Chapter 5 -The Northern Territory

5.1. Introduction

Cotton has been studied as a wet season crop in the NT on several occasions over the past 100 years. The Australian Cotton CRC is currently involved in research that is evaluating dry season cotton grown at the NTDPIF Katherine Research Station. There are several regions in the NT that could potentially grow cotton although the current work at Katherine appears focused on future land and water developments in the Katherine-Daly region. The Katherine-Daly development aims to subdivide the Daly Basin between the Town of Katherine and the Douglas-Daly area 150 km to the north-west. Subdivision of pastoral leases and accompanying road development is to provide land for pastoral, dryland and irrigated crop development (see Map 5.1).

In late 1999, the NT Office of Regional Development commissioned Cameron Agriculture Pty Ltd to conduct a Cotton Pre-Feasibility Study. The final report was completed in June 2000 but has not been submitted to the NT Cabinet or released for public comment. The Pre-Feasibility Study report complements this scoping study, as its focus is on infrastructure and industry development issues. Where possible the recommendations from the Cotton Pre-Feasibility Study report have been incorporated (and acknowledged) in this report.

5.2. Cotton research and development in the NT

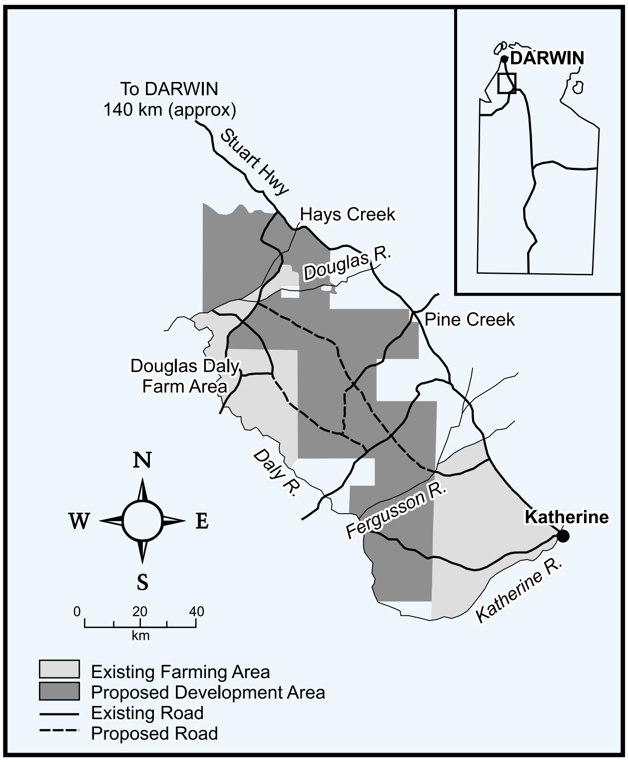
5.2.1. PRIOR TO 1946

Cotton was grown at Beatrice Hill near Darwin and probably at several other sites during this period. It is also possible that Maccasan traders introduced seed cotton to the Top End. These early introductions are believed to have been a source for some of the naturalised populations of *Gossypium* spp.

5.2.2. 1946 TO 1992

Cotton was evaluated by CSIRO during the period from 1946 to 1964 mainly at Katherine (Anon. 1959; Norman 1966). The crop was grown during the wet season as a rain grown low input crop that featured low rates of fertiliser due to a limited response, no insect control and low plant populations (1.4 plants/m^2). It is clear that the limited water holding capacity of the clay loam and sandy clay loam soils combined with a short growing season severely reduced yield potential and hence the response to management inputs. The average yield 1956 to 1964 for treatments that did not impede yield potential (e.g., zero fertiliser) was 956 kg/ha of seed cotton (337 kg/ha lint or 1.49 bales/ha). Crop establishment was considered a major problem for cotton on these soils under rain fed conditions. Soil surface sealing, high temperatures and moisture stress were the cause of poor establishment. Sorghum and peanuts were easier to establish than cotton. Bacterial blight (*Xanthonomas malvacean*) was severe in wet years and angular leaf spot was also reported.

MAP 5.1: *Proposed Katherine–Daly Development Area*



Insect pest species reported on CSIRO experiments at Katherine were *Earias huegeliana* (rough bollworm), *Pectinophora scutigera* (pinkspotted bollworm), *Pectinophora* spp (probably pink bollworm), *Dysdercus cingulatus* (cotton stainer), and several species of jassids. The latter were considered the most severe problem to dryland production (Anon. 1959).

The conclusions to the work by CSIRO 1946 to 1964, as summarised by Norman (1966) were: "*The economic prospects for dryland cotton in the Tipperary region are poor. On the other hand, on general hydrological grounds, groundwater reserves in areas of Tippera clay loam should be substantial. There is also a potential dam site on the Katherine River with an estimated 500,000 ac-ft storage*". However, more recently Wood and Hearn (1985) suggested rain-grown production merits further consideration in light of modern pest management, varieties and climatic assessment techniques. They also suggested that such production 'may not match the expectations of modern investors' because elsewhere in the world production of this nature is often a supplement to subsistence farming.

The NT Agricultural Branch attempted dryland cotton trials in the Douglas and Daly River areas, Katherine, Roper River and at Darwin River during the wet seasons of 1956 to 1965. Most suffered from lack of management due to isolation and difficulties with wet season access. (NT Agriculture Branch, Annual Reports 1956-65). The insect pests observed on these trials and the abundance of insects are summarised in Table 5.1.

The NT Agricultural Branch also evaluated irrigated cotton. Supplementary irrigation was evaluated at Douglas River in the wet season of 1963 to 1964 on a Blain soil (loamy-sand) and yielded between 1,357 and 3,135 kg/ha of seed cotton. Interestingly, dry season irrigated cotton was attempted at Darwin; the crop was successful although it was sown in August and harvested in early January. A dry season furrow irrigated crop was sown at Tortilla on 18 April 1961. Irrigation was scheduled at weekly intervals from flowering. The crop was stunted and it was thought that wet conditions on the duplex soil combined with cold nights inhibited crop growth.

The NT Agricultural Branch concluded, "*that the future for cotton growing in Australia lies in the large uniform irrigation areas – for example, the Namoi and the Ord*" (Mentz 1966).

5.2.3. 1992 TO 1994

For more detail on research conducted between 1992 and 1994 at Katherine see Yeates and Kahl (1995). To summarise, cotton was evaluated during the wet seasons of 1992-93 and 1993-94 using supplementary overhead irrigation. The need for a production system based on IPM was acknowledged, however small plot trials were conducted with the objective of determining what yields and lint quality were possible using high inputs of fertiliser and current husbandry practices. Where the growth regulator mepiquat chloride (MC) was applied small plot yields were good (7 to 10 bales/ha), although yields were 15 to 30% lower where MC was not applied. Lint quality was acceptable. The range of insects recorded in the trials was large and consistent with experience on the Ord during the wet season (Table 5.2).

TABLE 5.2: *Insect pests observed during the summer (wet) season at Katherine NT (1992-93 and 1993-94).*

Heliothis	-	*Helicoverpa armigera*
Native budworm	-	*Helicoverpa punctigera*
Pinkspotted bollworm	-	*Pectinophora scutigera*
Cluster caterpillar	-	*Spodoptera litura*
Rough bollworm	-	*Earias huegeliana*
Cotton stainer	-	*Dysdercus sidae*
Plant sucking bugs	-	*Graptostethus servus*
		Melanerythrus mactans
Redbanded shield bug	-	*Piezodorus hybneri*

TABLE 5.1: *Insects observed on wet season cotton in the Northern Territory 1946 to 1965*

SCIENTIFIC NAME	COMMON NAME
Mastotermes darwiniensis Froggatt (ISOPTERA: Mastotermitidae)	Giant northern termite
Oxycarenus arctatus (Walker) (HEMIPTERA: Lygaeidae) Note: the NT species is likely to be *O. luctuosus*.	Coon bug
Aulacosternum nigrorubrum Dallas (HEMIPTERA: Coreidae)	False cotton stainer also called the cotton plant bug
Aphis gossypii Glover (HEMIPTERA: Aphididae)	Cotton aphid
Earias huegeliana Gaede (LEPIDOPTERA: Noctuidae)	Rough bollworm
Earias fabis possibly = *E. vittella* (Fabricius) (LEPIDOPTERA: Noctuidae)	Rough bollworm = Northern rough bollworm
Pyroderces rileyi (Walsingham) (LEPIDOPTERA: Cosmopterigidae)	Pink cornworm
Anomis planalis (Swinhoe) (LEPIDOPTERA: Noctuidae)	Common cotton looper Possibly
Anomis flava (Fabricius) (LEPIDOPTERA: Noctuidae)	Cotton semi-looper
Tectocoris diophthalmus (Thunberg) (HEMIPTERA)	Cotton harlequin bug
(LEPIDOPTERA: Tortricidae)	Tortricid leaf-roller
Tonica effractella (Snellen) (LEPIDOPTERA: Oecophoridae)	No common name. This species has been recorded "tunnelling in the stems of cotton" in N. Aust.
Sathrobrota spp = old name for *Pyroderces rileyi* (Walsingham) (LEPIDOPTERA: Cosmopterigidae)	Pink cornworm
Dysdercus sidae (Montrouzier) (HEMIPTERA: Pyrrhocoridae)	Cotton stainer
Pectinophora scutigera (Holdaway) (LEPIDOPTERA: Gelechiidae)	Pinkspotted bollworm

The similarity of the insect pest fauna to that on the Ord during the wet season was cause for concern; hence winter (dry) season production was evaluated during 1994. The 1994 dry season was cold and the crop was exposed to 74 nights below 12°C. The coldest minima was 2°C and there were 17 minima lower than 7°C. Surprisingly all varieties tolerated the cold and produced good yields (8 bales/ha). The coldest night temperatures slowed the growth of the crop and appeared to cause flowers to abort. The early loss of flowers appeared to be compensated for by greater fruit retention late in flowering, after temperatures had risen. This had the effect of delaying maturity and picking occurred in early November. Fibre length was reduced compared with the wet season. More research was required to understand the effect of mid season sub-optimal temperatures on cotton growth and development.

5.2.4. 1995 TO 1999

This period saw an expansion from small plots to paddock size areas due, in part, to the involvement of Colly Cotton Pty Ltd. INGARD™ cotton varieties were also introduced during this period. Good yields were picked and there was a low requirement for insecticide (Table 5.3). All crops were grown on red earth soils known to be of low inherent fertility and structurally poor under intense cultivation. Due to high infiltration rates, flood irrigation is not practical and irrigation water must be applied using overhead or drip distribution systems.

Small plot trials were conducted into the following aspects of cotton agronomy: nitrogen fertiliser response using fertigation, variety assessment, sowing dates, and effect of irrigation water volume on yield. Much of this work is still in progress. Some early findings include:

- Crop nitrogen (N) uptake following fertigation was very high (> 90% of applied N) and yield peaked at 250 kg N/ha reflecting the low inherent N status of the soil.
- Using surface drip, yield peaked following application of between 5.8 and 7.6 ML/ha of irrigation water.
- There was a similar ranking of varieties to the Ord River; later maturing slightly indeterminate varieties yielded best.
- A mid to late March sowing date appeared optimal for yield.

Some monitoring of insect pests and beneficials was done, however the small areas sown limit the value of this data. There was generally a high proportion (63% to 83%) of *Helicoverpa* spp eggs parasitised by *Trichogramma* spp. There has been an increase in abundance of non-lepidopteran pests in recent seasons. Green vegetable bug (*Nezara viridula*), brown mirids (*Campylomma* spp) and redbanded shield bug (*Piezodorus hybneri*) being the most significant species.

The weediness of transgenic cotton is being investigated as part of the Kununurra based study described in Section 4.2.1.2.

The withdrawal of Colly Cotton, following their takeover by Twynam Cotton in late 1999, has left a significant gap in the research and development effort.

5.2.5. OTHER RELEVANT NON-COTTON RESEARCH

5.2.5.1. Insects

Entomological studies have been conducted at various times by the NTDPIF, CSIRO, the NT Museum and the NT Parks and Wildlife Service. Only the former two organisations currently employ full time entomologists.

A review of cropping related insect issues in north-western Australia stated '*In the context of new agricultural areas and new irrigation schemes, to predict if insects will be a greater or lesser problem as a result of irrigation is not possible with current information*' Allwood *et al.* (1985). In addition, the limited value of small plot trials in predicting insect pest problems at a larger scale was documented with the example of *Zygrita diva* on soybean in the Ord River Irrigation Area (Allwood *et al.* 1985).

The NTDPIF has a database of collections made on crops over many years. Most collections were made on horticulture crops although collections have been made on field crops and pastures. The database contains over 30,000 entries with host plant species listed (S. Smith, NTDPIF, pers. comm. 2000). Monitoring of *Helicoverpa armigera* and *Helicoverpa punctigera* was conducted during the 1980s and different trap designs were compared. Seasonal peaks occurred in the wet season

TABLE 5.3: *Summary of results from research at Katherine from 1995 to 1999. The number of Helicoverpa spp sprays are in brackets.*

YEAR	YIELD (B/HA)	INGARD™ VARIETIES	AREA SOWN (HA)	INSECT SPRAYS	IRRIGATION
1995	9.5 – 11.1*	No	<1	4(2)	Over-head
1996	10-12*	Some	1	9(6)	Surface drip
1997	10.5	Yes	1	4(2)	Surface drip
1998	9	Yes	4	2(1)	Lateral move & Surface drip
1999	7 – 8	Yes	18	5(4)	Lateral move & Surface drip

* = Hand picked

Simulating insect damage in crop compensation experiments, Katherine NT

Trichogramma pretosium, a critical beneficial insect, attacking a heliothis egg

during March at Katherine and Douglas Daly. Interestingly Savanna forest sites away from agricultural crops failed to detect moths (Strickland *et al.* 1983). The above data is mostly confined to the Darwin region and the Daly Basin. Collections were made along all major highways during the 1970s as part of a fruit fly host sampling survey. Insects other than fruit fly and their hosts were collected; this work was published internally by the NTDPIF. In 1999 non-crop insect collections were made as part of a quarantine risk assessment of military personnel involved in the Timor conflict, this work was confined to military use areas in Darwin and at Tindal RAAF base (Katherine).

Work by CSIRO has been ecological and focused on ants, beetles and grasshoppers and there is considerable knowledge of these species in the top end north of Katherine (Dr. A. Andersen, CSIRO Darwin, pers. comm. 2000).

5.2.5.2. Diseases

Northern disease surveys have been conducted by the Cotton CRC in 1999 and 2000. These surveys reported disease incidence on dry season crops and naturalised populations of *Gossypium hirsutum* (Nehl *et al.* 2000) in a number of locations in northern Australia. Tropical rust is widespread in the Northern Territory on naturalised populations of *G. hirsutum*, although no commercial varieties were found to be infected. However, given appropriate environmental conditions the disease may represent a potential threat to cultivated crops. Alternaria leaf spot was ubiquitous among all the cotton crops inspected. The severity of this disease was correlated with fruit load and/or nutritional stress, but was less severe than in 1999 when the cultivar Siokra L23*i* was widely grown. The 2000 report recommended:

- the investigation of the potential for native Malvaceae to harbour cotton pathogens
- the import of fuzzy cotton seed from the southern Australia represents a risk of Fusarium to the NT and quarantine needs to be addressed
- control of Alternaria leaf spot in the northern cotton areas should include planting the less susceptible cultivars and maintenance of good crop nutrition and rotation
- screening of commercial cultivars for tolerance to cotton rust should be undertaken.

5.2.5.3. Weeds

The evolution of the cropping system will be critical to weed management in this region. Conservation tillage systems developed for wet season dryland crops are being modified for dry season irrigated cotton (discussed further in section 5.3.2.1). The key components are mulch cover and zero-tillage. The mulch would be grown without irrigation over the wet season and killed prior to cotton being direct drilled into the dead or dying cover crop early in the dry season. There are three implications of this system for weed management:

- The species of cover and whether it could be a weed in the following cotton crop.
- Will the mulch suppress weed germination or change the species composition?
- The effect of mulch on residual herbicide efficacy.

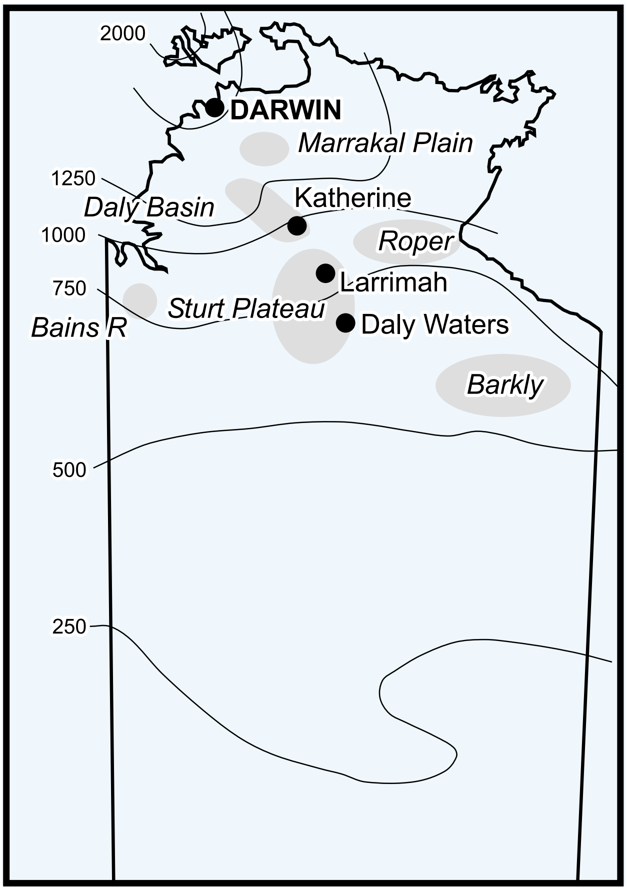
There has been little research aimed at weed issues. In 2000 a weed survey of seven irrigated paddocks in the Daly Basin and Sturt Plateau was instigated by NTDPIF.

The two fields at KRS were the only ones sown to cotton. The objective of the survey was to identify weeds occurring in irrigated crops and assess their potential as weeds in cotton. Obviously past cropping history, tillage system and current crop husbandry contribute significantly to the weeds observed.

5.3. Resource review

5.3.1. CLIMATIC POTENTIAL

Suitable areas for growing cotton must be hot enough during the growing season, and have suitable land and water. Research at Katherine has shown that it is possible to grow and pick a crop within the dry season despite mid season exposure to many minima below 11°C. Potential growing areas for winter season cotton in the NT fall into two groups, areas to the north and south (Marrakai to Daly Waters), and areas to the east and west (Kununurra to Roper Bar) of Katherine (Map 5.2). As rainfall declines from north to south hence the length of the dry season increases, however lower temperatures in the south will extend the growing season. There is less variation in rainfall from east to west. Distance from the coast effects temperature such that Katherine, in the centre, is coolest.



MAP 5.2: *General location of potential growing regions in the Northern Territory (areas are larger than the available irrigable land) and average annual rainfall (mm/yr).*

5.3.1.1. Temperature

The frequency of temperatures potentially detrimental to cotton growth and development increase from north to south (Figure 5.1a). There is less variability from west to east, distance from the coast being the major factor (Figure 5.1b). As discussed previously, except for delaying crop development and reducing fibre length, little is known of the effect of mid-season night temperatures on cotton growth between 11°C and 0°C. Therefore, it is not possible to extrapolate the effects of cold nights to regions with a greater frequency of cold nights than Katherine (e.g. Larrimah and Daly Waters).

Research at Kununurra and Katherine has found an average of 2,200 DDS_{12} (see Constable and Shaw 1998 for method of calculation) is required from sowing to picking during the dry season. Figure 5.2 shows that 2,200 DDS_{12} will be accumulated by mid October at all locations provided the crop is sown by March 15. Sowing on April 15 reduces the chances of a mid October pick to below 50% of seasons at Larrimah and Daly Waters on the Sturt Plateau (Figure 5.2b). A May 12 sowing would be picked after October 15 in the majority of seasons at all locations except Tortilla on the Marrakai Plain (Figure 5.2).

Long-term temperature records are almost nonexistent for the Marrkai Plain area. The majority of temperature data used in this analysis for this area was generated data provided by SILO and is for the former NTDPIF research station at Tortilla Flats where some records were collected. It is probable that the generated data underestimates the frequency of sub-optimal temperatures.

5.3.1.2. Rainfall

Due to superior trafficability, rainfall during the wet/dry transition is less likely to affect operations on the lighter textured soils that dominate the Daly Basin and the Sturt Plateau than the clay textured soils (e.g., Bains R). At Katherine, sowing had been possible by mid April in the majority of seasons using zero-tillage. Sowing operations are more sensitive to rain on clay-textured soils. Whereas at Kununurra, in four of the last six seasons, rain on clay soils has delayed sowing of the crop until after mid April.

Obviously the date of picking is influenced by the date of sowing (Figure 5.2). Picking prior to mid October has a low probability of rainfall at all sites (Figure 5.3). As expected rainfall variability is high. Except for the Marrakai Plain (Tortilla), all sites have a median rainfall of less than 30 mm prior to November 1 and only Katherine exceeds 30 mm by mid November. The later start to the wet season on the Sturt Plateau (Larrimah and Daly Waters) may compensate for cold temperatures extending the growing season. Roper Bar, with similar DDS_{12} to Katherine (Figure 5.2), has a lower risk of harvest rainfall (Figure 5.3).

5.3.1.3. Potential yield

Yield potential was high at all sites where sowing occurred prior to May (Figure 5.4). At Katherine and

FIGURE 5.1: *Potential NT winter growing areas: risk of cold shock. Median minima < ■ 11°C and < □ 12°C (1957 to 1999). Bars show range for 20% to 80% of seasons. (A) Sites east and west of Katherine and (B) Sites north and south of Katherine.*

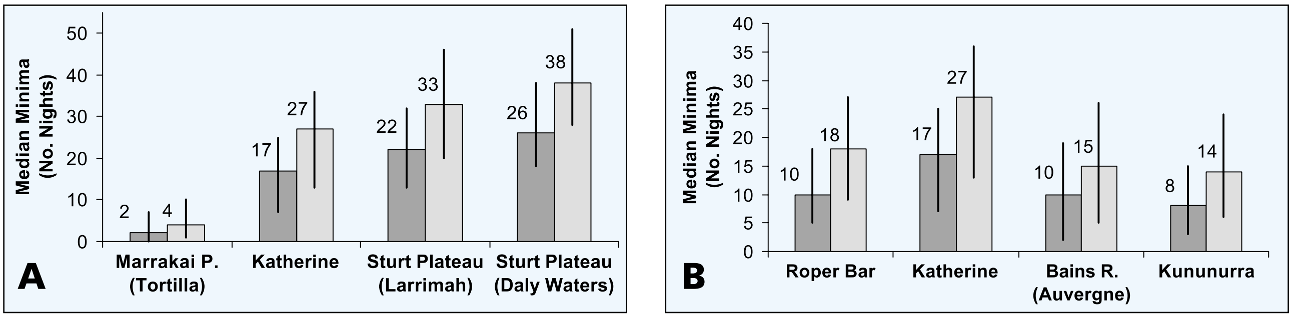


FIGURE 5.2: *Potential NT winter growing areas: seasonal heat units. Median DDS12 to October 15 (1957 to 1999) for March 15, April 15 and May 12 sowing dates. Bars show range for 20% to 80% of seasons. (A) Sites north and south of Katherine and (B) Sites east and west of Katherine.*

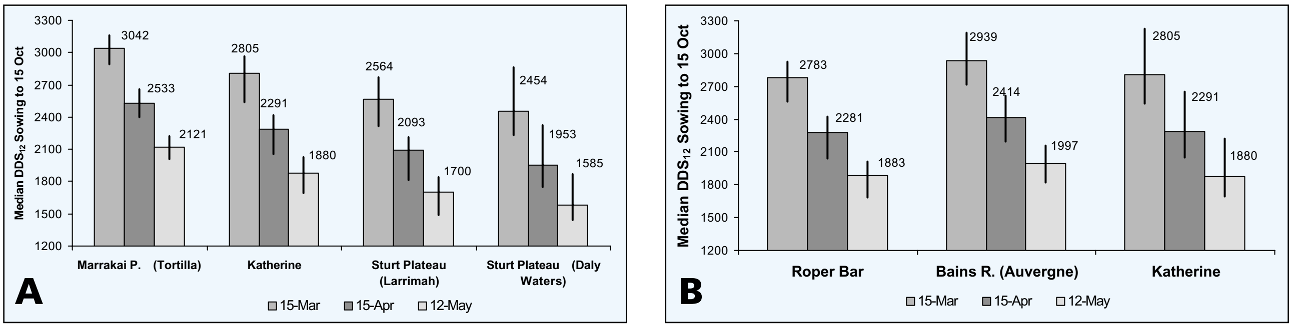


FIGURE 5.3: *Potential NT winter growing areas. Median fortnightly rainfall (1957 to 1999) over maturity and picking period. Bars show range for 20% to 80% of seasons. (A) Sites north and south of Katherine and (B) Sites east and west of Katherine.*

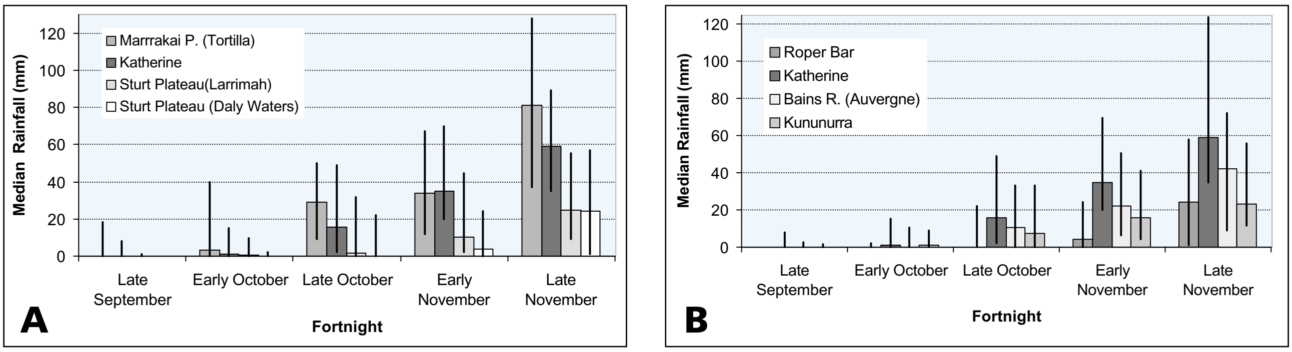
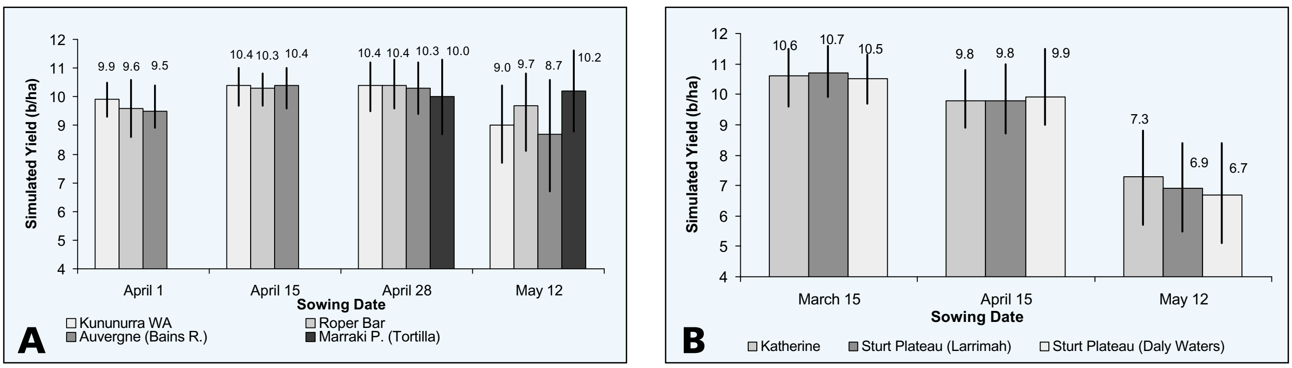


FIGURE 5.4: *Potential NT winter growing areas. Median potential yields simulated by OZCOT-APSIM (1957 to 1999). Bars show range for 20% to 80% of seasons. (A) Sites east and west of Katherine and (B) Sites south of Katherine. NB simulated yields assume 100% water allocation, no damage from insects, diseases, weeds, excellent crop management and prompt picking following defoliation.*

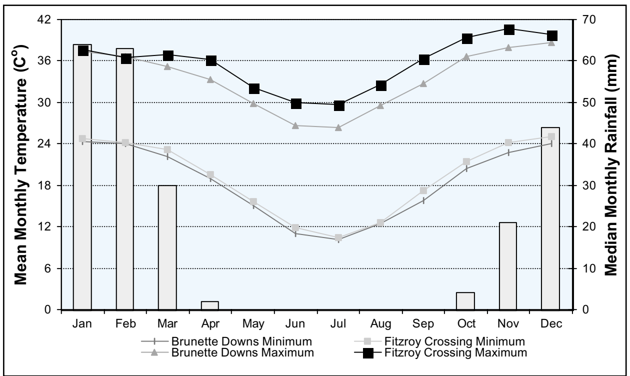


Kununurra, simulated yields were similar to the yields measured in well-managed small plot experiments. The sites with milder temperatures (Tortilla Flats, Roper Bar) appeared to produce the highest yields at a May 12 sowing.

5.3.1.4. Summer season sites

The Barkly Tableland could grow cotton, but low winter season temperatures may be problematical (Figure 5.5). Night temperatures during winter at Brunnette Downs (Barkly) are similar to Fitzroy Crossing (WA) but day temperatures are 5°C cooler on average. Sowing in February to early March appears feasible, as the crop could be sown on wet season soil moisture; it would avoid supra optimal temperatures during flowering and could be picked in the dry months of August and September. Before settling on a sowing date or the suitability of cotton to this region, detailed crop adaptation research is required in this environment.

FIGURE 5.5: *Mean monthly maximum and minimum temperatures for Barkly Tableland NT (Brunette Downs) compared with Fitzroy Crossing WA. Columns are mean monthly rainfall at Brunette Downs.*



5.3.2. SOILS AND LAND RESOURCE ASSESSMENT

Williams *et al* (1985) reviewed the soils and land suitability for the NT. Outside of the NT component of Ord stage II, the regions with a suitable climate where irrigated cotton may be grown are the Daly Basin, the Marakai Plains, the Sturt Plateau, the Bains/Victoria River, the Barkly Tableland, Legune/Keep Plains and the northern Gulf of Carpentaria (e.g., Roper catchment).

5.3.2.1. Daly Basin

Much of the Daly Basin (Tipperary Land System) has been surveyed at a 1:50,000 scale (see Aldrick and Robinson 1972). Prior to this Christian and Stewart (1953) had surveyed the Daly Basin at a larger scale. The land systems considered most suitable for dryland cropping are dominated by the red and yellow earths. There are approximately 170,000 ha of these soils in the basin (Williams *et al.* 1985).

In the early 1980s a more intensive land unit survey was conducted in the Douglas-Daly area (Lucas 1983, Lucas and Silversten 1983) to assist in farm development for the ADMA dryland farming scheme (See Cameron and Hooper 1985).

The Daly-Katherine development was initiated in 1994 to make more land available in the Daly Basin between Katherine and Douglas-Daly by subdividing larger holdings and constructing new roads. Consequently there has been increased activity in land and water resource assessment.

A key finding common to all surveys is the heterogeneity of land within the basin. Only about 10 to 15% of the basin will contain land systems favourable to cultivation and these tend to be fairly evenly distributed through the basin. Moreover, with respect to irrigation development, the arable soils are light textured (clay loams to sandy loams) and generally best suited to overhead or drip irrigation.

The red and yellow earths are usually well drained and deficient in many nutrients. Crop responses to nitrogen, phosphorous and zinc are well documented (see Jones *et al.* 1985, Day 1977, Myers 1978a,b, Jones *et al.* 1996). Nutrients such as sulfur, Cu, Mo and K often require supplementation (Jones et al. 1985). While the pH is neutral or slightly acidic, irrigation with high pH water from limestone aquifers has been observed to increase surface pH by 1 to 2 units and in extreme cases induce further nutrient deficiencies (P, Fe, Zn, Cu) (Yeates, unpublished data). Leaching of soluble nutrients (particularly N) during the wet season can be significant and can confound responses where N fertilisers are applied to crops that follow legume pastures (Dimes *et al.* 1996).

The red and yellow earth soils are inherently low in organic carbon, are highly erodable and very susceptible to surface crusting after disturbance (Arndt 1965; Mott *et al.* 1979). Consequently there has been a significant research effort into farming systems that incorporate soil surface management such as zero tillage (Carberry *et al.* 1996, Sturtz and Chapman 1996, McCowan *et al.* 1985). This work, however, has focused almost entirely on wet season crops and pastures. There has been limited research into soil surface management systems in dry season irrigated crops, although wet season cover crops such as bulrush millet (*Pennisetum* spp) and lablab have been evaluated (Smith *et al.* 1991). These are commercially grown in annual horticulture systems. As well as providing soil cover, bulrush millet is deep rooted and has been shown to be effective in recycling leached nutrients to the surface (Wetselaar and Norman1960).

The area of cracking clay soils is small and confined mainly to areas adjacent to streams where they tend to be inundated during the wet season.

5.3.2.2. Sturt Plateau

This is a featureless plateau of 250 m elevation that extends from approximately 50 km south of Katherine (15°S) to Tennant Creek. Of interest to agriculture is the area of the plateau north of Daly Waters incorporating the village of Larrimah (Map 5.2). Broad surveys (1:100,000) of the land resources of the area have been done (Day *et al.* 1986). There have also been some localised land system surveys at 1:100,000 and 1:50,000 scale (Day and Forster 1978, Day and Henderson 1985). The most arable soils are red earths, which are similar physically and chemically to those observed in the Daly Basin. Considerable areas (903,400 ha) of these soils were identified, however, due to the broad scale of the survey this was considered to be an over estimate.

5.3.2.3. Bains/Victoria River/Legune Area

Mapping of land systems in the early 1950s identified significant areas (about 79,000 ha) of land suitable for irrigation adjacent to the Victoria River and its tributaries the West Bains, East Bains and Angallari rivers (Stewart *et al.* 1970). There are considerable areas of the Ivanhoe Land System, as occurs at the Ord River Irrigation Area. There are also significant areas of cracking clay soils on the Legune Plain, however this area was considered less favourable due to low relief and potential salinity. The surveying by Stewart *et al.* (1970) is not sufficiently detailed for irrigation development as it was based on aerial photos with some soil sampling for validation. In 1998, Colly Farms commenced surveying the soils on Auvergne Station for potential use in irrigated cotton production (GHD 1998). A total of 59 test pits were dug to a depth of 3 m. Soil chemical analysis was made at 20 cm and 50 cm depths in 20 pits with 3 pits sampled at 2 m and was consistent with virgin Cununurra Clay at Kununurra. The exception being evidence of sodicity at ≥ 0.5 m in some pits. Electrical conductivity (ECse) was <1 in most pits indicating that inherent salinity was unlikely.

5.3.2.4. Barkly Tableland

Broad scale land resource surveys were conducted by CSIRO (Christian *et al.* 1952). There are large areas of black soils (Mitchell grass plains). The northern soils are considered similar to those occurring in the Ord River Irrigation Area, particularly those on the plains of the Gregory River (Qld) and its tributaries.

5.3.2.5. Marrakai Plains

This is part of the Adelaide River flood plain 100 km south of Darwin. Solodic–soloth soils are dominant (Olsen 1982; Story *et al.* 1969). These are duplex soils with a powdery surface underlain by dense heavy clay subsoil. There has been a considerable amount of research conducted by CSIRO and the NT government into rice and pastures on these soils (e.g., Chapman *et al.* 1985, Dasari 1996, Sawyer 1996, Diczbalis *et al.* 1996). Small areas of commercial rice are still grown in the Adelaide River area.

5.3.2.6. Gulf of Carpentaria

The land systems of the Roper River Catchment and the southern portion of the Gulf of Carpentaria have been described at a 1:250,000 scale by Aldrick and Wilson (1990 and 1992). A 1:20,000 survey of clay plains on Morak Station (80 km east of Mataranka) was conducted to assess the potential for irrigated crop production (Day and Wood 1976). St Vidgeon Station has also been surveyed (Fogarty 1984). There is a general similarity with other nearby NT land systems. Being further north the Roper catchment would have more favourable dry season temperatures for cotton than the southern Gulf. In the Roper catchment, there are small but significant areas suitable for irrigated cropping, these occur mainly on the clay plains. However, more intensive surveying is required with respect to future irrigation development.

5.3.3. WATER RESOURCES

No irrigation dams have been constructed in the NT. The Daly/Katherine, Victoria, Adelaide and Roper (and possibly the McArthur River) are the NT catchments most likely to support larger scale irrigated agriculture using surface water. Annual flows are high, for example 6,700 and 4,500 GL/annum for the Daly and Victoria Rivers at Gourley and Coolibah respectively compared with 3,639 GL/annum at Wagga Wagga on the Murrumbidgee (Bauer 1985b). However, seasonality of rainfall prevents year round removal of water, except for the Daly which runs permanently. Hence any irrigation development using surface water will require harvesting of wet season flows either by dams or off-stream storages. Preliminary studies of the area within a 150 km radius of Katherine suggest that there is potential to capture considerable quantities of irrigation water using off-farm storage e.g., sufficient to irrigate 8,400 ha from flow at Katherine town assuming 10 ML/ha/yr is required (DLPE 1999 unpublished data). Any development in the Adelaide River catchment will depend on dam construction, which is possible in about 10 years, to provide water for Darwin. There are two possible dam sites at Warri in the upper catchment and at Mt Keppler closer to the Marrakai Plain.

Groundwater is currently used to irrigate crops in the Daly-Katherine area and smaller areas on the Sturt Plateau near Daly Waters and Larrimah. The Daly-Katherine basin is underlain by three main aquifers; Tindal, Oolloo and Jinduckin. The Tindal and Oolloo limestone aquifers have the highest potential groundwater yields and may irrigate as much as 18,000 ha sustainably (DLPE 1999 Unpublished data).

The Department of Lands, Planning and Environment is currently reviewing these ground and surface water reserves of most of the NT, including Daly-Katherine Basin and Sturt Plateau. The objective is to calculate sustainable allocations for all users including irrigators.

5.4. Production system infrastructure issues

Cameron Agriculture (2000) reviewed ginning and handling, supply of inputs, power and skills training. Proximity of ginning facilities to major towns (Katherine, Kununurra and Darwin) would be favoured. Electricity would be too expensive for pumping water and diesel pumps would be required. Skills in irrigation management, agronomy and mechanical engineering would also be required.

5.4.1. RESEARCH INFRASTRUCTURE AND STAFF

There is good research infrastructure in the Katherine–Darwin area. NTDPIF maintain research stations at Katherine (formerly CSIRO), Douglas Daly and Darwin. There are irrigation facilities at all sites. At Katherine soils are of the Tippera family, which is a loamy red earth. At Douglas Daly irrigated soils are of the Blain family, which is a sandy red earth. A research agronomist (100%), entomologist (100%) (funded by Cotton CRC) and plant pathologist (20%) will be based at Katherine for the 2001 season. There are 2.5 full time technicians (one funded by the Cotton CRC). It is proposed that a further technician is to be funded by CRCD. Darwin and some Katherine based professionals use the facility at Douglas Daly. There is the equivalent of two full time professionals based in Darwin. However, cotton experience is limited at all locations.

CSIRO have an office and laboratory at Darwin. There is one professional funded by the Cotton CRC, the research coordination – liaison officer, who spends 25% of time on NT issues.

5.4.2. OTHER RELEVANT GOVERNMENT DEPARTMENTS

The NT Department of Lands, Planning and Environment is responsible for soil surveying, land system mapping and water resource planning and allocation (natural resource management strategies), land subdivision and granting of leases and titles and also oversee the EIS process and land use planning and procedures for development approval.

The Office of Regional Development pursues issues relating to new industry development and infrastructure issues.

The Parks and Wildlife Commission conducts flora and vertebrate fauna surveys.

5.4.3. TRANSPORT

Except for the Roper River, most potential growing areas have access to the Stuart or Victoria highways. Cotton requires bulky inputs (fertiliser) and lint could be exported via Darwin port, Asia being the major market. The proposed rail link with Adelaide will be of great value to a cotton industry.

5.4.4. OTHER

Most non-urban land is either under aboriginal ownership or is perpetual pastoral lease. The NT can resume land and reallocate more simply than other States (see Cameron Agriculture 2000 for more detail). Native Title issues will be important in land development.

The economic analysis by Cameron Agriculture (2000) suggested modest internal rates of return (about 6.5%) for cotton but importantly highlighted input/output knowledge deficiencies such as fertiliser requirement, volume of water used and its cost, weed control, and likely yields. Strong links between agronomic researchers and economists are essential.

There is need for a commercial partner to replace Twynam Cotton.

Development issues are coordinated by the NT Cotton Working Group, which is coordinated by Office of Regional Development. This group has representatives from most NT departments relevant to cotton development and the Cotton CRC. Cameron Agriculture (2000) recommended that this group be expanded to include land development and irrigation farming skills. To date this has not occurred.

Cameron Agriculture (2000) identified that locating a small-scale gin in the NT could be avoided if the Kununurra gin was accessible by overcoming WA quarantine restrictions.

5.5. Environmental issues

The Daly Basin is most advanced in the collection of relevant data prior to land development for agriculture. The bio-regional conservation plan and benchmarking flora and vertebrate fauna (not invertebrate) surveys are completed (Bruce Sawyer, NTDPIF, pers. comm., Dec 2000). There is a requirement for 30% of land to remain uncleared to perpetuity. Determination of water licencing and allocations is being worked through for each catchment / aquifer. Obviously all of the above will be required for the other regions.

The development of best management practices for the environmentally sound management of cotton based on local research and relevant external information is essential.

5.6. Political issues

- organised opposition to cotton (within environmental groups, amateur fishing, tourism and pastoral industry sectors)
- fear by NT politicians of voter backlash due to a poor public perception of cotton
- bipartisan political support for cotton is required.

5.7. Conclusions and recommendations

Small plot research at Katherine has shown that good yields of transgenic cotton varieties can be achieved in the dry season with minimal pesticide usage. However, it is clear that to fully assess the potential of achieving a sustainable and environmentally acceptable industry a significant amount of research and development is required. A strategic plan for cotton R&D over the next 5 years was drafted in early 2001 and accepted by relevant NT Government departments. This plan incorporates yearly objectives for production systems, natural resources, land availability, environmental impact, legislation, public awareness and economic issues. While it is essential that industry partners with a background in cotton be involved from the early stages, the R&D plan distinguishes a research phase from a commercial development phase, which could follow. Further pre-commercial cropping systems research is necessary but this must now proceed at a realistically large (commercial) scale.

An R&D plan for the NT aims to answer five broad questions:

1. Where are the best production sites? (i.e., what is the geographic limit of winter cropping in the NT? At the land title level, where are the arable soils with irrigation water available?).
2. Is cotton farming economic and how risky is it? (i.e., cost / returns, climatic and market risks).
3. Can production be sustained economically and ecologically? (e.g., will the Ord experience of 25 years ago be repeated?).
4. What is the environmental impact of cotton farming?
5. Can community perceptions of cotton farming be improved to the point of acceptance?

Many of the issues relating to the above questions are common to irrigation development irrespective of what crop is grown. Short to medium term (1 to 5 years) research and development needs and required methodology are summarised in Table 5.4.

TABLE 5.4: *Key NT research and development needs and methodologies/actions required.*

Research and Development Need	Methodology/Actions
Identification of suitable land and water	Collate soil surveys and, where needed, conduct surveys and geohydrological studies
Irrigation water allocation	Determine irrigation allocations, environmental flows, etc for potential growing areas
Integrated Pest Management strategy Area wide pest management strategy 2- Gene Bt registration & resistance strategy	Large-scale trials are essential Small-scale trials will support larger areas where needed Includes pest ecology of uncleared ecosystems
Disease management strategies / disease surveys	Large and small-scale trials. Disease surveys will include naturalised cotton plants. Focus on Alternaria and cotton rust and exclusion of fusarium. Nematodes on light soils
Crop husbandry and crop adaptation	Initially small plot experiments then move to large-scale. Preliminary work has identified drip irrigation as potentially superior to overhead sprinkler irrigation on light soils. Therefore small plot work required drip irrigation placement and emitter characteristics is required prior to research at a larger scale. Research into varieties, nutrition; weed management, growth regulation and defoliation also required. Crop adaptation studies to determine geographical extent of growing areas by determining effect of cold nights on growth, development, yield and fibre quality. Effects of rain on fibre quality grade. Crop adaptation studies have links with work in WA and Qld.
Wet season cover crops / rotations	Most evaluation in large-scale trials with some support work in smaller areas. Links with pest management. Includes measuring water use, deep drainage, etc.
Economic assessments of production practices	Pest management, agronomic management, rotations all require economic input to develop cost efficient scenarios
Quarantine protocol for interstate movement of people, machinery, seed and lint	Protocols developed by appropriate staff and negotiated with collaborating States. Relationship with WA very important for ginning of cotton from research areas.
Communication Strategy – includes interest groups, and cotton R&D team development	Should be developed in conjunction with all parties Cotton CRC, NTDPIF, etc and have the full support of respective management structures
Best Management Practices to minimise within site and offsite impact of cotton production	Developed from programs above and knowledge from elsewhere. Includes regional environmental management plan(s).

5.7.1. REGIONAL RANKING

This review has been able to broadly identify the regions where cotton could be grown on the basis of potential soils and water availability and climatic suitability. Table 5.5 synthesises this information and considers some research, infrastructure and political issues to give a ranking of each region for short to medium term potential for cotton development to occur within the next 10 years. No assessment has been made for the Barkly Tableland due to insufficient information.

In all areas suitable land and water requires identification. The question of crop adaptation also applies to all regions. The effect of mid season cold on crop growth, development and yield is not satisfactorily understood. It would also be advantageous to be able to quantify the relationship between rainfall and lint quality discounts (Table 5.4).

Table 5.5 suggests a trade-off between the more isolated locations with apparently favourable climates and resource availability (Roper, Bains Rivers) and locations closer to infrastructure with less favourable climates and soil and water resources (Daly Basin, Marrakai Plains).

The five-year R&D plan includes regional prioritisation of research effort. There are not the resources to focus on all regions simultaneously, the R&D list in Table 5.4 is simply too big.

- Where possible research needs to adopt a modelling approach to enhance extrapolation of research results (e.g. crop adaptation).
- Further 'desk top' studies are required ASAP. These should expand upon the analysis presented in this report with the objective being further regional prioritisation before involving a commercial development partner. Additional analysis could include a review of regional land ownership issues and overlaying this with available soil and water data. Obtain more detail on regional development activities e.g. non-agricultural developments that may improve some infrastructure constraints.
- Crop adaptation (including pest issues) in the northern Daly basin should be addressed as a matter of priority.
- Closer linkages with groups conducting soil surveying and water allocation studies.
- Meet with community and landholders in these areas to gauge their interest and willingness to participate.
- Soil and water resource issues are more important in the Bains Rivers area because successful transfer of production systems research from the Ord River is highly probable.
- Collection of additional temperature data in areas lacking data (e.g. Auvergne Station near the West Bains River, Marrakai Plains, Roper catchment).
- Strategic trapping of insects.
- There is little point doing much crop research in the Adelaide River until the timing and exact location of dam development is known. The only exception would be some small plot work to confirm cotton can be grown on the duplex soils of the Marrakai Plain.

5.7.2. NT ISSUES FOR THE AUSTRALIAN COTTON CRC

- A commercial partner to replace Twynam Cotton is required in the near future.
- A clear indication for bipartisan political the support for cotton development should be sought by the Cotton CRC.
- The Cotton CRC has a considerable contribution to the NT given the likely development timeframe (Table 5.5). In the short-term (three years) further support from the Cotton CRC could be in providing short-term research skills for specialised tasks, for example, skills in drip irrigation. These researchers may be from the Cotton CRC or other organisations and this work can form part of their broader projects. Assistance with training is another area.
- The Cotton CRC can play a valuable role by ensuring good communication with other Cotton CRC activities in northern Australia. Links with researchers at the Ord River are particularly important for future developments on the Bains Rivers.
- Broaden the NT Cotton Working Group to include more irrigation/cotton/land development expertise or create new group.
- Ongoing open dialogue with interest groups is critical.

TABLE 5.5: *Regional comparison for dry season irrigated cotton development. Ranking is based on the likelihood of completing adequate R&D and commercial development occurring within 10 years*

Region	Minimum Development Timeframe	Advantages	Disadvantages	Ranking
Katherine - Daly Basin	5 to 10 years	- Government driven land sub-division and road development - Soils and water surveying well advanced - Environmental benchmarking advanced - Research facilities - Major towns - Southern end is site of current cotton research - Existing irrigation development	- Community objections - fishing - Storage of water and cost unclear - Water distribution cost and method not known - Heterogeneity of soils - not one large block - Crop adaptation northern end unclear - Insect pest dynamics ecology not well understood - River has high banks	Medium-high
Bains Rivers	5 to 10 years	- Recent commercial interest - Location of suitable soil and water resource known - Similarity of soils and climate to Ord - Transfer of Kununurra production technology - Proximity to Kununurra for technical and some infrastructure support - Benefits to Timber Creek	- Detailed soil surveying, geohydrological, and environmental impact studies required - Water allocation to be determined - Quarantine may prevent ginning at Kununurra - Lack of a major town for ginning infrastructure - Relatively isolated and would need to import experienced staff - Perception that benefits > for Ord than NT	High-medium
Roper River	10 years	- River has low banks - Apparent land and water availability - Climatic suitability - The region will benefit from greater economic diversity	- Isolation / lack of infrastructure - Detailed soil surveying, geohydrological and environmental impact studies required - Water allocation to be determined May need local R&D (e.g., insects) - Lack of a major town for ginning infrastructure - Relatively isolated and would need to import experienced staff	Medium
Marrakai Plains	10 to 12 years?	- Possible dam - Large areas of identifiable land - Proximity to Darwin - Potential for rotation with rice	- Dependent on the dam, 10 years off - Longer wet season so length of growing season important - Inadequate temperature data to determine length of growing season - Crop growth on duplex soil is unknown - Will require local R&D - insects, agronomy	Medium
Sturt Plateau	5 to 10 years	- Land available with suitable soils - Less objections by fishing lobby, as not near major waterway - Extrapolation of some R&D from Katherine	- Water resource may be limited so area may be insufficient to support gin - Water distribution cost and method not known - Low temperatures - crop adaptation - More detailed soil and water resource surveying required - Insect pest dynamics ecology not well understood - Relatively isolated and would need to import experienced staff	Medium-low