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Cotton Research and Development Issues in Northern Australia

A Review and Scoping Study

By

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FOREWORD

Northern Australia has always presented a challenge for agriculture. With a different environment, widely distributed resources and infrastructure and a small population, Australia's north has seen the demise of several large scale agricultural projects. The failure in the early 1970s of a cotton industry in the Ord River Irrigation Area bears testament to these natural challenges.

The Australian Cotton Cooperative Research Centre was established in 1999 to coordinate a program of research, education and adoption focussed on both sustaining the Australian cotton industry and exploring the feasibility for expanded production in northern Australia. Various parts of northern Australia were chosen for thorough feasibility assessment because of climate, significant water resources, past experience and the availability of a suite of new technologies, which we believe enhance prospects for sustainable farming systems.

We are keenly aware, however, of the fragility and environmental values of northern Australia. Consequently our assessments and research must first demonstrate that cotton production can be achieved in an environmentally and economically sustainable way. If this can be achieved then significant social and economic benefits could flow to northern communities.

The Review and Scoping Document seeks to draw together all the available resource and research information relevant to a possible northern cotton industry. The document is a critical planning instrument for the Cotton CRC, the industry and community stakeholders wishing to identify key research needs. The document will guide future research directions of the Cotton CRC and help identify gaps where coordination with other agencies is necessary. Importantly the document also provides a resource of factual information to support widespread community interaction and discussion, essential if a northern cotton industry is to succeed.

Gary Fitt
Chief Executive Officer
September 2001

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EXECUTIVE SUMMARY

i) Background and Objectives

The potential availability of land and water combined with new knowledge and production technology has stimulated recent interest in growing cotton in northern Australia. Since the mid 1990s research and development and, in some cases, test farming have been undertaken near Broome and the Fitzroy River, at the Ord River Irrigation Area (ORIA) in Western Australia, at Katherine and Douglas-Daly in the Northern Territory and near Richmond and Bowen in northern Queensland. When the Cooperative Research Centre (Australian Cotton CRC) commenced in July 1999, it was thought it had an important role in coordinating and focusing these activities toward sustainable development objectives. The Australian Cotton CRC established a new program, 'Growth into northern Australia', with strong linkages to the other Cotton CRC programs in established growing areas. The philosophy of the Australian Cotton CRC in northern Australia is to assist to develop region-specific production systems, which are economically viable, but minimise chemical inputs and environmental impacts. The Cotton CRC will collaborate with other agencies in each region and ensure conservation of native fauna and flora is accommodated in development and management plans.

There is currently no commercial cotton production in northern Australia. The failure of the previous attempt at the commercial production in the ORIA during the early 1970s, due to uncontrollable insect problems, and the cessation of cotton farming in the Bowen region at about the same time for economic reasons, should serve as cautionary reminders for future attempts.

General Aims of the Scoping Study.

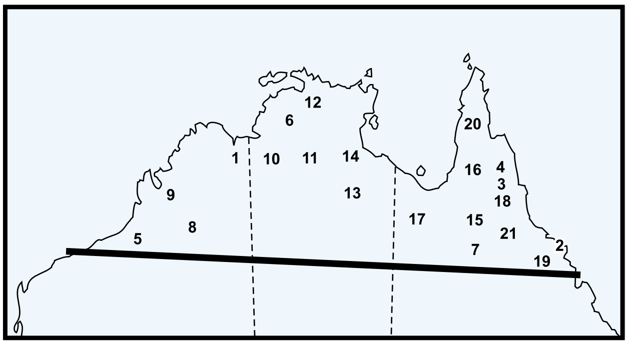
Work on the scoping study started in early 2000 to provide a reference document to assist with research planning in northern Australia. The scoping study has the following aim:

> ***To detail the status of current and past research activities and important production and environmental issues faced by each region in northern Australia that are relevant to cotton production.***

ii) The Study Region

The study region, defined as the area north of the line from 21°S on the east coast to 20°S on the west coast, is immense and represents about 30% of the land area of Australia (Map I). The potential land and water resources of the selected region for the scoping study are large. The Gulf of Carpentaria and the Timor Sea drainage divisions alone account for 43% of Australia's annual surface water run-off compared with 6% for the Murray-Darling. Groundwater resources are also significant.

MAP I: *The study region is north of the line and numbers are the location of the 21 catchments/regions reviewed.*



iii) Methodology

The scoping study reviews issues relating to cotton development in 21 catchments/regions across northern Australia (Map I). These catchments/regions can be categorised in terms of their irrigation development status and whether cotton is being researched (Table I).

Issues relating to Broome, the ORIA, the Katherine-Daly Basin and Richmond are considered in greatest detail, as these are the current sites for research into cotton (Map I, Table I). For each site a review is made of past cotton production and relevant non-cotton research and development, climatic potential, soil and water resource data, infrastructure, key environmental and community issues, and region specific recommendations made. A further 17 regions/sub-catchments that may have potential to grow cotton are reviewed using the same broad headings but at a level of detail sufficient to flesh out the key issues and provide guidance for future region specific research and development needs. In addition past attempts at large-scale agricultural development in northern Australia are reviewed.

The climatic potential for cotton is reviewed for 19 of the 21 regions shown in Table I. This analysis involves estimation of growing season length, as affected by sowing date and likelihood of rain at harvest, calculating the frequency of frost and sub-optimal temperatures and simulation of potential yields using the OZCOT-APSIM model (Hearn 1994, McCown *et al.* 1996).

iv) Outcomes

Outcomes are grouped in 5 categories:

- Lessons from past R&D aimed at large-scale agricultural development in northern Australia
- Physical resources and climatic suitability
- Cotton R&D issues common throughout northern Australia
- Cotton R&D issues specific to the regions of current Cotton CRC involvement
- A suggested approach to cotton R&D in regions undeveloped for irrigated agriculture.

TABLE I: *Irrigable areas reviewed and their development status. * = site of cotton R&D in 2000.*

DEVELOPMENT STATUS	MAP REFERENCE	CATCHMENT OR REGION	Town (s)	DRAINAGE AREA
1. Existing (non cotton) irrigated cropping and / or potential for expansion	1*	Ord River Irrigation Area	Kununurra	Timor Sea
	2	Bowen/lower Burdekin	Bowen, Ayr	Coral Sea
	3	Atherton, Mareeba - Dimbulah	Mareeba	Coral Sea
	4	Lakeland Downs	Laura/Mareeba	Coral Sea
2. New areas under develop-ment or evalua-tion	5*	La Grange Sub-basin	Broome	Indian Ocean
	6*	Daly Basin	Katherine	Timor Sea
	7*	Flinders	Richmond	Gulf
3. Undeveloped for large scale irri-gated cropping	8	Fitzroy River	Fitzroy Crossing, Derby	Indian Ocean
	9	Lennard River	Derby	Indian Ocean
	10	Bains/Victoria rivers	Timber Creek, Kununurra	Timor Sea
	11	Sturt Plateau	Larrimah, Daly Waters	Timor Sea, Gulf
	12	Adelaide River, Marrakai Plain	Darwin, Adelaide River	Timor Sea
	13	Barkley Tableland	Tennant Creek Brunette Downs	Gulf
	14	Roper River/north?western Gulf	Roper Bar, Boroloola	Gulf
	15	Gilbert/Einasleigh	Einasleigh, Georgetown	Gulf
	16	Mitchell/Lynd	Kowanyarma, Parmaville	Gulf
	17	Cloncurry/Corella/Leichhardt/Gregory	Cloncurry	Gulf
	18	Upper Herbert	Mt Garnet, Ravenshoe	Coral Sea
	19	Bowen/Broken	Collinsville	Coral Sea
	20	Cape York(e.g., Kendal, Holroyd, Ed-ward, Archer, Colman, Watson rivers)	Coen, Weipa, Pormpuraaw, Aurukun	Gulf/Coral Sea
	21	Upper Burdekin	Charters Towers	Coral Sea

Lessons from past R&D aimed at large-scale agricultural development in northern Australia

- A systems approach is required with clearly defined goals understood and accepted by all participating organisations.
- Agricultural researchers alone cannot be expected to provide an adequate basis for commercial success as small-plot research is quickly subject to diminishing returns and resources are then best allocated to large-scale trials or pilot farms for limited periods.
- Infrastructure issues must be addressed and action taken by the time commercial development starts. However, during the large-scale trial phase lack of infrastructure will impact on costs and such costs must be borne as part of the evaluation.
- Large-scale trials can provide data for environmental impact assessment, the development of guidelines for sustainable management practices and best practices for management of chemicals and other inputs.
- Ease of importation of production technology and skills are important factors in the feasibility assessment and industry establishment phase. (e.g., sugar at the ORIA).
- More successes with annual cropping have been with dry rather than wet season production (e.g., annual horticulture). Successful perennial crops are also harvested during the dry season.
- The variable climate necessitates a modelling approach to research outcomes, i.e., three year studies may not be representative of the seasonal range.
- Lack of capital combined with too rapid movement to commercial production (without adequate research) has resulted in many failures.
- Failed developments have provided initial capital (land) for subsequent successful industries, (e.g., Ord Stage I, Lakeland Downs).
- NT-Kenaf is a good model for a fibre crop R&D feasibility study.

Physical resources and climatic suitability

Physical resources

Outside the ORIA, the Katherine-Daly Basin and the established cropping areas in north Queensland (Table I) soil surveying and land resource assessment at too large a scale for irrigation development without further surveying. Moreover, with the exception of established irrigation areas in north Queensland and the ORIA (under review), water-licensing arrangements have not been determined. In some areas (e.g., Cape York) there is insufficient data to calculate these flows. This is because all watercourses are strongly seasonal and there is considerable between and within season variability in stream flow. In many areas (notably Cape York, the Katherine-Daly Basin and Sturt Plateau) the interaction between surface and groundwater systems requires further research.

With the exception of some of the established cropping areas in north Queensland the majority of the arable soils are similar. That is, red and yellow earths and poorly drained cracking clays all having moderate to low inherent fertility, which implies similar issues for crop nutrition, soil surface management and irrigation distribution system. Areas where inherent salinity occurs can be broadly identified from information currently available.

Climatic suitability

Climatic analyses suggested that cotton could be grown in all 21 regions reviewed in this study (Map I, Table I), provided that water and arable soil are available. However, these analyses found several limitations in the tools used to assess the climatic potential of northern Australia for cotton:

1. The current tools cannot predict the effect of rainfall or temperature on lint quality, which is an important component of economic return in an environment where rainfall is strongly seasonal.
2. The effect of mid-season temperatures between 11°C and 0°C on cotton yield is unknown. Hence it was not possible to determine the geographic range of potential winter growing areas.
3. A lack of long-term climatic records in many areas.

Resource development and land tenure

Many areas that are undeveloped for irrigated farming are leasehold and require a change to land title before irrigated cropping could occur. This will affect the timeframe for the development of irrigated agriculture (if it occurs). Moreover, land title is still being resolved in much of northern Australia.

Cotton R&D issues common throughout northern Australia

A sustainable production system with minimal chemical usage

This is a common objective to all potential growing areas and with local tailoring will have the following R&D outcomes:

- A pest management system that incorporates integrated pest management, area wide pest management, 2-gene Bt registration and associated resistance management strategy.
- Disease management/prevention strategies (Alternaria, cotton rust, Fusarium)
- Incorporation of physiological understanding of plant compensation from insect damage into insect pest management practices.
- Irrigation practices and distribution systems that maximise water use efficiency and minimise environmental impacts.
- Integrated weed management practices that minimise the use of residual herbicides and chemicals, which pose a higher risk to the wider environment.
- Rotations and cover crops incorporating tillage and soil surface management practices that are compatible with pest management strategies, maintain soil structure and prevent erosion and run-off.
- Selection of varieties adapted to the environment and compatible with the management systems.

The impact of summer and winter cropping on Helicoverpa armigera migration

There is a potential for a mixture of winter and summer cropping within close proximity, particularly in north Queensland, which may create an opportunity for migration of *Helicoverpa armigera* between growing seasons, thus increasing the risk of resistance to insecticides and the Bt proteins.

Cotton R&D issues specific to regions of current Cotton CRC involvement

Western Australia – Ord River and Broome

There is a significant commitment by many organisations to cotton R&D in the Kimberley region of WA. Both the west Kimberley and Ord River appear to have considerable potential as cotton growing regions.

Future commercial development at the Ord River will depend greatly on the outcomes of the current feasibility assessment for Stage II (33,000 ha) conducted under the Memorandum of Understanding (MOU) between Wesfarmers/Marubeni and the WA Government. The outcomes of R&D conducted in the Ord River Irrigation Area could be extrapolated to nearby clay soil areas with similar climates, e.g., Bains River (NT) and Fitzroy River (WA).

In the west Kimberley more than 20,000 ha could be grown using groundwater reserves south of Broome without any additional water from the Fitzroy River. Future commercial development in the west Kimberley will also depend on the outcomes of feasibility assessments under the MOU with the WA Government and land tenure resolution.

Given the significant in-kind contribution to the Cotton CRC efforts in WA by collaborating member and non-member organisations, and the coordinated approach to irrigation development via the Western Australian Government's MOU's, a greater contribution by the Cotton CRC in WA is well justified.

Northern Territory

During the 1960s cotton was previously researched as a low-input wet season crop. There are several regions in the NT that could potentially grow irrigated cotton although the current R&D at Katherine appears focused toward future land and water developments in the Katherine-Daly regions.

There are no irrigation dams constructed in the NT. The Daly/Katherine, Victoria, Adelaide, Roper and McArthur are the NT catchments most likely to support larger-scale irrigated agriculture using surface water. Annual flows are high compared with south-eastern Australia. Due to seasonality of rainfall any irrigation development using surface water will require harvesting of wet season flows either by dams or off-stream storages. Groundwater is currently used to irrigate crops in the Daly-Katherine area and smaller areas on the Sturt Plateau. The NT government is currently reviewing the ground and surface water reserves for Daly-Katherine Basin, Sturt Plateau, and other catchments.

A comparison of potential cotton production areas indicated 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, soil and water resources (Daly Basin, Marrakai Plains). Of these regions the Daly Basin is most advanced in the collection of relevant environmental information prior to land development for agriculture.

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, 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 next five years that incorporates necessary land and water resource, infrastructure, cropping systems and environmental protection research needs was released in 2001. This R&D plan distinguishes a research phase from a commercial development phase, which could follow.

The previous Country Liberal Government was drafting legislation to regulate the production of cotton. This legislation was partly in response to a fear of the public perception of cottons' impact on the environment and the concerns of important interest groups for example Amateur Fishermen's Association of the Northern Territory (AFANT) and The Environment Centre NT (ECNT). Following the recent (August 2001) change of government in the NT, Territory Labor's stance on this legislation and Genetically Modified Organisms (GMO) is unclear from policy documents published prior to the election.

North Queensland

Climatic analysis suggests that cotton could be grown during the winter season in the north and coastal areas and during the summer season in the south and inland areas of the region. In all potential growing areas some crop specific research would be required at some time prior to commercial development.

In undeveloped areas the timeframe for cotton development, if it were to proceed, is highly dependent on the status of infrastructure development/availability, resource surveying, water resource plans and environmental impact assessments. Except for the Flinders (Richmond), Broken (Collinsville) and possibly Gilbert rivers, the development of irrigation infrastructure is likely to have a > 10 year timeframe.

In the established cropping areas (Atherton Tableland, Mareeba-Dimbulah, Lakeland Downs and Bowen/Lower Burdekin areas), cotton would be substituted for other crops and factors such as economic competitiveness with existing crops and access to ginning and other cotton specific infrastructure (picking equipment) will influence whether cotton is grown. Due to a mix of crop species, area wide pest management would be essential in all these regions.

The Flinders River (Richmond) has the largest discharge in north-western Queensland. The clay-textured soils are derived from marine deposits having some accumulation of salt at depth. The extent to which salt is an impediment to crop growth or poses a salinity risk to irrigated agriculture is not known. The Queensland Department of Natural Resources has recently announced that a salinity risk assessment is a requirement prior to development of land for irrigation purposes.

Currently a landholder and Queensland Cotton Corporation Ltd provide most funds for production R&D work at Richmond. A team of locally based research staff is being established. The Cotton CRC funds technical support for entomological and agronomic research at the site. Queensland Cotton funds research and commercial agronomists, and Queensland Department of Primary Industry (DPI) provides professional entomological support.

Many potential growing areas drain into the Coral Sea, which could be an emotive environmental issue for cropping.

A suggested approach to Cotton R&D in regions undeveloped for irrigated agriculture.

In northern Australia there are many potential growing areas where cotton could be the first crop after land clearing (Table I). An R&D plan for cotton in a new irrigation area in northern Australia must aim to answer five broad questions:

1. Where are the best production sites? (e.g., what is the geographic limit of winter cropping in northern Australia? And at the resource 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 ORIA experience of 27 years ago be repeated?)
4. What is the environmental impact of cotton farming on-site and off-site?
5. Where the community perceptions of cotton farming are poor can they 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. Similarly Table II shows that the specific research required to develop a new irrigation area with cotton as a candidate crop is dominated by generic questions. The areas of expertise applicable to the Cotton CRC would only include point 3 and components of points 4, 5 and 6 shown in Table II.

Table II. *The basic research required to evaluate a new irrigation area with cotton as a candidate crop.*

1. **Geohydrological surveys/studies**
   These will determine potential salinity problems, water table effects and identify appropriate irrigation and agronomic practices.
2. **Detailed soils surveys**
   Currently most regions are at a scale not greater than 1:250,000 and irrigation development would require at least 1:100,000 with reference areas at 1:25,000 in locations having potential for irrigated cropping.
3. **Production system research**
   Integrated crop research is required with the objective of developing a management system that is sustainable economically and has minimal environmental impacts.
4. **Ecological studies** into pest and disease dynamics and effects on flora and fauna.
5. **Water licensing process** and associated studies.
6. **Infrastructure studies** – location of gin, transport links, container needs, etc.
7. **Whole scheme economic analysis** to put in State/national context. This should include an assessment of community value.

v) Recommendations

General

- The Cotton CRC should focus on its strengths, which are skills in sustainable cotton production systems research. **There is simply more to do than can possibly be funded by the Cotton CRC.** The Cotton CRC should facilitate/encourage complementary work by other agencies.
- The Cotton CRC should thoroughly review the likely timetable for land and water surveying and environmental impact assessment for irrigation development before making commitments to production systems R&D.
- A large-scale trial phase is essential and must be included in an R&D plan for any new area. Funding must be available to underwrite infrastructure (e.g., picking, mini gin) and the cost of production at sub-commercial scale.
- There is a lack of cotton research and cotton farming experience. Membership of the Cotton CRC can enable training to occur with partner organisations and others in southern Australia. The basing of experienced production agronomists on-site (as at the ORIA and Richmond) will assist farmer collaborators in gaining experience in growing cotton.
- Many specialised research skills are not available in northern Australia. The Cotton CRC could assist in finding specialised skills for short-term tasks. These researchers may be from the Cotton CRC or other organisations.
- A communication strategy is required and should incorporate interest groups, the general community and the Cotton CRC. The suggestion of sustainability issues symposium(s) with emphasis on community education in the research and development process should be adopted. However an integrated approach to community consultation/awareness is required and should include local tailoring. The Cotton CRC should instigate an evaluation process to provide a mechanism for internal review of communication methods employed and for the development of new methods.

Recommendations specific to regions of current Cotton CRC involvement

Western Australia

- There is a critical short-term need to continue the role of production agronomist, previously supplied by Twynam Cotton, in the large-scale trials at Kununurra. The Cotton CRC should assist in developing a means of funding this position.
- The Cotton CRC should contribute to research into sustainable wet season cover crops and crop rotations at Broome. The collaboration of Cotton CRC members with experience on similar systems in the NT would greatly benefit this work.

Northern Territory

- It is important that the 5-year R&D plan be supported and implemented.
- Studies are required as soon as possible to prioritise potential growing areas prior to involvement of a commercial development partner.
- A commercial partner to replace Twynam Cotton is required in the near future.
- A clear indication of the new NT Government's support for cotton development is required. The Cotton CRC should also seek bipartisan political support.
- Broaden the NT Cotton Working Group to include more irrigation/cotton/land development expertise or create a new group.
- Regular open dialogue with interest groups is essential (eg AFANT, graziers, ECNT).

Queensland

- The risk of salinity developing in the Richmond area needs to be addressed as soon as possible. This is the responsibility of the developer. The Cotton CRC has a role in ensuring the most appropriate methodologies are used. In north Queensland, this type of work is coordinated by the Department of Natural Resources, regional infrastructure development group.
- Cotton CRC involvement in the proposed stakeholders development committee for the Richmond area.
- Stronger links with the DNR regional infrastructure development group should be developed. Cotton CRC membership is also an option for some of this group as there is already a significant in-kind contribution to key research in the soils and geohydrological disciplines.
- The Cotton CRC should facilitate studies into the effect of gin location on possible production scenarios in this region. An analysis of the likely interest in growing cotton in established areas and the factors influencing the decision to grow cotton in addition to ginning infrastructure should also be made. The DPI at Mareeba should be approached to fund and conduct this study.
- As is the case in WA and the NT, there is a need for active Cotton CRC involvement in community consultation and general communication issues.

Chapter 1 - Introduction

1.1. Background

Although commercial cotton production was practised in northern Australia in the past, the industry was not sustained. The failure of the previous attempt at the Ord River Irrigation Area (ORIA) of Western Australia, due to uncontrollable insect problems and the cessation of cotton farming in the Bowen region of Queensland at about the same time for economic reasons, should serve as cautionary reminders for future attempts.

In recent years there has been increased interest in growing cotton in northern Australia. Research and development and, in some cases, test farming has been undertaken by different organisations (research and commercial) at several locations across northern Australia. The potential availability of land and water combined with new knowledge and production technology has stimulated this activity.

In 1998, at the time when the previous Australian Cotton CRC was preparing for refunding, cotton research, development and/or test farming activity was being undertaken near Broome, the Fitzroy River and at the ORIA in WA, at Katherine and Douglas-Daly in the NT, and near Richmond and Bowen in northern Queensland. This work involved the participation of several research and commercial organisations: AgWA, CSIRO, Northern Territory Department of Primary Industry and Fisheries, Twynam Cotton, Queensland Cotton, Western Agricultural Industries, Ord River District Cooperative and local farmers. It was clear that a future Cotton CRC had a role in coordinating and focusing these activities toward sustainable development objectives.

With the commencement of the new Australian Cotton CRC in July 1999, a new program, 'Growth into northern Australia' was established with strong linkages to the other Cotton CRC programs in established growing areas. Australian Cotton CRC programs are:

- Growth into Northern Australia.
- Innovative Technologies.
- Sustainable Farming Systems.
- Education, Technology Transfer.
- Cotton Textile Research.

In its first year the Cotton CRC established five initial projects to focus on the collection of baseline data on agronomy, pest and weed ecology in four target regions (Broome, the ORIA, Katherine and Richmond). The fifth project was the basis for this scoping report. The projects were:

- Northern Australian cotton disease survey.
- A baseline study of insects of cotton in far north Queensland (Richmond).
- Insect dynamics of the cotton ecosystems in the NT (Katherine).
- Integrated pest management systems for sustainable transgenic cotton production in the West Kimberley (Broome).
- Viable and environmentally responsible cotton production systems for northern Australia: Scoping studies and research liaison/coordination officer (Darwin).

A comprehensive research program was already well advanced at the ORIA with projects funded by AgWA, CSIRO, and Cotton Research and Development Corporation. This work is also part of the Cotton CRC's Program 1.

1.2. Program 1. Growth into Northern Australia: philosophy and general structure.

The published philosophy of the Australian Cotton CRC is to assist to develop region-specific production systems, which are economically viable, but minimise chemical inputs and environmental impacts. Recognising the fragility and conservation values of northern environments, the Cotton CRC will collaborate with other agencies to characterise the significant biodiversity of natural environments in each region and ensure conservation of native fauna and flora is accommodated in development and management plans.

The Australian Cotton CRC's philosophy for northern Australia incorporates the following:

- Cotton CRC is NOT an advocate for cotton production in northern Australia.
- Cotton CRC has a strategic research focus and a significant role in coordination.
- Government/community will decide on development.
- Research will focus on viable and environmentally compatible cotton production systems specific to new regions. Production systems will not be simply transplanted from south-eastern Australia and must be demonstrably sustainable through research.
- Develop solutions to specific regional environmental problems prior to promoting commercial activity.
- Production should be based on Integrated Crop Management (ICM) and a systems focus, with research teams reflecting this objective.
- Commercial partners should be willing to commit to R&D prior to commercial development.
- Collaboration with other agencies relevant to cotton development issues is essential.

The northern Australian program is lead by, Mr GR Strickland (Agriculture WA) and Dr MP Bange (CSIRO). A Northern Committee, comprising representatives from all Cotton CRC participants involved in Program 1 (CSIRO, AgWA, QDPI, NTDPIF, Qld

Cotton, CSD, WAI, Twynam Cotton) reviews R&D needs and advises the Cotton CRC management committee on priorities for research. To provide a coordinated northern effort, the Cotton CRC established northern liaison/coordination officer based in Darwin. This scientist participates in the Northern Committee and had the task of producing this document.

1.3. General aims of the scoping study

The scoping study was instigated in 1999, with work commencing in early 2000, to provide a reference document to assist with research planning in northern Australia. The scoping study has the following aim:

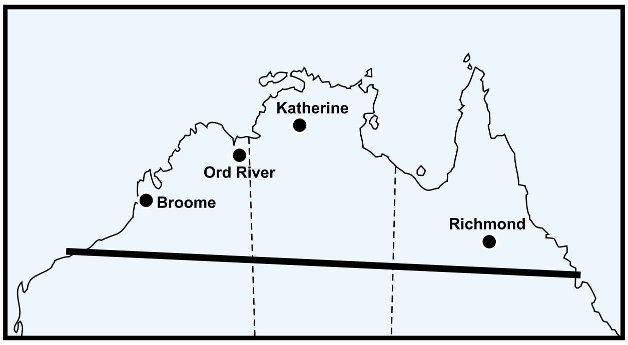
> ***To detail the status of current and past research activities and important environmental and production issues faced by each region in northern Australia that are relevant to cotton production.***

The specific methodology is described in chapter 2 of this study.

1.4. Definition of the study region

The study region is defined as the area north of the Broken River Catchment 21°S in the east to Wallall Downs 20°S in the west Kimberley (Map 1.1). Focus is on regions where R&D is in place or planned with the Cotton CRC partners.

Map 1.1: *Definition of Scoping Study region (north of the line), and current Cotton CRC research areas.*



Chapter 2 - Methodology

The study region is immense and represents about 30% of the land area of Australia (Map 1.1). Discussions with stakeholders showed that there was a great diversity of opinion on terms of reference for a scoping study. While there was agreement on the broad topic areas to be included the priority given to selected topic areas varied considerably, some are listed below:

- Identifying potential growing areas and the specific land and water resources available in different regions.
- Detailed regional reviews with emphasis on biodiversity and flora and fauna surveys.
- A review of past cotton research by region, including other information relevant to cotton.
- Must at least include all geohydrological and soil surveys collected within the study area.
- The document needs to be of sufficient detail that it provides an information resource capable of identifying R&D needs across all disciplines.

Clearly it was impossible to meet all the above criteria within the timeframe available. Thus the approach taken in Chapters 4, 5 and 6 is to review issues on a State basis. Within each State issues relating to the four regions where there is cotton research, namely Broome, the Ord River, Katherine-Daly Basin and Richmond, are considered in greatest detail. For these regions reviews are made of past cotton and other relevant research and development, climatic potential, soil and water resource data, infrastructure and key environmental and community issues. Across WA, NT and NQ a further 17 regions/sub-catchments that may have potential to grow cotton are reviewed using the same broad headings but at a level of detail sufficient to flesh out the key issues and provide guidance for future region specific research and development needs.

Chapters 3 and 7 are written to incorporate issues not included in the regional reviews. Chapter 3 briefly reviews past attempts at large-scale agricultural development in northern Australia and makes recommendations on successful research and development processes. Chapter 7 integrates the specific issues arising from the regional reviews and identifies global issues and common R&D philosophies.

The climatic potential for cotton growing is assessed for 19 locations in northern Australia, representing the majority of the potential growing regions reviewed. The rainfall pattern must be such that sowing and picking operations can be conducted with minimal risk of exposure to excessive rainfall. In northern Australia, the transition from the wet to the dry and dry to wet seasons are periods of high rainfall variability (Mollah 1986). The seasonal transitions have been shown to be important operationally for crops during the wet season in this region (Yeates *et al.* 1996, Yeates *et al.* 2000). The seasonal transitions will also be important in dry season cotton systems. The rainfall pattern during season transitions will impact upon trafficability, crop establishment, early season weed control and possibly insect pest pressure. Rain on mature cotton will discolour lint and significant price discounts can accrue. In addition, in environments where temperatures are warm during picking, as is the case in northern Australia, harvest rain can stimulate rapid regrowth after defoliation and this will also interfere with harvest operations and reduce lint quality.

Climatic data, except for Katherine and Kununurra, is obtained from the SILO database and included the period where temperature records were best, (>1956). Degree Day Sums with a base temperature of 12°C (DDS_{12}) are calculated using the method of Constable and Shaw (1988). Calculations of DDS_{12} and frequency of sub-optimal night temperatures (< 11°C or 12 °C) are made using the program SAS (1993).

The OZCOT-APSIM (1_55) yield simulation model (Hearn 1994, McCown *et al.* 1996) is used to calculate potential yields for different sites across northern Australia. A Cununurra clay characterised at the Ord River Irrigation Area (Yeates unpublished data) is used for all locations with a similar black soil. This assumption is consistent with soil surveys at WA, NT and Gulf of Carpentaria sites (Kinhill Pty Ltd 2000, Stewart *et al.* 1970, Speck *et al.* 1964, Christian *et al.* 1952). Locations with sandy textured soils having a high hydraulic conductivity were characterised as Blain Sandy Loam, which occurs in the NT (Williams *et al.* 1985). This assumption is also consistent with soil survey results (e.g., Cotching *et al.* 1990). Locations with red earth soils are characterised as the Tippera Clay Loam found at Katherine (Carberry *et al.* 1996; Yeates and Imrie 1993). At Mareeba, a Kraznozem soil characterised for maize at Kari is used (P. Poulton, CSIRO, Toowoomba, Qld, unpublished data).

Crop management inputs to simulations are:

- A plant density of 10 p/m2 using a late maturing variety.
- An adequate but not luxurious rate of N fertilisers of 200 or 230 kg N/ha on clay and earth/sandy soils respectively.
- Starting soil available nitrogen values are typical of these soils under cropping at 65 and 30 kg N/ha for black and sandy soils respectively.
- Irrigation water is applied by drip and furrow on sandy and black soils respectively.
- On black soils it is assumed the soil water content is returned to saturation following irrigation.

Chapter 3 - Lessons from past attempts at large scale cropping development in Northern Australia

The following section provides a brief review of some lessons learnt from past attempts at large-scale cropping development in northern Australia. The purpose is not to dwell on the negative aspects of northern agriculture development but to extract guidance as to successful research and development processes when assessing the feasibility of a new industry such as irrigated cotton.

Bauer (1985a) gave three reasons for failure of large-scale commercial agriculture in northern Australia:

1. Distance.
2. Ignorance of the physical environment.
3. A reprehensible aversion to learning by experience.

Interestingly, Bauer's review was written at about the same time, as the Ord River was tagged 'a white elephant'. However, since 1985 there has been considerable improvement in knowledge and infrastructure such that, in many regions, the limitations of distance and ignorance of the physical environment have diminished significantly (e.g., soil surface management and soil nitrogen dynamics, road transport development due to tourism and other industries). Given cotton's chequered history in northern Australia, it is point 3 that provided the impetus for writing this chapter.

The following lists some salient points from past research and development directed at large-scale cropping in northern Australia. This information has been extracted from several reviews of past research and development in northern Australia (e.g., Bauer 1977 and 1985a, Mollah 1986, Robertson and Chapman 1985, Chapman *et al.* 1996) and from discussions with some of those involved in these developments.

- Clearly defined goals understood and accepted by all participating organisations.
- A systems approach is required.
- Agricultural researchers alone cannot be expected to provide an adequate basis for commercial success.
- 'Small-plot research is quickly subject to diminishing returns and resources are then best allocated to large-scale trials or pilot farms for limited periods.' (Robertson and Chapman 1985) 'The pilot industry formula, although no guarantee of profitable short-term production, provides at least an opportunity for researchers to encounter real problems of the industry so that there is a greater chance that they will ask the right questions' (Cox and Chapman 1985).
- Ease of importation of production technology and skills. (e.g., Sugar at the Ord River Cox and Chapman 1985). This is important in the feasibility assessment and industry establishment phase. However, once farming commences, locally based adaptive research will provide the main mechanism for problem solving and innovation.
- In many areas more success has been achieved with annual cropping in the dry rather than wet season (e.g., melons and other horticulture).
- This is a high cost region so higher value crops are needed.
- Successful perennial crops are harvested during the dry season (e.g., mangoes, sugar).
- The variable climate necessitates a modelling approach to research outcomes, (i.e., three- year studies may not be representative of the seasonal range), (e.g., Yeates *et al.* 2000).
- Failed developments have provided initial capital (land) for subsequent successful industries, (e.g., Ord Stage I, Lakeland Downs).
- Lack of capital combined with too rapid movement to commercial production has resulted in many failures (Bauer 1977).
- Infrastructure issues must be addressed and action taken by the commencement of commercial development. However during the large-scale trial phase lack of infrastructure due to small-scale can impact on costs and such costs must be borne as part of the evaluation.
- Large-scale trials can provide data for environmental impact assessment, the development of guidelines for sustainable management practices and best practices for management of chemicals and other inputs.

The previous attempt at cotton farming at the Ord River is unique for Australia because commercial industry failure was due to unsustainable pest management practices. Moreover the collapse of the Ord cotton industry acted as a disincentive for both cotton and irrigation development in the Kimberley and NT until recent years.

NT Kenaf - an example of R&D process for a fibre crop

The NT Kenaf R & D program conducted between 1987 and 1991 was an excellent example of an integrated approach to assessing the commercial feasibility of a broad acre fibre crop in northern Australia. The program was initiated by the NT Government and was managed by a body named the 'The Kenaf Task Force'. The task force initiated studies into production technology/agronomy, sustainable farming systems, climatic risk using a yield simulation model developed specifically for the project, processing, infrastructure, land and water availability, marketing, environmental standards for processing, commercial scale trials and whole industry economic analysis.

There were two main outcomes of these studies:

- The first was a portfolio for investment, which attracted commercial interest, although investment did not follow.
- The second was a package that could be used in the future for reassessing economic feasibility should economic circumstances change.

Unfortunately except for some of the agronomic and yield modelling studies most of the Kenaf Task Forces' work remains unpublished as registered files of the NT Government.

Chapter 4 - The Kimberley Region of Western Australia

4.1. Introduction

Recent reviews of Western Australia's water resources calculate that the Kimberley region has 80% of that State's renewable water resources (KWRDO 1993). This equates to 7,400 GL/yr with only a few percent currently used for human purposes. In addition groundwater in the La Grange sub-basin south of Broome has an estimated sustainable yield of 194 GL/yr.

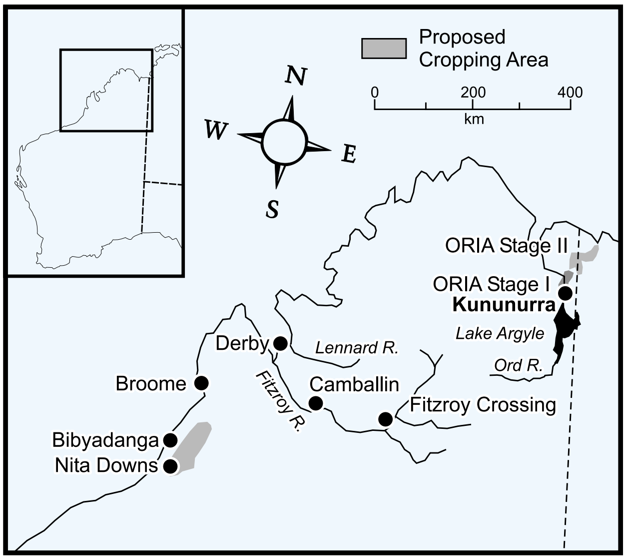
Interest in developing the Kimberley's two major rivers systems (Ord and Fitzroy) for irrigated agriculture has a long history in which cotton has often been a candidate crop. Irrigation dams have been constructed on the Ord, the Dunham River (an Ord tributary) and on the Lower Fitzroy at Camballin. Only the first stage of the Ord River Irrigation Area has seen significant agriculture development to date.

In the early 1990s the WA Government commissioned several studies to evaluate water resource development issues in the region (KWRDAB 1993; Kinhill *et al.* 1993; Hassell and Coffey 1993). With respect to irrigated agriculture the following conclusions were made:

- The second stage of the Ord River Irrigation Area (ORIA) should be developed before the Fitzroy. Because the 'Ord project ranks as one of the best regional development options available in north-western Australia'.
- The projected expansion of the Ord should be based on sugar, horticulture, pasture, seed and tree crops but not cotton. No explanation was given for the exclusion of cotton.
- Cotton was the favoured crop option for 40,000 ha black soils on the Fitzroy at Fossil Downs, Alexander Island and Camballin. Dam sites on the Margaret River and river barrages at Mt Krauss and Gogo was recommended. Production system research was recommended prior to development. Detailed feasibility studies would only be undertaken if experimental work proved successful.
- Irrigation development in other areas were considered longer-term opportunities (e.g., Lennard River).

In 1997 the WA Government called for expressions of interest in conducting feasibility studies into the development of Stage II of the ORIA and large-scale surface and groundwater irrigation development in the west Kimberley. In 1998 Memorandums of Understanding (MOU) were signed with Wesfarmers/Marubeni and the Water Corporation of WA for the Ord Stage II and with Western Agricultural Industries for surface water potential of the Fitzroy catchment and groundwater potential of the La Grange sub-basin. Obviously, the outcomes from these studies will directly impact upon any irrigation developments in the near future.

MAP 4.1: *Kimberly Locations. Note cotton production is being considered within proposed cropping area near Broome not the entire area shown.*



4.2. Cotton research and development in the Kimberley

4.2.1. THE ORD RIVER IRRIGATION AREA (ORIA) SINCE 1993

With respect to the Australian Cotton CRC's activities in northern Australia the ORIA is the most advanced site in terms of cotton production systems R&D. Prior to the Cotton CRC's formal involvement in late 1999 Agriculture Western Australia (AgWA) CSIRO, Cotton Research and Development Corporation (CRDC) Cotton Seed Distributors (CSD) Colly Cotton, Monsanto, the Ord River District Co-operative and local farmers have made a significant contribution to a dry season cotton production system R&D. The process used to conduct this work and the results obtained may serve as a planning guide for other northern regions less developed in their R&D.

The ORIA is also unique to the northwest of Australia because new irrigation land development is happening irrespective of cotton R&D; cotton is simply a candidate crop for the new development. Consequently cotton R&D can focus on issues of production and environmental management and feed outcomes on water requirements and other inputs into the separate land development activities.

Many outcomes of cotton R&D at the ORIA are expected to be transferable to neighbouring catchments, which have potential for irrigation development and have similar climate and soils (e.g. Fitzroy, Bains/Victoria).

4.2.1.1. Background

A feasibility report, prepared by Strickland *et al.* (1993), reviewed the previous attempt to grow cotton in the ORIA during the 1960s and 70s and recommended that the re-establishment of a cotton industry in the Kimberley should be seriously considered. However, due to the severe pest pressure associated with summer cropping, a new industry should be based on a winter cropping strategy and transgenic (INGARD™) varieties. To this end a joint Agriculture WA/CSIRO research project was developed to make preliminary judgements concerning agronomic potential and pest management scenarios. Importantly this feasibility report reviewed the previous attempt to grow cotton at the Ord.

Transgenic cotton varieties (INGARD™) containing specific insecticidal genes (initially the Cry1A(c) delta-endotoxin from *Bacillus thuringiensis* Bt) were seen as greatly improving the prospects of establishing sustainable cotton production systems. In an environment with the potential for high insect densities, such as tropical north-western Australia, it would be essential that the technology incorporate integrated pest management (IPM) methods, be supported by pre-emptive resistance management strategies (Fitt 1996) and merged with cultural and agronomic practices.

It was also recommended that the crop be grown in the dry season to avoid periods of highest insect abundance, particularly for two important species, pink bollworm (*Pectinophora* spp) and *Spodoptera litura*, which beset the previous attempt to grow cotton during the wet season. However, the tropical dry season is the reverse, in terms of temperature and daylength, to the typical summer season in temperate cotton growing areas. Therefore, agronomic studies were required into crop adaptation to the dry season, crop husbandry and operational issues.

Preliminary production systems research aimed at re-establishing a cotton industry in tropical north-western Australia was commenced in 1994 with the following objectives:

- Identify the most appropriate cotton plant types or varieties for dry season production in north-western Australia based on characteristics of yield, quality and maturity.
- Investigate the effects of specific agronomic/physiological factors on cotton growth and performance in the dry season and integrate those factors into a robust agronomic package tailored to the most appropriate varieties.
- Develop and evaluate pest management systems with minimal inputs of pesticide, maximal use of natural mortality factors based on transgenic cottons expressing Bt genes for management of lepidopteran pests.
- Integrate appropriate varieties, agronomy and pest management to provide a technological package for the establishment of an irrigated dry season cotton production system in north-western Australia.

4.2.1.2. Research station experiments 1994 to 1999

The experiments covered an area between 15 and 50 ha. In 1994 and 1995 seed of transgenic varieties was not available and non-transgenic varieties were sown. The area sown was also limited by the absence of ginning facilities; in 1996 it was estimated that $250,000 of lint was destroyed from this research.

In 1996 single gene INGARD™ varieties were grown for the first time although varietal choice was very limited. In the same year (1996-97), INGARD™ cotton was grown commercially for the first time in the established cotton areas of eastern Australia where it accounted for 10% of the total area sown that year (Wilson 1996).

Insect pest management research

The results from this research up to 1998 have been reported in the following publications (Strickland *et al.* 1996, 1998a and 1998b, Strickland and Constable 1995) and in reports to the CSIRO Tropical Initiatives Program, which supported collaborative involvement in the research.

In summary:

- Insect pest pressure was lower during the dry season.
- Parasitoids of *Helicoverpa* spp, the key dry season pest, were abundant particularly the egg parasitoid, *Trichogramma pretiosum*.
- INGARD™ varieties combined with IPM strategies reduced insecticide usage to 1/3 of that applied to conventional varieties.
- IPM systems involving the use of companion crops such as lucerne and niger to maximise beneficial insect numbers required the fewest insecticide treatments without compromising crop yield.

TABLE 4.1. *Key elements of a novel cotton production system for the ORIA contrasted with the previously unsuccessful system of the 1970s (from Strickland et al 1998a).*

1970s INDUSTRY	NEW INDUSTRY
Summer cropping (wet season)	Winter cropping (dry season)
Conventional varieties	Transgenic varieties
Broad spectrum insecticides	IPM systems
No pesticide resistance management	Pre-emptive Bt resistance management

Small plot and other research in progress in 2001 includes:

- Development and validation of heliothis thresholds for *Helicoverpa* spp, and the sucking pests, particularly mirids.
- Evaluation of new IPM compatible insecticides/food sprays including their effectiveness for managing beneficial insects.
- Population dynamics of *Helicoverpa armigera* within the Ord cropping system.
- Resistance testing aphids and *Helicoverpa armigera.*
- Ecology of *Trichogramma* spp, a key egg parasitoid of importance to IPM systems.

Agronomic research

The results of this work up to 1997 are summarised in Strickland and Constable (1995), Yeates *et al.* (1996), Yeates and Constable (1998), Strickland *et al.* (1998a). Research into developing crop husbandry practices (1994-1997) provided an initial technical package for the expanded IPM research and identified some future research priorities. It was expected that additional research questions would emerge from the commercial scale IPM research that commenced in 1997 (next section).

Crop adaptation/sowing date

Where insects were adequately controlled, experimental yields were found to be very comparable with experimental yields from summer grown crops in temperate Australia (Table 4.2). For mid-late and late maturing varieties, sowing from mid March to mid April optimised yield and permitted harvest from mid September to early October, well prior to the likely commencement of wet season rains in November. A very synchronous boll opening, which was due to rising end of season temperatures, reduced the boll periods of later pollinated flowers, ensured a prompt harvest and a degree of compensation from early fruit loss.

Fibre length appeared to be influenced by minimum temperature during the first 20 days after pollination. For late March–April sowing dates and flowering often coincided with cool temperatures; consequently fibre length was reduced compared with the same varieties grown in south-eastern Australia. High, possibly, supra-optimal temperatures during fibre growth appear to reduce fibre length at a June sowing date. As expected, rain on a mature crop could weather lint and reduce colour grade. The severity of weathering appeared related to the volume and frequency of rainfall events.

TABLE 4.2: *Comparison of machine picked small plot lint yields (kg/ha). Summer grown are the mean of 17 trials during 1996-1997 in NSW and Qld, winter grown is the mean of 3 years 1995 to 1997 inclusively at ORIA (from Strickland et al 1998).*

	Summer grown temperate Australia	Winter grown tropical Australia
Average Top 10 Varieties	2069	2043
Best	2529	2483
Range	1650-2529	1829-2483

The timing of crop development could be predicted using heat unit summation (base 12°C), however, the heat units required to reach early development stages were greater than for temperate Australia (e.g., first flower = 777 DD_{12} for a temperate crop, first flower = 884 DD_{12} for a tropical dry season crop). Supra-optimal temperatures are suspected to cause this deviation.

The effect of cold night temperatures on fruit growth and yield was not clarified from these studies for two reasons. Firstly, temperatures were not extreme in the seasons when the bulk of this work was conducted (1995 to 1997). Secondly, temperature effects were confounded by other factors such as insect damage, irrigation scheduling/management and rank growth.

Germplasm evaluation

Varieties and breeding lines have been evaluated since 1994. The previous attempt to grow cotton at the ORIA in the 1960s found varieties bred for mechanised agriculture were favoured over 'tropical adaptation' (Hearn 1996). The number of INGARD™ varieties was limited so emphasis was placed on the evaluation of conventional germplasm that could in future be backcrossed with INGARD™. Most *Gossypium hirsutum* material has come from the CSIRO/CSD breeding program with an additional 10 to 15% contributed by Deltapine Australia and small numbers of other varieties of USA origin. With the potential for sowing in March/April the focus has been on 'full season' or longer duration varieties that performed best in the warmer growing areas of SE Australia (Emerald, Bourke). These also proved to be the best at the Ord. To date, evaluation of genotypes for adaptation to reduced season length, as would be required with later sowing, has been confined to sowing date studies consisting of only three genotypes.

Gossypium barbadense varieties were evaluated during 1995-1997. Most material came from the 'Pima' breeding program in Arizona. Provided sowing was prior to the end of April, yields were good and vegetative growth was not an issue. However, fibre length was always below market acceptability in all genotypes screened. The resultant price discount would make G. *barbadense* less profitable than G. *hirsutum* types.

Crop nutrition

In southern Australia between 100 and 200 kg/ha of N fertiliser are required to grow cotton. Hence, given the low inherent N status of the Cununurra clay, early research focused on N fertiliser requirements. The average total uptake by unfertilised plants was about 80 kg/ha and a rate of 200 kg/ha of fertiliser N banded within a month of sowing was optimal for high lint yield (>2,200 kg/ha). This response was very similar over three years. At the optimal rate split applications did not improve yield. Current research is evaluating the interaction between N, P and irrigation interval/duration.

Growth regulation

During early growth in April and May, warm temperatures combined with management practices designed to minimise stress (e.g., nutritional and water) maximised production of 'Bt' protein, resulting in rapid and often rank growth. Consequently research focused on treatment from pre-squaring to early flowering with the growth regulator mepiquat chloride (Pix™). Mepiquat chloride (MC) reduced plant height and node number in proportion to the total amount of MC intercepted by the crop. Yield was generally unaffected by MC treatment. Further research was required into the interaction between MC and early season insect damage, operational efficiency, varieties and soil moisture.

Irrigation scheduling/water use

Research to determine appropriate irrigation scheduling and crop water usage is ongoing. This research has the following objectives:

- measure the plant available water holding capacity of the Cununurra clay
- to determine optimum irrigation scheduling, which includes frequency and duration of irrigation at different growth stages
- to measure crop irrigation water requirement and water use efficiency
- to measure the effect of irrigation on waterlogging
- to measure whether deep drainage occurs.

Plant density/arrangement

The response to plant density was similar to temperate Australia and the USA, where a density of between 60,000 – 180,000 plants per ha was optimal for yield. A population of 8-10 plants/m of row was recommended on the basis of plant height/lodging and stand evenness considerations. There was no yield difference between wide beds (2 rows separated by 80 cm on a single flat bed with 1 m between rows across the furrow) and narrow beds (single rows per bed separated by 1 m).

In-crop weeds

There are some potentially serious weeds to cotton (Table 4.3). Being an established irrigation area that grows a variety of crops during the dry season, weed management in cotton is integrated with practices adopted for existing crops. Seed bank management during a wet season fallow using knockdown herbicides forms the basis of weed management in annual crops, including cotton. Where possible winter season paddocks are pre-irrigated prior to sowing to germinate weeds, which are killed with a knockdown herbicide (often paraquat-diquat) at sowing. There is some use of selective pre-emergent herbicides in-crop.

The ease of in-crop weed control is influenced by the success of seed bank management during the wet season fallow, which in turn is related to the seasonal rainfall pattern. Rainfall directly influences timeliness and efficacy (rain fastness) of herbicide applications. Rainfall also necessitates the use of aerial application when soil is wet. On clay soils a further impact of rainfall on efficacy is through reduced weed vigour due to waterlogging.

To-date other than a small evaluation of Staple™ (pyrithiobac-sodium) with respect to crop safety and efficacy on *Hibiscus panduriformus*, there has been no research targeted at in-crop weeds or their management. In part this has been because adaptation of the existing practices has been reasonably effective. It is expected that weed problems will evolve if the area

TABLE 4.3: *Some potentially important weeds in cotton in the ORIA*

Weed	Species	Comments
Native Hibiscus Native Rosella	*Hibiscus panduriformus* *Abelomoschus ficulneus*	Both these weeds are important and difficult to manage. Hard seeded – several germinations
Wild Gooseberry	*Physalis minima*	
Pumpkin Vine	*Ipomea spp* *Operculina brownii*	
Black Pigweed	*Trianthema pertulastrum*	Common but controlled with existing herbicides (Stomp™, Treflan™)
Nut Grass	*Cyprus spp*	Only small areas to date
Wild Vigna	*Vigna spp*	Channels mainly
Tridax Daisy	*Tridax procumbens*	Channels mainly – tolerant of glyphosate.

sown to cotton expands. Future weed management research needs to be linked with research into rotations and cover crops.

Compensation

In 1997 the need for research to evaluate the physiological aspects of plant compensation under other types of pest damage, such as tipping of the main-stem terminal and the interaction of damage with growth regulator use, was recognised. Experiments commenced in 1999 are planned to continue for a further 2 to 3 seasons. Higher yields have been obtained from plants with early main-stem damage and early square removal (<9 nodes).

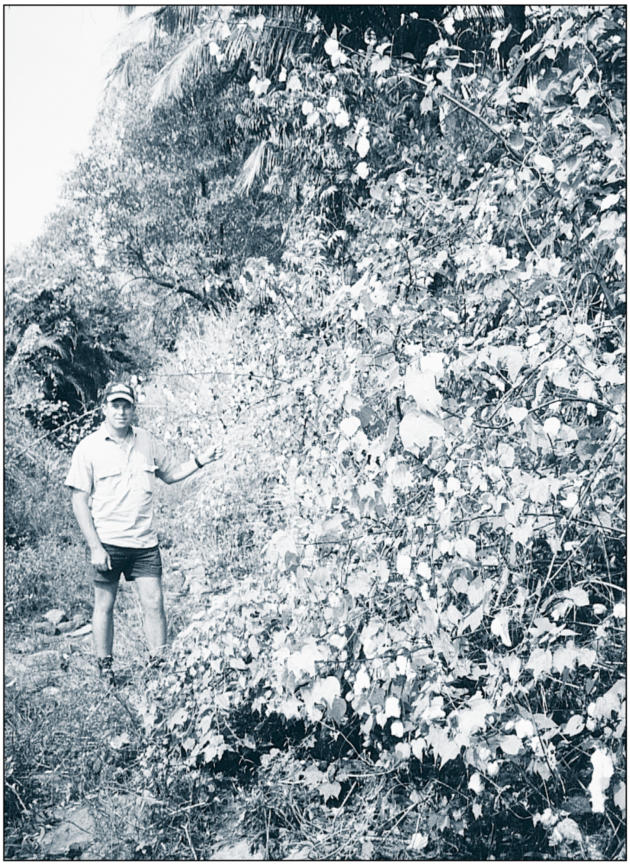
Other Research

Diseases

Disease surveys supported by the Cotton CRC have identified existing disease issues (Nehl *et al.* 2000). Alternaria leaf spot was the main pathogen observed on cultivated cotton. Charcoal rot (*Macrophomina* spp) was also observed where planting problems occur, but this disease was considered to be of minor importance. The presence of Verticillium wilt at Kununurra has not been confirmed. Cotton rust, although not observed during the survey, could be a potential problem. Importation of fuzzy cotton seed from the eastern States for use as stockfeed presents a risk for the introduction of Fusarium, Verticillium and other diseases to the north. Restrictions on movement of fuzzy seed for stockfeed should be given careful consideration.

Ecological risk assessment of transgenic Bt cotton

Prior to any commercial approval of transgenic Bt cotton for northern Australia a comprehensive ecological risk assessment has to be conducted in conjunction with the Genetic Manipulations Advisory Committee (GMAC), now the Office of the Gene Technology Regulator (OTGR), and Environment Australia. A number of aspects (i.e., risk of gene escape, resistance management, impacts on non-target insects) have been addressed. An ongoing component is assessing the potential for the Bt cotton to become a weed in the tropical environment. Experimental studies centre on the ability of the Bt gene to confer additional fitness to cotton in natural habitats outside the areas of cultivation. Potential routes for seed movement into natural environments have been identified and are being quantified. Experimental work is being conducted in four habitats at each of three locations, Kununurra, Katherine, and near Broome where the demography of conventional and transgenic genotypes is being compared. Each site was planted over the wet season to three genotype treatments: conventional, single gene (INGARD™) and two gene Bt cotton (BollgardII™), with each of three seed types: black seed, fuzzy seed, and seed cotton, over two populations.



Andrew Dougall from NTDPIF standing beside naturalised cotton at Bees Creek, NT

Monitoring of small numbers of transgenic plants that have established in areas outside cotton fields (e.g., roadsides) is ongoing. This enables determination of the seasonal growth and development phases of volunteer cotton to better understand factors that may affect the potential to establish and reproduce in non-crop environments.

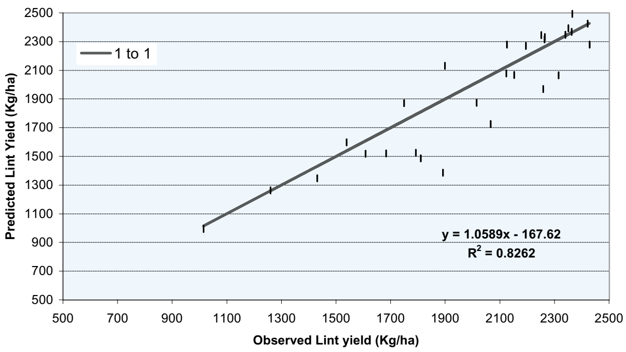
Monitoring of feral populations of conventional cotton is also being conducted. These populations are descended from introductions made many years ago and are small, isolated sites which have not moved from their site of introduction. This aims to address the issue of the potential for the transfer of the Bt gene to these populations, and if this occurred, whether this would provide additional fitness to contribute to increased weediness.

Additional transgenic Bt registration studies are being conducted and funded by Monsanto. These studies are being conducted to meet National Registration Authority requirements to demonstrate field efficacy and effects on non-target insects. Supporting data is being generated from pest management studies conducted by AgWA.

OZCOT-APSIM (1-5) Simulation Model Validation

Validation of the OZCOT-APSIM crop simulation model showed that yields could be adequately simulated provided insect damage was minimal and irrigation did not induce waterlogging (Figure 4.1). However, because of deviation in the thermal time summations described above, OZCOT's predictions of the timing of reproductive development and crop maturity deviated from the observed. The OZCOT model does not simulate the effect of night temperature on fibre length or the effect of weathering rainfall on colour grade. It is not clear whether OZCOT will account for irrigation-induced waterlogging effects in this environment. Validation needs also to extend to include a wider range of seasonal conditions, particularly where sub-optimal night temperatures are more common (e.g., Katherine, NT).

FIGURE 4.1: *Validation of the OZCOT yield simulation model using observed data collected at Kununurra 1995-1997.*



4.2.1.3. Commercial Scale Integrated Pest Management Research 1997–1999

In 1997 Colly Cotton Pty Ltd (now Twynam Cotton) a NSW based integrated cotton business that grows, processes and markets cotton installed a 'research gin' as a joint venture with the Ord River District Cooperative at Kununurra. This permitted research to move onto farms and be expanded to paddock size areas.

The area sown ranged from 300 ha in 1997 to 1,000 ha in 1999. The bulk of this was INGARD™ cotton grown under a research permit granted by GMAC. Three to four IPM treatments were replicated in paddock size areas (>20 ha/plot) with one replicate of all treatments being located on each farm. Each paddock was intensively monitored for pest and beneficial insects. Since 1997 an agronomist from Colly Cotton assisted farmers with agronomic management.

Key results from large Scale IPM research have been:

- INGARD™ / IPM treatments have required an average of four total insecticide sprays, considerably less than the 10–12 needed on conventional cotton, and the 40 sprays of the previous ORIA industry (Table 4.4).
- Lucerne strips in combination with INGARD™ have consistently reduced the number of insecticide sprays by about one compared with INGARD™ only treatments. There has been a trend for higher yields with lucerne strips. Lucerne strips provide a nursery habitat for beneficial species and act as a trap crop for mirids.
- The selection of a nursery/trap crop should also be influenced by agronomic practicalities. Lucerne is often difficult to establish and weeds can infest stands. Niger flowered for a short period and timing of sowing required precision to sustain a flowering stand that would be attractive to insects. Recently lablab has been tried and found to be easy to establish while having a long flowering period. Pigeon Pea is to be evaluated in 2001.
- The levels of *Helicoverpa* spp egg parasitism by *Trichogramma* spp wasps have been variable. Higher in 1996 and 1997 than 1998 and 1999.
- Efficacy of single gene Bt declined after late flowering, with some within season variability as well. Overall efficacy has been higher and more consistent than in south-eastern Australia.
- Food spray (Envirofeast™) had little effect on the requirement for insecticides or beneficial insect numbers.
- Established spray thresholds for major pests heliothis and mirids need validation.
- Endosulfan has not been considered as part of any IPM system and none has been used in on-farm research.

TABLE 4.4: *The mean lint yields, number and purpose of insecticide sprays in the IPM trials, Kununurra, 1996 and 1997 (Strickland et al. 1998)*

TREATMENT[1]	MIRID SPRAYS	APHID SPRAYS	HELICOVERPA SPRAYS	TOTAL SPRAYS	YIELD KG LINT/HA
1. Siokra L23°C alone	2.13	0.25	2.25	4.63	1,584
2. Siokra L23°C + Envirofeast™ + lucerne	1.48	0.15	2.13	3.66	1,610
3. Siokra L23°C + lucerne	1.25	0.13	1.75	3.13	1,756
4.# Siokra L23°C + niger	1.50	0.25	3.00	4.75	1,630
5.* Conventional cotton + Envirofeast™ + lucerne	3.0*	0	7.50	10.50	1,594

[1] all treatments were sprayed when entomoLOGIC thresholds were reached
* includes rough bollworm as a target pest (*grown 1996 only)
\# grown 1997 only

Lincoln Heading from Agriculture WA in Kununurra sampling cotton for beneficial and pest insect species

Non-pest management observations from commercial scale IPM research

As expected the large-scale trials identified new problems and research questions:

- Regrowth following defoliation was very rapid due to high temperatures and was influenced by the timing of final irrigation. Significant price discounts resulted from staining of lint by green leaves during picking. Small plot research to investigate the optimum timing of final irrigation was initiated in 1998.
- Why was between paddock yield variability so high?
  - 1997 4.9 to 9.17 b/ha
  - 1998 6.8 to 9.33 b/ha
  - 1999 3.9 to 7.73 b/ha
- Although some of this variability could be attributed to inexperience and non-optimal treatments, it was clear that there was a need for a greater focus on paddock benchmarking (e.g., soil chemical analyses) and increased within season agronomic monitoring (e.g., water use, nutrient uptake).
- Irrigation scheduling required research to account for slope, run length, sowing date, growth stage and variety.
- Were cold temperatures the major cause of lower yields in 1999 or were other factors involved (e.g., long periods of near threshold heliothis larvae numbers or severe alternaria damage)?
- How frequently will fibre quality be down graded by rain at harvest?
- Operational efficiency – are current land preparation and other cultural operations cost effective and timely?
- Optimal defoliation management (e.g., chemicals x timing x irrigation management) has not been determined.

4.2.1.4. Future research direction

Entomology

Entomological research at the Ord is planned to continue until at least two to three seasons of research with two gene Bt cotton is complete (4-5 years hence). This research is supported by substantial funds from Agriculture WA and the CRDC. A research entomologist and technical support is in place. In 4-5 years time an effective appraisal of the potential for sustainable cotton production using BollgardII™, combined with a locally developed IPM and resistance management strategy could be made. Moreover, the specifics of the Stage II development and the potential for cotton to be included will be clear in five years. Concurrent research by Monsanto (with support data from Cotton CRC research) to support registration of BollgardII™ cotton for northern Australia will be completed within five years.

Agronomy

CSIRO will be largely responsible for this aspect by providing a research agronomist with technical and operational support funded by CRDC. Agronomic research will follow the same timeframe as entomological research. The objectives for future work will be to evaluate suitable rotation/wet season cover cropping systems, address problems identified in large-scale trials, continue variety evaluation, complete MC, nutrition and compensation research.

Future links with non-cotton research programs

There are other research programs in the Ord that have objectives or outcomes that are relevant to cotton research and linkages with these programs need to be maintained or initiated:

- Soil water characterisation research for sugar cane.
- The Ord Land and Water Management Plan, which includes crop water use, watertable and chemical best management practice issues.
- The Ord–Bonaparte project, which aims to coordinate a catchment scale environmental study of the impact of agricultural and other development in the east Kimberley.
- Valley wide programs to encourage wet season cover crops for soil and weed management.

4.2.2. Cotton research in the Broome area

For the purposes of the following review the Broome area consists of the La Grange sub-basin, which contains well-drained uniform textured soils (Pindan) of the Yeeda Land System and the clay textured soils of the lower Fitzroy catchment to the north.

4.2.2.1. Prior to 1993

Evaluation of cotton was conducted at Bibyadanga (La Grange) mission during the late 1800s. In 1922 cropping was attempted at Knowsley Agricultural Area near Derby as small lots 160–220 acres for returned soldiers; four blocks were allocated for cotton, which apparently failed due to drought, heat and insects (bollworms). In 1923 it was recommended that the activity be moved to clay textured soils rather than the Pindan soils (Millington 1977).

4.2.2.2. 1993 to 1996

Mr John Logan, a former cotton farmer from NSW, through the company Kimberley Agricultural Industries, initiated a very small-scale evaluation during 1993-96. Sites were established on small horticultural farms near Broome and at Shamrock Station 160 km south of Broome. At least one further site was established inland from Broome at Dampier Downs Station 170 km to the east/southeast. Varieties (mostly conventional) were screened during the wet season. Sowing date varied to evaluate wet season growing (December to early February) supplemented with irrigation. Because the soils were sandy textured, drip irrigation was used. There was some involvement with AgWA who monitored insects at the sites.

4.2.2.3. 1997 to 2000

Background

The research was expanded with the formation of Western Agricultural Industries (WAI) a company comprising Kimberley Agricultural Industries and Queensland Cotton Holdings. WAI employed full time research agronomists and support staff and established a research site at Shamrock Station.

In respect to the Broome area (La Grange sub-basin), WAI signed a memorandum of understanding with the State of Western Australia in August 1997 to conduct feasibility studies into all aspects relevant to the establishment of a large-scale, integrated, irrigated agricultural industry. WAI was given prime responsibility for pursuing all factors associated with the proposal. In summary WAI had to demonstrate to the government's satisfaction that, within the study period, large-scale irrigation activity is environmentally, financially, technically and economically feasible and sustainable using groundwater resources. The study period was till 30 June 2000 with an option to extend for a further three years subject to approval by the State. An extension of the MOU was granted in late 2000.

Cotton production system research

Research conducted to date was located at Shamrock Station in small plot trials with a best-bet test area of 5 ha evaluated in 1999. Cotton production in the west Kimberley contrasts greatly with current cotton production systems in Australia. The cotton is grown on sandy loams and irrigated by sub-surface drip irrigation. The key findings of this research are summarised below:

Crop adaptation

A May sowing date seems optimal in that it avoids temperature extremes (hot and cold) during critical development stages minimises exposure to high insect densities and produces good yields and quality with a low risk of rainfall during the picking period.

Water

Crop water requirements, scheduling, the delivery system (included a range of commercially available drip irrigation systems) and off-site impacts have been the major research issues. Sustainability issues such as water quality and groundwater recharge are also being considered. The developers consider that sufficient progress has been made with the crop water requirements, scheduling and the delivery system to establish a blue print for production on larger areas. Ongoing work is required for issues of environmental impact, particularly groundwater recharge.

Crop nutrition

Nutrient requirements and method/timing of application for most of the major nutrients have been identified, as has the cost of applying different fertiliser forms of each nutrient. Macro nutrient requirements appear similar to the light textured soils in the NT.

Variety assessments

This is ongoing. Better performing varieties have been similar to Kununurra and Katherine. That is, longer season maturity types suited to the hotter areas (Emerald/Bourke) are also best suited to Broome. Obviously selection of adapted BollgardII™ varieties is a critical research task for the future.

Insect pest management

Agriculture WA is a collaborator in pest management research. Little is known of the pest and beneficial insect species present and their abundance in this region. Emphasis has been placed on characterising the insect fauna and seasonal patterns of abundance measurement through trapping and sampling of trial sites and native vegetation. Key pests likely to occur include *Helicoverpa* spp, *Spodoptera litura,* pink bollworm (*Pectinophora gossypiella*) and rough bollworm (*Earias* spp). A study into the population dynamics and movement of *Helicoverpa* spp is proposed. Pesticide efficacy trials are ongoing, as is the quantification of resistance levels in key pests. In the future it is recommended that research move to larger area IPM studies similar to those currently undertaken in the Ord. Research for BollgardII™ registration is essential.

Environmental and social studies

As a requirement of the MOU these studies include:
i) sustainable groundwater yield assessment
ii) impacts on terrestrial flora, fauna and soils
iii) management of aboriginal and native title issues
iv) social and cultural impact assessments.

WAI employ an environmental consultant to advise and coordinate these activities.

Due to the very poor community perception of cotton production, there has been a requirement for extensive community consultation in the above. Moreover the effectiveness of the research development and extension process aimed at these issues is seen by WAI as a critical factor in the success of the project.

4.2.2.4. Future research direction

BolgardII™ registration process
Cotton production systems in this region will need to incorporate BollgardII™ cottons. A clear process for timely registration is essential.

Continue insect pest management research
IPM research must move to a larger scale incorporating BollgardII™ varieties and supported by ecological studies of the pest complex. The Australian Cotton CRC has already agreed to fund an entomologist (employed by AgWA) to support the research.

Modelling of environmental impact
This includes, groundwater recharge, movement and breakdown of pesticides and fertilisers and changes in soil chemistry and structure. This work would also involve a stochastic assessment. WAI are currently investigating models to conduct these tasks; the model developed by the University of Western Australia is an example.

As listed above, impacts on terrestrial flora and fauna must be assessed and compliance with federal biodiversity and similar legislation must be integrated into development plans.

Wet season cover crops/rotation crops
The production system proposed has the potential to leave a highly erodable sandy textured soil exposed to intense rainfall and wind during the wet season and early dry season prior to sowing. Soil cover in the form of a cover crop is required during the wet season between cotton crops. In the monsoon climates of the NT, a system of sowing wet season cover crops is used where annual horticulture crops are grown during the dry season on sandy textured soils. This system utilises forage grass crops such as millet (*Pennisetum uniloidies*), which are deep rooted and can capture residual fertiliser before it is leached below the rootzone (M. Smith NTDPIF, Katherine NT, unpublished data). In the Broome area a range of wet season cover crops need to be evaluated for their value in erosion prevention, soil structural maintenance and capture of residual fertiliser. A cotton monoculture is not desirable so rotation crops need to be evaluated in addition to cover crops. Rotation crops may substitute for wet season cover crops or substitute for cotton in the dry season.

General crop protection
This includes being proactive and reactive to problems (weeds, pests, and diseases). The light textured soil has the potential to harbour nematodes.

4.2.3. OTHER POTENTIAL GROWING AREAS

Currently the Fitzroy Catchment is the only other area to be seriously considered for irrigated cotton development. The Lennard River is relatively isolated and is unlikely to develop sufficient basic soil and water resource data within the next ten years.

Kinhill *et al.* (1993) in their report 'Fitzroy Valley Irrigation: A Conceptual Study' commissioned by the Western Australian Government concluded that irrigated cotton was the favoured crop on black soils. In 1994 the Buster Farming Partnership, which grows cotton near Bourke NSW, evaluated small areas of cotton at Camballin. No conclusive results were produced; cattle entering the site severely disturbed the trials and no further research was conducted. Uncertainty regarding land title was sited as the reason for terminating research.

WAI, as a component of its MOU with the WA Government, is studying the irrigation potential of the Fitzroy River Catchment. Initially centred on the construction of a dam, the surface water component of the project is now focussed on aquifer recharge of the bore-fields from the Fitzroy River, combined with off-river storage at strategic locations. WAI is presently focussing its efforts on the groundwater resource south of Broome. Crop production system research and much of the associated environmental impact research can be extrapolated to an expanded cropping area supplied by surface water.

4.3. Resource review

4.3.1. CLIMATIC POTENTIAL

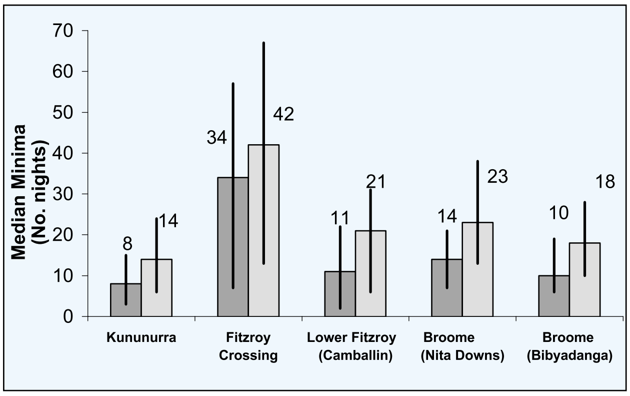
The Kimberley climate is semi-arid tropical. Most rainfall is in the summer months (November to March) and winters are dry and mild. Rainfall is highest in the north and east. Winter season temperatures are coldest to the south and inland from the ocean or where topography is favourable. Consequently the key issues for dry season cotton production are having sufficient heat to sow and pick the crop within the confines of the dry season.

4.3.1.1. Temperature

Figure 4.2 shows the risks of minima below the optimum for cotton growth and development (11°C or 12°C).

Kununurra in the north-east has the lowest frequency of cold shock temperatures. The modulating effect of the Indian Ocean is evident at the southern-most locations of Bibyadanga and Nita Downs. Fitzroy Crossing has significantly greater frequency of cold shock temperatures.

FIGURE 4.2: *Potential Kimberley winter growing areas, risk of cold night temperatures. Median minimum temperatures below; ■ 11°C and □ 12°C (1957 to 1999). Bars show the range for 20% to 80% of seasons. Note that the Lower Fitzroy data is constructed from the Silo database for Camballin, which was derived from observed data collected at Derby.*



Research at Kununurra and Katherine has found an average of 2,200 degree day sums with a base temperature of 12°C (DDS_{12}), (see Constable and Shaw 1998 for method of calculation) are required from sowing to picking during the dry season. Figure 4.3A shows that 2,200 DDS_{12} will be accumulated by mid-October in 80% of seasons at Kununurra and Lower Fitzroy provided the crop is sown by April 15. At Fitzroy Crossing sowing prior to April 15 is required for picking by October 15. To be consistent with research outcomes, a mid May sowing date was considered for the Broome coast (Figure 4.3B). In this case a mid November harvest date is most likely.

4.3.1.2. Rainfall

Due to superior trafficability, rainfall during the wet/dry transition is less likely to affect operations on lighter textured soils that dominate the Broome coast. Sowing operations are more sensitive to rain on clay-textured soils. At Kununurra, rain has delayed sowing of the majority of the crop until after mid April in four of the last six seasons. Obviously the date of picking is influenced by the date of sowing and growing season temperatures (Figure 4.3).

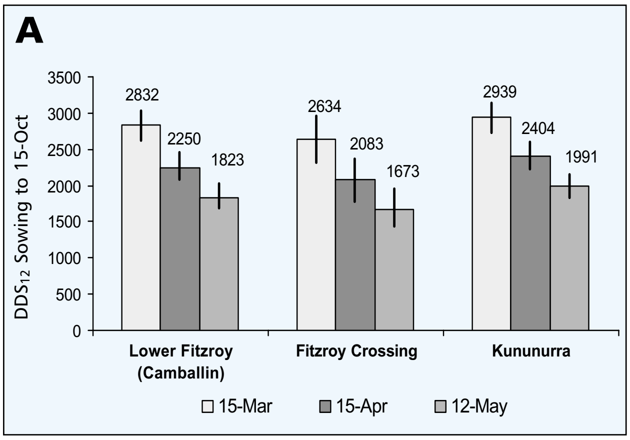
Picking prior to mid October has a low probability of rainfall at all sites (Figure 4.4). As expected rainfall variability is high. Median fortnightly rainfall only exceeds 20 mm after mid November at Kununurra. At Fitzroy Crossing the later onset of rainfall may compensate for cool temperatures extending the growing season. The Lower Fitzroy appears to have a good balance combining mild temperatures and a late onset of rain. Harvest rain is of minor consequence on the Broome coast as median rainfall is less than 5 mm / fortnight until mid December (Figure 4.4B).

4.3.1.3. Potential yield

The good correlation with observed data at Kununurra (Figure 4.2) suggests that the OZCOT-APSIM model will give accurate yield data for similar climatic conditions and management assumptions.

Yield potential was high at black soil sites where sowing occurred prior to May. Maximum yield required a mid-late April sowing date (Figure 4.5A). Simulated yields were very high on sandy soils at the Broome coast (Figure 4.5B). A notable feature of Figure 4.5 is the low variability of yields at the optimal sowing dates. Super optimal temperatures (>38°C) combined with a greater chance of waterlogging during boll growth may explain the lower and more variable yields at May 12 (Figure 4.4A) and May 31 (Figure 4.5B) sowing dates at the Kimberley and Broome coast locations respectively.

FIGURE 4.3: *Potential Kimberley winter growing areas. Variation in degree day sums base = 12°C (DDS_{12}) 1957 to 1999. (A) Sites other than Broome coast at 15 March, 15 April and 12 May sowing dates, and picked on October 15, (B) Broome coast. Bars show range for 20% to 80% of seasons.*



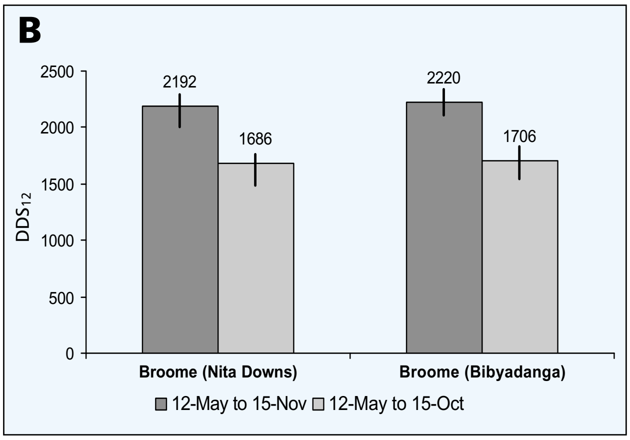


FIGURE 4.4: *Median fortnightly rainfall (1957–1999) over the maturity and picking period for (A) Kimberley and (B) Broome coast. Bars show range for 20% to 80% of seasons.*

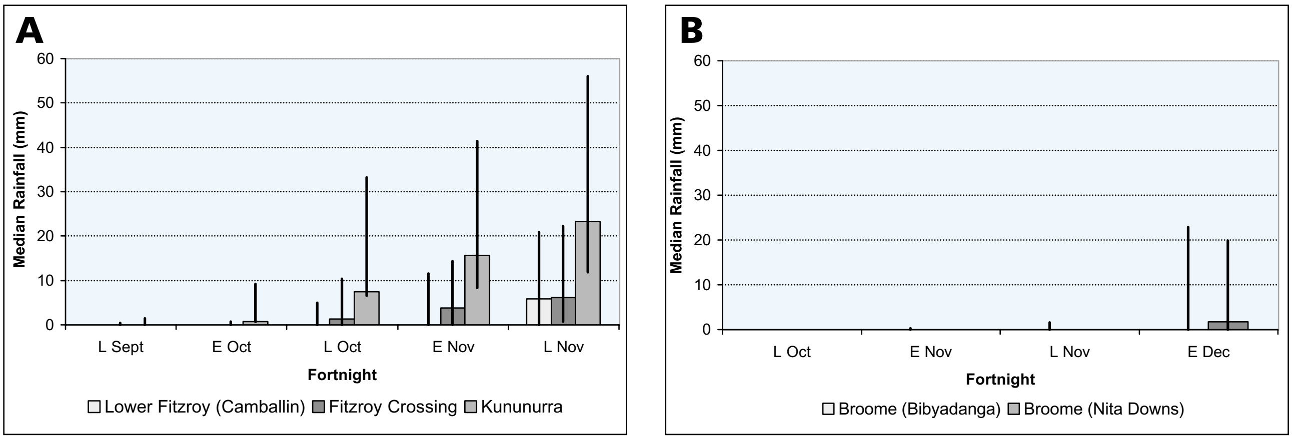
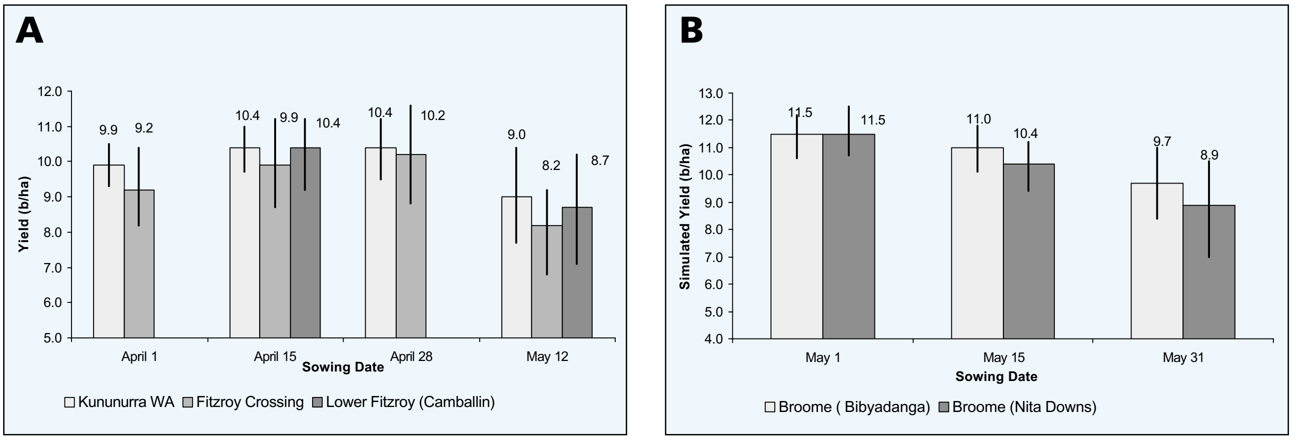


FIGURE 4.5: *The effect of sowing date on median potential yields simulated by OZCOT-APSIM (1957-1999). (A) Kimberley and (B) Broome coast. Bars show range for 10% to 90% of seasons. NB simulated yields assume 100% water allocation, no damage from insects, diseases and weeds, excellent crop management and prompt picking following defoliation.*



4.3.2. SOILS AND LAND RESOURCE ASSESSMENT

Outside the ORIA, soil surveying and land system characterisation has been on a broad scale (see Speck *et al.* 1964, Speck *et al.* 1960 and Stewart *et al.* 1970). The most recent details of the soil surveying and hydrological assessment conducted in the area covered by the M2 development of the ORIA were presented as part of a draft EIS and environmental review and management program submitted for public comment in March 2000 (Kinhill Pty Ltd 2000).

The early surveys identified areas in Ord, Fitzroy, Lennard and small areas of the Robinson catchments as potentially suitable for furrow irrigation (Speck *et al.* 1964, Speck *et al.* 1960 and Stewart *et al.* 1970). These river systems were considered the most likely to have sufficient annual water flow for irrigation combined with Cununurra clay or similar soils in the areas with potential for flood irrigation.

The Ord River is an example of the enormous research effort required to predict the irrigation potential of areas where clay textured soils are dominant. History shows that initial surveys claiming the 'largest area of uniform soils in the world' (Stewart 1944 cited by Chapman 1994) have been continually proved wrong, as the intensity of sampling has increased (see Parberry *et al.* 1968, Gunn 1969, Aldrick and Moody 1977, Aldrick *et al.* 1990, Kinhill Pty Ltd 2000). The Cununurra clay is now described as having five different phases: normal, leached, eroded, brown and darker (Kinhill Pty Ltd 2000).

The La Grange sub-basin south of Broome can irrigate soils that are predominantly deep sandy-loams of the Yeeda Land System (Cotching 1990, Cotching *et al.* 1990). These uniform textured soils are well drained and rapidly permeable (Cotching 1990). Roads formed on these soils are firm and stable. They have few or no weathered minerals and are deficient in phosphorus. They have low capacity to store water for plant growth. WAI consider favourable economies of scale would result by growing cotton on the large areas of apparently uniform soils in this area. Flood irrigation is not feasible on these soils; therefore alternative delivery systems such as subsurface drip are required.

For reviews of soil nutrient status and fertiliser responses for the cracking clay and other soils found in the region see Williams *et al.* 1985, Jones *et al.* 1985 and Chapman 1994. Virtually all soils are inherently low in organic carbon, N, P, S, Zn and possibly Mo, Cu, Fe, B and Mn. On cracking clay soils responses to N, P, S and Zn fertiliser have been reported for a number of crops. Nutrient stratification (natural and induced by fertiliser placement) in the surface layers, particularly P, has been observed and commented upon. There has been little research into the effects of and the amelioration of nutrient stratification. Leaching of nitrate and denitrification has been reported in clay and red earth soils. Nitrogen losses are affected by irrigation management and crop species. Sorption of P has been observed to vary between sites.

4.3.3. WATER RESOURCES

Specific details of proposed water allocations for the Ord M2 development are given in Kinhill Pty Ltd (2000). Briefly it is proposed (subject to public review and comment) to irrigate an additional 33,000 ha. Water allocation is to be sufficient to grow sugar cane, a crop with high water requirement compared to cotton (Dorrinbos and Depruit 1983).

The Dunham River Dam (60 km west of Kununurra) with a potential irrigation allocation of 12 GL/yr could irrigate about 1500 ha of cotton. The dam currently irrigates pasture and hay crops (Ag WA, unpublished data).

The Fitzroy River has a mean annual discharge into King Sound of around 8000 GL. Currently, there is no use of this resource other than by cattle stations and by small communities like Fitzroy Crossing. WAI is expected to complete full Environmental Impact Study (EIS) as part of the feasibility investigations. The groundwater study is to be completed in 2001, with surface water studies to be completed at a later date.

- WAI consider that the combined water resource (including the La Grange-sub basin) could support a total irrigable “green” area of approximately 175,000 ha.
- WAI anticipate that commercial development from bores will begin in 2001, and increase rapidly to the extent of water availability identified in the groundwater studies.
- Subject to the successful introduction of groundwater commercialisation, and a satisfactory EIS, production from the surface water resource would commence.

4.4. Infrastructure issues

4.4.1. ORD RIVER IRRIGATION AREA

- Stage I of the ORIA is fully developed and grows a range of crops on about 10,000 ha. The area is serviced by pesticide spraying contractors, rural merchandisers, transport companies and consultants. The port of Wyndham is 100 km to the north-west. Darwin is 820 km north-east by an excellent all weather highway. There are daily flights to Darwin, Broome and Perth.
- AgWA has a well-maintained research facility near Kununurra. A cotton research team of 10 staff from AgWA, CSIRO and a student from the University of Queensland are located at Kununurra, and are all part of the Australian Cotton CRC. The Cotton Research and Development Corporation provide support funding for three projects. Outside the Cotton CRC, the Ord River District Cooperative provides support through part ownership of the research gin and Monsanto will continue to fund research supporting BollgardII™ cotton registration.
- In December 2000, Twynam Cotton withdrew from the Cotton CRC and direct involvement in northern Australia, due to changing priorities in the company. A replacement for Twynam Cotton as a commercial R&D partner is essential. In 2001 Twynam’s involvement will be confined to part owner and operator of the research gin and marketing of the lint produced.
- Increased farmer participation in large-scale trials is needed. Small scale ginning and picking infrastructure requires at least 400 ha to maintain viability. Currently demand from other crops for existing land in Stage I combined with the unfavourable economies of growing cotton at this small-scale are a disincentive for farming cotton. The perception that there is additional economic risk due to these being research trials, and hence unproven management practices, is also a disincentive.

4.4.2. BROOME/WEST KIMBERLEY

- The MOU granted to WAI also requires that Aboriginal and Native Title issues be resolved as a requirement of the MOU. These issues have short-term implications for field research near Broome because the availability of land to conduct research is currently restricted. Land to expand research to large-scale trials to 200 ha in 2002 is urgently needed. WAI have made an application to obtain a clearing permit to develop land for this purpose.
- WAI provide the majority of funding for cotton R&D in the west Kimberley, while research is coordinated through the Cotton CRC. A project manager (Perth), research agronomist (to be employed at Broome) and support staff (on-site) are employed by WAI. AgWA collaborates with WAI by providing entomological research with two staff currently based at Broome. WAI and AgWA staff are committed to the Cotton CRC, which will fund an entomologist commencing in 2001. The Cotton CRC funded research coordinator / liaison officer has a 20% time commitment to Broome issues. The main research site is at Shamrock Station 160 km south of Broome. A research site

for smaller scale work located closer to Broome is currently under investigation. Funding for a new building and laboratory to house AgWA staff at Broome has been approved.

- Broome has a port facility, international airport and road linkage to Perth and Darwin by the Great Northern Highway. Derby also has a port facility, a domestic airport and is also connected by the Great Northern Highway.

4.5. Environmental issues

- As discussed previously, the relevant work is being conducted in both regions to meet the requirements of the respective MOUs with the WA Government. It is important that production systems R&D collect data critical for environmental impact assessment.
- There is organised opposition to cotton in the west Kimberley (e.g., Environs Kimberley). Community consultation is a requirement of the MOU. WAI emphasised the need for a mechanism that can achieve more effective involvement of interest groups (particularly environmental groups). WAI suggested sustainability issues symposium(s) as proposed by the Cotton CRC Director at a Cotton CRC Northern Committee meeting. WAI felt that these symposia should focus on informing groups on critical issues and achieving a better community understanding of the research and development process.

4.6. Conclusions and recommendations

There is a significant commitment by many organisations to cotton R&D in the Kimberley region of WA. Both the west Kimberley and Ord River appear to have considerable potential as cotton growing regions. Future commercial development at the Ord River will depend greatly on the outcomes of the current feasibility assessment for Stage II (33,000 ha) conducted under the MOU between Wesfarmers/Marubeni and the WA Government. It is important to note that the cropping mix in the initial proposal (mainly sugar) is not final (P. McCosker, KDC, pers.comm. 2000). A final decision is expected to be made in late 2001. While in the west Kimberley more than 20,000 ha could be grown using groundwater reserves south of Broome without any additional water from the Fitzroy River. Future commercial development in the west Kimberley will also depend on the outcomes of feasibility assessments under the MOU with the WA Government and land tenure resolution.

The pest management research at Broome, which is to be supported with Cotton CRC funds, is critical. However, given the significant in-kind contribution to the Cotton CRC by collaborating member and non-member organisations and the coordinated approach to irrigation development via the MOUs, a greater contribution by the Cotton CRC in WA is well justified.

Recommendations for Cotton CRC future involvement in WA cotton R&D are listed:

- There is a critical short-term need to continue the role of production agronomist previously supplied by Twynam Cotton in the large-scale trials at Kununurra. This person acts as a development officer, on-farm researcher and data collector. The value of large-scale trials at this critical time in the development and testing of sustainable pest and agronomic management practices would be significantly diminished without this position. The Cotton CRC should assist in developing a means of funding this position either by full / part funding or assisting to secure funding from elsewhere.
- The Cotton CRC should contribute to research into sustainable wet season cover crops and crop rotations at Broome. The need for this research is discussed in section 4.2.2.4. Expansion of research areas will enable this work to occur. However, it is clear that the involvement of Cotton CRC members with relevant expertise and experience on similar systems in the NT would greatly benefit this work and is strongly supported by WAI.
- There is a statewide need for active Cotton CRC involvement in community consultation and general communication issues. The suggestion of a sustainable issues symposium (or something similar) and follow up activities that also include an emphasis on community understanding of the research and development process should be pursued. The Northern Committee of the Cotton CRC has a key role in facilitating this process.

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

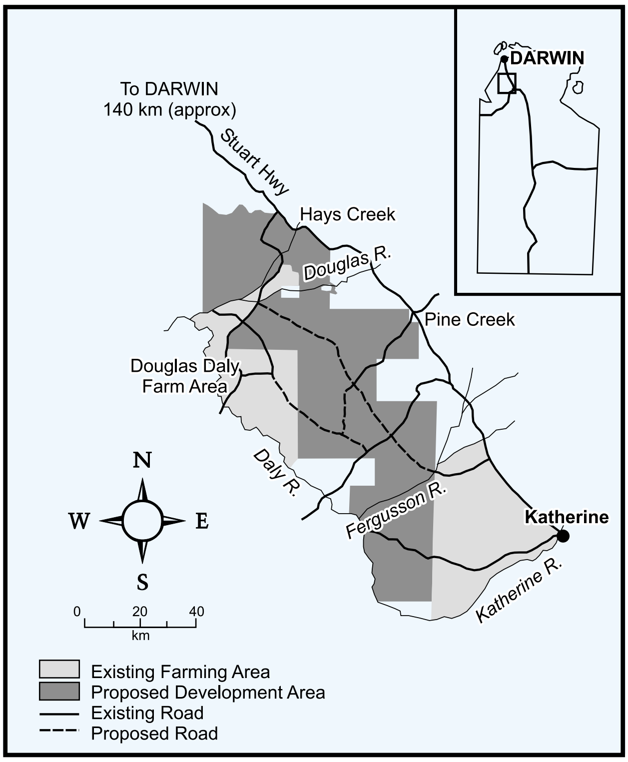
5.2.1. PRIOR TO 1946

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

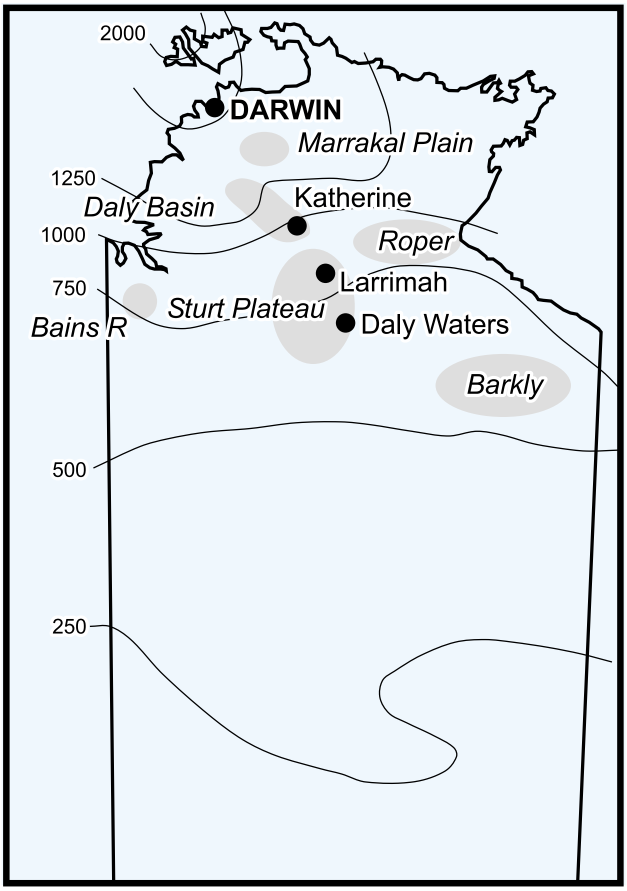
Suitable areas for growing cotton must be hot enough during the growing season, and have suitable land and water. Research at Katherine has shown that it is possible to grow and pick a crop within the dry season despite mid season exposure to many minima below 11°C. Potential growing areas for winter 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.

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.



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).*

5.3.1.2. 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.*

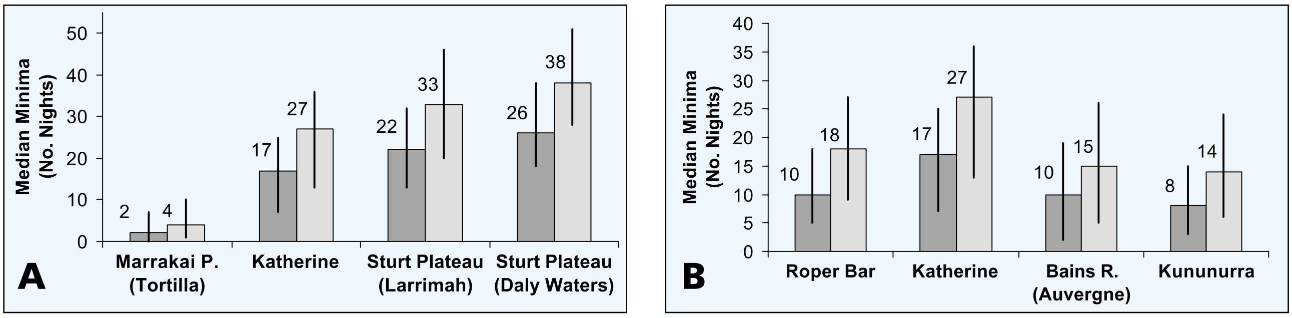


FIGURE 5.2: *Potential NT winter growing areas: seasonal heat units. Median DDS12 to October 15 (1957 to 1999) for March 15, April 15 and May 12 sowing dates. Bars show range for 20% to 80% of seasons. (A) Sites north and south of Katherine and (B) Sites east and west of Katherine.*

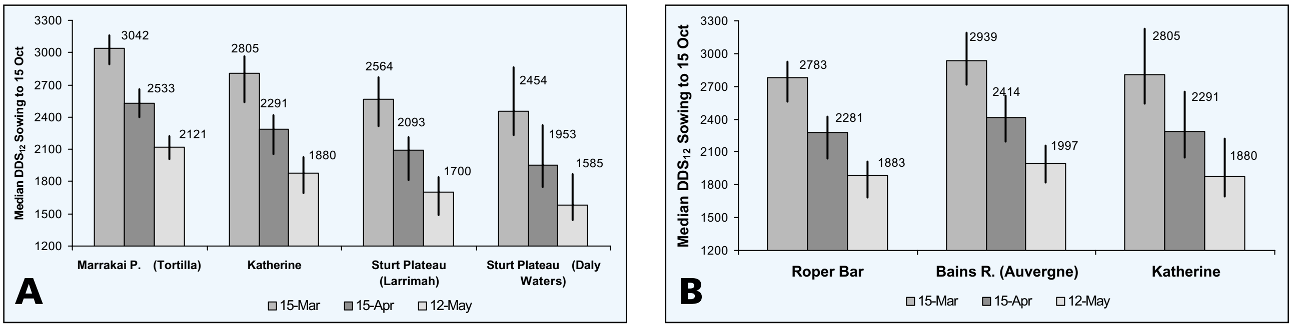


FIGURE 5.3: *Potential NT winter growing areas. Median fortnightly rainfall (1957 to 1999) over maturity and picking period. Bars show range for 20% to 80% of seasons. (A) Sites north and south of Katherine and (B) Sites east and west of Katherine.*

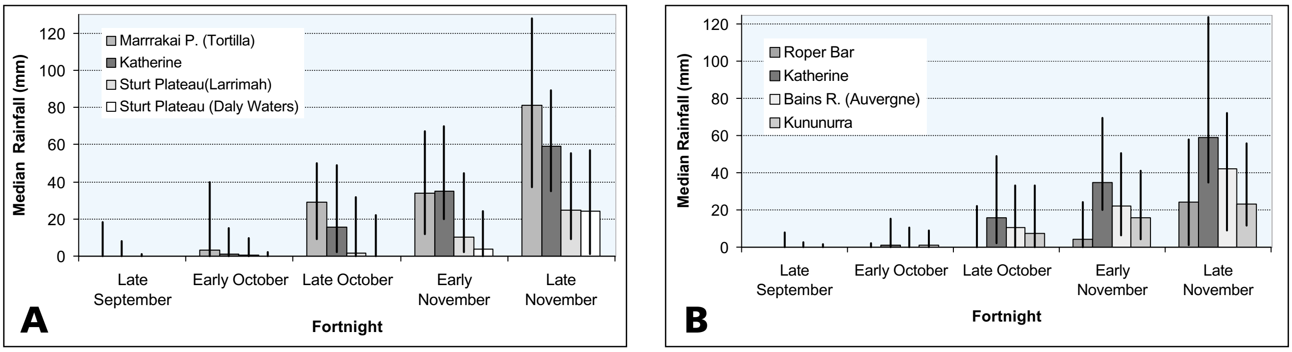
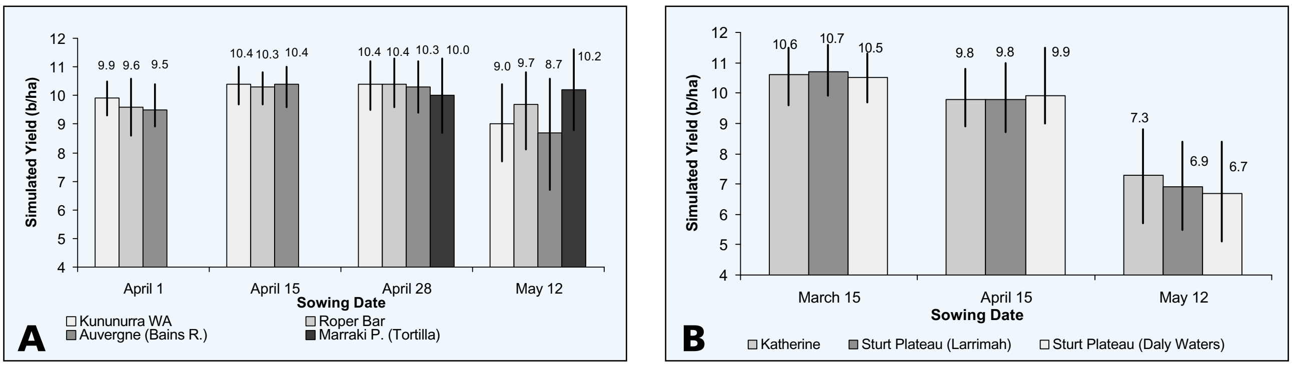


FIGURE 5.4: *Potential NT winter growing areas. Median potential yields simulated by OZCOT-APSIM (1957 to 1999). Bars show range for 20% to 80% of seasons. (A) Sites east and west of Katherine and (B) Sites south of Katherine. NB simulated yields assume 100% water allocation, no damage from insects,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

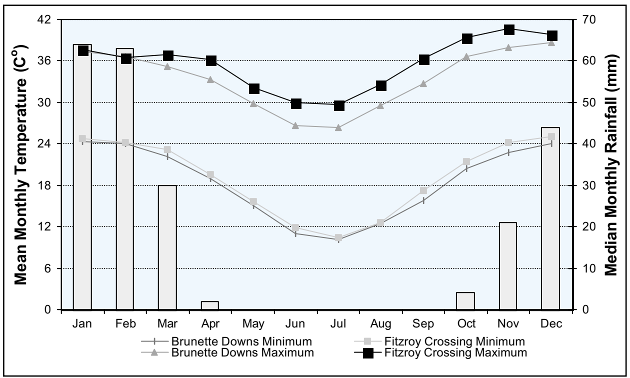


Kununurra, simulated yields were similar to the yields measured in well-managed small plot experiments. The sites with milder temperatures (Tortilla Flats, Roper Bar) appeared to produce the highest yields at a May 12 sowing.

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 $\geq$ 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 adapta-tion - 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

Chapter 6 - North Queensland

6.1. Introduction: past cotton research and production

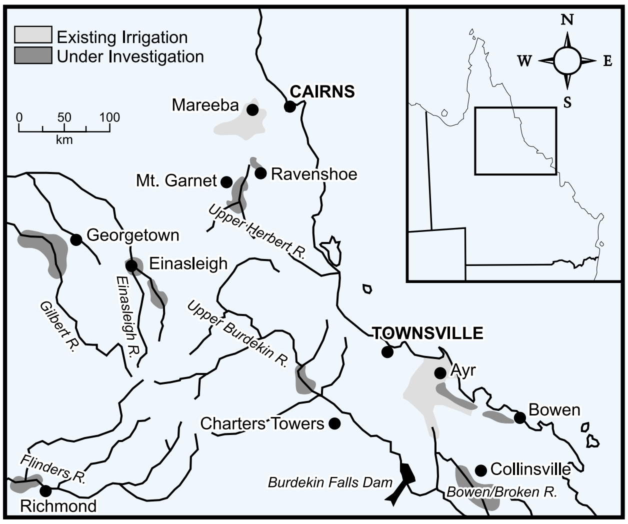
There are several new areas that could potentially grow cotton in north Queensland (NQ). This report will consider key issues relating to cotton production in these new areas. The Australian Cotton CRC is currently involved assessing the feasibility of cotton near Richmond on the Flinders River. Consequently there is an immediate need for research and development prioritisation in the Richmond area and a more rigorous review of issues in this area has been made.

With respect to cotton industry development, NQ is different to NT and WA in the following aspects:

- Queensland has an established cotton industry
- the level of irrigation infrastructure development is more diverse in potential production areas (Table 6.1)
- many potential growing areas drain into the Coral Sea (Table 6.1, Map 6.1), which could be an emotive environmental issue if cotton is a candidate crop
- the climate is more diverse, due to topography and a greater latitude range.

Cotton has been grown or tested on several occasions in the past in different areas of NQ, e.g., Kowanyama, Georgetown and Richmond. Commercial cotton was grown near Bowen during the 1960s. The most recent published research was conducted at the Burdekin Irrigation Area (Ockerby *et al.* 1999). The objective was to assess the yield potential of cotton, rice, maize and peanuts. Cotton was grown during the summer seasons 1993-94 to 1995-96. Non-transgenic varieties were grown. Heliothis (species not stated) were spayed 7 to 11 times. Small plot yields ranged from 6 to 8.2 bales/ha. It was suggested that yield improvements could be made with increased N and better irrigation scheduling.

MAP 6.1: *Potential and existing north Queensland irrigation areas (excluding Cape York) under investigation by Department of Natural Resources Regional Infrastructure Development Group, Townsville.*



6.2. The Flinders River–Richmond

6.2.1. BACKGROUND

Much of the Flinders catchment is representative of Queensland's northern Mitchell grass plains that extend from Longreach in a northwesterly arc through the towns of Hughenden, Winton, Julia Creek, and Richmond to Cloncurry (Clewett 1985). The plains are undulating covering 4 million hectares. Beef cattle grazing is the principal land use. Limited irrigated cropping is practised within the region.

6.2.1.1. Past cropping history including irrigated cotton

Many past attempts at cropping have been driven by the

TABLE 6.1: *Development status of irrigable areas in north Queensland.*

DEVELOPMENT STATUS	CATCHMENT OR REGION	TOWN (S)	DRAINAGE AREA
1. Existing (non cotton) irrigated cropping and/or potential for expansion	Bowen	Bowen	Coral Sea
	Mareeba/ Dimbulah	Mareeba	Coral Sea
	Lakeland Downs		Coral Sea
2. New area under development for cotton Richmond	Flinders	Richmond	Gulf
3. Undeveloped for irrigated cropping	Gilbert/Einasleigh	Georgetown	Gulf
	Mitchell/Lynd	Kowanyarma, Palmerville	Gulf
	Cloncurry/Corella/Leichhardt/Gregory	Cloncurry	Gulf
	Upper Herbert	Mt.Garnet, Ravenshoe	Coral Sea
	Bowen/Broken	Collinsville	Coral Sea
	Cape York	Coen/Weipa	Gulf/Coral Sea
	Upper Burdekin	Charters Towers	Coral Sea

IPM research at Richmond; pigeon pea companion crop growing within the cotton crop.

need for supplementary stock feed (Skerman 1978). During the 1950s dryland forage sorghum for ensilage was the most significant attempt at crop production in the region. In 1959 there were 38 properties with underground silage storage. Several factors acted as the stimulus for silage production. These included high wool prices, favourable seasons and tax rebates for the purchase of agricultural machinery. The cessation of dryland silage production was attributed to declining wool prices combined with many difficulties associated with dryland cropping (Skerman 1978). The latter included variable rainfall, high costs, the low protein content of the silage and high losses in storage and retrieval. The limitations of dryland cropping in the region where reviewed by Weston (1972).

The problems of dryland cropping led to the evaluation of irrigated agriculture. Shallow storage irrigation systems were researched during the 1960s and 1970s (Clewett 1985, Clewett 1991). The location for much of this work was a 160 ha storage on a tributary of O'Connell Creek, 1.5 km east of the town of Richmond. Variability in water supply (42% of seasons sufficient for grain sorghum) combined with a high likelihood of negative gross margin (46% of seasons) lead to the conclusion that shallow storage for grain sorghum production was unlikely to be adopted (Clewett 1991). However, this work highlighted within and between season variability in rainfall run-off as critical factors in the supply of irrigation water in this region.

Cotton and a range of other irrigated crops (lucerne) had been tried during the 1960s, 1970s and in 1992 at "Silver Hills" (15 km northwest of Richmond). Failures were attributed to inexperience, insect problems (grasshoppers in 1968), cotton prices and unreliable water storage from local run-off (E. Weston, QDPI, 2000, pers. comm.).

In recent years interest in irrigated agriculture has shifted toward harvesting water from larger watercourses and some landholders have been given harvesting and storage rights for water in the Flinders River (McClymnont 1999). The Flinders River is the largest in northwestern Queensland with the annual discharge estimated to be 3,030 GL (McClymont 1999). However, stream flows are highly variable within seasons and between years (Bird 1998).

6.2.1.2. The Upper Flinders River Irrigation Proposal

For more detail see Turner and Hughes (1983). The irrigation potential of the Flinders River based on a dam located about 40 km upstream from Hughenden was assessed by a reconnaissance survey at 1:250,000. The brown cracking clays of the Mitchell grass plains mainly to the south and west of Hughenden were considered to have some potential for irrigated crop production. Further intensive research was recommended before any development could occur. Proposed research included detailed soil surveys at 1:25,000 of selected lands, geohydrological studies, agronomic and irrigation research based on pilot farms (including offsite consequences e.g., salt mobilisation and deep drainage), environmental studies into potential pests and diseases and effects on flora and fauna, marketing studies and whole scheme economic analysis.

6.2.1.3. The current Richmond Development

In 1999 a pre-feasibility study for an irrigation dam on the Flinders River near Richmond was conducted for the Department of Natural Resources following a recommendation from the government's Water Infrastructure Task Force (Maunsell McIntyre & Associates 1999). The Queensland government has not supported the dam development. The diversion of some water from Flinders River into a weir located on O'Connell Creek at the western edge of Richmond is currently being considered as an alternative, although, the potential for smaller off-stream storages along the Flinders River has not been evaluated.

In 1998, off-stream storage was developed at Mr Corbett Tritton's property "Meadowlands" 20 km north of Richmond. Queensland Cotton Corporation Ltd (QC) was approached to support cotton trials at the site and agreed to make an assessment of the potential for cotton in the region. In December 1998 and January 1999 18 ha of cotton was sown and the crop supervised by an agronomist appointed by QC with further technical and marketing advice made off site by the company. Results were promising, particularly for transgenic varieties.

In 1999 the Australian Cotton CRC became involved with research at Richmond by supporting base line studies of insects on cotton grown during the 1999-2000 season by Dr Richard Sequira and Dr Ian Titmarsh of Queensland DPI. For economic reasons the area sown to cotton was increased to 180 ha with 25 ha of single gene transgenic varieties. The increased crop area permitted an aerial applicator to be based on-site. QC funded Kelleher Agricultural Services (Rockhampton) to provide agronomic and insect management for the bulk of the trial block.

6.2.2. RESOURCE REVIEW

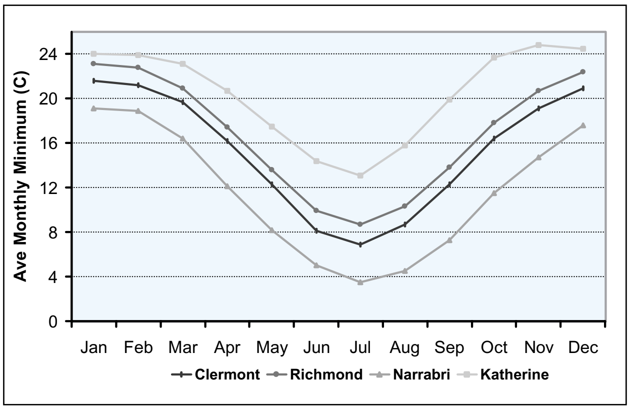
6.2.2.1. Climatic potential

There have been at least three recent reviews of the climate of the area with respect to irrigated cropping (Anning *et al.* 1999a, McClymont 1999, Maunsell McIntyre & Associates 1999). Richmond (20.73 S, 143.14 E, elevation 211 m) is representative of the Flinders Catchment. The climate is arid tropical (median = 429 mm/yr) with approximately 75% of the rainfall received during December to March. The major climatic factors likely to affect irrigated cotton production are minimum temperatures during the winter season, supra-optimal temperatures during the summer and variability in summer rainfall.

Temperatures

The risk of frost is likely to preclude cropping during the winter months of June, July and possibly August. Minimum July temperatures at Richmond are closer to Clermont than Katherine (Figure 6.1). Light frosts can occur during June, July and August. Screen temperatures drop below 2.2°C on at least one night during both June and July.

FIGURE 6.1: *Mean monthly minimum temperature comparisons*



Maximum temperatures that exceed 40°C frequently occur at Richmond during October to March. Mean monthly maximum temperatures show greater similarity with Katherine than Clermont during October to April (Figure 6.2). It would be desirable to avoid flowering during November to January when at least one day in seven exceeds 40°C, which can reduce pollen viability. Evaporative demand is greatest during the September to December period. The annual pan evaporation is high 2,810 mm and comparable with Katherine and Kununurra 2,740 mm and 2,901 mm respectively, however the annual rainfall at Richmond is significantly lower.

The generally warm climate permits flexibility in sowing date that can avoid temperature extremes at critical growth stages.

Rainfall variability

Between and within season rainfall, is highly variable. Median values are lower than the mean and the coefficient of variation of monthly values is very high (Table 6.2). The implications of variable rainfall for summer

FIGURE 6.2 *Mean monthly maximum temperature comparison*

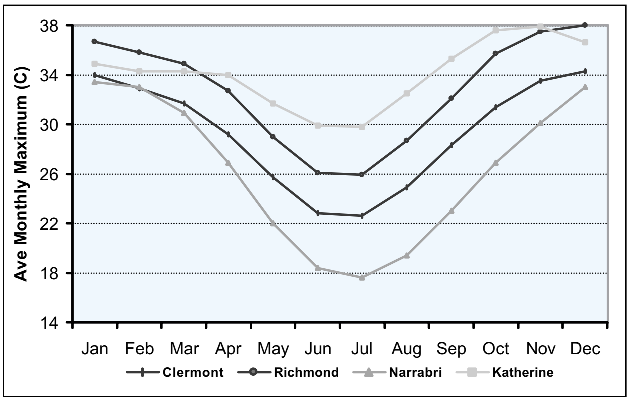


TABLE 6.2. *Median monthly rainfall (mm/month) at Richmond (110 years)*

	Median	Mean	CV %
January	88	119	93
February	3	105	79
March	38	61	108
April	4	22	168
May	5	16	169
June	4	15	167
July	0	10	190
August	0	4	250
September	0	7	200
October	7	17	159
November	18	29	124
December	50	70	83
Year	295	474	44

season cotton are in off-stream storage replenishment and the effectiveness of in-crop rainfall.

Seasonal variation in the Southern Oscillation Index (SOI) provides some predicability for the mean, median and probability distributions of seasonal rainfall. At Richmond wet summers were more frequent when the spring SOI was strongly positive and less frequent with negative spring SOI (Table 6.3). The effect of SOI was also reflected in simulations of annual run-off from native pasture catchments (Clewett 1991).

6.2.2.2. Soils and land resource assessment

Surveying of soils has been very limited in the region. A land resource survey was conducted by CSIRO in the 1950s (Perry *et al.* 1964). In the Richmond area (100 km up and downstream, including the Maxwelton area), the land systems adjacent to the Flinders River fall into three broad categories. The Balbirini (Barkley and Wanardo soils) and Glenore, which are within the broader land unit classification – Blue Grass – Browntop Plains. Otherwise Mitchell grass plains – Julia sub-system (Barkley, Wonardo soils). These soils are derived from marine deposits and are mostly grey and brown clays (approximately 64% clay). There are also areas of red and yellow sandy-loams (McClymont 1999). The duration, frequency and depth of annual flooding events determine the suitability of these soils for agriculture (Anning *et al.* 1999a).

Barkley and Wanardo are alkaline clay soils with no texture contrast, uniform colour, self-mulching, uneven surfaced with Calcium carbonate and or sulfate within a depth of 30 cm. These are impermeable, high-swelling clay soils with moderate nutrient status and high clay content. With respect to their irrigation potential these soils were seen as similar to the soils in the Ord River Irrigation Area except they have a higher salt content. Irrigated plots were considered feasible adjacent to trunk streams. "Good quality irrigation water would be required in sufficient quantities to assure downward leaching of salt to lower depths in the profile" (Sleeman 1964). Clewett (1985) described the soil reaction as "alkaline with high base saturation and accumulation of salt at depth (about 90 cm). The level of salt is not restrictive to plant growth and values of sodium are not sufficiently high to cause dispersion". Balootha soils were considered less attractive due to an impermeable surface horizon (Sleeman 1964).

Clewett (1985) measured the plant available moisture content for the Mitchell grass plains soils near Richmond to be 228 mm for 0 to 90 cm depth of profile with low infiltration rates (6 mm/hr) when the soil is non-cracking, which are comparable with similar textured soils in southern Australia.

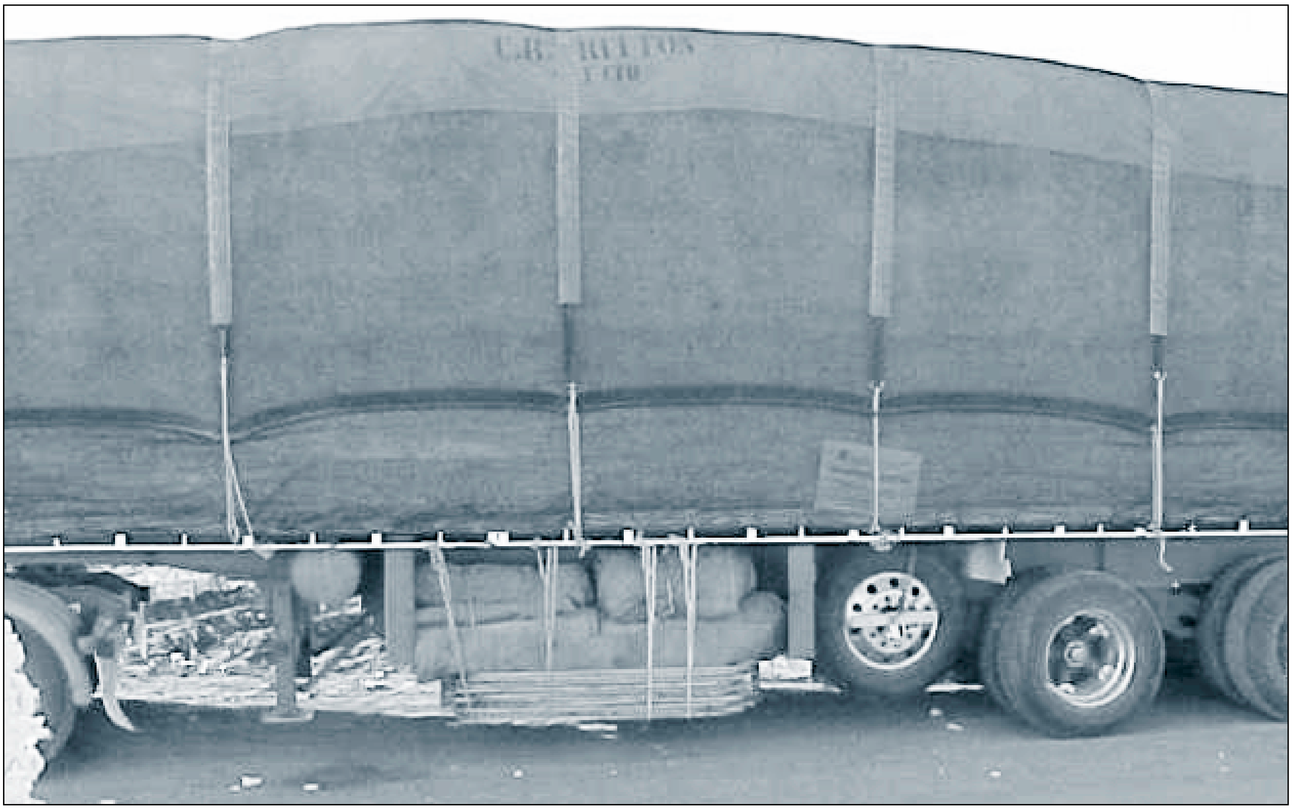
Soils were sampled from the Baronta Plateau to the north and east of Hughenden and 20 km either side of the Flinders River on the plains (Turner and Hughes 1983). The survey extended 25 km downstream from Hughenden. The clay soils on the plains were considered suitable for 'irrigation with moderate limitations'. These soils appear very similar to the plains soils found near Richmond having some accumulation of salt between 60 and 120 cm below the surface and being of modest fertility. This report classified most of the potential irrigation area as very low to low salinity hazard, provided low order preventative measures were taken.

In recent years soils have been sampled in four studies near Richmond:

1. As part of the Flinders Dam Pre-feasibility study, a small number of soils within a 50 km radius of Richmond were sampled (ACTFA 1998, McClymont 1999), where the physical structure of the soils was considered suitable for irrigated cropping. The chemistry of the soils may present problems for cropping, for example, high pH, Na, Cl and S and low levels of P, Zn and OC. The concerns

TABLE 6.3: *The influence of SOI phase calculated during September–October on likelihood of rainfall from January to March at Richmond (adapted from Rainman)*

			SOI Phase		
	Falling	- ve	neutral	Rising	+ ve
% Seasons (1890–1999)	13	21	26	14	33
Median Rainfall (mm)	235	220	278	258	333
% Chance > median all years: 269 mm	43	30	54	50	64



Rigorous containment of Bt seed cotton before transport from Richmond in Queensland for ginning

about soil salinity and irrigation were: (a) poor internal drainage of soils due to sodicity leading to increased volumes of irrigation tail water; (b) leaching and movement of salts from the soil to the wider environment; (c) the need for large amounts of fertilisers, that may enter the environment.

2. From cotton research sites at 'Silver Hills' and 'Meadowlands' where there are high chloride levels (850 mg/kg) at 120 cm depth. This site and the site at 'Meadowlands' could be used to monitor any changes in salinity due to irrigation, both off and within-site.
3. As a follow up to the first study, an electro-magnetic induction survey was conducted of a 5 km radius of the Maxwelton area (40 km west of Richmond) and the 20 Mile Reserve adjacent to the Flinders River between Maxwelton and Richmond (Gordon *et al.* 1999). The objective was to provide preliminary information as to the inherent soil salinity levels of the area. Electro-magnetic induction was used with some soil samples taken for calibration. Due to insufficient samples the robustness of the calibration was questioned. However, the survey did find that significant areas had high levels of inherent soil profile salinity. Of the 14,000 ha at Maxwelton about 6,500 ha had moderate to low inherent salinity levels. A further 7,000 ha was considered to have a soil profile salinity level that may limit crop production. It was considered that there might be significant areas in the 20-mile reserve area that would pose a limit to crop production, although a more thorough assessment is needed. The alluvial soils adjacent to the Flinders River were of low conductivity. Further work was recommended to validate calibration. Moreover an assessment of the impact of irrigation on salinity and offsite movement of salt would require more detailed study of soils, geology and groundwater systems within the area.
4. Soil samples commissioned by the local shire near Maxwelton in 1999. The Gulf Agro-economic Study commissioned by the Queensland Department of Natural Resources (Anning *et al.* 1999a) estimated the potentially irrigable land area in the Flinders River sub-catchment as 12,200 ha. Land systems data and local knowledge were used to identify potentially suitable land, however, there was little detailed information on the irrigable proportion. The areas of soil for crops were based on conservative estimates. Six suitable enterprises were identified. These were cotton, soybean, leuceana, hay, citrus and grapes. Based on an analysis of market and infrastructure availability, cotton was considered the most likely base crop for any future irrigation development. The scenario developed included 8,000 ha sown to cotton and a total demand for irrigation water of 83,680 ML/year of which 48,000 ML/year would be required for cotton.

6.2.2.3. Climatic risk assessment

McClymont (1999) made a preliminary assessment of the sowing date options. Yields were simulated using the OZCOT cotton simulation model. Assuming 8 ML of irrigation, 200 mm soil water holding capacity, and non-limiting soil nitrogen, highest average yields (7.5 to 8 bales/ha) were simulated for mid to late August and late December to late January sowing date. No assessment of the impact of sowing date on the risk of harvest rainfall was made. Based on heat unit summation (Constable and Shaw 1988) crops sown during January to early February optimise both yield and harvest rainfall risk. Crops sown at this time commence opening bolls during mid-April to late June and are harvested from about late May to early August a period of very low rainfall frequency (1 day/month). Conversely, crops sown during mid August to September would open bolls from mid December and be picked during January, a period of relatively high frequency of rainfall (6 to 8 days/month).

There is insufficient knowledge of the seasonal insect pest abundance to assess sowing date options with respect to insect pest management risks. This is an objective of research recently funded by the Australian Cotton CRC.

6.2.2.4. Water resources

In 2001 the Queensland government is to commence a Water Resource Plan (WRP) for the Flinders catchment, which should take approximately two years to complete (2002). The WRP will calculate the volume of water that can be withdrawn from the catchment for irrigated crop production. The plan accounts for the requirements of other users and allocates environmental flows including groundwater recharge. Importantly the WRP does not identify land suitable for irrigation nor does it assess the on-site or off-site environmental impacts of irrigated agriculture.

6.2.3. INFRASTRUCTURE ISSUES

At Richmond there is strong local government and landholder support for irrigation development. The Flinders Highway and the rail line between Mt Isa and Townsville service Richmond, Julia Creek and Hughenden.

Queensland Cotton has proposed a stakeholders' development committee to coordinate broader issues beyond production system research. This group will have membership representing the Cotton CRC, local primary producers, Queensland Department Primary Industry, Queensland Department Natural Resources, the Environmental Protection Agency, local government, Monsanto, commercial agricultural consultants, and Queensland Cotton Corporation.

6.2.4. MAJOR ENVIRONMENTAL CONCERNS

- salinisation
- offsite movement of chemicals and contamination of marine and/or riverine habitats, pastures, flora and fauna
- codes of practice for crop management and chemical usage to avoid offsite contamination
- issues relating to the broader Gulf ecosystem, which are discussed in Sections 6.3.3.2 and 6.4.2.

6.3. Other north Queensland regions

There are several other regions in north Queensland, within the mandate region of this study, considered to have potential for irrigated cotton development. These regions are Cape York Peninsula (excluding the Mitchell River and Lakeland Downs), the Gulf area (Mitchell/Lynd, Gilbert, Einasleigh and Cloncurry/Corella/Leichhardt/Gregory Sub-catchments), the Burdekin catchment (Broken/Burdekin, Upper Burdekin and Burdekin/Bowen), the upper Herbert River and the Atherton Tableland/Mareeba and Lakeland Downs areas.

The Cape York Land Use Strategy (CYPLUS) incorporates the most recent reviews and studies covering the soil and water (ground and surface) resources and agricultural land suitability of the Cape York Peninsula (Horn *et al.* 1995a,b; Biggs and Philip 1995). The objective of CYPLUS was to provide a basis for public participation in planning for the ecologically sustainable development of Cape York Peninsula (Horn *et al.* 1995a). Projects within CYPLUS collected and interpreted base data on natural resources including vegetation mapping, fauna (marine, insect, fish, terrestrial vertebrate and wetland fauna distribution), mineral resources, geophysical, land resource inventory, groundwater. Land use projects included surface water resources, fire, feral pest animals, weeds, land degradation and erosion and land projects (pastoral industry, forest resources, fisheries, tourism industry, current land use and tenure). Population projects included infrastructure, population, secondary and tertiary industries, economic assessment, traditional activities and community values needs and aspirations.

Significant contribution to resource development in the Gulf, Burdekin, Herbert and Atherton/Cairns regions has come from projects coordinated by the Queensland Department of Natural Resources Regional Infrastructure Development Group based in Townsville. Three such projects are the Agro-economic Studies published for the Burdekin River (Anning *et al.* 1999b), Gulf area (Anning *et al.* 1999a) and Herbert River (DNR, in press 2001). These projects had objectives highly relevant to this report as follows:

- identify suitable areas, viable crops, and cropping systems to best use the available natural resources
- identify the potential for freshwater and marine aquaculture
- propose the scale of production that is sustainable
- investigate the markets for prioritised agricultural industries and aquaculture
- provide advice on agronomic matters including the suitability of climate and soils, and water requirements
- establish farm economic viability
- comment on environmental and infrastructure issues relevant to the catchments under consideration.

6.3.1. CLIMATIC POTENTIAL

The potential growing regions in NQ are more diverse climatically than potential growing areas in WA and NT. This is due to a greater latitude and altitude range. The following analysis compares the climatic suitability of six locations in NQ for cotton production. All locations had good climatic data and are representative of the major potential growing areas in NQ: Coen (Cape York), Bowen, Georgetown (Gilbert/Einasleigh), Collinsville (Bowen/Broken) Mt Garnet (Herbert / Western Tableland) and Mareeba (North-West Tableland / Lakeland).

Temperature

Because of the risk of frost, only Bowen and Cape York (Coen) could grow cotton during the winter (dry) season. As was the case in WA and NT, potential winter growing areas in Qld also risk exposure to sub-optimal temperatures mid way through the growing season. Figure 6.3 shows that at Coen and Bowen sub-optimal temperatures occur less often than at Katherine, NT (Figure 5.1).

Based on research at Kununurra and Katherine, to grow a crop from sowing to picking requires about 2,200 DDS_{12}. From sowing to first open boll (10% of plants) requires 1,850 DDS_{12}. Figure 6.4A shows growing season DDS_{12} for the winter season sites. Coen is similar to Katherine and Kununurra (Figures 4.3, 5.4), sowing by mid April will ensure a mid-October pick in most seasons. At Bowen picking would be after this date, even at a March 15 sowing. Crops sown at Bowen during March/April would require picking in November and possibly early December.

For summer growing areas (Figure 6.4B), at a November 1 sowing date bolls will have opened at all sites except Mt Garnet by March 15 and Georgetown would be at harvest maturity. At a December 1 sowing date only Georgetown would have open bolls by April 1.

6.3.1.3. Rainfall

Figure 6.5A shows for winter grown sites that significant rainfall does not occur until early December, although there is high variability in late November. Thus sowing at Bowen would need to occur by early May to ensure maturity by late November (Figure 6.4A).

For summer growing regions the median rainfall declines during late March to early April (Figure 6.5B). Thus by combining with Figure 6.4B, to avoid significant rain when bolls are open (susceptible to weathering), sowing must be made after November 1 at Mt Garnet and after December 1 at Mareeba, Collinsville and Georgetown.

6.3.1.4. Yield potential and optimum sowing date

For summer growing regions, potential yield is optimised for sowing dates between October and December (Figure 6.6). Presumably lower yields at February and March sowing dates are due to frost and sub-optimal temperatures at the cooler sites (Collinsville). Summer growing areas have more variable yields than winter growing areas. This may be due to the model simulating waterlogging effects. Future model validation with soil characterisation data collected at the site could determine whether waterlogging is restricting yields. Combining the yield response in Figure 6.6A with the sowing date most likely to avoid harvest rain (Figures 6.4, 6.5), yield and quality risk appear optimised at a December sowing date in summer growing areas.

FIGURE 6.3: *Potential north Queensland winter growing areas. The seasonal frequency of sub-optimal night temperatures, minimum temperatures below 11°C and 12°C (1957 to 1999). Bars show the range for 20% to 80% of seasons.*

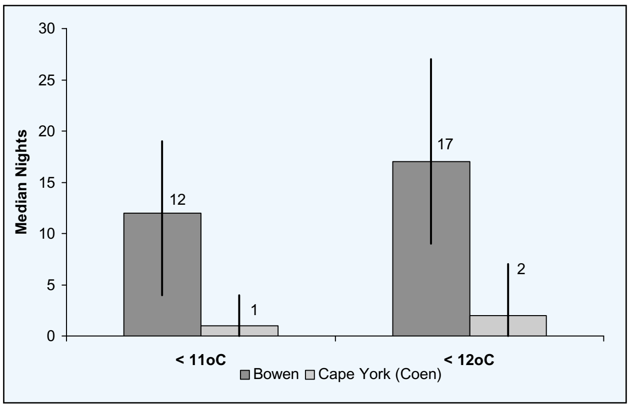


FIGURE 6.4: *Potential north Queensland growing areas. Median DDS_{12} for selected growth periods calculated for 1957 to 1999. (A) Winter growing areas, (B) Summer growing areas. Bars show range for 20% to 80% of seasons.*

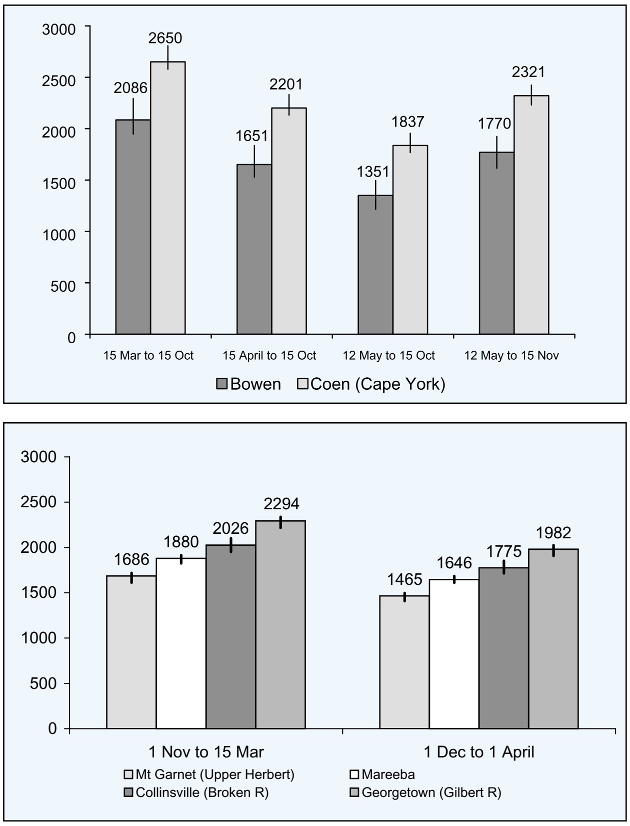


FIGURE. 6.5: *Potential north Queensland growing areas. Median fortnightly rainfall (1957-1999) over the boll opening and picking period for (A) Winter and (B) Summer growing areas. Bars show range for 20% to 80% of seasons.*

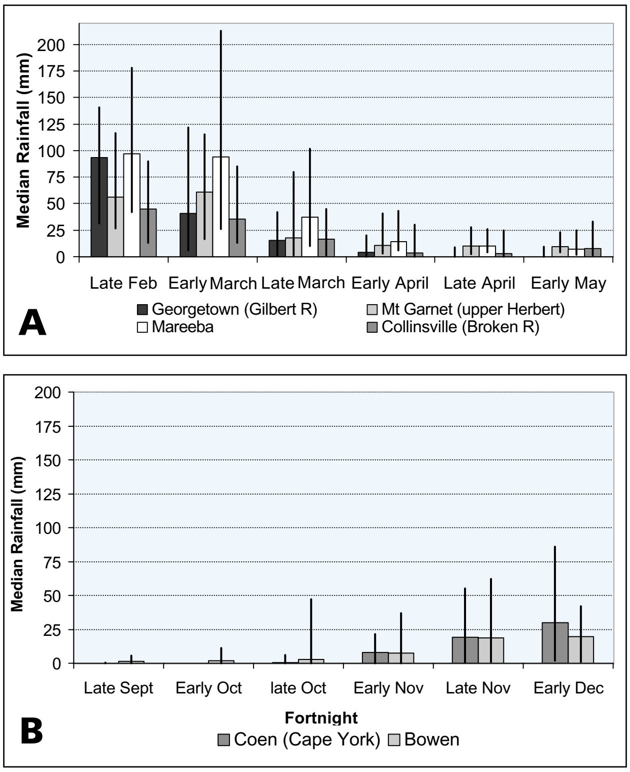


FIGURE 6.6: *Effect of sowing date on median potential yields simulated by OZCOT-APSIM (1957-1999). (A) Summer growing areas, (B) Winter growing areas. Bars show range for 10% to 90% of seasons. NB simulated yields assume 100% water allocation, no damage from insects, diseases and weeds, excellent crop management and prompt picking following defoliation.*

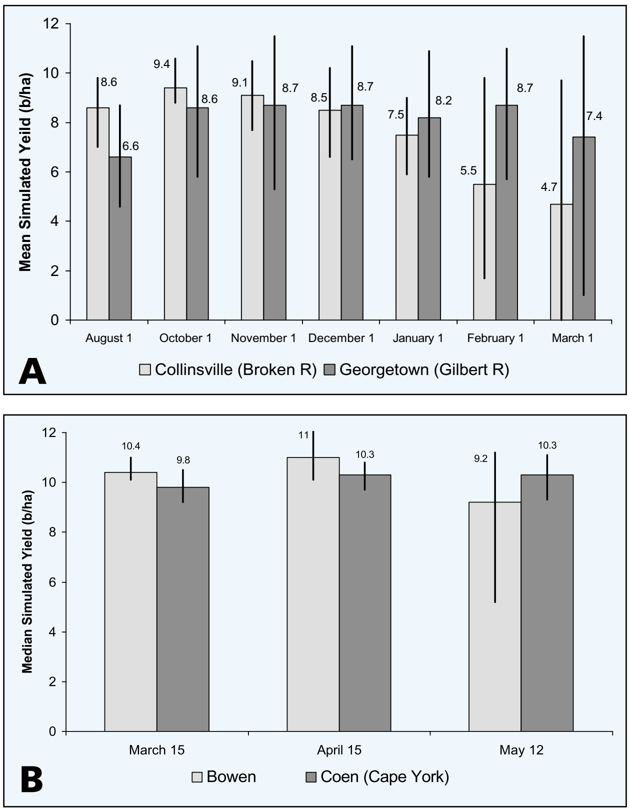


Figure 6.6B shows median yields and their range for winter growing areas. The effect of sowing date on simulated yield trends was similar to the Kimberley analysis (Figure 4.5). At Bowen, sowing by late April appears optimal for yield and harvest rainfall considerations. As Coen has a longer sowing window, sowing could extend to mid May without comprising yield or significant risk of harvest rain.

6.3.2. WATER, SOIL AND LAND RESOURCES

6.3.2.1. Cape York Peninsula

Groundwater resources

As part of CYPLUS, Horn *et al.* (1995) conducted an overview of the nature of the Peninsula's groundwater resources and those features that relate to their ongoing use and protection. Generally there is considered to be abundant quantities of groundwater. Groundwater is the major water source for human activities in the region (mining, stock and domestic). The report details the broad location of supplies, recharge areas, some yields and water quality, which is considered to be good. Risks of over exploitation and a paucity of data in many areas with respect to sustainable removal were noted. Although yields varied from 0.5 to > 40 l/s there was no attempt to comment with respect to the prospects of using groundwater for irrigated agriculture. It could be assumed that some use of groundwater for irrigation would be possible, however, it is not clear over what area this would be sustainable.

Surface water resources

The report by Horn (1995) overviews the 'nature of surface water resources of Cape York Peninsula'. While the report collates available data on the flows from the major catchments, data is relatively scarce with only 17 river gauging stations currently operating. Data is available from a further 31 stations that have been closed since 1988. A major focus of the report was to assess the environmental flow requirements of the peninsula waterways. However, this was not possible due to a paucity of data combined with the variability in water body types and the unpredictability of hydrological flows.

There are several significant rivers within the peninsula (the Mitchell River is included in the Gulf of Carpentaria section). For example the Jardine has the highest base flow of any river in Queensland. The potential divertible supplies on the eastern peninsula were estimated at 4,600 GL/yr of which 6 GL is currently being used. Irrigation licenses are confined to the Lakeland and Cooktown areas. A total of 3,158 ha are currently irrigated with 34 possible dam sites being identified.

Although, the western peninsula has the largest areas of soils suitable for irrigated or dryland cropping (Biggs and Philips 1995, Ockerby 1997) much less is known of irrigation water availability near to these soils. Geology may preclude the construction of major dam sites in the western peninsula.

Soils and agricultural land suitability

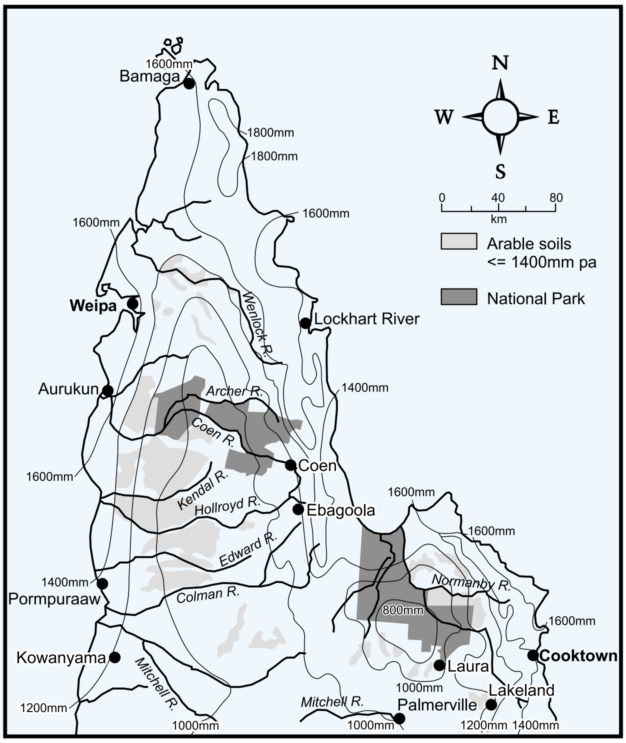
Soil surveying has been limited and at a broad scale. The most recent survey (Biggs and Philip 1995), which built on previous work, produced a soil map for the Cape York Peninsula for use at 1:900,000 scale. A short project length, remoteness and poor access due to weather, prevented production of a map at 1:250,000 scale. This study also reviewed published geological literature for the area and includes a geological map.

Using the Australia soil classification standard (Isbell 1996), the kandosols (43%), dermosols (17%) and hydrolsols (14.6%) were most extensive. Vertisols (5.56%) were less extensive but still cover more than 650,000 ha. A total of 113 different soils were mapped and described. The former two soils lack a strong texture contrast and have structured B-horizons. The kandosols fall mostly into the red and yellow earths of the great soil grouping. The dermisols have higher silt content and tend to be naturally hard setting. The dominant soils are low in available P, S, K, Zn, Cu, EC, Ca and Mg (Table 6 p 68-69). Vertisols were better supplied with Ca, Mg, K, P and S, although the latter two were still considered low.

Land-use assessments have identified soils suitable for irrigated sugar and tea tree (Map 6.2). At the scale of the map produced individual map units comprise up to four soil types. The dominant soil is 60% of the map unit. Cropping land fell into classes 2 and 3, suitable land with minor and moderate limitations respectively. The area of each class suitable for irrigated cropping was 1,544,000 ha and 4,184,000 ha respectively (Ockerby 1997). The overlay with irrigation water availability has not been made.

Combining the proximity of arable soil to river channels with an annual rainfall of 1,400 mm/annum and annual river flow data, (Horn *et al.* 1995a) can identify

MAP 6.2: *Areas of Cape York Peninsula potentially suited to irrigated cotton. Where = Class 2 soils with potential for irrigated sugar and tea tree and annual rainfall ? 1400 mm pa, and = National Park Areas. Adapted from Ockerby (1997).*



river catchments that could possibly support irrigated cotton (Map 6.2). Table 6.4 shows that land inland (60-80 km) on several west flowing rivers between Pormpuraaw in the south and Aurukun in the north and west of Coen may fit these requirements. Modelling data also suggests that cotton could be grown during the winter season in climates similar to Coen (Figure 6.6). Where surface water flow is into the Coral Sea, outside the existing cropping area at Lakeland downs, areas near the upper Normanby Basin may be suitable (Table 6.4)

Conclusions Cape York

- Much to be done to quantify environmental flows. This includes the development of processes that can merge the biophysical and sociological aspects.
- The harvesting and distribution of water for irriga-

TABLE 6.4: *Catchment areas of Cape York that could have soil and water resources and suitable climate for irrigated cotton during the winter season.*

DRAINAGE	CATCHMENT/RIVER	ANNUAL RAINFALL (MM)	LAND SUITABILITY CLASS	MEAN ANNUAL DISCHARGE (GL)
Gulf	Kendal	<1000-1200	2/3	?
	Holroyd	<1000-1200	2/3	3856
	Edward	<1000-1200	2/3	?
	Archer/Coen	<1000-1200	3/2	4828
	Colman	<1000-1200	2/3	4197
	Wenlock	1200-1400	2	3373
	Watson	1000-1200	3	3556
Coral Sea	Normanby	800-1200	2/3	5954

tion purposes require more detailed study for river systems with soils favourable to crop production.

- The land resource inventory is at too broad a scale to adequately locate irrigation areas.
- Offsite impacts other than the diversion of water require thorough investigation.
- Water quality is generally good.

6.3.2.2. Atherton Tableland/Mareeba-Dimbulah/Lakeland Downs

These are established agricultural areas that currently do not grow cotton. The opinion of Mareeba QDPI staff was that the area west of Mt Garnet and Ravenshoe and Lakeland Downs would be more favourable for cotton than the Mareeba/Atherton areas. Where farms are small, there is a diversity of crops and there are important insect pests such as *Helicoverpa armigera* and silver leaf white fly. The area west of Mt Garnet and Ravenshoe could grow dryland cotton but would require additional dam development for irrigated production. At Lakeland Downs there are individual large farmers with irrigation capacity that would consider cotton if ginning facilities were available.

There is potential to expand the Mareeba Dimbulah Irrigation Area (MIDA) through a new dam constructed to meet increased domestic demand in the Cairns region (Hyder Consulting 1999). The proposed Nullinga Dam could irrigate an additional 7,630 ha in the western sector of the MDIA. The capacity could be further enhanced if the Leadingham Creek dam were developed in conjunction. Further expansion in agricultural use of irrigation water was expected for sugar cane, mangoes, tea tree and other horticulture. Tea tree was expected to be a major user in the western MDIA (Hyder Consulting 1999).

6.3.2.3. The Burdekin Catchment

There are four potential irrigation sites focused on the Bowen, Gumlu, Collinsville and Charters Towers areas. These are Burdekin/Bowen, Bowen/Broken and the Upper Burdekin sub-catchments (Map 6.1).

The Burdekin/Bowen area is an extension of an existing area with established cane and horticultural industries via the extension of the Elliot Main Channel from the Burdekin Irrigation Area (Map 6.1). While there has been interest in growing cotton by some horticultural producers and small areas (40 ha) have been evaluated in recent years (G. Todd, Bowen, pers. comm. May 2000), Anning *et al.* (1999b), do not consider cotton to be a major crop in the future. There are two further reasons to be cautious when considering cotton production in this area. Firstly, negative public perception of cotton being grown very close to the coast and the Great Barrier Reef. Secondly, there is a high risk of serious insect pest problems. The area already has problems with whitefly and *Helicoverpa armigera,* both of which are highly resistant to major insecticide groups (J. Brown, QDPI Ayr, pers. comm. 2000). However, cotton could be grown in the winter season and therefore comply with local pest management practices (mainly for white fly) of a susceptible crop free period during the wet season.

Water resources

Potential development near Collinsville on the Bowen/Broken Rivers is dependent on the development of the Urana Dam Scheme. The Department of Natural Resources recently revised estimates of water supply to Collinsville to be 143,300 ML at 85% reliability (April 1999).

The upper Burdekin, north of Charters Towers, relies on development of the Hells Gate Dam. A WRP is required for both areas; the timeframe for irrigation development in the upper Burdekin is likely to be > 10 years (P. Unta, DNR, Townsville, pers. comm. 2000).

Soils and land suitability

Anning *et al.* (1999b) reviewed the available soil data. The intensity and detail of soil survey data varied between the regions ranging from about 1:100,000 in the Bowen and Collinsville areas (Hyder Consulting 1998) to 1:500,000 based on land systems in the Upper Burdekin. From this a likely total area available for cropping was calculated. This calculation allowed for roads, channels and other infrastructure as well as land at risk of flooding, erosion, etc. Total available cropping areas estimated for Burdekin sub-catchments are shown in table 6.5.

6.3.2.4 Gulf of Carpentaria (except Flinders River)

This region includes the Mitchell/Lynd, Einasleigh/Copperfield/Bundock/McKinnon, Gilbert and Cloncurry/Corella/Leichhardt/Gregory sub-catchments, which have potential for irrigation development (Maps 6.1, 6.2). In most of the region, agricultural development is minimal with extensive grazing and some dryland improved pastures the principal enterprises. There is a small amount of irrigated horticulture (500 ha) near Georgetown on the Gilbert River. A range of horticulture and broadacre crops (including cotton) were successfully grown at Kowanyama (Mitchell River) more than 25 years ago when it was a church run mission station.

TABLE 6.5: *Total available cropping area for each of the sub-catchments (from Anning et al. 1999b)*

SUB-CATCHMENT	NEAREST TOWN	POTENTIALLY AVAILABLE CROPPING AREA (HA)
Burdekin/Bowen	Ayr/Bowen	23,008
Bowen/Broken	Collinsville	28,551
Upper Burdekin	Charters Towers	10,500

Water resources

The mean annual discharge of all streams (including Northern Territory and Cape York) draining into the Gulf account for more than 20% of Australia's annual surface water run-off. There are several significant rivers within the Gulf region defined here. The Mitchell River is considered to have the greatest annual discharge (11,998 GL). As is the case for all Queensland rivers, a Water Resource Plan (WRP) is required to determine water availability for irrigation and other purposes (environmental flows).

The Queensland Department of Natural Resources regional infrastructure development group is coordinating studies to evaluate the potential of water resources in this region. The timeframe for developing a WRP, the more detailed environmental impact assessment and development of irrigation infrastructure is expected to be > 10 years for the majority of Gulf catchments. The Flinders River and possibly the Gilbert River could have irrigation infrastructure in five years. In all catchments the development timetable would depend on the level of commercial interest in irrigated land in the area.

McIntyre and Associates (1998) have undertaken a pre-feasibility study into water resource development in the Einasleigh area. This study has identified a range of potential crops suitable for irrigation at Einasleigh and the surrounding areas and has identified the Kidstone Dam as having the potential to irrigate between 2,500 and 4,500 hectares of land. However, recent hydrological studies (Lait 2000) recommended that a large-scale irrigation project should not be developed on the western section of the Einasleigh Town Common owing to a high probability of rising saline groundwater as a result of irrigation.

In the Gilbert catchment a dam feasibility study is being conducted by DNR as part of the Gulf Planning Study (due for completion 2001). There are indications that a cost efficient dam could be constructed. Groundwater options are also available.

Similar studies are being commissioned for other catchments in the region.

Soils and agricultural land suitability

Generally most soil and land suitability data is on a broad scale and dates to earlier CSIRO and Queensland Government surveys (e.g., Perry 1964; Galloway *et al.* 1970, Grundy and Bryde 1989). The Gulf Agro-economic Study (Anning *et al.* 1999a) combined available soils data with local knowledge to estimate suitable land areas. 'Land systems data identified very large areas of land with little detail and information on irrigable area'. The soil data for the Cloncurry, Corella, and Leichhardt/Gregory sub-catchments were considered inadequate to identify suitable areas. Table 6.6 gives potentially irrigable areas for the other three sub-catchments in the Gulf.

The potentially irrigable land in the Mitchell/Lynd sub-catchment is isolated, lying 120 km to the east of Palmerville and 230 km to the west of Kowanyama. Soils lie adjacent to the major watercourses and are at risk of seasonal flooding. Close to the river, cracking clay soils of the Koolatah family are dominant (Galloway *et al.* 1970). Soils are poorly drained and possibly saline at depth. Soils 5 to 10 km from watercourses may be better suited for crop production.

In the Einasleigh/Copperfield/Bundock/McKinnon sub-catchments, land resource assessments have been made at a scale of 1:250,000 (Grundy and Brydle 1989). Within the Einasleigh/Copperfield catchments an area of 61,500 ha was assessed as Agricultural Land Class A1 and was within 5 km of the river (Anning *et al.* 1999a). Recently a map of the soils of the Einasleigh Town Common at a 1:50,000 scale was completed (Enderlin 2000). This study confirmed the limitations of the concurrent hydrological study (Lait 2000). Of the 6,070 ha surveyed 2,970 ha was considered unsuitable for irrigated cropping due to physical limitations, 2,148 ha of poorly drained heavy textured soils were considered suited only to dry season cropping with shallow rooted crops, due to poor drainage and salt > 60 cm. The remaining 943 ha were not limited by salt but slope could present an erosion hazard. Most soils were considered low in N, P, S, Cu, Zn and B.

The Gilbert catchment has significant areas of deep sandy red and yellow earth soils that have few limitations to crop production (Anning *et al.* 1999a). Flood irrigation would not be possible on these soils.

Although soil and land suitability data is limited for Cloncurry/Corella/Leichhardt/Gregory sub-catchments, considerable areas of land systems similar to the Flinders River are reported (Perry 1964; Galloway *et al.* 1970). Clay textured soils on the plains of the Gregory River were considered similar to the Ord River (Christian *et al.* 1952). Further data on soils needs to be collected in this region before any realistic assessment of agriculture potential can be made.

TABLE 6.6: *Potential areas of irrigable soils on Gulf of Carpentaria (excluding Flinders River) sub-catchments (from Anning et al. 1999a)*

SUB – CATCHMENTS	NEAREST TOWN(S)	POTENTIALLY AVAILABLE CROPPING AREA (HA)
Mitchell/Lynd	Kowanyama, Palmerville	15,000
Einasleigh/Copperfield/Bundock/McKinnon	Einasleigh	6,850
Gilbert	Georgetown, Forsayth	7,555

6.3.2.5. Upper Herbert River

Department of Natural Resources are investigating the feasibility of an irrigation scheme in the Upper Herbert Catchment between Gunnawarra Station, Mt Garnet and Kaban (see Map 6.1). An Agro-economic Study (due for publication in late 2001) and water resource planning process are currently in preparation for this region. Irrigation development is dependent on dam construction. An assessment of the land suitability for irrigated agriculture has been recently completed (Enderlin and Neenam 2000). Monthly temperature and rainfall averages indicate the Kaban/Ravenshoe area could be too cool and wet for cotton.

6.3.3. PRODUCTION SYSTEM INFRASTRUCTURE ISSUES

Key points are summarised below for each region.

6.3.3.1. Cape York Peninsula

- Little knowledge of insect pest fauna, but some benchmarking surveys conducted (e.g., CYPLUS).
- Infrastructure poorly developed outside the south-east (transport, power, skilled labour).
- Few major population centres.
- Proximity of Weipa port is an advantage.
- A scale of production large enough to support cotton-processing infrastructure appears possible provided soil maps are verified with more detailed surveys and water available.
- Community attitude to natural resource development. The CYPLUS study implies different attitudes within the Cape to that of the external community. The latter having a stronger view that this is a pristine environment requiring preservation.
- There are no government run crop research facilities in the Cape. The closest specialist professionals (e.g., entomologists) are located at Mareeba.
- This is a longer-term development.
- Climatic similarity with Katherine and Kununurra may permit some transfer of production technology.

6.3.3.2. Gulf of Carpentaria

- Smaller catchments may not support ginning infrastructure. Thus a common ginning facility for several areas may be required.
- Some areas poorly serviced by transport infrastructure.
- Insufficient knowledge of soil and water resource although work is ongoing.
- Distance from population centres in some catchments.
- Except for Flinders and possibly Gilbert rivers in the absence of commercial farming interests, other areas are unlikely to have significant irrigation development within 10 years.

6.3.3.3. Burdekin catchments

- Near Collinsville there is a possibility of insect pest species similar to the nearby Bowen area, including resistant *Helicoverpa armigera.*
- Opportunistic cotton growing in the Bowen area could occur if a gin was constructed within freighting distance (Collinsville, Charters Towers, possibly Richmond). This could result in winter and summer cropping in close proximity and may exacerbate insect pest problems.
- Infrastructure to service irrigated agriculture is generally better in this area than the Gulf or Cape York.
- Production system R&D would be required prior to commercial development. This would include pest management/ecology, crop agronomy and irrigation management. The integration of cotton into more complex cropping systems would be critical, as a wider range of crops could be grown alongside cotton in this area.
- Agronomic practices to minimise run-off and soil erosion would be important in the upper Burdekin due to slope and lighter textured soils.
- Irrigation development on the Broken River (Collinsville) and upper Burdekin catchments is dependent on the development of the Uranna and Hells Gate dams respectively. The latter development is likely to take more than ten years.

6.3.3.4. Upper Herbert

- This area is reasonably near infrastructure at the Atherton Tableland.

6.3.3.5. Atherton/Mareeba/Lakeland Downs

- Cotton would be a crop substitution issue in most of these areas.
- Insect pests inherited from current farming practices could be problematic. Area wide management incorporating cotton would be essential.
- Cotton farming is likely to be opportunistic and dependent on a gin development in a neighbouring area.
- The proposed Nullinga and Leadingham Creek dams could provide an additional cropping area to support a gin.

6.4. Environmental issues

6.4.1. CAPE YORK PENINSULA

- Calculation of environmental flows – essential as demands are increasing from a number of sources including irrigation. These are difficult to calculate because of a lack of environmental data and extreme natural variability of stream flows.
- Biodiversity – the Peninsula is one of the most diverse areas in the State and Queensland has the highest level of biodiversity of all Australian States (Roberts 1992). Many areas are considered to have

a high wilderness value and are described as near pristine.

- Impact of Cape waterways beyond the coastline, which can impact on estuarine wetlands, offshore fishing industry and perhaps the Great Barrier Reef.
- Groundwater management issues – sustainable exploitation, deteriorating quality, saltwater intrusion, groundwater pollution, rapid infiltration and reduced buffering capacity, seasonality of recharge. Current knowledge is considered insufficient to address the above issues.
- Minimising off-site impacts of irrigated agriculture.

6.4.2. GULF OF CARPENTARIA

- Impact of diverting water for irrigation on Gulf of Carpentaria - the southern Gulf supports commercial, recreational and traditional fisheries. The principal catch is prawns and finfish. In 1993, the prawn catch was worth about $70 million. Over 20 % of the approximate 107 species of finfish are found in the Gulf and estuaries and are sought by commercial fisheries. Biological information is lacking about the condition of the Gulf population of any fish species and whether the fish stocks can sustain the current demands being imposed on the Gulf system. Moreover, data on the contribution of different streams to Gulf biota is lacking.
- Calculation of environmental flows – seasonal variability is important here, as the ecosystem is adapted to such variability, which is strongly linked to the El Nino – SOI influence. Dams can have positive and negative impacts.
- Salinity is a risk on many soils due to salt accumulation deep in the profile. Appropriate irrigation methods are essential to prevent remobilisation in the profile. This risk will be exacerbated by exposure of the subsoil during land levelling. Geological investigations are required to assess the risk of rising watertables from irrigation.
- Biodiversity/Remnant Vegetation – there have been no widespread flora studies since the CSIRO land systems surveys (Perry 1964; Galloway *et al.* 1970). It is estimated that 35 species of flora and fauna, rare in Queensland, occur in the region. Eleven regional ecosystems occur in the Einasleigh uplands and twelve in the Gulf region (Anning *et al.* 1999a). Regional and farm scale planning of remnant vegetation is a priority prior to land development.
- Erosion–the alluvial plains are already severely eroded by water. Management practices for cropping must minimise this risk.
- Chemical contamination off-site, flooding combined with high intensity rainfall creates a risk of nutrient and chemical movement off-site. Well-defined codes of practice for chemical use will be essential.

6.4.3. BURDEKIN CATCHMENTS

- Concerns of the beef industry regarding contamination by chemicals used in cotton growing. This is an important issue at Collinsville and in the upper Burdekin.
- The general issue of the effect of irrigation development on the coastal fishery and waterways.
- Erosion and increased turbidity of waterways.
- A management plan to be developed to link sustainable agricultural production with environmental consideration to downstream users. This is very important to the Burdekin catchment to meet the requirements of all users. The river system will act as both a water supply channel and drainage conduit.

6.4.4. ATHERTON TABLELAND/MAREEBA/LAKELAND DOWNS

- Well-defined codes of practice for chemical use will be essential.
- Negative community perception of cotton so close to the Cairns area and the Great Barrier Reef.

6.5. Conclusions

Recent research into growing cotton in north Queensland has been minimal. This analysis shows there are many areas of north Queensland that could potentially grow cotton. In all areas some crop specific research would be required at some time. However, irrigation development in potential growing regions ranges from nil to fully established. Hence in undeveloped areas the timeframe for cotton development, if it were to proceed, is highly dependent on the status of infrastructure development/availability and resource surveying. In developed cropping areas, cotton would be a substitute for other crops and other factors such as competitiveness with existing crops, access to ginning and other cotton specific infrastructure (picking equipment) will influence whether cotton is grown.

A general concern for cotton production in north Queensland is the potential for winter and summer cotton growing in close proximity (e.g., Bowen and Collinsville) and the impact this may have on pest management.

In addition to soil surveying and geohydrological studies, all new irrigation areas require the development of irrigation storage and delivery infrastructure (mostly dams) and accompanying Water Resource Plans and detailed environmental impact assessments. Except for the Flinders (Richmond), Broken (Collinsville) and possibly Gilbert rivers the development of irrigation infrastructure is likely to have a >10 year timeframe. However, active involvement by a commercial farming interest (funding some of the work) could be expected to speed up this process.

In the established farming areas at the Atherton Tableland, Mareeba/Dimbulah, Lakeland Downs and Bowen/Lower Burdekin areas, cotton is likely to be grown opportunistically if a gin was constructed in a neighbouring region. For example there are about seven farmers in the Bowen area, some currently trialling cotton, who would grow cotton if a gin were constructed at Collinsville or at Charters Towers some 50 km and 200 km away respectively (Todd, Bowen, pers. comm. 2000). Due to a mix of crop species, area wide pest management would be essential in all these regions. Consequently the location of ginning infrastructure will impact on future cotton production scenarios in these regions.

With the exception of some of the established cropping areas, the majority of arable soils appear similar to the NT and the Kimberley. That is red and yellow earths, and cracking clays all having low to moderate inherent soil fertility. This implies similar issues for crop nutrition, soil surface management and irrigation distribution systems. Inherent salinity occurs in some areas (e.g., Flinders, Einasleigh).

6.5.1. RECOMMENDATIONS-RICHMOND

There is a need for basic research in the following areas.

- Geohydrological surveys/studies.
  These will determine potential salinity problems, water table effects and identify appropriate irrigation and agronomic practices.
- Detailed soils surveys.
  Currently most of the surveys are at a scale not greater than 1:250,000. Irrigation development would require at least 1:100,000 with reference areas at 1:25,000 in locations having potential for irrigated cropping.
- Production systems research.
  Integrated crop research with the objective of developing a management system that is sustainable economically and has minimal environmental impacts. This will include research on crop adaptation, crop management practices, soil water studies, irrigation management, integrated pest management, area wide management, BollgardII™ registration work and the development of best management practices. The applicability of practices used in Emerald will be important to this research. Evaluation at the 'pilot farm scale' would be essential.
- Ecological studies into pest and disease dynamics and effects on flora and fauna.
- Water licensing process and associated studies.
- Infrastructure studies – location of gin, transport links, containerisation needs etc.
- Whole scheme economic analysis to put in State/national context. This should include an assessment of community value?

The areas of expertise applicable to the Cotton CRC would include the third point and the pest and disease dynamics components of the fourth point.

6.5.2. RECOMMENDATIONS - OTHER NORTH QUEENSLAND AREAS

The research and development actions required to evaluate cotton growing in new irrigation areas are essentially the same as the points listed for the Flinders River near Richmond (shown above). For established cropping areas research and development would need to address the third, fourth, sixth and seventh points.

As was the case in the Northern Territory, prioritisation of regions may be required. Commercial development interest combined with knowledge of the water resource development timeframe should achieve this goal for the undeveloped areas. For the existing areas a review of likely gin development scenarios and other issues that may influence the adoption of cotton should be conducted.

6.5.3. NORTH QUEENSLAND ISSUES FOR THE AUSTRALIAN COTTON CRC

- The risk of salinity developing in the Richmond area needs to be addressed as soon as possible. In north Queensland, this type of work is coordinated by the DNR regional infrastructure development group. A meeting organised by the Cotton CRC (early December 2000) developed a plan for assessing salinity risk that incorporates local and cotton industry skills in this discipline.
- In December 2000, the landholder (Mr Corbett Triton) and Queensland Cotton provide most funds for R&D work at Richmond. A team of locally based research staff is the key short-term objective at Richmond. This will be achieved by the Cotton CRC funding technical support for entomological and agronomic research, whilst Queensland Cotton funds a research and commercial agronomist. QDPI will provide professional entomological support.
- Cotton CRC involvement in the proposed stakeholders development committee for the Richmond area will provide an important link with the broader development issues.
- Stronger links with the DNR regional infrastructure development group should be developed. Cotton CRC membership is also an option for some of this group as there is already a significant in-kind contribution to key research questions in the soils and geohydrological disciplines.
- The Cotton CRC should facilitate studies into the effect of gin location and infrastructure on possible production scenarios in this region. In addition an analysis of the likely interest in growing cotton in established areas and the factors influencing this interest should be made. QDPI at Mareeba should be approached to fund and conduct these studies. The outcomes should indicate the need for any follow up work, for example, entomological aspects of summer and winter cropping in close proximity.

- As is the case in WA and NT there is a need for active Cotton CRC involvement in community consultation and general communication issues.
- The Cotton CRC will need to take a strategic approach, as there are potentially more growing regions and issues than can hope to be funded. It is important to keep well informed on the status of infrastructure development, and commercial development interests in different regions.

Chapter 7 – Global issues for cotton research and development in northern Australia

7.1. Physical resources

Outside the Ord River, the Daly Basin, and the established cropping areas in north Queensland (Atherton Tableland/MDIA, Lakeland Downs and Lower Burdekin/Bowen areas) soil surveying and land resource assessment is not in sufficient detail for large-scale irrigation development.

The potential water resources of the region are immense. The mandate region for this study includes the Gulf of Carpentaria and the Timor Sea drainage divisions, which account for 43% of Australia's annual surface water run-off. Groundwater resources are also significant. Except for established irrigation areas in Queensland and the Ord River (under review) water resource allocations for larger scale developments have not been made. In many areas there may be insufficient data to calculate these flows. This is because all watercourses are strongly seasonal and there is considerable between and within season variability in stream flow. In many regions the interaction between surface and groundwater systems is poorly understood.

With the exception of some of the established cropping areas in north Queensland the majority of arable soils appear similar. That is red and yellow earths, and poorly drained cracking clays all having low to moderate inherent soil fertility. This implies similar issues for crop nutrition, soil surface management and irrigation distribution systems. Inherent salinity occurs within many areas (e.g., Flinders, Einasleigh and Legune plains).

7.2. Production systems research and development

7.2.1. CROP ADAPTATION

The analyses presented in Chapters 4, 5, and 6 suggest there are three common crop adaptation issues across northern Australia as follows:

1. length of growing season as determined by rainfall pattern and temperature
2. for winter season crops, the lower extreme of adaptation to sub-optimal night temperatures during reproductive growth
3. lack of long-term climatic records in many areas.

7.2.1.1. Length of growing season

A summer dominant rainfall pattern is common to northern Australia but, more importantly, so is high rainfall variability during the seasonal transitions. Temperature determines the length of the growing season and the sowing date required for avoidance of harvest rainfall. Obviously a modelling approach is required to account for climatic variability, although current modelling tools can simulate potential yield and predict the timing of boll opening and harvest maturity, they cannot predict the effect of rainfall or temperature on lint quality.

Research is required to develop relations between fibre quality and rainfall that can be applied to the evaluation of new growing regions.

Trafficability can be a problem on clay-textured soils where rainfall variability has a greater impact on sowing and harvesting operations than on lighter textured soils. Operations research will be required to evaluate options for avoiding the effects of sowing delays through changed cultural operations. In addition, variety duration x sowing date options should also be considered.

7.2.1.2. Crop adaptation to sub-optimal mid season temperatures

The extent of potential winter growing areas and production risks associated with extreme seasons in regions currently trialling winter production requires an understanding of the relationships between minimum temperature and fruit growth, development and retention. The Cotton CRC could facilitate a collaborative research effort to address these questions. This would involve field research at cool locations and links with controlled environment studies conducted by Cotton CRC researchers in southern Australia.

7.2.1.3. Lack of long-term climatic records.

Climatic records are inadequate for some sites (e.g., Marrakai Plains, Lower Fitzroy River, Mitchell River, Bains River). Lack of records can only be addressed by simulating data and/or collection of local data to develop correlations with nearby long-term stations.

7.2.2. Sustainable production systems with minimal chemical usage

This is a very important objective for cotton R&D in northern Australia. Research and development needs, although broadly the same across northern Australia, will require regional tailoring. Obviously the Cotton CRC has a key role in facilitating collaboration among researchers in this area of research.

Common sustainable production research outcomes are as follows:

- integrated pest management strategy
- area wide pest management strategy
- BollgardII™ registration and resistance management strategy
- disease management/prevention strategies (alternaria, cotton rust, fusarium)
- incorporation of physiological understanding of plant compensation from insect damage into insect pest management practices

- irrigation practices and distribution systems that maximise water use efficiency and minimise environmental impacts
- integrated weed management practices that minimise the use of residual herbicides and chemicals with a higher risk to the wider environment
- rotations, covercrops, tillage and soil surface management practices, compatible pest management strategies to maintain soil structure and prevent erosion and run-off
- varieties adapted to the environment and compatible with sustainable management systems.

7.2.2.1. The impact of geographic spread and summer and winter cropping on insect migration

Climatic analysis suggests December/January sowing dates for summer cropping areas in Queensland (e.g., Richmond), and optimal winter sowing dates from late March (north Queensland, Katherine) through to May (Broome). Will insect pests such as resistant *Helicoverpa armigera* migrate from the Emerald area (September sown) to Richmond (January sown) a distance of about 600 km and then on to winter growing areas in Qld, NT, and WA? Insect migration models should be applied to evaluate the insect migration scenarios.

7.3. Regional development and infrastructure issues

Most potential growing areas in northern Australia are undeveloped for irrigated farming. Therefore the timeframe for development is dependent on land and water availability. The Cotton CRC should develop a strategic approach for supporting research in new areas. **There is simply more to do than can possibly be funded by the Cotton CRC.** Some suggestions for a strategic approach to R&D participation by the Cotton CRC in new areas are listed below:

- The Cotton CRC should focus on its strengths, which are skills in sustainable cotton production systems research.
- The Cotton CRC should thoroughly review the likely timetable for land and water surveying and environmental impact assessment for irrigation development before making commitments to production systems R&D.
- A large-scale trial phase is essential and must be included in an R&D plan for any new area. Funding must be available to underwrite infrastructure (e.g., picking equipment, mini gin) and the cost of production at sub-commercial scale.

Land title issues are very important in much of the region described in the Scoping Study and will have a

TABLE 7.1: *A comparison of region specific production systems issues for the 4 sites where the Australian Cotton CRC is currently involved in northern Australia.*

	BROOME	ORIA	KATHERINE - DALY	RICHMOND
Growing Season	May-November	April-October	March-October	December-July
Arable Soil Type	Sandy loam	Cracking clay	Clay loam and sandy clay loam	Cracking clay, some inherent salinity
Irrigation System	Sub surface drip	Furrow	Sub surface drip/Overhead	Furrow
Crop Rotation/ Tillage system	Wet season cover crop + alternative dry season crop. Conservation tillage	Wet season cover crop + alternative dry season crop. Tillage system yet to be determined.	Wet season cover crop + alternative dry season crop. Conservation tillage	Wet season rotation crop. Need for dry season crop and tillage system are yet to be determined
Potential Pests(in addition to Helicoverpa armigeria, H. puntigera, Fusariam and Verticillium)	Nematodes, cotton rust, Altenaria. Others yet to be determined	Mirids, malveaceous weeds, red shouldered leaf beetle, cotton rust, Altenaria. Others yet to be determined	Mirids (brown and green), green vegetable bug, nematodes, cotton rust, Altenaria, annual grass weeds in zero till crops. Others yet to be determined	Yet to be determined
Climatic Issues	Low night temperatures.Impact of relatively low and variable wet season rainfall on cover cropping	Effect of rainfall combined with clay soil on sowing and picking operations Low mid season night temperatures	Relatively high frequency of sub-optimal mid-season night temperatures. Higher rainfall toward crop maturity	Variable within season rainfall, potential for supra optimal temperatures

major bearing on the timeframe for the development of irrigated agriculture (if it occurs). With respect to land with potential to grow cotton, land title is currently being negotiated for agriculture usage in the M2 development of the ORIA, the Katherine/Daly area and in the Broome area.

7.4. Communication

A communication strategy is required and should incorporate interest groups, the general community and within the Cotton CRC. The suggestion of sustainability issues symposium(s) with emphasis on community education in the research and development process should be adopted. However an integrated approach to community consultation/awareness is required and should include local tailoring. The Cotton CRC should instigate an evaluation process to provide a mechanism for internal review of communication methods employed and for the development of new methods.

An objective for the Cotton CRC by the end of its life (5 years hence) would be to have '*community acceptance of cotton farming as an environmentally friendly industry*'.

7.5. Environmentally and politically sensitive areas

There are several areas where cotton farming could be emotive and politcaly sensitive should possibly avoid. These include cotton growing in close proximity to the Great Barrier Reef, damming the Fitzroy River (WA) and cotton farming in near the lower Daly River (NT). Dam development could be a locally sensitive issue and in some cases may have national significance (e.g., Fitzroy River, WA). The Cotton CRC requires a mechanism to assess the sensitivity of areas and potential political issues before committing to support cotton R&D. Direct community or interest group consultation may identify new sensitive or emotive issues in areas where cotton research is currently conducted (e.g., under what conditions would AFANT support cotton in the lower Daly?).

7.6. Staffing

Successful R&D requires qualified and committed staff. There are three main issues with respect to cotton R&D staffing in northern Australia:

- Most local staff lack cotton experience and have had little exposure to cotton farming. Membership of the Cotton CRC can enable training to occur with partner organisations and others in southern Australia. The basing of experienced production agronomists on-site (as at the ORIA and Richmond) will assist farmer collaborators in gaining experience in growing cotton.
- High staff turnover is a characteristic of the more isolated areas of northern Australia.
- Attracting experienced professional staff to isolated areas (geographically and professionally) is very difficult. Employers need to ensure that periods working in isolated locations form part of a career path within their organisations.

7.7. Funding options

The Cotton CRC has a role to assist in finding funds for research and development in addition to the existing sources of funds (i.e. commercial partners, CRDC, government agencies). Possibilities include: ACIAR, and the Federal Government's salinity initiative.

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10. Abbreviations

ACIAR....................Australian Centre for International Agricultural Research
ACTFR ....Australian Centre for Tropical Freshwater Research
ADMA....................Agriculture Development and Marketing Authority (NT)
AFANT ....Amateur Fishermen's Association of the Northern Territory
AgWA ....Agriculture Western Australia
APSRU ....Agricultural Production Systems Research Unit
CRDC ....Cotton Research and Development Corporation
CSD ....Cotton Seed Distributors
CSIRO ....Commonwealth Scientific & Industrial Research Organisation
CYPLUS..................Cape York Peninsula Land Use Study
DDS_{12} ....Degree Day Sum base 12Co
DLPE ....Department of Lands Planning and Environment, NT.
DNR........................Department of Natural Resources, Queensland
DPI..........................Department of Primary Industry, Queensland
ECNT ....Environment Center NT
GMAC....................Genetic Manipulation Advisory Committee
GMO ....Genetically Modified Organism
ICM ....Integrated Crop Management
IPM ....Integrated Pest Management
KRS ....Katherine Research Station
KWRDAB ....Kimberley Water Resource Development Advisory Board
KWRDO ....Kimberley Water Resource Development Organisation
MC..........................mepiquat chloride
MDIA ....Mareeba Dimbulah Irrigation Area
MOU ....Memorandum of Understanding
NTDPIF..................NT Department of Primary Industry and Fisheries
ORIA ....Ord River Irrigation Area
OTGR ....Office of the Gene Technology Regulator
QC ....Queensland Cotton Corporation Limited
QCC ....Queensland Conservation Council
SOI..........................Southern Oscillation Index
WRP ....Water Resource Plan (Queensland)