A FORK IN THE RIVER

The consequences of a major new cotton industry in the Northern Territory

TERRITORY RIVERS
KEEP 'EM FLOWING

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Acknowledgement of country: We pay our respects to the Elders past and present of the Traditional Owners and Custodians in the Northern Territory, as well as the regions from where we work. We celebrate their enduring connections to Country and their deep spiritual and ecological knowledge of lands, inland waters and sea. We respect and strive to be informed by this knowledge to guide the work we do protecting Australia's natural environment.

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CONTENTS

Daly River. Image: Jason Fowler

SUMMARY

The Northern Territory (NT) is at a critical juncture. Its rivers and aquatic ecosystems – with outstanding natural and cultural values that are central to the wellbeing and economy of many Territorians – are largely still in good condition. But a major new cotton industry could put much of this at risk.

KEY FINDINGS

COTTON INDUSTRY GROWTH PROJECTIONS

- The cotton industry plans to rapidly embark on large-scale production in the NT, with more than 50,000 hectares of cropping forecast within a few years and up to 200,000 ha in the longer term.
- Because the land required for cotton is 2–3 times the area that can be cropped at any one time (due to the need for fallowing or crop rotations), the cleared arable area needed to meet short-term industry forecasts may be 100,000 to 150,000 hectares.
- Neither the industry nor the NT Government has specified how much water a major cotton industry is likely to use, but there is a push to harvest hundreds of gigalitres annually from rivers and floodplains.

ENVIRONMENTAL CONSTRAINTS AND IMPACTS

Water use constraints:

- Major aquifers in the Daly and Roper river regions are already overallocated (the volumes of allocated water exceed the NT Government's estimated sustainable yields), and there is insufficient water available to meet commitments for strategic Aboriginal water reserves.
- Almost three-quarters of the water granted under NT licences is from water sources with no water allocation plan. These allocations lack appropriate planning oversight, a rigorous and transparent scientific basis, and appropriate stakeholder and public engagement.

Proposed flood water harvesting:

- A claim in 2020 that 520 GL of flood waters are potentially available as a sustainable yield in the Daly River region is not backed up by science.
- The seasonal inundation of floodplains is a primary driver of ecological processes in NT river systems. Large-scale harvesting and storage of floodplain and river waters would compromise aquifer recharge, river flows and wetland ecology and productivity.

Inadequacies of NT water management:

- The NT's water management and planning frameworks have not incorporated reforms agreed to under the 2004 National Water Initiative and are widely acknowledged as deficient. Major gaps are a lack of water allocation plans for many aquifers and a lack of catchment planning.
- The granting of several water licences for very large volumes of water outside water allocation plans has been widely criticised, including in public reviews.
- There is a lack of science to reliably inform water allocation decisions, as acknowledged in water allocation plans.
- Environmental law specialists consider the NT's water law and governance to be 'amongst the poorest in the country'.

Impacts on water quality:

- Cotton farming requires substantial use of fertilisers and biocides, which are likely to contaminate aquifers and surface water habitats.
- Aquifers in the Daly River region are highly vulnerable to contamination due to the highly permeable soils and hundreds of sinkholes.

Soil constraints:

- NT soils typically have low nutrient levels and poor structure. The limited water-holding capacity of many soils necessitates irrigation for cropping.

Land clearing:

- Land clearing has accelerated in the NT to average more than 20,000 ha/year in the past 6 years and publicly stated proposals for cotton cropping will precipitate much more. The proposals on just 4 properties listed in the NT Farmers' 2019 business case for the construction of a cotton gin would require clearing of at least 80,000 ha.
- The NT Government offers a fast-track approval process for clearing that precludes comprehensive assessment of impacts and consideration of cumulative impacts.
- Large-scale clearing will cause biodiversity loss, degrade water quality and increase carbon emissions.

Climate constraints and climate change:

- The NT climate with its highly variable rainfall and extreme weather events does not provide stable conditions for predictable cotton yields.
- Climate change will make difficult growing conditions even more challenging, with predictions of more-intense rainfall events, higher temperatures, higher rates of evapotranspiration and reduced groundwater levels in some aquifers.

Impacts on fisheries:

- Significant water extraction is likely to compromise the productivity of important NT fisheries, particularly barramundi and prawns, with extraction of 20% of Daly River flows in some wet or dry seasons predicted to reduce recruitment (the number of young fish that survive to transition to a later stage of life) by 20–25%.

THE VALUES AT RISK IN THE DALY RIVER REGION

- Most proposals for cotton growing are currently focused on the Daly River region, an area of outstanding environmental and cultural values and economic activities dependent on healthy rivers.
- The outstanding natural values at risk include vast wetlands of national and international significance, a highly diverse biota with several threatened species and unique groundwater-dependent ecosystems.
- Water is of immense spiritual, cultural and economic importance to Traditional Owners, and any degradation of river and catchment health is likely to cause hardship and distress.
- Valuable industries in the Daly River region depend on maintaining river and catchment health, particularly nature and cultural tourism and recreational fishing.

RECOMMENDATIONS

1. Place a moratorium on new water licences and allocations and cap extractions at current levels in the Daly and Roper river catchments.
2. Protect vital ecological processes by prohibiting large-scale extraction of flood waters in the Northern Territory.
3. In recognition of the limited science to inform decisions about large-scale cotton farming, apply the precautionary principle in a meaningful way to prevent irreversible harm.
4. Undertake integrated catchment planning with a priority focus on maintaining the health of NT's rivers and protecting their environmental and cultural values. Accord strict protection to largely intact rivers.
5. Enact reforms to prioritise the public interest and increase public trust in government decision-making.
6. Ensure that environmental impact assessment processes related to freshwater resources fully address cumulative and indirect impacts of proposed developments.

1. INTRODUCTION

The Northern Territory is at a critical juncture. Its rivers and other aquatic ecosystems – with outstanding natural and cultural values that are central to the wellbeing and economy of many Territorians – are largely still in good condition. But a major new cotton industry could put much of this at risk.

Australia's cotton industry has major ambitions in the NT, projecting a future of hundreds of thousands of hectares of cropping (mainly on pastoral properties) watered by billions of litres of water extracted from aquifers, rivers and floodplains [1,2].

In 2020, Australia's cotton crop was the smallest in 40 years, down by almost 90% on the 2018 crop due to the impacts of drought [3]. The climatic uncertainties and water constraints and costs in southern cotton-growing areas are driving a strong push by growers to transform northern Australia into a major cotton-growing province [4,5]. But the industry is ignoring the numerous government and CSIRO studies on the environmental constraints to cropping in the north [6–8] and downplaying the potential for major environmental, cultural and economic impacts [6,9–12].

Previous proposals for large-scale cropping (focused mainly in the Daly River region) have also been constrained by public concerns about the impacts of land clearing and irrigation [9]. These concerns remain. In a February 2021 poll of Territorians, 69% of respondents said the cotton industry shouldn't be allowed into the NT until they 'fix up their mess' in the Murray-Darling Basin [13]. Rivers are important to Territorians – 63% of respondents said they use Top End rivers for fishing, boating or other recreation – and this poll indicates that the cotton industry lacks a social license in the NT.

The NT has an opportunity to learn from and avoid repeating the mistakes so evident in the Murray-Darling Basin. But to achieve this, there needs to be a much greater community focus on the potential consequences of a major cotton industry and a strengthening of the science, laws and policies needed to protect the environmental, cultural and economic values of NT rivers.

We provide this review as a contribution to community dialogue about whether a major cotton industry in the NT is viable and compatible with maintaining the values of Territory rivers. Section 2 provides an overview of the cotton industry's plans in the Territory. Section 3 is focused on potential environmental constraints and impacts. Section 4 describes some of the values at risk in the Daly River region, the initial target area for major developments. Section 5 provides recommendations to strengthen the NT's capacity to protect the values at stake.

The Roper River will come under increasing pressure from proposals to extract groundwater for agriculture and mining. Image: Krystle Wright

2. COTTON INDUSTRY GROWTH PROJECTIONS

The cotton industry plans to rapidly embark on large-scale production in the NT, with more than 50,000 hectares of cropping forecast within a few years and up to 200,000 ha in the longer term.

Because the land required for cotton is 2–3 times the area that can be cropped at any one time (due to the need for fallowing or crop rotations), the cleared arable area needed to meet short-term industry forecasts may be 100,000 to 150,000 hectares.

Neither the industry nor the NT Government has specified how much water a major cotton industry is likely to use, but there is a push to harvest hundreds of gigalitres annually from rivers and floodplains.

Plans for large-scale cotton cropping in the NT are rapidly gathering pace, with government-sponsored trials, interstate and international cotton growers buying up pastoral properties, and proposals for cotton gins [1]:

> *Recent successful trials of growing cotton in the north have sparked significant interest from local and interstate growers and international investors... the industry is looking to significantly expand its cotton production.*

The projected areas for cotton growing in the NT vary but range up to about 200,000 ha. Currently, the main focus is in the Tipperary, Douglas Daly and Katherine areas, including the 60,000-hectare Douglas Daly greenfield development [2]. Other regions identified by the industry include the Adelaide River Valley, Roper Valley, Sturt Plateau and Barkly Tablelands (Table 1) [1].

In 2019, cotton industry proponents claimed that cotton production in the NT could reach about a quarter of a million bales by 2024 and eventually almost a million bales (Table 1) [1]. If we assume yields that are consistent with national figures [1,14] – about 10 bales/hectare for irrigated crops and 3 bales/hectares for dryland crops – with 80% dryland cropping (as predicted by the NT Government [15]), the 2024 forecast equates to more than 50,000 hectares of cotton and a long-term 'potential' of about 200,000 hectares. More recently, in its 2022–23 budget, the NT Government predicted 40,000 hectares by 2025, requiring a doubling of the area harvested each year [16].

Cotton bales await gin processing at Moree (New South Wales). Image: Alamy Stock Photo

Table 1. Industry forecasts of annual cotton production in the NT

Region	Projected 2024 (bales)	Projected 2024 (ha)	Potential (bales)	Potential (ha)
Douglas / Daly	48,570	11,000	233,200	53,000
Manbulloo / Katherine	43,900	10,000	165,000	37,500
Auvergne	9,000	2,000	45,000	10,200
Roper Valley	12,600	2,900	84,000	19,100
Sturt Plateau	52,400	11,900	100,200	22,800
Barkly Tablelands	40,000	9,100	120,000	27,300
Adelaide River Valley	40,000	9,100	160,000	36,400
Total	**246,470**	**56,000**	**907,400**	**206,300**

Source: PricewaterhouseCoopers Australia (2019) [1]. The area columns were calculated based on 80% dryland cotton (with a 3 bales/ha yield) and 20% irrigated (10 bales/ha).

A 2020 economic analysis by the NT Farmers Association also projects estimates of the likely cotton cropping area [2]. The executive summary identifies 85,000 hectares for new agricultural development, including 62,000 ha for cotton, but the areas identified in the report for greenfield developments exceed 165,000 ha, with cotton described as the 'cornerstone' to their success. In particular, land clearing would be required for the following developments (for which cotton is one of the proposed crops) [2] (Figure 1):

- Douglas Daly Stage II – 62,000 ha across 4 pastoral properties (50,000 ha for cropping, with 23,000 ha for cotton)
- 3 proposed NT Land Corporation agricultural precincts:
- Keep Plains – 67,500 ha (Stage 3 of the Ord agricultural district)
- Larrimah – 2,180 ha (the area of suitable soils)
- Wildman – 26,000 ha

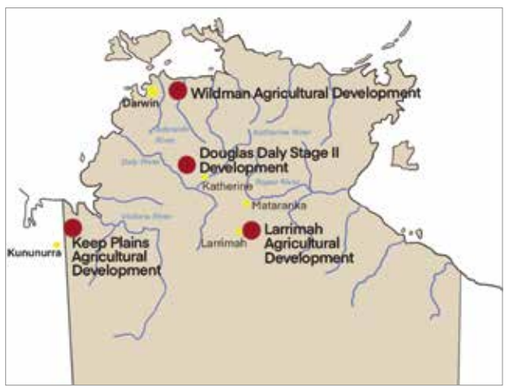


Figure 1. Proposed NT agricultural developments with a focus on cotton

More than 20 NT properties have been identified, in industry reports or in the media, as potential sites for cotton growing (Table 3, Figure 2) [17–19]. They include several pastoral leases recently bought by large foreign cropping companies or interstate cotton growers. Interest has been surging among southern growers, whose existing operations are limited by drought and high water charges [1,17,19–21]. A potential area of cotton cropping has been publicly stated for about half the properties, totalling more than 150,000 hectares (Table 2).

To obtain the industry's forecast annual production, the cleared arable land required for growing cotton may be triple the area on which cotton crops are grown each year. For best practice soil and pest management – to limit the evolution of pest resistance and loss of soil fertility – industry advice is to leave a cropped area fallow or rotate it with other crops such as fodder in a 2–3 year cycle [22–24]. In the Daly region it has been estimated that annual dryland crop sowings of 100–400 ha require 300–1,000 ha of arable soils [12]. In the eastern states, to manage high levels of pest resistance in cotton crops now requires longer rotation periods of 1 in 5–8 crops [24]. Another reason for crop rotation is that NT dryland cotton must be planted into a thick mulch layer to prevent surface soil crusting that prevents penetration by cotton seedlings [24]. Refuge crops must also be grown alongside cotton – currently requiring up to 15% of the area of Bollgard 2 cotton crops and 7.5% of Bollgard 3 crops [22,23]. Therefore, to meet the industry forecasts in Table 1 would likely require the availability of 100,000 to 150,000 hectares of cleared arable land in the short-term (2024) and potentially 400,000 to 600,000 ha in the longer term.

To meet the industry-projected cotton production in the NT will require substantial land clearing. This is cleared cropping land in the Ord River region (Western Australia).

The NT cotton industry will also require water, but the volumes required to meet the forecast production have not been specified. The industry and the NT Government claim that no more than about 20% of the NT cotton crop will be irrigated [15,25] and that irrigated crops will need only half the water used nationally for irrigated cotton [26]. From 2016–17 to 2019–20, the average water use for irrigated cotton across Australia was 7.3 ML/ha [27]. If we apply the assumptions that 20% of the NT crop will be irrigated with an average 3.6 ML/ha, about 40 GL of water would be needed to irrigate 11,000 hectares (20% of the 2024 production forecast, Table 1). This is equivalent to almost 70% of the allocations already granted under licence to properties for which there has been interest expressed in growing cotton (Table 3), suggesting that the industry demand for water will inevitably quickly grow.

A major cotton-driven growth in water demand is implied by the industry's push to be allowed to harvest overland flows. In the Daly River region alone, the industry has mooted the harvesting of more than 500 GL of water from overland flows, as well as the use of groundwater, to grow cotton and other crops [2]. This is almost triple the current allocation of groundwater. Recognising the limitations of groundwater, the NT Farmers CEO Paul Burke has said [28]:

> *We have no desire to pressure government to take more groundwater than is already nominated in the water allocation plan. What we do have a desire for is to be able to flood harvest ...*

The prediction of just 20% irrigated cropping is based on existing water licenses, mostly for groundwater in the Daly River region, and is likely to change should more water become available – for irrigation offers far higher and more reliable yields than dryland cropping. Simulations and recent field trials at the NT Government's Katherine Research Farm yielded 1–5 bales/ha for dryland crops compared to 5–10 bales/ha for irrigated crops [29–31]. Whether such yields will be typical is not known. The results of recent NT trials are not publicly available – the 2020 and 2021 data from the Katherine Research Farm have not been published and data from trials by growers are mostly treated as commercial-in-confidence, with information on dryland and irrigated crops bundled.

Dryland cotton is planted earlier in the wet season than irrigated cotton to take advantage of a longer period of predicted rainfall. But there is a very narrow sowing window for dryland crops – too early risks rain on maturing or open bolls, causing boll rot and fibre discoloration; too late and the crop becomes water stressed before the bolls are mature, reducing yield and fibre quality [32]. Achieving acceptable yields requires a 140–150-day period of reliable rainfall [32]. When this does not occur – for example, in a drier-than-average wet season or when there is no rain for several days – a crop can fail or yields are low [29], as noted by the project manager for NT's cotton gin under construction [33]:

> *Cotton takes about five months to grow and it only rains for 3.5 months. The yield is limited by the duration of the wet season.*

The viability of dryland cropping has not been assessed in several of the proposed NT growing areas. In regions where the wet season is shorter or less reliable than in the Daly River region, irrigation may be necessary to achieve economic yields [29,31,34]. The NT Government has indicated that cotton production in some areas, including Mataranka and Larrimah, would likely require irrigation [25]. Irrigation is also likely to be required where soils have low water-holding capacity, soil types that are common in the regions proposed for cotton growing [29]. Cotton can become water stressed in just over a week without rain [29].

Even if only 20% of the cotton cropping area in the NT is irrigated, the projected extent of cropping will lead to an increased demand for water, including in already overallocated regions. This is a cotton irrigation canal at Moree (New South Wales). Image: Alamy Stock Photo

Table 2. Northern Territory properties for which there has been an expressed intent or interest to grow cotton.

Property	Region	Recent cotton crop (ha)[A]	Indicated cotton crop area (ha)	Land clearing – historical (<2003), clearing permits & applications (ha)[B]	Source of licenced water & volume (GL)
Auvergne [1,20]	Victoria River		25,000	50 (permit, pastoral purposes)	
Newry [1,20]	Victoria River			50 (permit, pastoral purposes)	
Scott Creek [1,35–37]	Daly River		Up to 100,000	31,700 (historical), 1,400 (application, pastoral crops)	
Manbulloo [1,36]	Daly River			12,000 (historical), 580 (permit, horticulture).	Tindall Limestone (2.1) Jinduckin (1.2)
Douglas South [2,28]	Daly River	200	23,000 (part of Douglas Daly Stage II development)	856 (historical), 9,700 (permit, introduced pastures)	
Claravale [2]	Daly River			927 (permit, pastoral purposes)	
Jindare [2]	Daly River			6,800 (historical)	Oolloo Dolostone (13.9) Surface water (0.1)
Florina [2,17,20]	Daly River			1,000 (historical)	Oolloo Dolostone (1.2)
Ucharonridge [1,38]	Barkly Tablelands		Up to 100,000	5,200 (permit, pastoral purposes), 4900 (application, cotton & grain cropping)	
Rockhampton Downs [1,38]	Barkly Tablelands				
Tipperary [39,40]	Daly River	1,500	Not specified	44,500 (multiple permits)	Jinduckin (15.4) Surface water (1.1)
Lakefield [1,41]	Sturt Plateau		5,700	2,700 (permit, crops & pastures)	
Elizabeth Downs [20]	Daly River		Not specified	2,100 (permit, introduced pastures)	
Flying Fox [1,20]	Roper River		Not specified	190 (permit, pastoral purposes)	
Vermelha [1]	Sturt Plateau		Not specified	4,000 (application, introduced pastures)	Mataranka Tindall (3.0)
Edith Springs (freehold) [20,30,42]	Daly River	Area unknown	Not specified	1,100 (permit, introduced pastures)	Surface water (0.4)
Ruby Downs [1]	Daly River		Not specified		Oolloo Dolostone (2.8)
Ceres Downs (freehold) [1]	Daly River		Not specified	2,600 (permit, introduced pastures)	Tindall Limestone (1.4)
Blackbull (freehold) [1,184]	Daly River	800	>4,000	2,600 (permit, forestry & pastures)	Oolloo Dolostone (8.5)
Maneroo (Bindaroo) [43]	Daly River	80	Not specified	3,900 (permit, pastoral purposes)	Oolloo Dolostone (4.6)
Newcastle Waters [40]	Barkly		Not specified	506 (permit, pastoral purposes), 485 (application, pastoral purposes)	
Kingfisher (freehold) [44]	Daly River		Not specified	360 (historical), 900 (permits, introduced pastures)	Oolloo Dolostone (3.0)
Willeroo [45]	Daly River		Not specified		
Dry River [46]	Sturt Plateau		Up to 697 ha	415 (permits, pastoral), 697 (application cotton & introduced pastures)	Tindall Limestone (2.6)
Keep Plains [47]	Victoria River District		Not specified		

Data sources: Cotton interests and proposals (as referenced in the table), land clearing [48–50], water licences [51]

Notes: A. In 2021, 6,000 ha of cotton was reportedly grown by 9 growers, but their locations have mostly not been publicly disclosed [26,52]. B. The 'historical' clearing is clearing additional to areas subject to clearing permits. It includes areas that were cleared prior to the commencement of the permit system in 2003 or areas under permit that are not recorded in the publicly available data. The historical data comes from a vegetation survey of the Daly region in 2012.

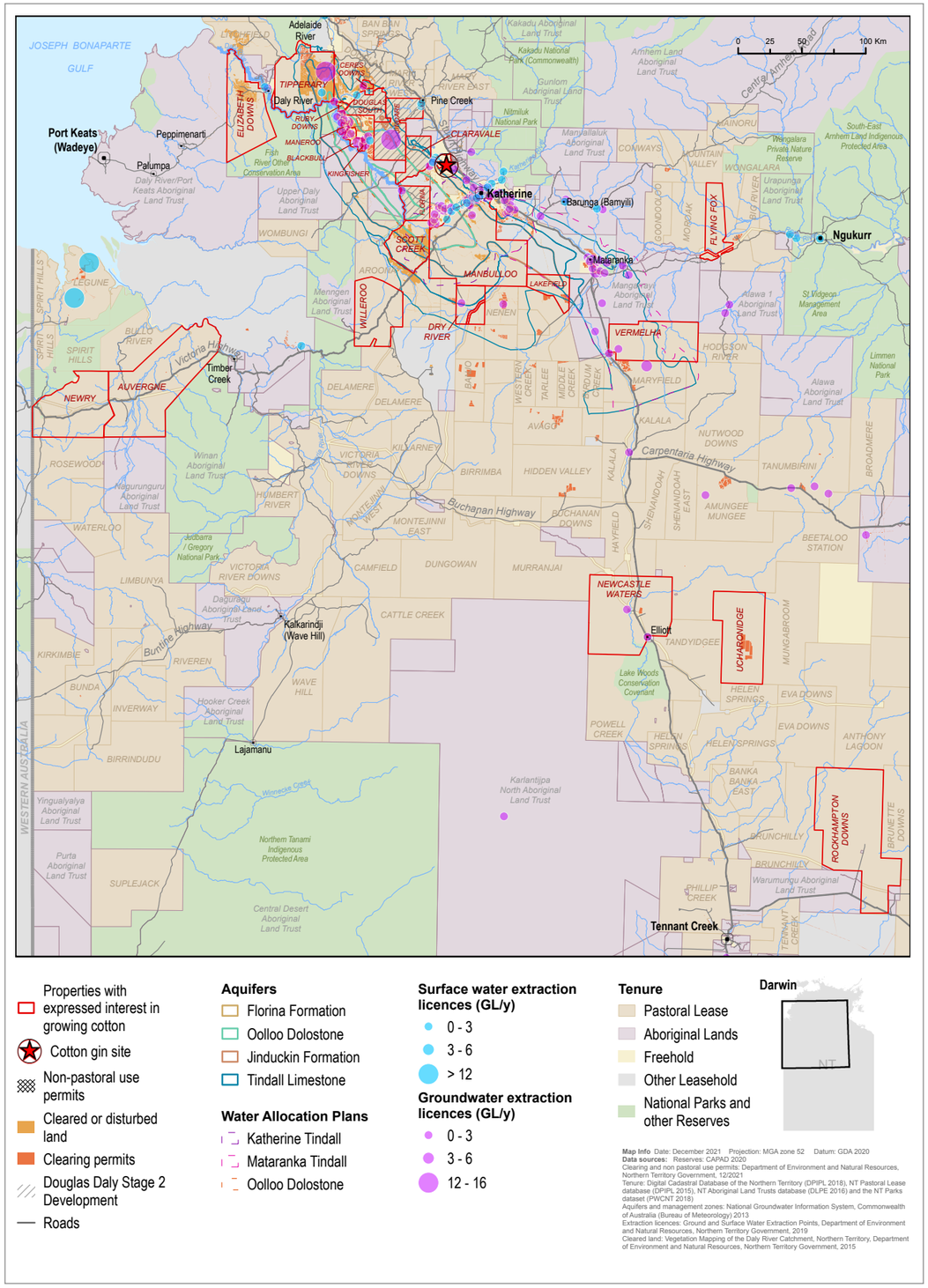


Figure 2. Properties for which there has been an expressed interest in growing cotton, showing cleared land and water allocations

3. ENVIRONMENTAL CONSTRAINTS AND IMPACTS

Although cotton industry proponents have claimed the NT offers ideal growing conditions and ample water and land, studies by the CSIRO and the NT Government have identified major constraints and potentially significant environmental impacts. In this section we outline environmental limits to the predicted growth trajectories and potential impacts. We also consider whether the NT's environmental law and policy frameworks are sufficiently robust to protect the environment and the public interest from unsustainable cumulative impacts.

3.1. GROUNDWATER CONSTRAINTS

Major aquifers in the Daly and Roper river regions are already 'overallocated' (the volumes of allocated water exceed the NT Government's estimated sustainable yields), and there is insufficient water available to meet existing commitments for strategic Aboriginal water reserves.

Almost three-quarters of water granted under NT licences is from water sources with no water allocation plan, and therefore lack appropriate planning oversight, a rigorous and transparent scientific basis, and appropriate stakeholder and public engagement.

Key to the viability of a major cotton industry in the NT are substantial volumes of water for irrigation. Water for cotton will inevitably mean less water for other purposes, including for environmental and cultural flows. After all, water in the NT's rivers, creeks, aquifers and floodplains is already 'used' for many different purposes – sustaining human settlements, Indigenous cultures, recreation (especially fishing), tourism, extractive and agricultural industries, and nature [11].

The Daly River already supports many human activities, including some cropping, fishing, tourism and cultural practices, many of which would be undermined by large-scale irrigation. Several tourism businesses rely on the river being healthy, including the tourist park shown here, Woolianna on the Daly. Image: Jason Fowler

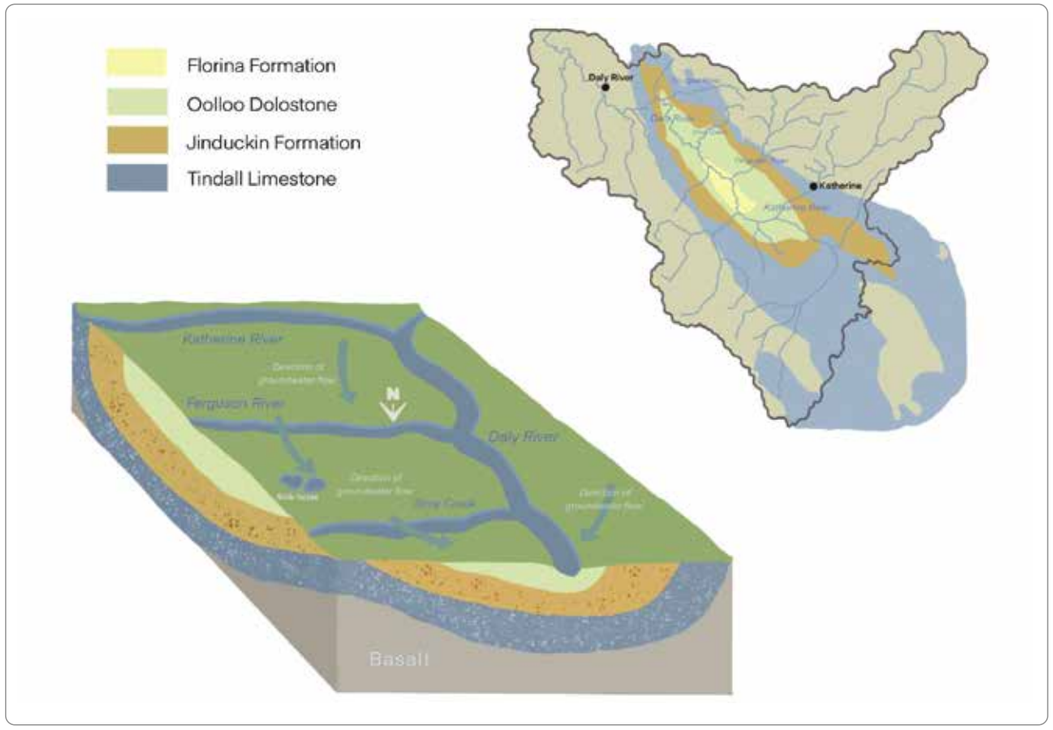


Figure 3. Groundwater aquifers in the Daly region

Source: Adapted from Bureau of Meteorology (2018) [55]

Under current NT policy settings, there appears to be little or no additional water available for irrigating cotton crops in the areas being primarily targeted for cotton farming. Major water resources in the Daly and Roper river regions are already 'overallocated' or there has not yet been any water planning to determine sustainable yields and govern allocations. By 'overallocated', we mean that the volumes of water allocated under water licences exceed the NT Government's 'estimated sustainable yield' (ESY) under operational or draft water allocation plans (see Box 1 for definitions and Table 4 for current water allocations).

There are 2 allocation plans operating in the Daly River region, for the following aquifers (Figure 3):

- the Katherine Tindall Limestone Aquifer WAP 2019–2024, with an ESY of 38 GL [53],
- the Oolloo Dolostone Aquifer WAP 2019–2029, with an ESY of 97 GL [54]

As Table 3 shows, the water resources allocated under both plans exceed the ESYs. There is insufficient water available to meet the commitments for strategic Aboriginal water reserves. Allocations to these reserves are notional until water from other allocations can be clawed back, and under current policies, no new water licenses will be available until those commitments can be met. There is no water allocation plan yet for the Mataranka Tindall Aquifer, but a 2012 draft plan indicates it has already been overallocated [56].

Of great concern is that an estimated 72% of water granted under NT licences is from water sources with no water allocation plan. These allocations therefore lack appropriate planning oversight, a rigorous and transparent scientific basis, and appropriate stakeholder and public engagement [57].

BOX 1. RELEVANT WATER LAWS, POLICIES AND CONCEPTS

The **NT Water Allocation Planning Framework** provides the overarching law and policy for the allocation of water, governed by the Water Act 1992 [58].

The **National Water Initiative** is an intergovernmental agreement providing a framework for water policy, signed by COAG (the Council of Australian Governments) in 2004. It commits governments to transparent statutory water planning 'in which there is adequate opportunity for productive, environmental and other public benefit considerations to be identified and considered in an open and transparent way' [59].

Water control districts are areas declared under the NT Water Act to allow for more intensive management of the water resources.

Water allocation plans (WAPs) apply to specific water resources within water control districts, and are intended to ensure that 'water is equitably managed to preserve quality of life and the integrity of the water-dependent ecosystems' [60]. Under the NT Water Act, a WAP should ensure that 'water is allocated within the estimated sustainable yield to beneficial uses'. As WAPs have been developed after licences to take water were already granted, some WAPs are already over-allocated, particularly in the Daly Beetaloo Water Control District, which covers much of the Daly River Basin.

Estimated sustainable yield (ESY) is the principal limit in NT water planning to water extraction from a given region. It is not defined in legislation but has been specified in NT Government documents as [61]:

> *the amount of water that can be taken from a water resource without compromising: key environmental values, Aboriginal cultural values, ecosystem functions, the productive base of the resource, or declared water quality standards, criteria or objectives.*

The **80:20 rule** is the 'rule of thumb' principle for establishing the 'estimated sustainable yield', requiring 80% of a water resource to be retained for environmental flows and a maximum 20% to be allocated for consumptive use. For groundwater, this requires that extraction for consumptive uses not exceed 20% of annual recharge. For surface water, it requires that no greater than 20% of flows in a given place at a given time are extracted [61].

Table 3. Water allocations in the Daly and Roper river regions

Water source (aquifer)	Water allocation plan	ESY (GL/yr)[A]	Total allocated under licence (GL/yr)[B]	Rural, stock & domestic (GL/yr)[C]	Aboriginal strategic water reserve (GL/yr)[D]	Total allocated (GL/yr)[E]	Over-allocated (GL/yr above ESY)[F]
DALY RIVER REGION							
Oolloo Dolostone	2019–2029	97.3	95.69	1.55	19.31 (partially allocated)	116.55	19.25
Katherine Tindall Limestone	2019–2024	38.4	36.6	6.04	3.23 (none allocated)	41.84	7.47
Jinduckin Formation	No plan	Not assessed	18.66	1.84	Not calculated or allocated	20.49	Unknown
ROPER RIVER REGION							
Mataranka Tindall Limestone	Draft in progress	43.6 (draft estimate)	27.07	2.0 (max)	13.00	42.00	Over-allocated in southern zone[G]

Sources: Oolloo Dolostone [54], Katherine Tindall Limestone [53], Mataranka Tindall Limestone [62], Jinduckin Formation [63]

Notes: **(A)** ESY is 'estimated sustainable yield'. **(B)** This figure includes all allocations subject to licensing. **(C)** Rural stock & domestic water is not licensed and the volumes are estimates only. **(D)** An Aboriginal strategic water reserve is required to be made available as an allocation under all WAPs, but is in most cases only notional due to the resource already being overallocated when a WAP is prepared. **(E)** The total allocated is the sum of allocations B, C and D. **(F)** The amount overallocated is the difference between the total allocation in E and the estimated sustainable yield. **(G)** The draft estimates for this aquifer indicate that it is almost fully allocated, and already over-allocated in the southern zone.

Although water licences granted under WAPs are informed by 'estimated sustainable yields', water planners do not have a high level of confidence in these estimates. The Tindall Limestone WAP, for example, says 'there is insufficient information to determine environmental and cultural water requirements in the plan area' [64].

The waters in the Daly Basin aquifers are relatively young in geological terms (30–500 years old), which means they are highly sensitive to over-extraction [65]. This risk was exemplified by declining groundwater levels in the Katherine region in 2018–20 after very low wet season rainfalls (the lowest on record) [66]. Due to insufficient recharge, the 2020 allocations for license holders in the Katherine Tindall Aquifer WAP were cut by over a third [67].

The ecological impacts of current water allocations are largely unknown. The effect on discharges to the Daly River are unlikely to be observable until many years after extraction – an estimated 23 years for key aquifers in the Daly, well beyond the timeframe of existing studies [68]. And only a proportion of the total allocated volume is being used. In 2018, water use was only 27% of the allocation under the Oolloo Dolostone WAP and 31% of the allocation under the Katherine Tindall WAP [54,62,67].

Other water resources in the Daly region do not yet have allocation plans. The Mataranka Tindall WAP (in the Douglas Roper Beetaloo Water Control District) stalled from 2019 until early 2021, when meetings reconvened. A proposed WAP for the Jinduckin Formation and the Daly Basin management plan have not yet been initiated.

The cotton industry's planned expansion into the NT will increase pressure on water resources. Many potential NT growers do not have a water license or are licensed for only a small volume. The properties listed in Table 4 have no water allocations and are either in areas where water allocation plans are overallocated or where there is no allocation plan.

So, where does the cotton industry propose to source water from in over-allocated regions? The solution, according to industry spokespeople, is the extraction and storage of water during floods – 'What we do have a desire for is to be able to flood harvest' [28]. But this could compromise ecological processes of fundamental importance to river and wetland health (Section 3.2).

Table 4: Properties on which cotton farming is proposed that lack water allocations

Pastoral property	Water region	Relevant water allocation plan	Mooted area of cotton farming (ha)
Auvergne & Newry	Victoria River	No WAP	5,000 irrigated / 20,000 dryland
Lakefield	Sturt Plateau	Mataranka Tindall (draft WAP) / Katherine Tindall (overallocated)	1,200 irrigated / 4,500 dryland
Douglas South & Claravale	Daly River	Katherine Tindall (overallocated) / Oolloo Dolostone (overallocated)	20,000
Rockhampton Down & Ucharonidge	Barkly Tablelands	No WAP	10,000

Sources: See Table 2.

The NT Government issued a permit in 2020 for land clearing on the Lakefield pastoral property, including for irrigated cotton cropping – in a region in which groundwater has already been overallocated (see Table 4). Image: David Hancock / AUSCAPE

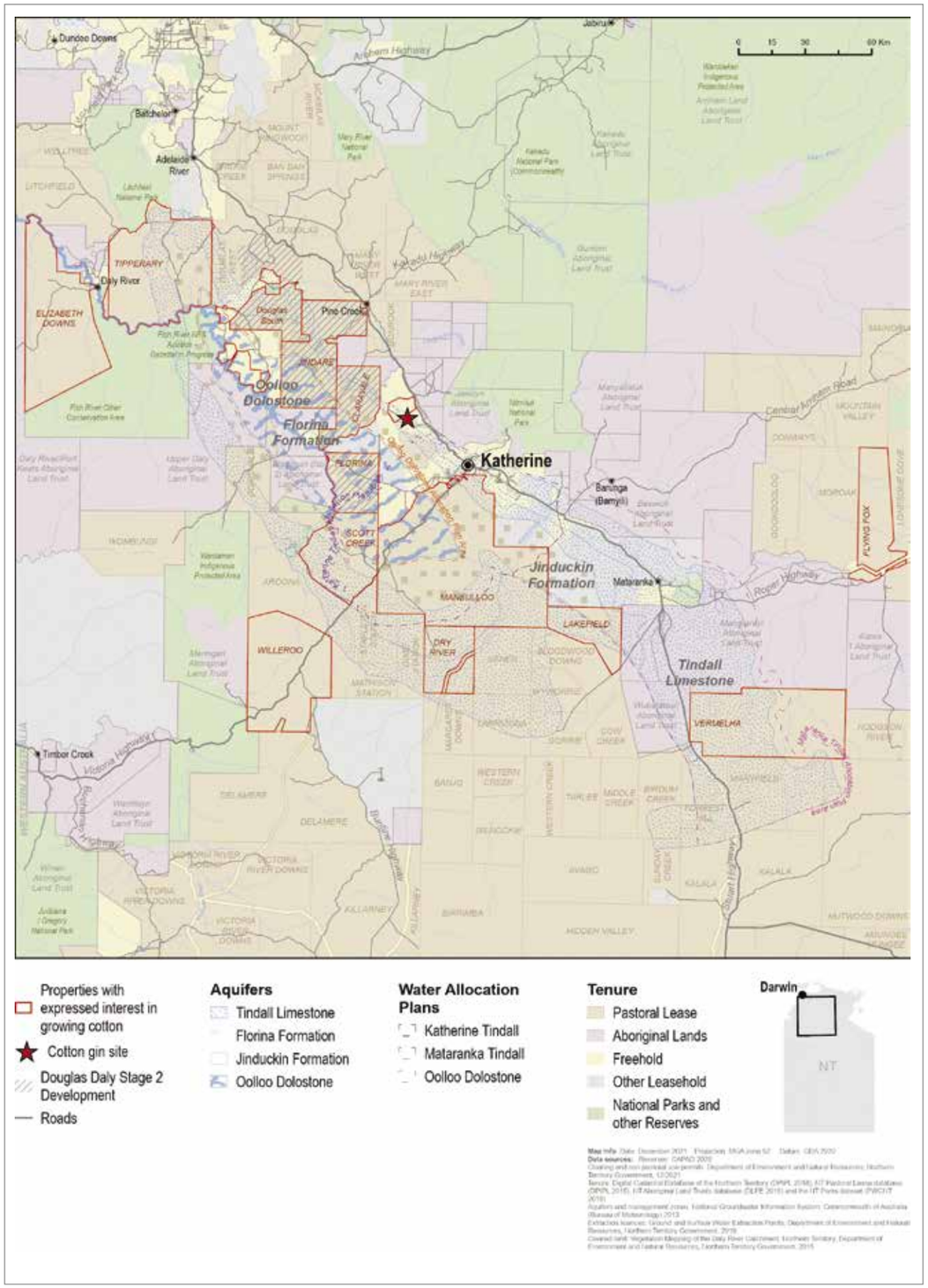


Figure 4. Groundwater resources and allocation plans in the Daly River region

3.2. PROPOSED FLOOD WATER HARVESTING

A claim by the NT Farmers Association in 2020 that 520 GL of flood waters are potentially available as a sustainable yield in the Daly River region is not backed up by science.

The seasonal inundation of floodplains is a primary driver of ecological processes in NT river systems. Large-scale harvesting of flood waters (from floodplains or rivers) would compromise aquifer recharge, river flows and wetland ecology and productivity.

Tropical floodplains are highly biodiverse and productive ecosystems, and their seasonal inundation and drainage are thought to be 'the primary drivers of ecological processes in large floodplain rivers' such as the Daly [69]. Wet season flooding triggers a dramatic surge in primary productivity, providing 'the energy that fuels aquatic food webs'. About 60% of the fishes recorded in the Daly River, including barramundi and sawfish, use floodplain habitats [70]. The increased food and habitat available during floodplain inundation is vital for the breeding and migration of many species, including fishes, turtles, waterbirds, frogs, file snakes and crocodiles [69,71]. Maintaining connectivity between the elements of the entire riverine landscape is critical for the natural ecological functioning of rivers in this region.

The seasonally inundated floodplains of rivers in the NT contain Australia's largest mostly intact wetlands. Maintaining river flows and peak floods is essential for maintaining their ecological productivity and rich biodiversity. The floodplains of the Adelaide River (top) and Mary River (middle) support globally significant numbers of waterbirds and both are vital for maintaining populations of fish important for recreational and commercial fishers as well as wildlife. In the photo left, a crocodile has captured a barramundi. Images: Janelle Lugge / Shutterstock (top and middle), David Hancock / AUSCAPE (bottom)

With the limited availability of groundwater resources in the NT, cotton industry proponents have recently advocated capturing and storing flood waters [2]. On floodplains, long engineered structures such as access roads, channels and levee banks can intercept and divert large volumes of water that would have otherwise flooded wetlands, flowed into waterways or soaked into aquifers [72]. Storage options include dams or managed aquifer recharge (pumping floodwaters back into aquifers for later use).

The NT Farmers Association claims that 520 GL of wet season water may be available 'for further agricultural and horticultural developments' in the Daly region [2]. This figure has been repeated numerous times in the media as the rationale for a major increase in water extraction to support a cotton industry [28,73,74]. It is more than triple the current water allocations in the Daly region (Table 4).

However, the claim that 520 GL is available is contradicted in technical reports by the CSIRO and NT Government [6,9]. It is based on a claimed regional 'runoff coefficient' (the proportion of rainfall that is converted into runoff) of 0.5 (with annual rainfall of 1,000 mm and a 20% potential capture rate) [2]. There is no evidence for a rainfall runoff coefficient of 0.5. The CSIRO's study on sustainable yields in the region references coefficients ranging from 0.03 to 0.3 in different parts of the catchment [5].

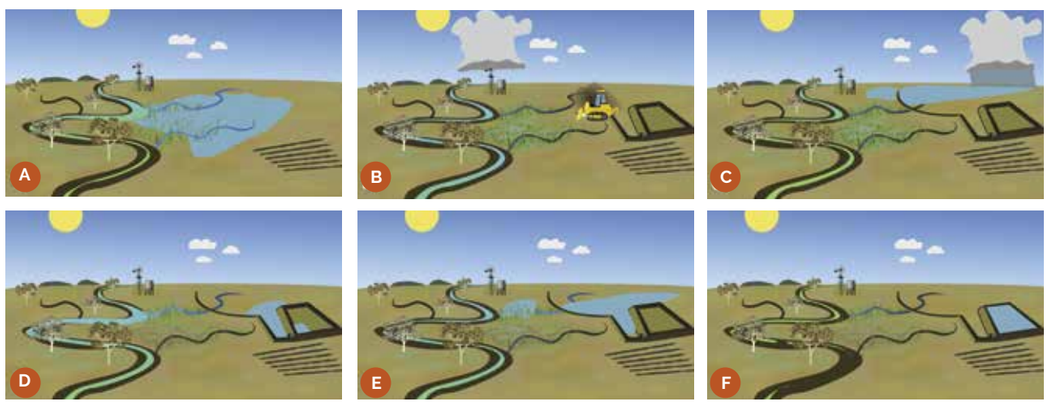
Overland flows are not a separate additional source of water for they flow into creeks, rivers and aquifers. Modelling groundwater and surface water together is essential to prevent the problem of double dipping [75].

Due to the highly permeable nature of soils across most of the Daly catchment, true overland flow rarely occurs, except after intense rainfall events. Most water spends part of its journey from where it falls to the nearest waterway beneath the ground [76]. The numerous sinkholes characteristic of the region's geology provide a direct connection from the surface to an aquifer. The Tindall Limestone, in particular, is connected via many sinkholes and caves [1].

Wet season flow is essential for aquifer recharge, including in very wet years. The Oolloo Dolostone Water Allocation Plan states [54]:

> ***Additional water that recharges the aquifer in wet years should be reserved to boost aquifer levels****. … Above average rainfall years are extremely important for topping up the aquifer and maintaining groundwater levels and discharge during drier, lower recharge periods. This is important for water management as it means that even though the aquifer is recharged each year, there will be periods in the future that may last for several years or more when groundwater levels will fall and river discharges are reduced.* ***Thus, there is a need to "bank" aquifer recharge in wetter than average years****. [Bolding added.]*

Floodplain harvesting reduces flows into rivers, which in turn reduces the volumes of water available for downstream ecosystems and town and rural communities. Diverting large volumes of water from rivers and floodplains can have major impacts on wetlands that depend on overland flows to maintain their ecological character [77]. In eastern Australia, floodplain developments have affected waterbird breeding, vegetation health, frogs, microbats and woodland birds [78,79]. The risks of floodplain harvesting include failures to replenish some wetland habitats, reduced input of food and energy into the river channel, compromised access by fish to rich food resources and lower fish recruitment [80].



Floodplain water harvesting
(a) During the wet season, big rains bring floodplains to life and replenish the river and aquifers. (b) Levees are built to prevent floodplain water reaching the river channel so that it can be stored and used later for irrigated cropping. (c) Floodplain water is stored in large, typically shallow, private dams subject to high levels of evaporation. (d & e) The diverted water means less water for rivers, wetlands, aquifers and wildlife. (f) Significant capture of floodplain waters will deprive some wildlife of the peak flows important for breeding success and reduce the capacity of river systems to sustain life during dry times. Schematic: Max Phillips

One of the reasons the Murray-Darling Basin has suffered so much environmental degradation is the diversion of large volumes of floodplain water into massive dams, shown here in Outback New South Wales. Image: Shutterstock

The NT Government is developing a 'wet season flow' policy to establish an assessment process for wet season extraction, whether from the river channel or floodplain. A consultation draft is expected by mid-2022 [66]. Current licensing arrangements fall well short of the reform commitments made under the 2004 National Water Initiative [57,59], and the scientific foundations and governance capacity in the NT to regulate this practice are deficient. Water allocation committees have highlighted the gaps in knowledge needed to predict impacts, including surface hydrology and the dependency of ecosystem functions on flood phases such as the first flush being a trigger for fish movement in the Roper and Daly rivers [62].

Because of high evaporation rates, the storage of flood waters would require large dams [6–8]. In the Daly region, the potential evapotranspiration rate of 1,942 mm is almost double the average annual rainfall (1,019 mm) [6]. Storage in the Katherine-Douglas-Daly area would require a dam area at least 40% as large as the irrigated area (based on a conservative annual evaporation loss of 1 metre, depth of 3 metres and annual application of 10 ML/ha) [9].

A proposed alternative is managed aquifer recharge (MAR) – the injection of water into an aquifer for later use [9]. The NT Farmers Association has proposed the building of weirs on the Lower King River and Stray Creek for MAR storage [2]. But these options are mostly not feasible for economic or technical reasons or would breach the NT Water Planning Framework's 80:20 requirements for the provision of environmental flows [81]:

- Lower King Ring and Stray Creek MAR options – not technically feasible because they are water discharge sites
- Upper King River MAR options – technically possible, but injection and extraction volumes are constrained by the 80:20 policy (even the smallest of 3 modelled scenarios, storing 6 GL/year, would breach the policy in most years); only economic for high-value horticultural crops such as melons and okra.

3.3. INADEQUACIES OF NT WATER MANAGEMENT

The NT's water management and planning frameworks have not incorporated reforms agreed to under the 2004 National Water Initiative and are widely acknowledged as deficient. Major gaps are a lack of water allocation plans for many aquifers and a lack of catchment planning.

The granting of several water licences for very large volumes of water outside water allocation plans have been widely criticised, including in government reviews.

There is a lack of science to reliably inform water allocation decisions, as acknowledged in water allocation plans.

It is widely acknowledged that the NT's water management and planning frameworks are deficient and do not incorporate many of the reforms agreed to under the 2004 National Water Initiative [59,82–85]. The NT's frameworks are still in a developmental phase, and water planning, in particular, is deficient. More generally, the NT Government itself recognises [86]:

> *...the need for substantial reform of the Northern Territory's environment protection framework. Reforms are long overdue and critical to achieving a robust regulatory system that the community will trust to ensure the Territory's ecologically sustainable development...*

Environmental law specialists consider the NT's water law and governance to be 'amongst the poorest in the country' – because of deficiencies in water planning (e.g. the lack of legislated requirements for planning or specified WAP content), sustainable yield estimates (e.g. the lack of a legislated definition, methodology and enforceability), annual allocations (the lack of a clear, legally binding and consistent methodology) and licensing (e.g. the 'very broad discretion' of the Water Controller) [87]. In a 2021 analysis, the Northern Land Council found that the NT has failed to meet the requirements of the National Water Initiative to provide secure water to meet environmental and other public benefit outcomes, address overallocated and overused systems, and recognise the needs of Aboriginal people [88].

While the 80/20 principle applied in water allocations is an acknowledgement that water must be retained for the environment (Box 1), the NT has not yet developed a truly catchment-based approach to water management. Developments are assessed in a disjointed way across a range of government departments and agencies.

Past intentions for integrated planning have also not been realised. In 2002, cotton farming, dams, subdivisions and clearing were banned in the Daly Region until a sustainable land use plan could be developed [89]. Much work went into developing this plan in 2011–2014 [90], but it was abandoned by subsequent governments.

NT water allocation decisions have been repeatedly criticised, with accusations of corruption, a lack of transparency, discrimination against Traditional Owners and inconsistency with science. The critics have included Indigenous groups, the NT Farmers Association and environmental organisations [59,83–85]. An independent review of water licence decisions commissioned by the NT Government in 2017 found numerous 'substantive issues', including the lack of a scientific foundation for some allocations and inconsistencies with the planning framework. Procedural errors were also rife [82].

Large water allocations continue to be granted outside the governance and scientific frameworks provided by water allocation plans. Some allocations are based on poor or limited science and exceed what was later assessed as the sustainable yield [82]. While the NT Government has addressed these issues to some extent, recent decisions such as those outlined in Box 2 indicate ongoing flaws [85,91,92]. When water is over-allocated, it is financially, socially and politically difficult to subsequently reduce the allocations [93].

The lack of a strong scientific foundation for major allocations outside water allocation plans, such as those granted to Tipperary and Singleton stations and the Larrimah Agricultural Precinct, and the poor performance in monitoring, enforcement and compliance [82,84,85,91,92,94] are of great concern in the face of pressures to allow large-scale extraction of flood waters.

Even in jurisdictions with a more mature water management framework than the NT and much greater capacity and resourcing, there have been systemic failures to counter the influence of strong irrigation lobby groups [95–98]. The devastating ecological, social and cultural impacts of cotton farming in the Murray-Darling Basin have been due to poor planning and failures to regulate floodplain harvesting and the cumulative impacts of agricultural developments. Efforts to re-establish environmental flows in the Murray-Darling Basin continue to be undermined by poor compliance, corruption and the political challenges of rolling back water consumption [95,99].

New South Wales' Independent Commission Against Corruption has found:

> *a repeated tendency on the part of the NSW Government's water agencies to adopt an approach to water management that was unduly focused on the interests of the irrigation industry.*

Furthermore:

> *certain decisions and approaches taken by the department with responsibility for water management in NSW over the last decade were inconsistent with the object, principles and duties of the [Water Management Act] and failed to give effect to the legislated priorities for water sharing.*

With the NT's water regulatory capacity much weaker than that in the Murray-Darling Basin, it is unclear how it will be able to avoid similar pitfalls.

Regular fish kills in the Murray-Darling Basin serve as a warning to NT residents that water quality can suffer from large-scale irrigation. In the lower Darling River (top), several million fish died in 2018–19 due to low oxygen levels and high water temperatures. In the Edward-Wakool river system (bottom), hundreds of thousands of fish died in 2016–17 in a blackwater event. The lack of regular inundation of the floodplain (due to diversions for irrigation) had resulted in a build-up of carbon that led to excessive bacterial growth and low oxygen levels during a big flood. Images: Graeme McCrabb (top right), Alamy Stock Photo (bottom)

BOX 2. EXAMPLES OF PROBLEMS WITH WATER LICENSING

The following 3 cases exemplify deficiencies with licensing processes, particularly for licences granted outside water allocation plans.

2015: A major allocation granted despite a lack of science and capacity to use the water

In 2015 Tipperary Station was granted an increase in their water license from 5.15 GL to 15.4 GL, then the largest single water allocation in the NT [84]. A government review found this decision to be problematic for reasons including the following [82]:

- The existing allocation was not being fully used, contrary to government 'use it or lose it' policies.
- The company had no existing capacity to use the allocated water, and no realistic projections for its use.
- There was insufficient evidence in government documentation to establish whether the data and assumptions used to base the ESY on 20% of recharge from Tipperary Station were appropriate.
- The allocation exceeded the estimates of sustainable yield for the area by 10% on what was already a highly questionable estimate not supported by scientific advice.

The water was allocated from the Jinduckin Formation Aquifer, for which there is no water allocation plan declared or under development [100]. There has been no scientific modelling of this resource or studies to investigate the potential environmental and cultural impacts of this allocation.

2021: 10 GL licence revoked due to assessment deficiencies

In June 2021 a 10 GL water license for development of the 5,700-ha Larrimah Agricultural Precinct was revoked by the Health Minister (after the Water Security Minister revealed a potential conflict of interest) following an independent review which found that the allocation (granted outside a WAP) was inconsistent with the NT Water Framework's 80:20 rules [91], was not precautionary, did not consider climate change, used the wrong allocation rules, and relied on a technical report with significant shortcomings [92]. Further work has been completed, and the proponents have been encouraged by the NT Government to resubmit their application [101].

2021: Largest-ever NT water licence granted despite 'extreme' risks

In April 2021, a water licence was approved (in 4 stages) for extraction of 40 GL a year from 144 bores for a 3,500 hectare horticultural development on Singleton Station, under the Western Davenport Water Allocation Plan [102]. It came after the NT Government issued a guideline in 2020 allowing for destruction of up to 30% of groundwater-dependent vegetation in the Western Davenport area [103]. The licence was issued despite the Western Davenport WAP rating the risk of changes to future estimates of water availability as 'extreme' due to limited data and modelling uncertainties [85]. And although the WAP highlights the lack of knowledge about Aboriginal cultural values in the drawdown area as an 'extreme' risk, the licence conditions didn't include any requirements to protect Aboriginal cultural sites [85]. After a review triggered by objections from Traditional Owners and environment groups [104], the licence was re-issued in November with revised conditions that include a detailed assessment of the aquifer, an impact assessment of cultural values and a referral to the NT EPA for assessment under the Environment Protection Act [105].

3.4. IMPACTS ON WATER QUALITY

Cotton farming requires substantial use of fertilisers and biocides, which are likely to contaminate aquifers and surface water habitats.

Aquifers in the Daly River region are particularly vulnerable to contamination because the soils are highly permeable and there are hundreds of sinkholes.

Broadacre cotton farming is likely to reduce water quality, potentially risking human and ecological health – due to the industry's substantial use of fertilisers (eg nitrogen and phosphorus) and biocides (herbicides, fungicides and insecticides). These are discussed mainly here with reference to the Daly River region. Soil erosion and increased sedimentation from land clearing and cropping are also threats to the health of aquatic ecosystems [106] (see section 3.6).

In the Daly River region, the Oolloo Dolostone Aquifer and the rivers fed by groundwater are highly vulnerable to contamination [107]. Because recharge frequently occurs rapidly through sinkholes – thus bypassing the filtering effect of the soil – these highly transmissive systems can act as conduits for poor quality drainage water [108]. Fertilisers, herbicides and pesticides leaking past the root zone are able to drain laterally through aquifers. The impacts of these chemicals on downstream ecosystems are, according to CSIRO studies, likely to be of great concern – particularly because of the very strong connectivity between the groundwater system and Daly River [108]. The drainage of poor quality water into groundwater and then into the Daly River may also impact drinking water for towns and Indigenous communities downstream [108].

Groundwater in the Daly River region has already been polluted, demonstrating its vulnerability to contamination [109–111]. The Tindall aquifer is contaminated with per- and poly-fluoroalkyl chemicals used for firefighting at the RAAF Base in Tindall, and the Oolloo aquifer in the Douglas Daly and Katherine areas has traces of pesticides and nitrates [112]. Government-funded surveys in 2018 found that [112]:

> *nitrate concentrations were elevated under agricultural land, indicating that such land uses, likely involving fertiliser application, are having an impact on Oolloo aquifer groundwater.*

Contaminants in groundwater will also impact water quality of the Daly River in the dry season, when it relies on discharge from groundwater. Government surveys have detected 9 different pesticides, mainly herbicides, in groundwater and dry season flows in the Daly [109]. Atrazine – 'very toxic to aquatic life with long lasting effects', according to safety information [113] – was the most common contaminant, found in 15 of the 25 bores tested. The potential for further contamination of the Tindall aquifer is of great concern as it forms part of the Katherine town water supply [110].

Cotton farming in northern Australia requires large inputs of nitrogen. Tropical cotton growing manuals advise 38 kg/ha for optimal growth [32], but simulations of dryland cropping in the Daly River Basin, where soils are highly deficient in nitrogen, suggest that 100 kg/ha is needed to optimise dryland yields [29].

Most commonly used nitrogen and phosphorus fertilisers are soluble, intended for use in sites where rainfall averages less than 600 mm or for soils that can retain these nutrients [114]. Rainfall in potential cotton growing areas in the NT is much higher – averaging about 1000 mm in the Daly River region and over 800 mm in the Roper River region [114]. High rainfall makes it more likely that these nutrients will leach into groundwater and be washed into waterways [114].

With naturally very low levels of nitrogen (0.004–0.04 mg/L) and phosphorus (>0.005 mg/L), the Daly River is highly susceptible to pollution by fertilisers [115]. Nitrate contamination can lead to the eutrophication of aquatic ecosystems and cause algal blooms and other changes to the aquatic flora [110]. Nitrates can also cause human health problems if contaminated groundwater is used for drinking. They may be particularly harmful to young children and can combine with food to make cancer-forming compounds [114].

Extensive use of pesticides is essential for NT cotton crops, particularly during the wet season, when crop pests such as pink bollworm, looper caterpillars, Spodoptera and locusts are most abundant (see Box 3) [116]. Genetically modified cotton crops also require significant use of herbicides to manage weeds, defoliate cotton and manage fallow areas to prevent the development of pest resistance [32]. Because of the Daly's extremely permeable soil types and geology, cotton farming is likely to increase pesticide levels in groundwater systems and dry season flows.

All cotton grown in the NT will be genetically modified to be resistant to glyphosate [117]. This herbicide is generally considered a non-persistent, relatively safe compound in the environment due to its rapid inactivation in soil [118], but it has been assessed as 'toxic to aquatic life with long lasting effects' [119,120]. GM cotton in the NT will require aerial application of glyphosate (the wet season precludes ground application) and there do not appear to have been any NT studies evaluating the potential impacts of aerially applied glyphosate during the wet season.

BOX 3. PESTICIDES AND HERBICIDES USED ON DRYLAND COTTON

Recommended biocides for growing dryland Bollgard3 cotton [32]:

- Sulfoxaflor (500 g/L), an insecticide for mirids, in December
- Diafenthiuron (500 g/L), an insecticide for silverleaf whitefly, aphids and mites, in February
- Pendimethalin (455 g/L), a herbicide, in October
- Roundup Ready® Plantshield® (690 g/kg glyphosate)
- S- metolachlor (960 g/L), a herbicide, in November, December and January
- Thidiazuron, Diuron and Ethepon, defoliants.

Recommended biocides for fallow management [32]:

- Glyphosate (450 g/L) in November and March
- 2,4-D amine (625 g/L) in November
- Flyroxyprin (333 g/L) in January
- Pendimethalin (440 g/L) in March.

Sinkholes in the Katherine region facilitate a rapid transit of storm waters (and any chemical contaminants they carry) into aquifers. Image: Garry Enright

Cotton is vulnerable to damage by a wide array of insects – mites, aphids, whiteflies, mirids – some of which require spraying with pesticides. Image: Alamy Stock Photo

3.5. SOIL CONSTRAINTS

NT soils typically have low nutrient levels and poor structure. The limited water-holding capacity of many soils will necessitate irrigation

Northern Territory soils are often considered poor for cropping, with low levels of nutrients and poor structure (low water-and-nutrient-holding capacity) [121]. Many Top End soils are able to hold only 80–125 mm of plant-available water in the root zone [29]. When actively growing, a cotton crop on soils with 90 mm of water will extract about 6 mm a day, initiate water stress avoidance in 8–10 days and suffer severe stress after another 15 days. Simulations indicate that growers would need soils with higher water availability for viable yields of dryland cotton [29].

A 2019 study of the potential for dryland cotton cropping in the NT identified 2 main suitable soil types in the Top End and on the Sturt Plateau: Tipperary clay loams and Blain sandy loams [29]. The following characteristics of these soils (identified in a study of dryland yield potential) will nonetheless limit the viability of dryland cotton cropping or increase the likelihood of environmental impacts [29]:

- low fertility, particularly of nitrogen and phosphorous, but also of micronutrients and carbon
- mostly low plant-available water (80 to 160 mm soil depth) although some blain soils have higher availability (the better dryland cotton areas in New South Wales and Queensland have self-mulching clays with 250–350 mm of plant-available water)
- high susceptibility to surface crusting after ploughing
- risk of poor establishment (patchy stands or replanting required) due to high soil temperatures and soil crusting
- risks of erosion, particularly the Blain soils
- high soil temperatures, which could kill establishing seedlings
- a high risk of nitrates leaching below the root zone or being lost in runoff.

At all proposed locations the soils are highly deficient in available nitrogen. There is a limit to the extent that this can be rectified for cotton, with results showing only a marginal yield benefit with applications over 100 kg/ha, as water and climate factors limit the yield potential [29].

Where the climate may be suitable for cotton in the Baines and Roper river catchments and the Barkley Tableland there are large areas of heavy clays [29]. Experience in the Ord and Burdekin regions has shown that lack of wet season trafficability and water logging are major constraints of cropping on clay soils [29].

Clay soils such as those found in the Ord River region, the Baines and Roper river catchments and on the Barkly Tableland are challenging for crop growing due to their bogginess and water logging in the wet. Images: Alamy Stock Photos

A 2018 assessment of failures in past large-scale agriculture in the Top End (with a view to not repeating mistakes of the past) found that despite the constraints of soil type being known in some cases, suboptimal practices were still used and 'some soils risks were not considered or even ignored at the time', including secondary salinisation due to rising water tables [122].

Given the water and other requirements (e.g. soil, slope, access), the land in the Daly region identified as having high potential for cotton is mostly concentrated in the Douglas River, Stray Creek and Fergusson River catchments [123], which means potentially intense pressure on local water resources and native vegetation. An NT Government report on the effects of agriculture on soils in the Daly region identified risks of erosion, loss of carbon, crusting, acidification and nutrient loss [124].

The identified risks to soils of irrigated cropping in the Daly River region include erosion, loss of carbon and nutrients, crusting and acidification. Images: Jason Fowler

3.6. LAND CLEARING

Land clearing has accelerated in the NT to average more than 20,000 ha/year in the past 6 years and publicly stated proposals for cotton cropping will precipitate much more. The proposals on just 4 properties listed in the NT Farmers' business case for the construction of a cotton gin would require clearing of at least 80,000 ha and probably much more to allow for fallow periods and crop rotations.

The NT Government offers a fast-track approval process for clearing that precludes comprehensive assessment of impacts and consideration of cumulative impacts.

Large-scale clearing will cause biodiversity loss, degrade water quality and increase carbon emissions

Approvals for land clearing on pastoral properties have surged more than 10-fold in the past decade, rising from an average of about 1,000 ha/year in 2010 to 2015 to more than 20,000 ha/year in the past 6 years, for a total exceeding 120,000 ha (Figure 5).

A significant proportion of recent clearing is either explicitly linked to cotton developments or likely to be in anticipation of future cotton projects.

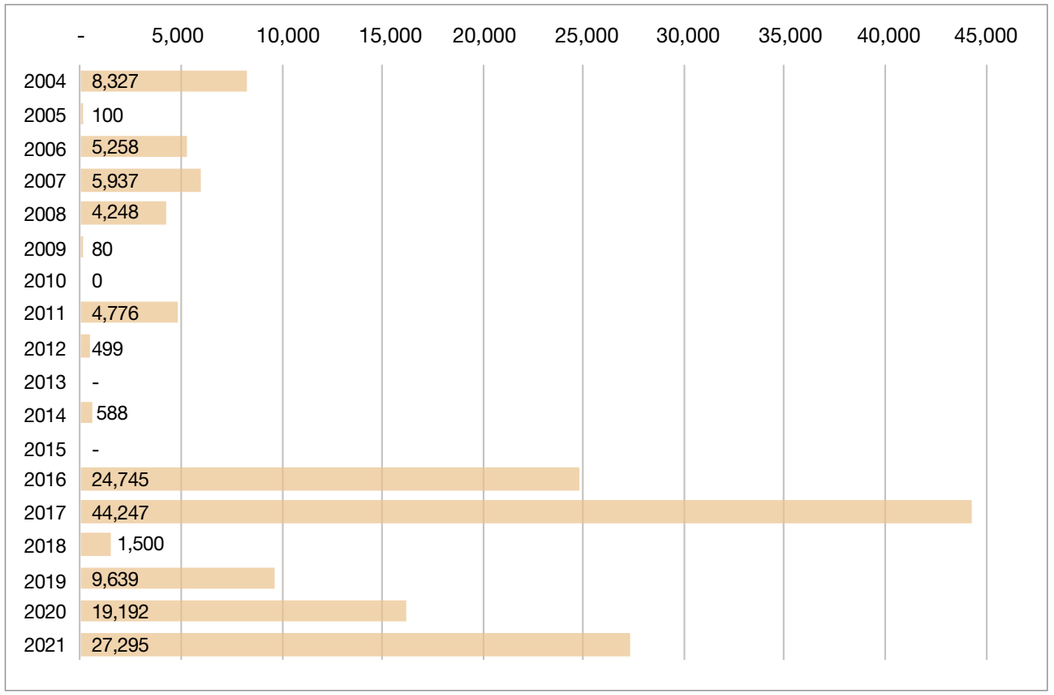


Figure 5. Permits for land clearing (hectares per year) on NT pastoral properties

Note: The 2021 figure includes areas for clearing applications under consideration as well as areas approved for clearing.

Cotton industry proponents claim that little additional land clearing will be required. The NT Farmers Association is promoting the idea that the industry can be developed 'on land that is already cleared and has been used for other crops' [125] and that there is 'enough cleared land already to kickstart the industry' [126]. But many properties mentioned in industry growth projections lack cleared land, and pastoralists with a publicly expressed interest in growing cotton have secured approvals or applied to clear about 20,000 ha since 2020 [127] (although not all has been specified as intended for cotton growing, Table 3).

Cotton-growing proposals for just the 4 properties (Auvergne, Newry, Manbulloo and Scott Creek) listed in the NT Farmers' business case for the construction of a cotton gin [1] would likely require clearing of at least 80,000 ha (Table 3). But, as discussed in section 2.1, the area of cleared land required for cotton cropping is likely to be 2–3 times the area under cultivation in any given year to enable crop rotation and companion planting. If dams are required, additional clearing of up to 40% of the area under irrigation may be required [9].

Clearing is of imminent concern in the Daly River and Sturt Plateau regions, where major cotton developments are proposed (Table 3, Figure 6). Already, more than 10% of the Daly Basin bioregion has been cleared [128] – 12% if all recent clearing permits are counted – and there are no controls in place to prevent more large-scale clearing. Despite government commitments to undertake bioregional assessments and development an integrated catchment management plan that would limit land clearing in the Daly region, clearing continues to be approved on a property-by-property basis, including by a new fast-track process that precludes comprehensive assessments of cumulative impacts and meaningful public consultation (Box 4).

Current cotton farming proposals are concentrated in a few subregions, intensifying the risk of environmental harm. The Daly Basin subregion is of particular concern, with the cumulative approval of more than 40,000 hectares of clearing on Tipperary station alone, and large cropping developments proposed on other pastoral properties. Other subregions at risk include Hermit Creek and Angalarri (see Figure 6).

Clearing in the NT has increased 10-fold over the past decade. This clearing is on Claravale Station, a property on the Daly River with high biodiversity values. Image: Environment Centre NT.

BOX 4. FAST-TRACKED APPROVAL FOR LAND CLEARING ON CLARAVALE STATION

The Claravale Station pastoral lease and an adjacent freehold property, Claravale Farm, are part of the proposed Douglas Daly Stage II development that would involve up to 60,000 ha of land clearing [2].

In 2021, the owners applied under a new fast-track process [92] to clear 998.5 ha (just below the 1,000-ha threshold) at Claravale Station and 700 ha on Claravale Farm. This process takes just 6 weeks and requires minimal assessment of environmental impacts, precluding consideration of the cumulative impacts of multiple clearing proposals. It also severely limits the opportunity for stakeholder input.

The clearing on Claravale station could impact at least 8 threatened species detected on or near the land in question [129]:

- ghost bat
- partridge pigeon (eastern)
- Gouldian finch
- pale field rat
- Victoria River squat snail
- Mertens water monitor
- Mitchell's water monitor
- a rare bladderwort.

The impacts on some species could be significant. For example, the partridge pigeon population on Claravale Station is at the outer edge of the species range and may therefore qualify as an 'important population' under federal environmental law [130].

This land clearing application highlights the risk that the NT cotton industry will develop in a piecemeal way, evading consideration of cumulative impacts.

Land clearing can destroy the habitat of wildlife already in decline, including these species, all unique to northern Australia, listed nationally as threatened, and potentially impacted by clearing on Claravale Station (Box 4). The eastern partridge pigeon (top left) has disappeared from the western, eastern and southern parts of its ranges over the past century and is now found in only about half of its former range in the Northern Territory's Top End. The Gouldian finch (bottom left) used to occur in large flocks of several hundred birds, but these days are sighted in tiny flocks in only a few locations across northern Australia. The ghost bat (right), numbering fewer than 10,000, has declined due to habitat loss, climate change and competition for prey from invasive species. Images: Daniel Zupanc / AUSCAPE (top left), Shutterstock (bottom left), Lochman Transparencies (right)

The impacts of large-scale land clearing include loss of biodiversity, soil erosion, degradation of water quality and riparian ecosystems, and carbon emissions [131,132]. Clearing destroys wildlife habitats, and as habitats become increasingly fragmented, populations of threatened species become more vulnerable to other threats, such as predation by cats and adverse fire regimes (exacerbated by gamba grass invasion), and lose the ability to recolonise suitable habitat [133].

Land clearing contributes to climate change. The predicted greenhouse gas emissions from the proposed clearing of more than 20,000 ha on Maryfield Station in 2018 were an estimated 2–3 million tonnes, 15–20% of the NT's annual emissions [134]. The NT Supreme Court revoked a permit for this clearing due to deficiencies in the assessment process [134].

In Australia, increasing evidence links deforestation from agriculture to weather extremes, including a hotter and drier climate, and increases in the duration and severity of droughts [135,136]. International research suggests that 'even localised clearing might ultimately switch entire continental climates from wet to arid' [137].

An NT Government report found that agricultural land clearing and subsequent use can 'dramatically increase surface runoff' and increases the conversion of rainfall to runoff by up to 25% [11]. Severe soil erosion in the Daly River Basin followed cropping in the late 1960s [12]. A recent major dust-storm in Katherine has increased residents' concerns about the potential impacts of large-scale land clearing on their town and its drinking water [28].

Soil disturbance and erosion from land clearing, tilling and rainfall have major riverine impacts. Removal of native vegetation alters soil and catchment hydrology, amplifies flood events and accelerates soil erosion, leading to increased sedimentation in waterways [115]. The mean annual soil loss for undisturbed areas in the Daly River catchment is an estimated 0–2.8 tonnes/ha while the rate for tilled areas is 1.9–8.1 tonnes/ha [115]. Other hydrological impacts include reduced groundwater recharge, reduced baseflow discharge and increased incidents of fish kills [11,12]. Likely impacts on riparian and wetland habitats from reduced recharge are noted in section 4.1. Wetland loss due to land clearance for cropping has been a major problem throughout eastern Australia [12].

Irrigated cropping has resulted in large-scale clearing in the Ord River region in Western Australia.

Water extraction can exacerbate the impacts of the dry season and drought on aquatic wildlife, including fish and crocodiles. In 2018, more than 40 critically endangered largetooth sawfish died in the Kimberley when they became trapped in drying floodplain pools (top).

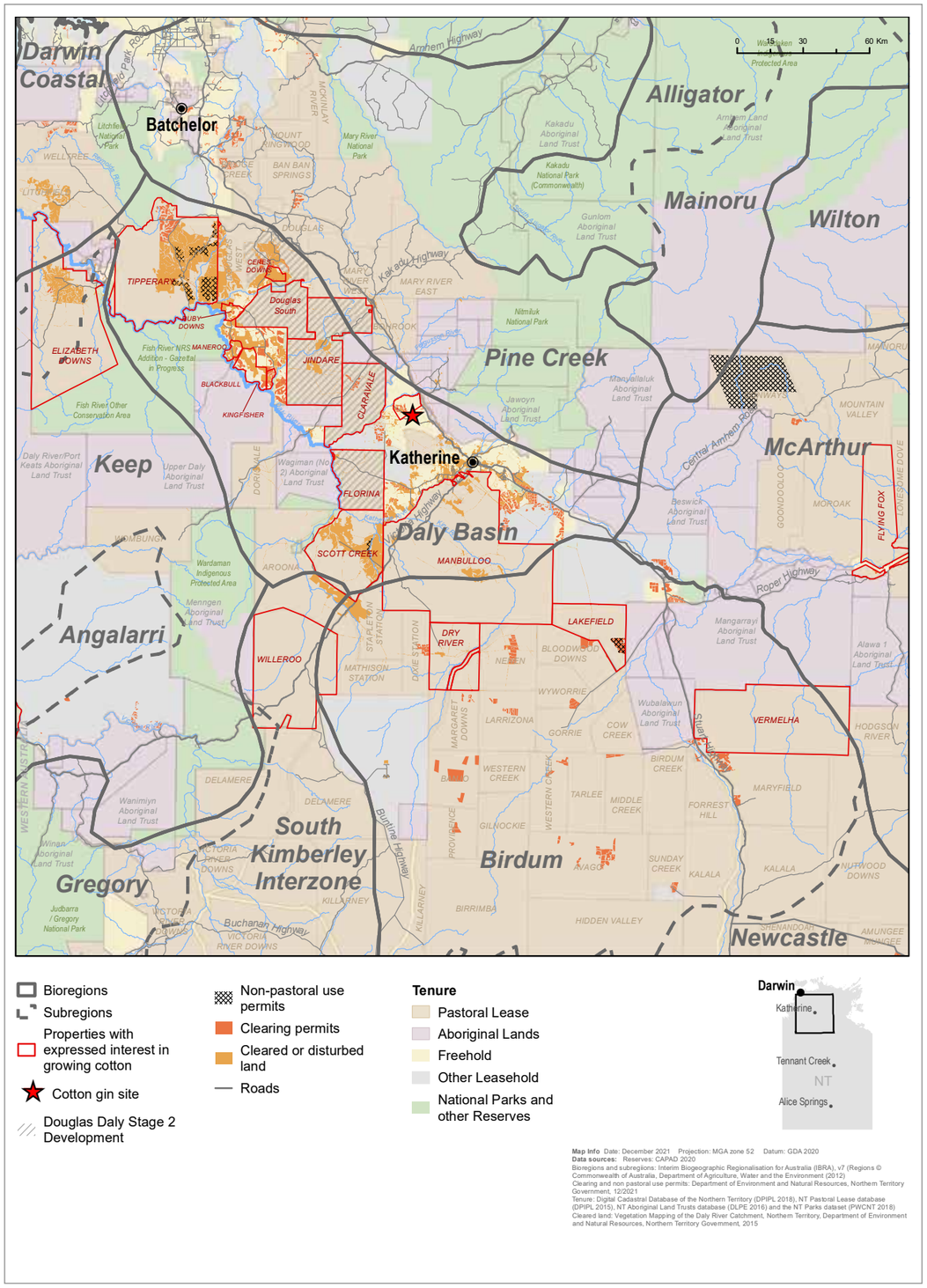


Figure 6. Land that has been cleared or disturbed or subject to a clearing permit in the Daly Basin and surrounding subregions and properties subject to potential interest in cotton cropping and therefore at risk of further land clearing

3.7. CLIMATE CONSTRAINTS AND CLIMATE CHANGE

The NT climate with its highly variable rainfall and extreme weather events does not provide stable conditions for predictable cotton yields.

Climate change will make difficult growing conditions even more challenging, with predictions of more-intense rainfall events, higher temperatures, higher rates of evapotranspiration and reduced groundwater levels in some aquifers.

Cotton is generally sold to futures markets abroad 3 years ahead of production, a strategy that requires reliable growing conditions to provide predictable yields. The NT climate provides the opposite – in particular, extreme weather events and highly variable rainfall.

The rainfall in regions where cotton farming is proposed is highly variable year to year and also over longer periods – there are runs of very wet and very dry periods in the climate record spanning several years to decades [54]. Variability over shorter periods, including the transition between the wet and dry seasons, can also be a problem. Dry periods of several days to several weeks in the middle of the wet season can significantly reduce yields of dryland cotton [11]. Even for irrigated crops, climatic events in northern Australia lead to the abandonment of about 10% of crops [32]. The rate of abandonment of dryland crops is likely to be even higher.

The weather affects access to fields, crop establishment and growth, early season weed control, insect pest pressure and transport to market [10]. The variability is likely to result in major reductions in predicted yield, lower prices due to reduced quality, and challenges for wet season cropping [10,29,138]. These pressures may lead to larger areas being cultivated or require more irrigation to ensure economic yields.

Climate change predictions for northern Australia include rising temperatures, a higher frequency of hotter-than-average days, an increase in the number and severity of extreme rainfall events and a rise in the potential evaporation rate [139]. Projections for the Australian monsoon are highly uncertain, with about half the models predicting an increase in rainfall and half predicting a decrease [140]. Some predictions are for severe decreases.

A 2008 CSIRO assessment of water resources in the Daly predicted median groundwater levels in the main carbonate aquifers would drop, reducing discharge by 14–22 GL/year, including from the Tindall Limestone aquifer into the Katherine River [6]. For the Oolloo Dolostone aquifer, the predictions varied considerably under different scenarios – discharge decreasing by up to 43 GL/year under an extreme dry climate scenario and by about 9 GL/year under the median scenario, and increasing by up to 60 GL/year under an extreme wet weather scenario [6].

Australian cotton production is likely to be impacted in complex ways by several aspects of climate change – reduced water availability, rising atmospheric CO_2, higher temperatures and higher vapour pressure deficit [141,142]. In eastern Australia, models mostly predict less favourable growing conditions and declining yields with a greater risk of extreme low yields [142].

Climate change impacts on the natural environment are likely to be severe – a 2021 study by 38 scientists found that the tropical savannas are one of 19 Australian ecosystems at risk of collapse – 'potentially irreversible change to ecosystem structure, composition and function' – due to global climate change and multiple regional human impacts [143]. Preventing land clearing and limiting water extraction will be essential to optimise the resilience of the savannas to climate change impacts [144].

In the unpredictable NT climate, relying on rainfall to sustain a cotton crop can be a risky strategy. Here is one failed dryland cotton crop (adjacent to an irrigated field).

3.8. IMPACTS ON FISHERIES

Significant water extraction is likely to compromise the productivity of important NT fisheries, particularly barramundi and prawns. Extraction of 20% of Daly River flows in some wet or dry seasons is predicted to reduce recruitment by 20–25%.

The discharge of waters from rivers is an important driver of the productivity of estuarine and coastal fisheries [145] and there are strong positive relationships between streamflow and catches of species of commercial and recreational importance, including barramundi and prawns, which can be compromised by water extraction [146,147]. Exemplifying the vulnerability of barramundi, a poor wet season in 2019 resulted in a 'failed recruitment event' and the lowest barramundi catch on record [148]. Other species were also badly affected – bony brim, mullet, tarpon and catfish.

The abundance of barramundi is regulated by 'a complex array of environmental factors and ecological processes' [149]. Recent scenario modelling predicts that water extraction from the Daly and Roper rivers in both wet and dry seasons could have 'strong' negative impacts on barramundi recruitment [146]. In the Daly, under scenarios of 20% extraction, declines in year-class strength were predicted to exceed 20% for dry season extraction in high-flow years and 25% for wet season extraction in low-flow and moderate-flow years [146]. Extraction of 40% of wet or dry season flows could result in declines of year-class strength by 40–50%.

Studies in NT rivers have identified 3 different barramundi life history strategies: some live mainly in coastal and estuarine habitats; others migrate into a river as juveniles and return to the estuary after a few years; and others remain in a river for many years, returning to the estuary only as large females [150]. Water extraction could alter the frequency of these life history strategies. If, as a result, more barramundi adopted the slower-growing, estuarine life strategy, 'the productivity of barramundi fisheries and their ability to sustain fishing pressure may be adversely affected' [150].

Most NT estuaries are in good condition, an increasing rarity around Australia. Large-scale cropping would compromise the health and productivity of estuaries and the fisheries they sustain. Image: Boyloso

The iconic fish of the north, barramundi, rely on natural flows, peak floods and good water quality to sustain their populations. They are highly vulnerable to decline if water extraction reduces recruitment or reduces populations of their prey species. Image: Shutterstock

Barramundi would also be impacted if lower flows reduced the abundance of their important prey species (fish and crustaceans) [149]. Conversely, altered flows could increase the predation pressure by barramundi on certain prey species [151]. Predicting such impacts is difficult because there is scant information about the flow-related ecology of most NT fish species [151]. However, there is increasing evidence that significant water extraction during any season is likely to impact some species – a recent study in the Daly found that fish spawning occurs 'throughout the hydrological phases, throughout the full extent of catchment and in differing hydrological classes' [152].

Water extraction is also likely to reduce prawn populations. Juvenile banana prawns rely on freshwater flows, which lower salinity, to force them to emigrate from estuarine nurseries to coastal waters. The sensitivity of prawns to altered flow regimes is indicated by the complete lack of juvenile prawns in the Ord River subsequent to its damming [153]. Scenario modelling for 3 rivers in the Gulf of Carpentaria predicts a 'proportional decline in banana prawn catch' if flows are reduced [147]. Overall profits for prawn fishers could decline by 7–12% for at least half of the time if the currently granted entitlements for irrigation and the planned allocations are extracted from these 3 rivers [154]. Water extractions for irrigation 'appear likely to impose financial impacts on the banana prawn fishery' under all flow patterns assessed. The greatest impacts would be in low-flow years, which is when catches would already be low.

4. THE VALUES AT RISK IN THE DALY RIVER REGION

Most proposals for cotton growing are currently focused on the Daly River region, an area of outstanding environmental and cultural values and economic activities dependent on healthy rivers.

The Daly River, shown here at its confluence with the Douglas River, is the Northern Territory's largest perennial river. It has extremely high ecological, cultural and scenic values. The Daly hosts more than 90 species of fish and 8 of the NT's 9 freshwater turtle species. Image: Alamy Stock Photo

The dire state of rivers in southern Australia – among them the Darling River, shown here at Bourke, upstream of a weir, with cotton fields in the distance – is one reason many NT residents don't want a major cotton industry in the north. Image: John Carnemolla

Past proposals for broadacre cropping in the region have sparked major concerns from residents about the impacts of irrigation, land clearing and use of agricultural chemicals [12,89,115,155]. There is considerable wariness that the mistakes of the Murray-Darling Basin will be repeated in the Daly River region [93].

In the early 2000s, efforts were made to halt development pressures until holistic land use planning and catchment management could be implemented [115]. The NT Government imposed a moratorium on major developments in the central catchment, pending completion of an integrated regional land use plan. In 2011, the government initiated integrated catchment management planning, but this was not implemented due to changes in government [90,156]. The lack of such planning leaves the catchment vulnerable to cumulative degradation as development pressures increase.

While the river catchment is considered to be generally healthy, some tributaries subjected to intensive agriculture, particularly Green Ant Creek, have already suffered degradation [12]. The Katherine River, the major contributor to the Daly River, is also under pressure due to cumulative agricultural impacts [12]. The Oolloo Dolostone WAP acknowledges that [54]:

> *Future development has the potential to place increased pressure on the river system through direct impacts caused by water extraction and from indirect impacts arising from native vegetation clearing and land use activities. This and the environmental and Aboriginal cultural significance of the Daly River, requires ongoing planning and community engagement to ensure that outcomes reflect social, economic, Aboriginal cultural and environmental values.*

In this section, we provide an overview of the environmental, cultural and economic values in the Daly region at potential risk from a cotton farming industry.

Policy decisions by the NT Government over the next few years about water licences and land clearing will determine the fate of rivers such as the Katherine (shown here) and their nationally and internationally significant wetlands. Image: Jason Fowler

4.1. NATURAL VALUES

The outstanding natural values at risk from cotton cropping include vast wetlands of national and international significance, a highly diverse biota with several threatened species and unique groundwater-dependent ecosystems.

The Daly River is the largest perennial river in the Northern Territory, with a dry season flow 5 times larger than any other NT river [157], sustaining vast wetland areas and unique ecological communities [108]. The catchment is recognised nationally and internationally for its high ecological, cultural and scenic values. In the upper catchment lies World Heritage-listed Kakadu National Park and Nitmiluk (Katherine Gorge) National Park. Extensive parts of the Daly and Katherine rivers are listed as nationally important wetlands [65] and the estuary and lower floodplains meet criteria for listing as a Ramsar Wetland of International Importance (based on the abundance of waterbirds) [65].

During the 8-month dry season, when surface runoff is negligible, inflows from a complex set of aquifers are continuous along most of the river length. These groundwater flows sustain abundant and diverse wildlife, including 90 fish species and 8 freshwater turtle species [158].

Species likely to be impacted by water extraction include the pig-nosed turtle, listed by the IUCN as endangered. The Daly River population is recognised as the largest, least impacted and most significant for this species [54]. But a small reduction in water flow (by 3 m3/second) would increase the probability of 'cease-to-flow' years (which do not occur under natural conditions) and potentially lead to substantial depletion of the local population [159]. Lower water levels would impede their movement between pools [54]. Other threatened species in the Daly potentially at risk from water extraction include the largetooth sawfish (listed by the IUCN as critically endangered) [160,161], the northern river shark (listed as vulnerable) [162] and the speartooth shark (listed as vulnerable) [163]. These risks have not been assessed, but recent research in the Fitzroy River in the Kimberley found 'a clear relationship between wet season volume and recruitment success' for freshwater sawfish, with substantial recruitment only recorded in 3 of 17 years, corresponding to the highest-flow years [164].

The critically endangered largetooth sawfish and the endangered pig-nosed turtle are are potentially at risk from altered water flows in the Daly River. Images: David Wachenfeld / AUSCAPE (left), Shutterstock (right)

Groundwater-dependent ecosystems in the Daly River Basin that could be impacted by water extraction (and water pollution) include the following riparian habitats, wetlands and stygofaunal communities:

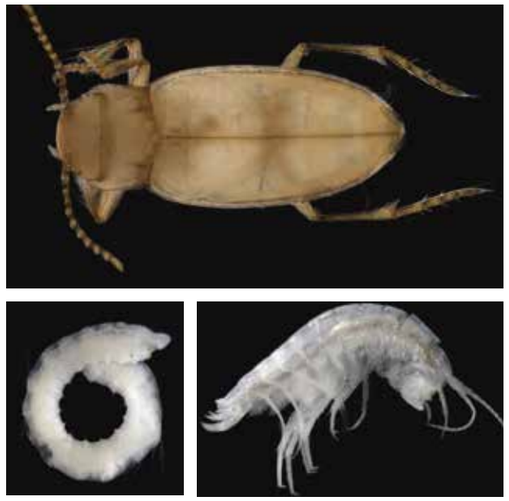
Riparian habitats: Groundwater is essential to maintain riparian vegetation during the dry season – it may account for more than 50% of the water transpired by riparian trees in the dry – and a reduction in groundwater levels below the tree root zone would likely change the composition of riparian habitats [165,166]. Maintaining healthy riparian vegetation is essential for protecting water quality, for it filters surface and subsurface flows, regulates water temperature (through shading), prevents turbidity and maintains bank stability [167].

In the rivers of the NT, including the Daly (shown here), riparian habitats are typically sustained during the long dry season by groundwater. Image: Nick Gouldhurst

Wetlands: The Daly supports a diverse array of wetland types on one of the NT's largest floodplains [168]. Government studies have predicted that a 5-fold expansion of intensive agriculture in the Daly River catchment is likely to alter the hydrological regimes for 5–15%, and possibly for up to 50%, of major wetlands, due to land clearance and water extraction [12].

Although the abundance of water during wet season floods in the Daly can give the impression of there being plenty of water to spare for irrigation, the peak floods are immensely important for connecting and sustaining wetlands like this. Image: Shutterstock

Stygofaunal communities: Animals such as crustaceans, beetles, worms and snails (and occasionally fish) often inhabit groundwater – and the NT is known to have a diverse range of stygofauna – but they have not been surveyed in the Daly River region [169]. Stygofauna typically have small ranges and are therefore likely to be highly vulnerable to loss of habitat through groundwater extraction.



Living in the perpetual darkness of underground aquifers, stygofauna are typically colourless and eyeless but have highly developed chemical and touch receptors. They rely on organic matter seeping from the surface to sustain bacteria, archaea and fungi at the base of their food web. Images: Jane McRae / Bennelongia

Flood waters are also very important in maintaining the rivers of the Daly Basin and floodplain ecosystems. A growing body of research indicates that peak floods play a vital role in sustaining fish breeding and long-term groundwater recharge cycles [6,9,115,170,171]. Swift-flowing water is likely to support unique ecological communities water [108]. An unusual insect, the sea skater Halobates acherontis, known from just one location 112 km from the mouth of the Daly, 'seems to prefer fast flowing areas' and therefore may be threatened by excessive water extraction [172].

The Daly River also has an important marine influence, with its discharge into the Timor Sea the second highest of any Australian river [168]. Unimpeded movements between freshwater and estuarine habitats and between different freshwater parts of the river are critical for maintaining healthy fish populations [9,65,170,171].

4.2. INDIGENOUS VALUES

Water is regularly identified as being of immense spiritual, cultural and economic importance to Traditional Owners. Degradation of river and catchment health could cause great hardship and distress.

For Jack Davies (left) and Robert Austral (right), who live on the Daly River at Nauiyu, the health of the river is of central importance to their lives: 'We fish this river year in, year out. We catch and eat barramundi, cherabin, shark depending on the season. We need a healthy river for healthy people. We must keep our rivers flowing so my kids and grandkids can live on the river like we have.' Image: Nick Gouldhurst

The Daly River Basin is a living cultural landscape, with around 12 Indigenous language groups having ongoing connections to the catchment [173]. Water is of central importance in Indigenous cosmology and belief systems [174] and many sites of great cultural significance are connected to water – rivers, creeks, gorges, waterfalls, waterholes, springs, billabongs, wetlands and floodplains [174]. Traditional Owners have customary obligations to keep the water clean, protect access to particular places along the river, maintain and pass on cultural knowledge, and share songs and stories involving the river [68]. These cultural values depend on maintaining a healthy river, including the linkages between the river and land, floodplains and aquifers [175].

> *Our culture is really important to us. Our culture sits in the river system... We believe the river provides for us properly, and for birds and animals. If something did happen, it's our life: it provides bush tucker for us traditional owners.*
>
> Marranangu representative on the Daly River Aboriginal Reference Group [173]

Maintaining the health of the Daly is also essential for the provision of safe drinking water to Indigenous communities and to sustain fishing, as well as the harvest of foods, fibres and medicines. The most commonly caught and harvested species in the Daly River are barramundi, sooty grunter (black bream), long-necked turtle, lotus lily, magpie goose and short-necked turtle [176]. The river is also central to a growing cultural tourism industry [144].

The creation of Aboriginal water reserves is a relatively recent addition to the NT water planning framework – as part of government efforts to create economic opportunities for Aboriginal people. Under this system, a proportion of water is to be reserved for economic use by Aboriginal landholders, proportionate to their landholdings. However, this policy is far from being realised in practice and is an economic incentive not designed to deal with cultural, ecological or social impacts.

Traditional Owners in the Daly River region (and elsewhere) continue to harvest magpie geese (the birds and eggs) and sacred lotuses (root tubers and seeds), as they have for millennia. Images: Alamy Stock Photo (left), Jean-Paul Ferrero / AUSCAPE (right)

Only recently have there been efforts to more fully incorporate Indigenous people's knowledge of and interests in rivers into environmental research and economic activities [173]. Water resource developments have typically neglected the social, cultural and economic impacts on Indigenous communities, and contemporary management processes still do not adequately involve Indigenous people in decisions fundamentally impacting their lives and cultures [173].

The creation of Aboriginal water reserves is a relatively recent addition to the NT water planning framework – as part of government efforts to create economic opportunities for Aboriginal people. Under this system, a proportion of water is to be reserved for economic use by Aboriginal landholders, proportionate to their landholdings. However, this policy is far from being realised in practice. In the Daly catchment, these water reserves are only partially provisioned or not provisioned at all (due to overallocation of aquifers) or have not been created because there is no water allocation plan (see Table 4 for their status).

Water can be said to be already fully used in supporting aquatic life and ecosystem functions and providing cultural, spiritual and recreational fulfilment for humans. Here, people enjoy a dip in Beswick Creek (Roper River region) during the Barunga Festival Image: Shutterstock

4.3. ECONOMIC VALUES

Valuable industries in the Daly River region depend on maintaining river and catchment health, particularly nature and cultural tourism and recreational fishing.

A substantial cotton industry in the Daly River Basin is likely to compromise economic activities that rely on river and catchment health, and potentially reduce water security for existing irrigators [144].

Nature-based tourism is a leading industry in the area. In the Big Rivers Region, which encompasses the Daly and Roper river regions, tourism contributed $156 million to the economy in 2017–18 and employed about 10% of the working population [177]. In 2019–20, tourism and hospitality sales in the Litchfield Council area alone generated $74 million in spending, and the total value added was $35 million [178]. Eleven tourist parks and 7 guided fishing tours operate on the lower Daly [179]. The tourism appeal of the Daly River region is largely focused on nature-based experiences (parks, rivers, fishing, hot springs) and cultural experiences [180].

Harold Sinclair, owner/operator of Sinclair's Daly River Fishing Retreat (top). 'This is one of the very few healthy rivers left and it's already earning big dollars for the Territory.' Tourists enjoy Bitter Springs at Mataranka, part of Elsey National Park.
Images: Nick Gouldhurst (top), Krystle Wright (bottom)

The Daly arguably offers some of the best fishing in northern Australia [181]. Recreational fishing is a major activity for both locals and tourists and a primary economic driver [182]. Fishing contributes an estimated $26 million/year, about 80% from interstate or overseas visitors [183]. It offers development opportunities for remote Indigenous communities [183]. Annual fish competitions such as the Barra Nationals, Barra Classic and the Million Dollar Fish generate significant investment in the region (and Darwin). The Barra Nationals generate over a million dollars in entry fees, and significant flow-on benefits to the regional economy and local communities [144].

River-centred cultural industries – art and cultural tourism – are important and growing sources of income for Aboriginal people. The Nauiyu Nambiyu Community Council and Merrepen Arts, near the Daly River, bring in millions of dollars of income [144].

Fishing is one of the NT's most popular recreational activities, bringing in about $26 million a year. The Barra Nationals (top, middle), held each year on the Daly River, is a catch-and-release competition that attracts many interstate visitors. At bottom, boats line up on the Daly River to fish the runoff from Bamboo Creek. Images: Barra Nationals (top), Robert Corbin, Valley Photography NT (middle), @WildVisits (bottom).

Cultural industries are an important source of income for Traditional Owners and rivers are important sources of inspiration. Here, Aboriginal artists demonstrate weaving at Merrepen Arts in Nauiyu (left), and paint magpie geese at the Barunga Festival (Roper River region) (right). Images: Jasmine Burke (left), Nick Rains / AUSCAPE (right)

The Barunga Festival, held alongside Beswick Creek (about 80 km south-east of Katherine), is one of the NT's largest and longest running events. Thousands of people travel there to camp and take part in music, sport, traditional arts and other cultural activities over the 3-day long weekend in June each year. Image: Nick Rains / Shutterstock

5. RECOMMENDATIONS

1. Place a moratorium on new water licences and allocations and cap extractions at current levels in the Daly and Roper river catchments.

Water is already overallocated in these catchments or being allocated without a water allocation plan and there is some evidence of ecological stress, especially in the Daly with the failure of barramundi recruitment in 2019 and springs at their lowest level in recorded history – stresses that are likely to be exacerbated by climate change. There is a high degree of scientific uncertainty regarding the water flow requirements to protect the environmental and cultural values of these catchments.

2. Protect vital ecological processes by prohibiting large-scale extraction of flood waters in the Northern Territory.

Tropical floodplains are highly biodiverse and productive ecosystems, and their seasonal inundation are primary drivers of ecological processes in large floodplain rivers such as the Daly. By compromising the connectivity between floodplains and other riverine habitats, large-scale extraction of flood waters, including from floodplains, would likely compromise vital ecological processes in complex, poorly understood ways. It would also reduce aquifer recharge. Given these risks, the lack of ecological knowledge of floodplain ecosystems, and the difficulties of regulating floodplain harvesting (as is evident in the Murray-Darling Basin), it should be prohibited in the Northern Territory.

3. In recognition of the limited science to inform decisions about large-scale cotton farming, apply the precautionary principle in a meaningful way to prevent irreversible harm.

The precautionary principle is a core feature of environmental law and policy to achieve ecologically sustainable development. Given the limited knowledge of the NT's aquatic ecosystems – their values and environmental and cultural flow requirements – and the impacts of current allocations and land uses, application of the precautionary principle should preclude large water allocations, floodplain harvesting and large-scale land clearing.

4. Undertake integrated catchment planning with a priority focus on maintaining the health of NT's rivers and protecting their environmental and cultural values. Accord strict protection to largely intact rivers.

In recognition that rivers, aquifers and floodplains are highly interconnected systems, whole-of-catchment planning is needed for NT rivers. Catchment planning should include consideration of protection measures for rivers and floodplains, and be driven by community desires to protect the environmental and cultural values of rivers and support local economies, rather than primarily by industry aspirations.

5. Enact reforms to prioritise the public interest and increase public trust in government decision-making.

To engender public trust in decision-making about land and water resources, the NT Government needs to enact reforms to require much greater transparency in decision-making, rigorous assessment processes and independent assessment bodies, community rights to appeal decisions on merit and genuine community engagement in planning.

6. Ensure that environmental impact assessment processes related to freshwater resources fully address cumulative and indirect impacts of proposed developments.

Recognising the interconnected nature of water resources, and the strong community interest in their protection, strengthen environmental impact assessment processes to ensure that any proposals for cotton growing or development of industry infrastructure are subject to comprehensive environmental assessments, including indirect impacts and cumulative impacts of multiple proposals.

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TERRITORY RIVERS

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