre-determined target for total carbon storage in woody biomass)

Consistent compilation and regular updating of SEEA Ecosystem Accounts would make them considerably more useful for informing policy direction along the lines suggested above. Informed, iterative consultation during the Account design phase with experts who produce relevant data and undertake on-ground ecosystem management, will be essential for ensuring that ecosystem accounts are well suited to informing relevant policy issues and also for ensuring that the Accounts can be updated regularly within a reasonable budget.

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[25] These suggestions for potential uses of SEEA Ecosystem Accounts to inform policy direction were developed in collaboration with Mr Ken Horrigan (Manager – Environmental Reporting: Sustainable Environment, Environmental Policy and Planning Branch, Environmental Policy and Programs Division, Department of Environment and Science, Queensland Government).

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