STRIKING

the BALANCE

Sustainable Farming & Grazing Systems for the Semi–arid Tropics of the Northern Territory

Fergal O'Gara

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Conservation Farming and Grazing Systems for the Semi-arid Tropics of the Northern Territory.

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DEPARTMENT OF PRIMARY INDUSTRY AND FISHERIES

NATIONAL LANDCARE PROGRAM

SHAPING THE FUTURE RIRDC RURAL INDUSTRIES RESEARCH & DEVELOPMENT CORPORATION

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PREFACE

A considerable amount of research, experience and information on agriculture in northern Australia is available to the scientist. Much less is available to the wider audience interested in agricultural development and farming in the Top End of the Northern Territory (NT). This publication seeks to remedy this deficiency and is the first of its kind for northern Australia. The booklet is a snapshot of broadacre agriculture in the Top End. It deals with the recent and innovative concept of conservation and ley farming in the Semi-arid Tropics (SAT). It also describes the crops and pastures suited to the Top End and covers aspects such as nutrition, irrigation, pest management and sustainable grazing practices. As the demand for agricultural land in the NT increases, the need for practical and relevant information on sustainable farming principles must be satisfied.

The purpose of this book, *Striking the Balance*, is twofold:

(1) to inform farmers, agriculturalists, agribusiness, students and other interested parties about the nature, potential and implications of broadacre farming in the Top End.

(2) to highlight the principles and practices which are necessary to achieve viable production while protecting the natural resources of northern Australia.

Striking the Balance is written with particular emphasis on the Top End but the book has wider application as the principles are relevant to many parts of the world's Semi-arid Tropics.

However, the book is not intended to be a prescription or manual for agriculture in the Top End and the information it contains should not be seen as an end in itself, but a foundation that must be built upon as our knowledge, experience and technology advance.

ACKNOWLEDGEMENTS

This book is the culmination of a project devoted to developing and demonstrating sustainable mixed farming systems for the Top End. The project and this book would not have been possible without the generous financial support and collaboration of the Northern Territory Department of Primary Industry and Fisheries and the National Landcare Program.

Rural Industries Research and Development Corporation and CSIRO have also sponsored this publication and their support is gratefully acknowledged.

I would also like to acknowledge the assistance received from the Doug Peake Memorial Trust Fund through the Australian Institute of Agricultural Science and Technology, NT Zone. Doug Peake was a pioneer researcher of conservation farming until his untimely and accidental death in 1982. He was strongly committed to the conservation ‘message’ and the free flow of ideas, so it is fitting his memory and message lives on in this publication.

I am indebted to Mr Andy Chapman for his tireless editorial comment and assistance. His encouragement and advice was generously provided throughout.

I thank the following authors for their contributions to various sections. Malcolm Bennett, (sesame production); Arthur Cameron and Barry Lemcke, (improved pastures); Rowena Eastick, Leslee Hills and Colin Wilson, (weeds, herbicides and biological control); Phil Hausler, (crops); Val Hristova, (economics); Rex Pitkethley, (plant disease); Tom Price, (herbicide roller); Bruce Sawyer, (rice production); Stuart Smith, (insect pests); and Kandiah Thiagalingam, (plant nutrition).

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Photographs of the assassin bug, predatory shield bugs, the green vegetable bug, the crusader bug and *Riptortus sp.* were reproduced from *Insects on Grain Legumes in Northern Australia* by Shepard, Lawn and Schneider, with kind permission from Queensland University Press.

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Much of the information has been developed and supplied by the NT Department of Primary Industry and Fisheries, CSIRO Tropical Agriculture and the NT Department of Lands Planning and Environment. Information is also drawn from the author's personal experience and other areas both within and outside Australia, where conservation farming and sustainable grazing systems are practised or being developed. References from which information has been sourced appear in the back of this book.

Farmers and pastoralists of the Top End, instrumental in pioneering agricultural systems have contributed to this publication. I gratefully acknowledge the information and assistance provided by these sources and the many workers who have contributed and are continuing to contribute to the development of sustainable farming systems in the tropics.

1. INTRODUCTION

Agricultural development in the NT is relatively recent and although there were attempts at commercial cropping in the early 1900s, organised crop and pasture research began after World War II. CSIRO established Katherine Research Station in 1948 and Coastal Plains Research Station (CPRS), south-east of Darwin in 1959. Other research facilities were established at Tortilla Flats, Berrimah in Darwin, Douglas Daly and at the Katherine Experimental Farm by the Northern Territory Administration.

In addition to the establishment of research facilities in the 1950s, '60s and '70s a number of large scale, but ill-fated, commercial developments were undertaken. In 1955 'Territory Rice' set up a rice operation at Humpty Doo near Darwin; Tipperary Station established a large grain sorghum enterprise in the Daly Basin in 1967 and in the early 1970s, the Northern Agricultural Development Corporation began growing sorghum at Scott Creek and Willeroo Stations south-west of Katherine. These ventures failed partly due to isolation, remote management and the high cost of production. However, the major cause was, undoubtedly, a fundamental lack of understanding of the physical environment and the complexities of agriculture in the tropics.

There is now over 50 years of research and experience in the agronomy of crops and pastures and a greater understanding of the environment in northern Australia. Infrastructure and communications have improved and there are better market opportunities. Through research and practical experience, especially during the past 20 years, advances have been made in farming methods and there is now good reason for cautious optimism with regard to agricultural development in the NT.

However, there are many challenges. The region is characterised by high energy storms, high temperatures and poorly structured, infertile soils which are easily degraded. Soil degradation is a global problem.

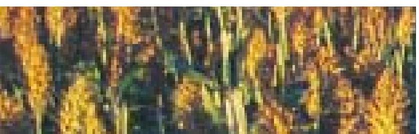
Plate 1
Katherine Research Station as it stands today.

The annual rate of loss of arable land throughout the world is estimated at 5-7 million hectares/year with a predicted loss of 10 million hectares/year before 2000 AD.

Over 51% of the grazing and cropping land in Australia has been degraded to some extent. The cost in lost production is estimated to be between $600 million and $1.2 billion/year. One of the major challenges for researchers and land managers is to develop farming systems specific to the NT which protect the natural resource base while allowing sustainable production.

Early research in the NT highlighted the disadvantages of conventional farming methods. In the 1980s various government departments began investigating ways of overcoming the problems by using conservation tillage, pasture ley systems and by managing soil surface cover. The work showed that conservation tillage gave more reliable yields and greatly reduced soil loss.

Conservation farming is a practice and philosophy which strives to protect the soil, minimise land degradation and environmental pollution and improve the conditions for plant growth. It is now recognised as one of the most important innovations in modern agriculture. Experience suggests it is not only desirable but essential for the long-term protection and productivity of NT soils.



2. THE PHYSICAL ENVIRONMENT OF THE TOP END

"... there is no more difficult challenge to applied science in Australia than that presented by the environment of the North-West."

So said Sir John Crawford of the Australian National University at a conference in Darwin in 1983, on agricultural research and development in Northern Australia. His statement highlights the significance of the physical environment in agricultural development in the NT.

Intensive agriculture is possible in the portion of the NT commonly called the 'Top End'. This geographical area above latitude 16° South is classified as part of the world's Semi-arid Tropics (SAT) or the wet-dry tropics. Elsewhere, the SAT consists of either part or all of 48 countries on four continents including Africa, India, South America and South-east Asia. The physical environment of the Top End has more similarities with these areas than it does with southern or temperate Australia.

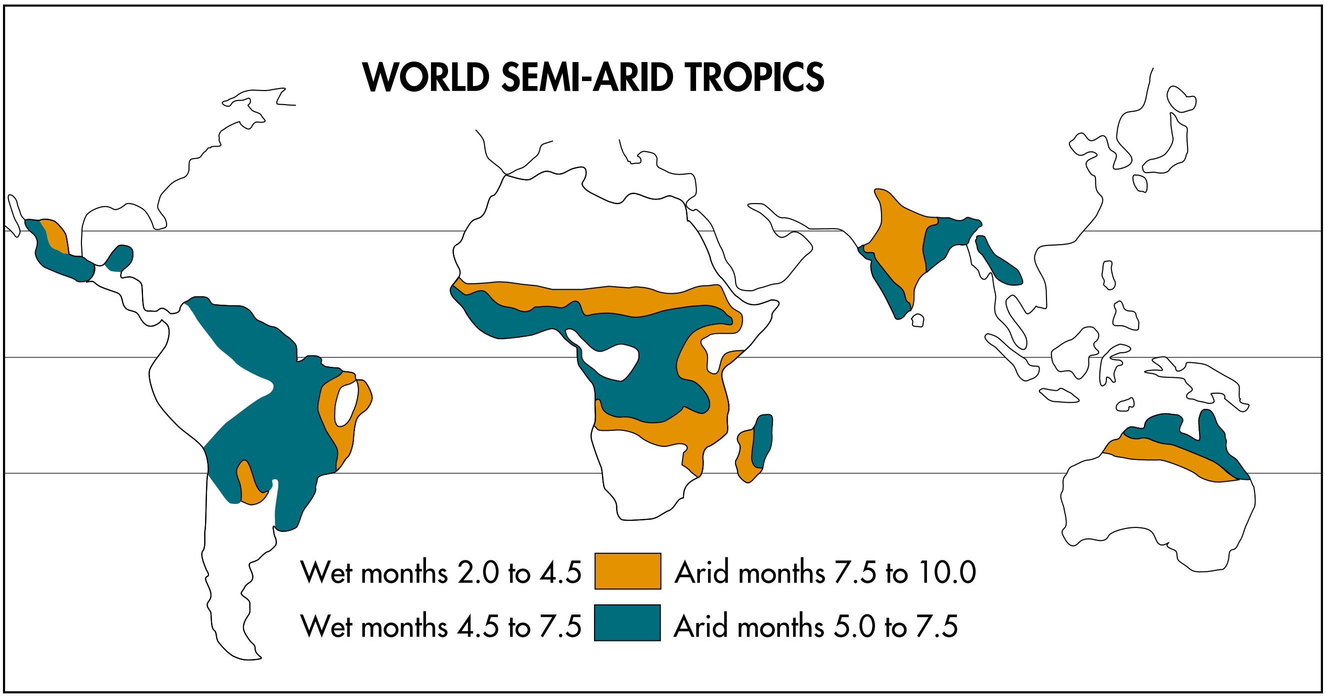


Figure 1
The distribution of the world's semi-arid tropics shows the relationship between the Top End and parts of Africa, South America and Asia.

2.1 CLIMATE

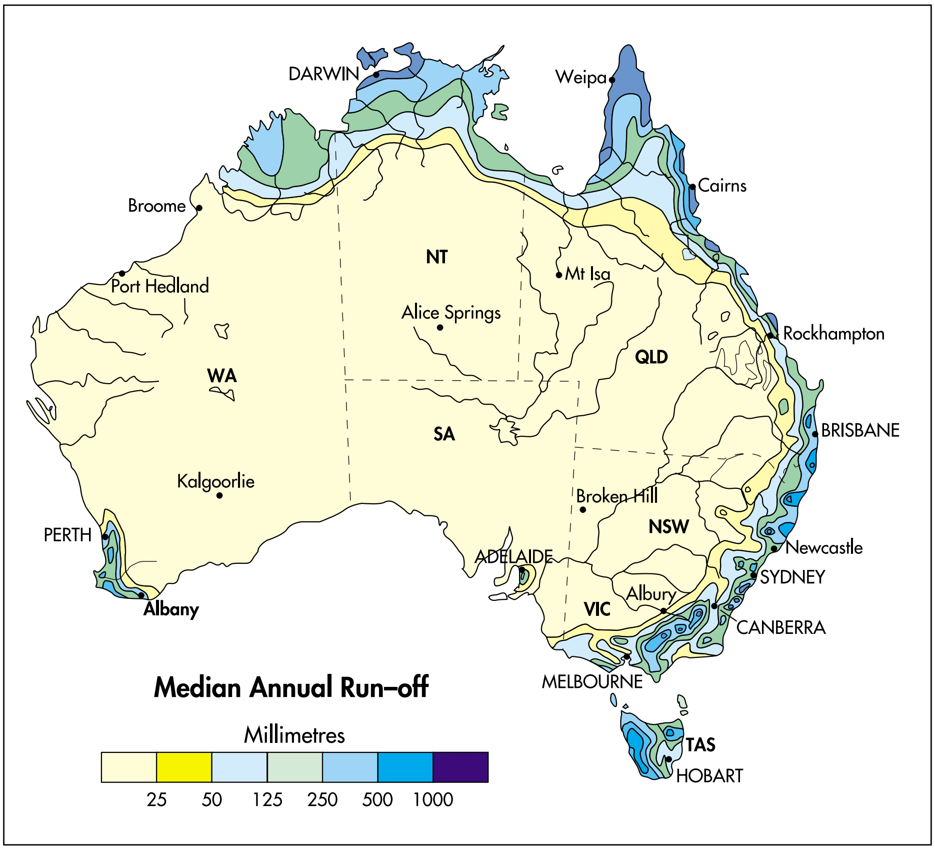
Rainfall and Evaporation

The climate is characterised by two distinct seasons, the wet and the dry. The wet season lasts for 4 to 6 months from November to April and receives over 90% of the annual rainfall. Sporadic thunderstorms start in September/October and continue through to December.

Rainfall is heaviest in January and February due to monsoonal activity and tapers off in March and April. May to October is the dry season and little or no rain is received in most years.

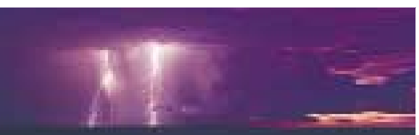
Cyclones are a feature of the Top End and can result in several days of continuous heavy rainfall. Tropical rain, on average, has a bigger droplet and more energy than temperate rain and therefore has greater potential to damage the soil. Annual average rainfall in the Darwin region is about 1660 mm and decreases approximately 238 mm every 100 km south-eastwards. Rainfall at Douglas Daly, Katherine and Daly Waters is 1250 mm, 1000 mm and 550 mm respectively.

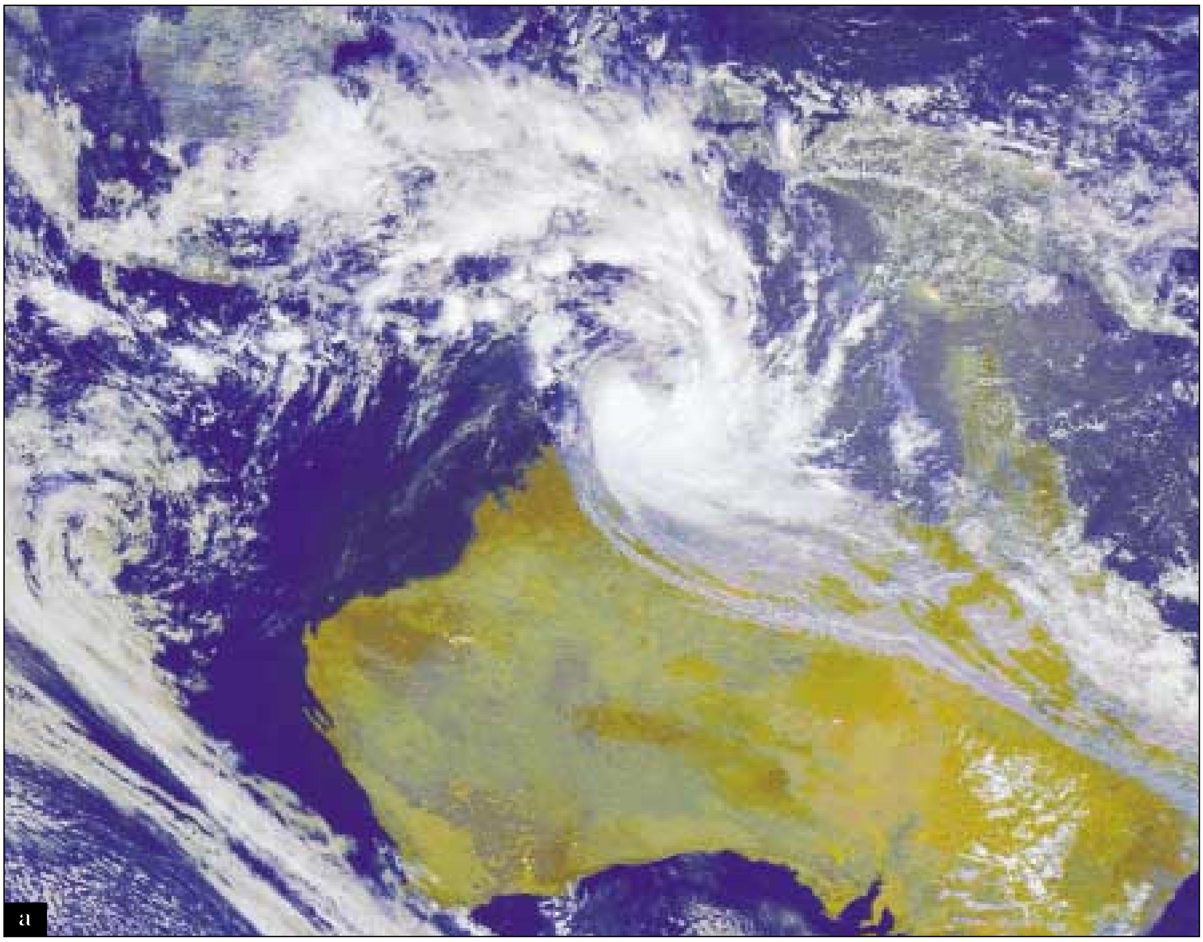
Figure 1b
Runoff is very high in tropical regions.



Seasonal rainfall variation is relatively low by Australian standards but weekly and fortnightly variations are high and may exceed 100 %. The extreme variation within a season can result in intermittent periods of wet and very dry conditions occurring within the same month or even the same fortnight.

Individual storms often provide surplus moisture which is subsequently lost as runoff or infiltrates beyond the root zone.





Up to 60% of the rainfall from a storm may run off depending on soil type and surface conditions. One or two heavy storms may result in a month's rainfall being received in a few days with the remainder of the month being dry. Several short "droughts" can occur within a wet season and these can vary from several days to several weeks.

Evaporation exceeds rainfall in every month except January, February and March. In January and February evaporation ranges from about 150 to 200 mm increasing to 350 mm in October. Evaporation from the soil surface can account for up to 50 % of moisture loss.

Plate 2a, b
(a) Cyclone Rachel over the Top End in 1997.
(b) A storm over the Top End.

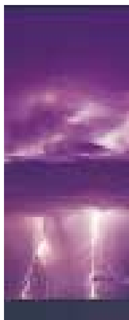


Plate 3
Tropical rain has bigger droplets and more energy than temperate rainfall.

Soil water availability, which is the principal factor determining plant growth, is influenced more by rainfall distribution and evaporation than by total rainfall.

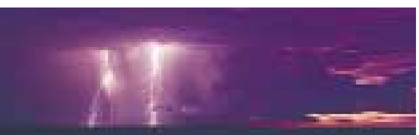
The distribution rather than the total seasonal rainfall largely determines crop and pasture performance in dryland farming in the tropics.

Temperature

The average maximum wet season temperature is 32°C near the coast and 38°C at Katherine and inland areas. Temperatures in the 'build-up' (from October to November) are generally 1 to 2°C degrees higher but decrease slightly once the monsoon develops. The average maximum temperature in the dry season ranges from 29 to 31°C, while the average minimum temperature varies from 13 to 23°C. Frost does not occur except on rare occasions in southern inland areas.

Daylength in the Top End varies little throughout the year, ranging from 11.2 hours in June to 13 hours in December. Sunshine hours peak in August with 300 hours/month and can go as low as 100 hours/month in February at Darwin. Inland areas experience more sunshine during the wet season due to shorter periods of cloud cover.

The tropical climate is extremely demanding and sustained physical work becomes stressful. When measured in terms of human discomfort there are over 200 stress days per year in the Top End compared to 5-10 in southern areas of Australia!



2.2 SOILS

The soil pattern in the Top End is complex and the region lacks extensive areas of uniform soil types. Most soils are highly erodible, difficult to manage under conventional cultivation and have relatively poor natural fertility and low water holding capacities. Soil types range from massive red, yellow and grey earths to shallow ironstone gravels. There are considerable areas of shallow stony and sandy soils interspersed with massive red and yellow earths throughout the Top End.

A feature common to most soils is a massive structure consisting of kaolinite clay and iron oxides. Surface textures range from sands to clay loams. Most soils are permeable in the surface layers but increase in clay content at depth.

Black and brown cracking clay soils occur to a limited extent throughout the Top End but are common on the seasonally flooded coastal areas. Available soil water storage capacities per metre of soil range from 50 to 80 mm in ironstone gravel soils, 75 to 140 mm in red earths and over 200 mm in cracking clays. Growing crops on stored soil moisture is not an option in the Top End.

Plate 4a, b, c
(a) Cracking black clay of the coastal floodplain.
(b) Floodplain in the Adelaide River area, suitable for rice production.
(c) Dry cracked soil may hinder seeding emergence.

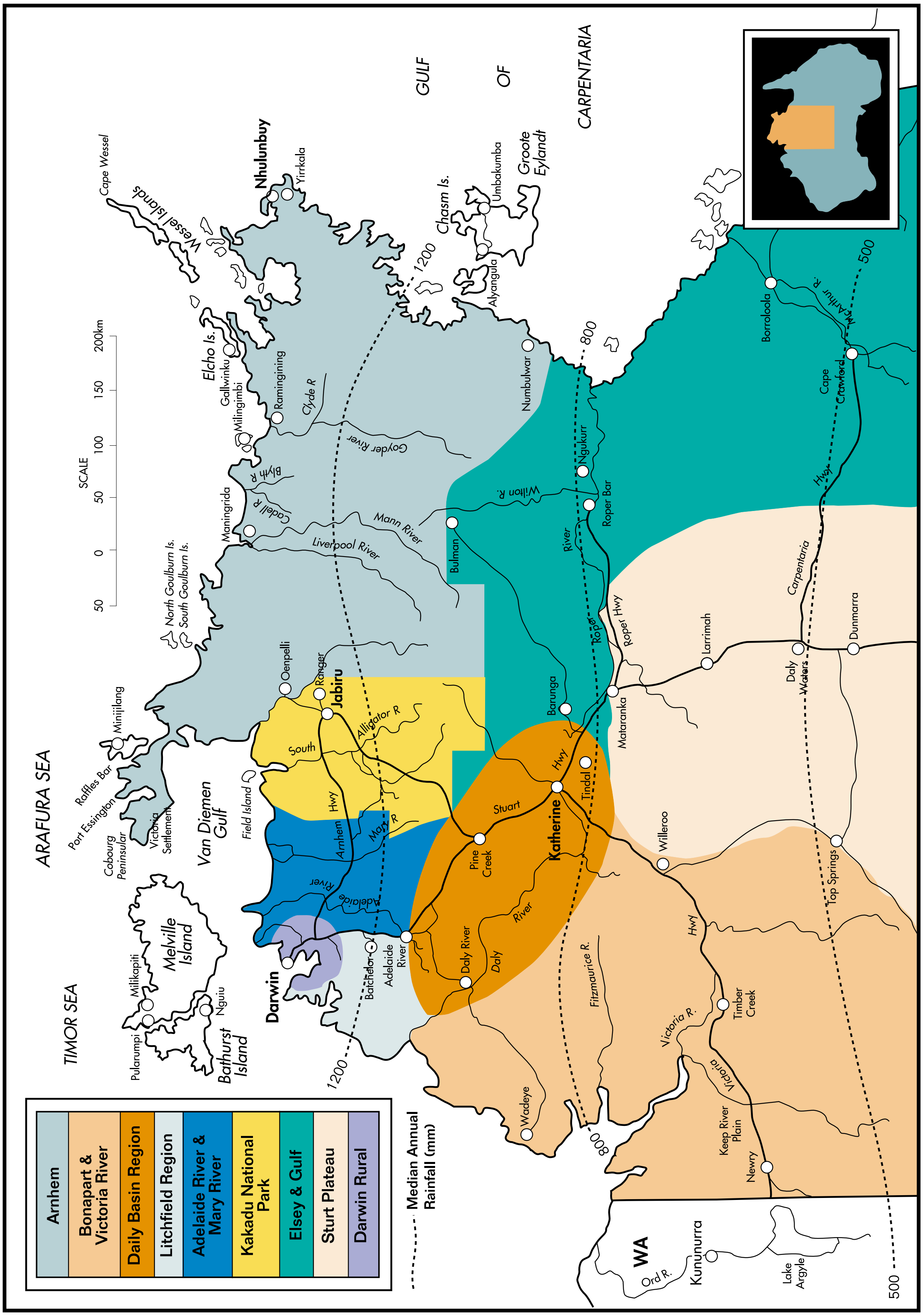
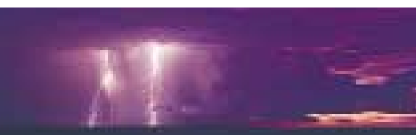


Figure 2
Broad geographical–agricultural regions of the Top End.



Sub-Coastal Areas
Parts of the sub-coastal plains of the Adelaide, Mary, Finniss, Daly, Moyle and Mary Rivers consist of dark heavy textured soils subject to deep and sometimes prolonged flooding in the wet season. The massive cracking clays vary in their natural fertility. They crust and crack when dry and become extremely boggy when wet.

The other major group of soils of the sub-coastal regions of the Adelaide River and the Marrakai plains are the solodic yellow and grey earths or 'bull-dust' soils and the more recent red earths.

These soils are slightly higher, drain more freely but are subject to seasonal waterlogging. Surfaces vary from light sandy loams to massive clay loams which are hard-setting. They generally have low levels of natural fertility.

Katherine-Daly Basin and Sturt Plateau

The major soil group used for intensive agriculture in the Katherine-Daly Basin and Sturt Plateau are the Red Earths which are classified according to surface and profile characteristics.

The sandy sub-group consists of the Venn, Oolloo and Blain families.

Plate 5
Lateritic ironstone gravel soils common in the Darwin region.

These are free draining sandy textured, dark red soils which graduate to a sandy loam or sandy clay loam at depths of 1-2 metres. The loamy sub-group consists of Tippera, Tindall and Emu families. They have been derived from limestone parent material and are hard surfaced, massive clay loams.

Other soils of potential economic importance in this region include Yellow Earths, Lateritic Podzolics and Grey, Brown and Red Clays but these are at present secondary to the red earths in terms of agricultural use.

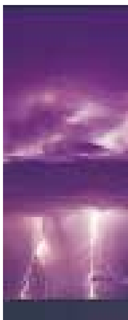


Plate 6a, b
Clay loam red earths are important agricultural soils of the Daly Basin and Sturt Plateau.

Plate 7a, b
Sandy surfaced Blain soil, suited to peanut production.

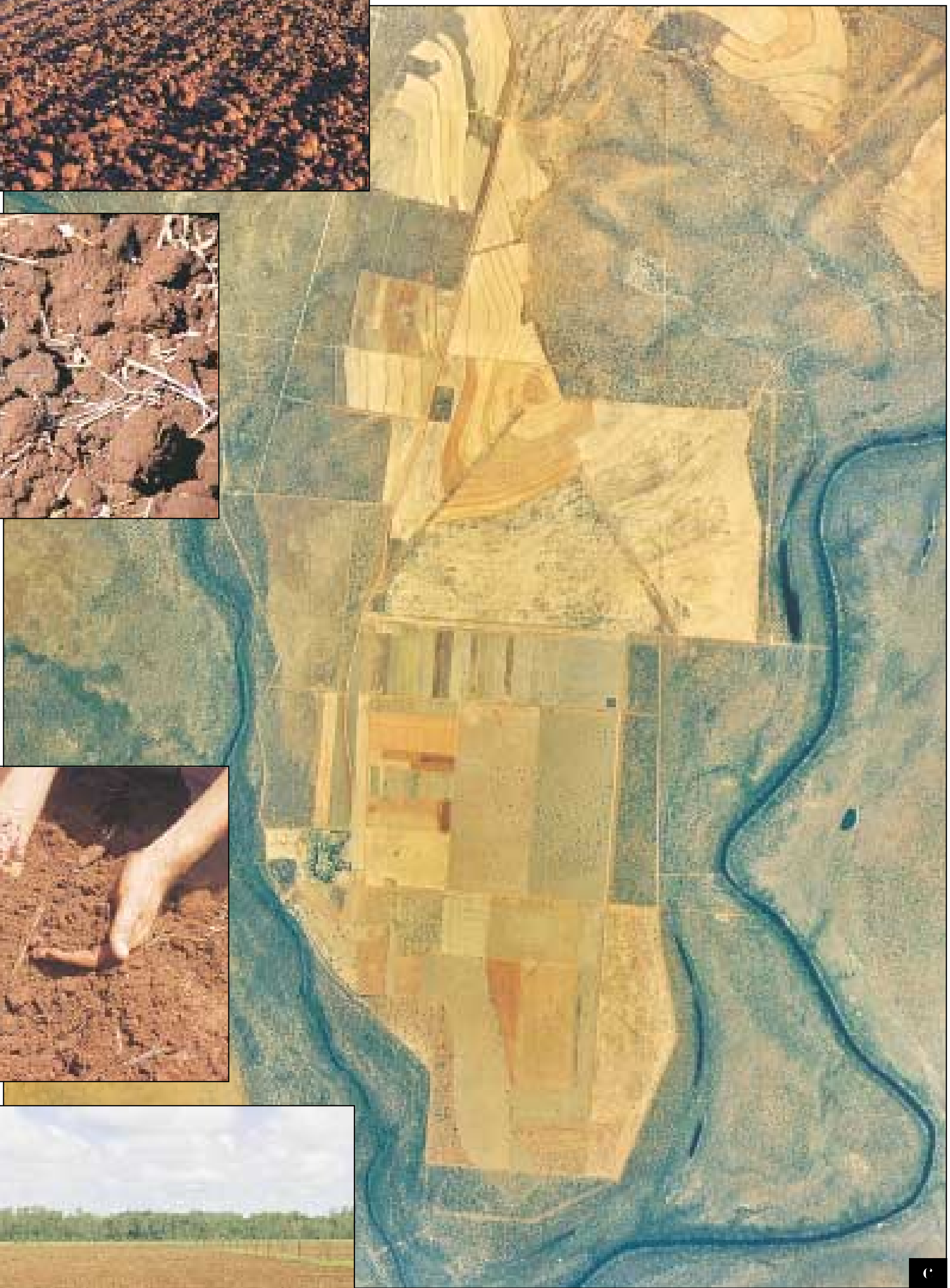
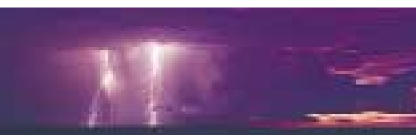


Plate 6c *Aerial photograph of the Douglas Daly Research Farm.*



3. WHAT IS CONSERVATION FARMING?

Conservation farming is any system or practice which aims to conserve soil and water by using surface cover (mulch) to minimise runoff and erosion and improve the conditions for plant establishment and growth. It involves planting crops and pastures directly into land which is protected by a mulch using minimum or no-tillage techniques.

Conservation farming systems are designed to:

- use mulch cover to reduce soil erosion and land degradation
- reduce soil temperature and conserve moisture for plant growth
- increase organic matter levels and improve soil structure and fertility
- reduce reliance on cultivation
- achieve viable and sustainable productivity

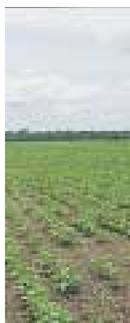
Many individual practices can be integrated into a conservation farming program. These include:

Conservation farming - components and practices

- no-tillage
- minimum and reduced tillage
- agro-forestry
- trap cropping
- cover and green manure cropping
- alley cropping
- contour farming & strip cropping
- organic and biodynamic farming
- stubble mulching
- integrated pest management (IPM)
- crop and pasture rotation

3.1 THE BACKGROUND TO CONSERVATION FARMING

Conservation farming was first investigated in the 1940s in Nebraska, USA where mulch was used to control wind erosion. Since the introduction of new herbicides and specialised machinery in the 1960s, '70s and '80s, development of the technology has accelerated.



Conservation farming in the NT is largely based on crop and pasture rotations using no-tillage, minimum tillage and integrated pest management.

No-tillage, also referred to as zero-tillage, replaces all cultivation with herbicides so that soil disturbance occurs only at sowing time when the planting implement engages the soil. Mulch cover is maintained at a maximum level.

Minimum tillage involves some primary cultivation for weed control, mulch management and seed bed preparation. Herbicides are usually used in conjunction with tillage. Minimum and no-tillage can be used alternatively, depending on conditions which will vary from paddock to paddock and season to season. Conservation farming is a flexible system where tillage practice is chosen to suit the particular situation.

a

The objective of conservation farming is to reduce runoff and erosion. This can only be achieved by reducing cultivation and maintaining soil surface cover.

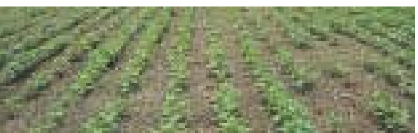
b

c

Plate 8a, b, c
(a) Seeding no-tillage sorghum into chemically killed pasture.

(b) Established no-tillage sesame in Katherine.

(c) No–tillage mungbean.



3.2 Why we need Conservation Farming!

There are many good reasons for the adoption of conservation farming. Some of those are presented below.

What will grow when 100 tonnes per hectare of top soil is lost?

This question will need to be answered if soils in the Top End are continually cultivated or over-grazed. Over 40% of tropical storms result in runoff with the potential to cause erosion. High energy raindrops dislodge soil particles which are carried away in runoff water. Over 100 tonnes of soil per hectare per year can be lost from exposed land in the tropics.

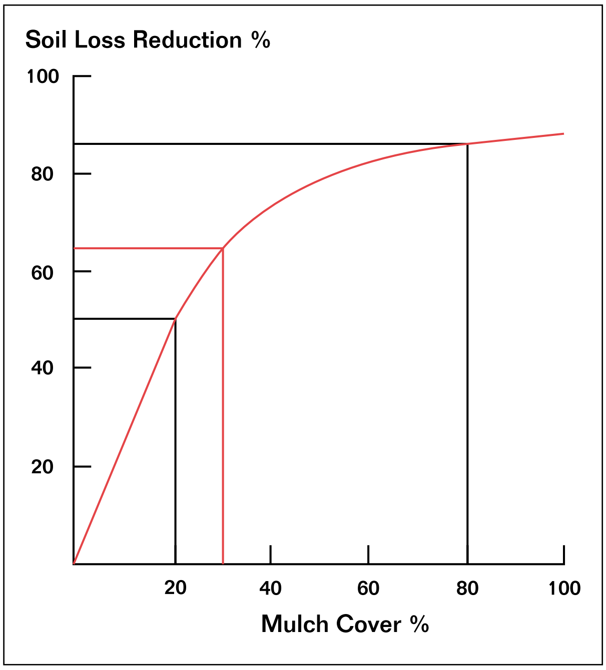
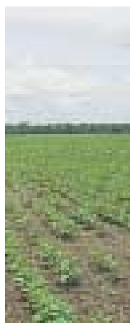


Figure 3
The effect of soil surface cover in reducing erosion. With 80 to 100% mulch cover there is a 90% reduction in soil loss.

Plate 9
Erosion risks are increased under cultivation.

Mulch cover protects the soil by absorbing raindrop impact, increasing infiltration and slowing the speed at which water runs over the land, thereby reducing soil movement. A study in the Daly Basin showed that conventionally cultivated areas produced twice the runoff and lost on average 1.5 to 6 times more soil than no-tillage areas despite all areas being protected by soil conservation banks. In some seasons no-tillage areas suffered negligible soil loss while cultivated areas lost up to 8 t/ha.



Average soil loss in conventional farming systems in the Top End may range from 20 to 40 t/ha. Continued losses of this magnitude would result in a loss of 1 to 2 cm of top soil over five to ten years.

Erosion rates will vary depending on storm intensity, soil conditions and other factors but surface cover has the potential to decrease soil loss by 90%.

Can seedlings survive temperatures of 55-60° Celsius?

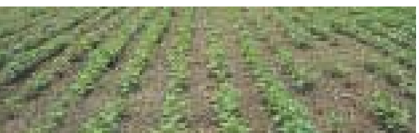
The short answer is **no**, but in many instances they are expected to! Dry conditions at, or after, planting are accentuated by high soil temperature. Bare soils can reach temperatures of 55-60°C, killing seedlings and reducing plant stands. Protecting the soil with mulch has the combined effect of conserving moisture and reducing temperatures by 8-16°C.

Reducing ground temperature is critical as many crop seedlings are adversely affected by soil temperatures over 30°C. Maintaining mulch is the only way a farmer can reduce soil temperature in dryland agriculture in the tropics.

Conserving moisture and increasing yields!

Moisture availability determines crop and pasture productivity. Crop failures can occur despite ample rain because much of the moisture is lost through runoff and evaporation.

Plate 10
Sorghum seedlings dying due to high soil temperature. Temperatures over 55°C are common on sandy surfaced soils.



In the Top End exposed soil can lose 60% of the rainfall through runoff and up 50% of soil moisture can be lost through evaporation directly from the soil surface.

For example when a 30 mm storm falls on bare soil, up to 18 mm may run off leaving only 12 mm to enter the soil. Evaporation from the soil surface may leave only 6 mm for plant use. Mulch retention can halve runoff and will decrease evaporation, making more moisture available for plants. Specific studies in various tropical regions have shown that by maintaining mulch, yield could be increased by up to 80%, 78% and 33% in sorghum, upland rice and peanut, respectively.

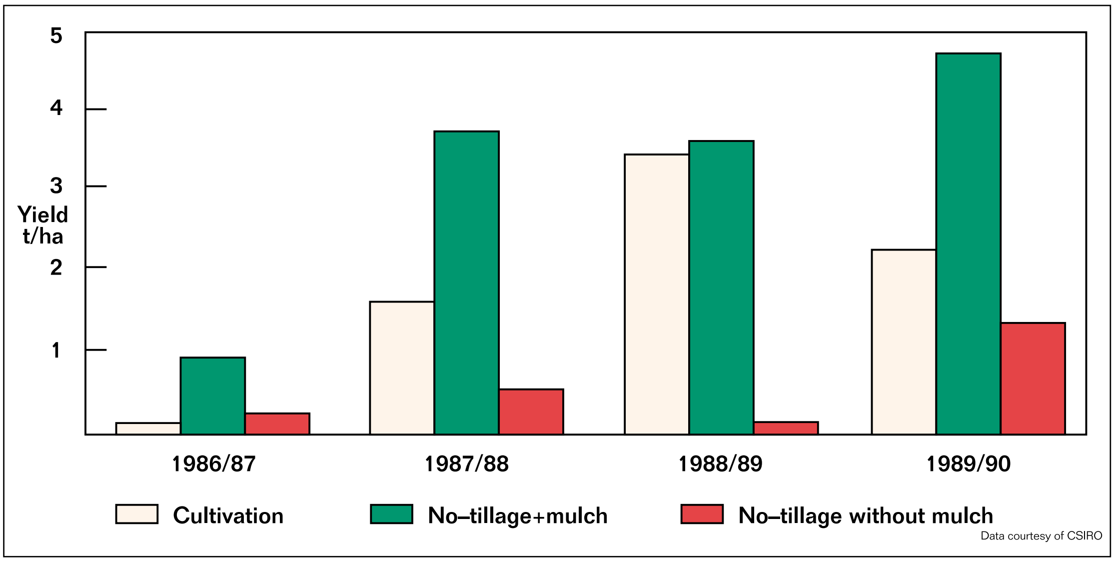
Mulch cover will conserve more rainfall and turn it into productive plant growth.

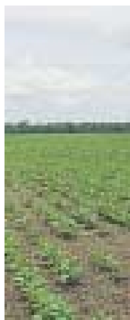
Better crops and healthier soil!

Mulch plays a vital role in promoting the uptake and cycling of plant nutrients. Earthworm numbers and beneficial microorganisms increase under mulch, improving soil structure and increasing its capacity to hold water and nutrients. Up to 90% of the nitrogen, phosphorus and potassium lost from farming systems can occur through erosion. Mulch helps to reduce this loss and also acts as a storehouse for many essential nutrients which are gradually released and used by plants.

Conservation farming provides more reliable yields than those achieved under conventional tillage. In a four year study at Katherine, no-tillage grain sorghum averaged 3.22 t/ha while conventionally sown crops averaged 1.80 t/ha.

Figure 4
The effect of tillage practice and mulch cover on sorghum grain yield over 4 years at Katherine. No-tillage with mulch produced on average 6 times more grain than no-tillage without mulch, highlighting the importance of mulch in the system.





At Douglas Daly Research Farm, no-tillage maize and soybean, on average, out-yielded conventional crops by 33% and 31%, respectively, over nine years. In dry seasons, conservation tillage has produced double the yield of conventionally sown crops.

Optimum planting time gives optimum results!

There are many reasons for poor crop performance but two factors have been largely responsible in this environment.

They are:

- the failure to sow at the optimum time
- the failure to achieve adequate plant populations

The optimum sowing period for any crop in the Top End is about 7-14 days. In many seasons only one or two sowing opportunities may occur when moisture and other factors are favourable. Optimum conditions may last for as little as 24-48 hours and missing such an opportunity may result in sowing late or sowing into declining moisture. This invariably results in poor establishment or moisture stress at the end of the season.

Conservation tillage enables sowing to be carried out as soon as moisture conditions are favourable and many of the delays associated with cultivation are avoided. Moisture is retained for longer enabling plants to better withstand dry spells after sowing.

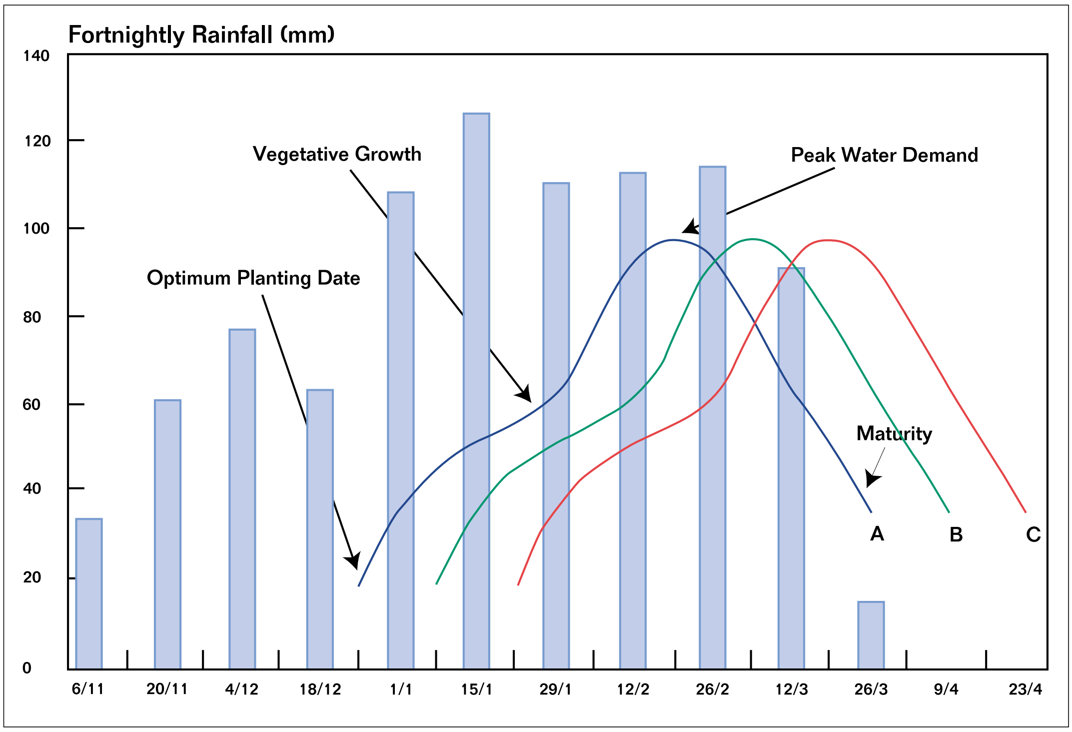
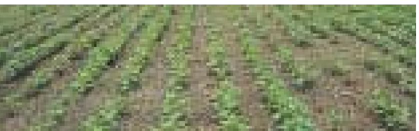


Figure 2
The effect of three different planting dates on relative water demand for a mid-maturity grain sorghum at Katherine.
Line A: *represents the relative water requirement of a crop sown at the optimum time. Peak water demand occurs during a reliable rainfall period. There is a high probability of a good crop yield.*
Line B: *represents a later sown crop where peak water demand occurs when the likelihood of rainfall is reduced, decreasing the chances of a good yield.*
Line C: *represents a crop sown well beyond the optimum date. Peak water demand occurs when the reliable rainfall period is over. There is a high probability that this crop will fail.*
This principle applies to any dryland crop sown in the Top End.



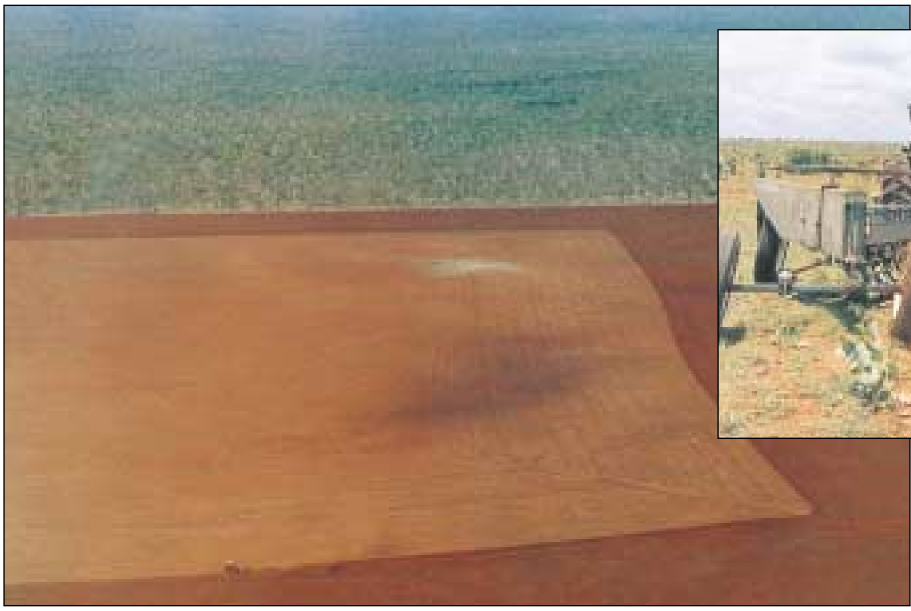


Plate 11
Conventional cultivation requires high inputs of labour, time and energy.

The ability to sow crops earlier into optimum moisture is one of the major advantages of conservation tillage and experience has proven that this translates into better yields.

Optimum time of sowing is critical for good yields. Conservation farming enables sowing to be undertaken on time and into good conditions.

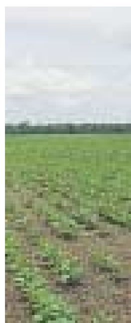
Farming with less energy, labour and machinery!

Machinery and fuel costs have risen by over 500% in the past 20 years. Fuel is now the largest single cost, with tillage consuming over 11% of total energy used on farms. Ploughing and cultivating can use between 6.0 and 17.0 L/ha of fuel while no-tillage uses between 2.0 and 4.0 L/ha depending on the operation.

Conservation tillage can reduce fuel consumption, tractor hours, maintenance and labour by as much as 40-60 %.

Conservation farming offers many benefits to Top End agriculture including:

- reduced erosion and improved soil structure
- improved infiltration and moisture efficiency
- improved soil health and nutrient retention
- lower soil temperatures and better establishment
- increased planting opportunities and flexibility
- lower machinery, labour and maintenance costs and
- more reliable yields



3.3 SO WHAT'S THE CATCH?

No single farming system or technique is perfect for all applications and conservation farming is no exception. Conservation farming involves more planning, management and a commitment to sustainability. Trade-offs are necessary and extra costs may be incurred in the initial years. Herbicides and specialised machinery are needed in most conservation farming systems.

Conservation farming will not always result in higher yields especially in seasons where rainfall is ample and well distributed. The effectiveness of some herbicides is reduced by mulch on the surface as high rates of organic matter 'tie up' many chemicals. Fertilisers such as nitrates and herbicides may leach more readily through the soil due to higher infiltration rates under conservation tillage, however, runoff losses will be reduced. These aspects are being addressed through improvements in fertiliser and herbicide formulation, application technology and better management practices.

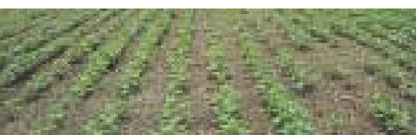
Conservation farming systems are dynamic and call for innovation and continual improvement. Grazing, weed, insect and fertiliser management are required for successful conservation farming and it takes time and experience to develop these skills.

A good understanding of the interaction between plants, animals, the soil and the environment is necessary. Conservation farming systems are intended to be flexible, responsive and to work within the constraints of the environment rather than against it.

Management aspects of conservation farming:

- longer term planning and commitment to sustainability
- commitment to learning and developing a system
- skills in mulch management, weed control and herbicide use
- skills in soil nutrient and pest management
- understanding soil, plant and animal interactions
- rotations and integrating crops, pastures and livestock
- requires specialised or modified planting machinery

No technique yet devised by mankind has been anywhere near as effective at halting soil erosion and making food production truly sustainable, as no-tillage.



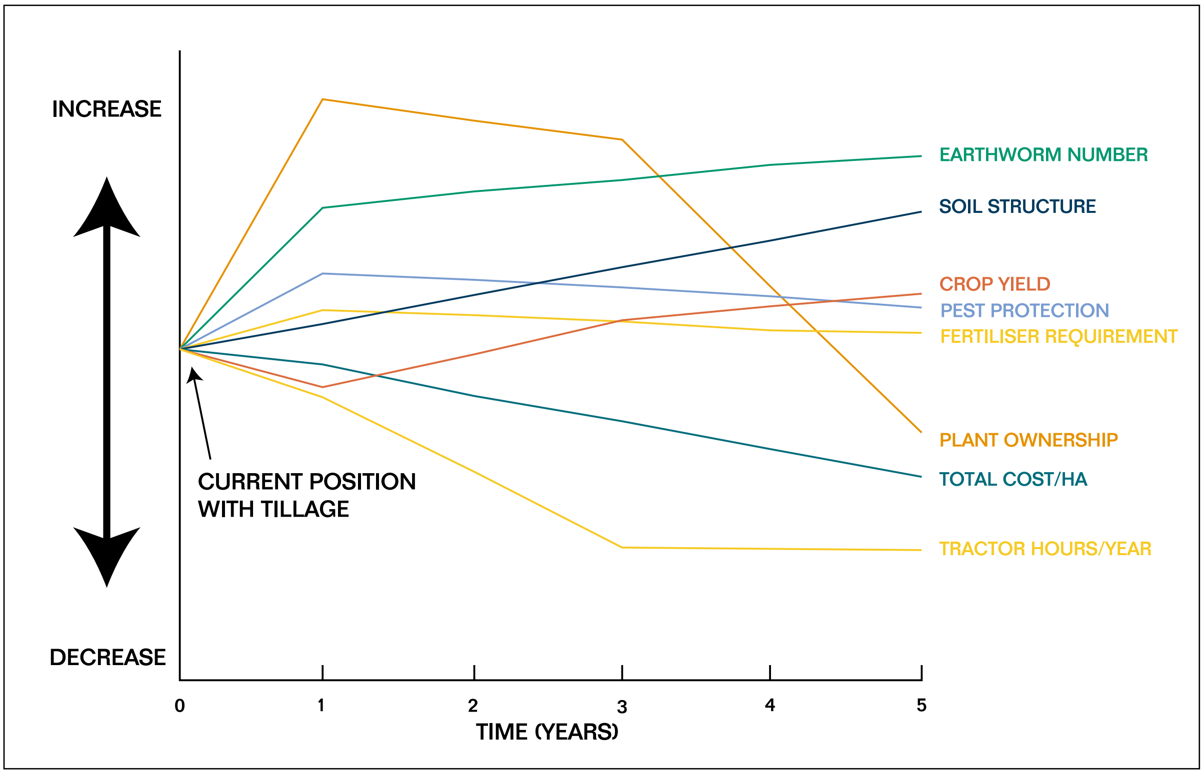
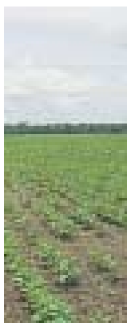


Figure 6
Likely outcomes resulting from conservation farming in the NT. Average crop yields are likely to improve and be more stable than conventional farming once experience with the system has been developed.



4. PLANNING A CONSERVATION FARMING PROGRAM

Plate 12
Learning from other farmers is an important part of developing knowledge about conservation farming.

Conservation farming should be undertaken initially on a small scale and developed gradually in line with skills and experience. Learning from others is vital and all sources of information including other farmers, advisers, government departments and publications should be used. Conditions for conservation farming don't occur automatically, but are created by design and management.

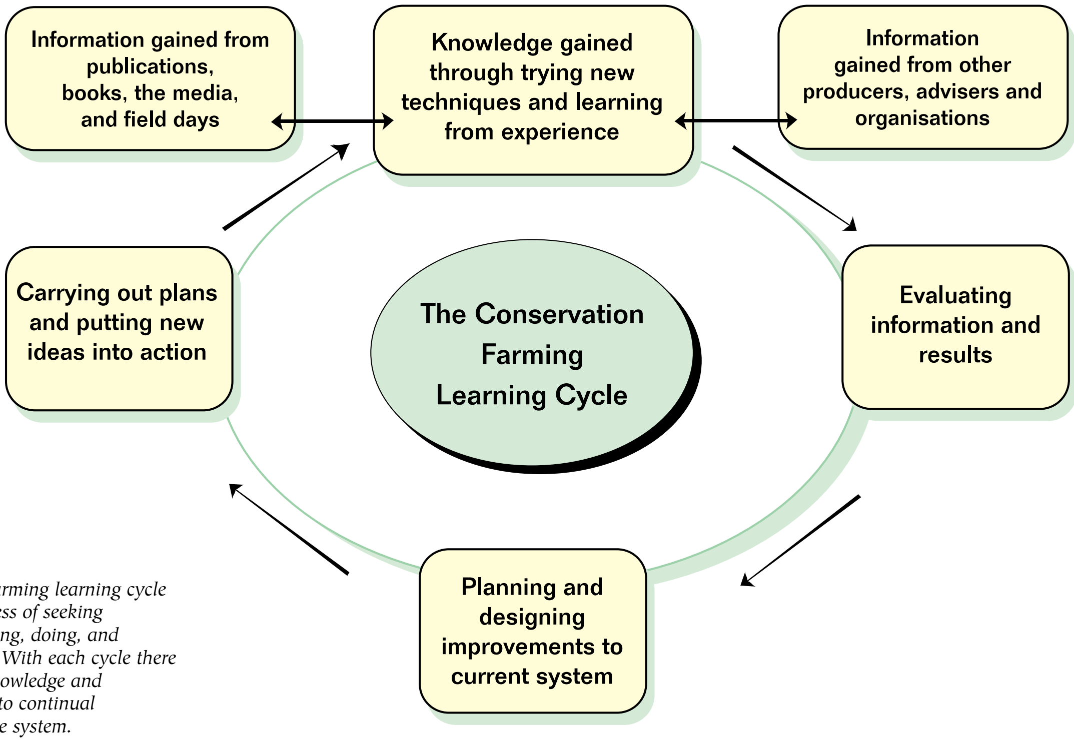


Figure 7
The conservation farming learning cycle is an ongoing process of seeking information, planning, doing, and evaluating results. With each cycle there is an increase in knowledge and experience leading to continual improvements in the system.

Considerations in planning conservation farming systems:

Long Term	Short Term
• locality and environment	• crop selection and rotations
• land and soil types	• current markets
• financial resources	• grazing system and stock control
• machinery and labour requirements	• pasture selection and compatibility
• markets, costs and returns	• weed spectrum
• personal preferences and objectives	• mulch management
• skills and experience	• insect and disease control
• sources of information	• sources of information

4.1 PLAN FOR HIGH RISK PERIODS

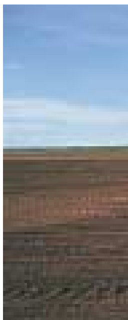
Situations often arise in which there is a particularly high risk of runoff and erosion. These occur especially at the beginning of the wet season when there is an absence of protective mulch and soils are exposed to intense storms.

High risk situations occur as a consequence of:

- clearing and developing new country
- late dry season fires
- over-grazing during the dry season
- early cultivation for crop/pasture land preparation
- production of low-mulch crops in the previous season

Developing new country
Developing new country and preventing soil loss is a major challenge. Heavy cultivation, stick raking and secondary tillage is required to remove stumps and to prepare an arable surface.

Plate 13
Stick raking and preparing newly cleared country, can leave the land exposed and susceptible to erosion.



In the process, soils are left exposed to intense and damaging storms. Once erosion commences, the potential for further land degradation increases.

Clearing small areas at a time and avoiding fragile or sloping country will help prevent problems. Leaving uncleared or grassed buffer zones, constructing contour or diversion banks and sowing an early cover crop are other practices which will minimise soil damage.

Plate 14
The effect of fire on the establishment of sorghum. The stubble in the foreground was burnt in a dry season fire which resulted in very poor establishment while plants established well where stubble was maintained.

Plate 15
Cultivation leaves the soil exposed and susceptible to erosion.

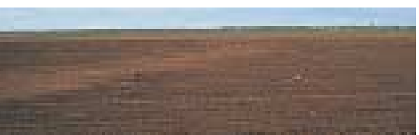
Timber windrows on sloping country will often concentrate runoff water, causing rilling or scouring. They should be burnt prior to rainfall to avoid such problems.

Late dry season fires or over-grazing

Late dry season fires or over-grazing have the same effect in stripping the land of protective mulch and predisposing soils to erosion. Maintaining effective fire breaks and managing grazing pressure will help to ensure sufficient mulch cover is maintained to protect the soil from early season storms.

Land preparation

Land preparation involving cultivation usually coincides with early wet season rains. Cultivation exposes the soil at a time when heavy storm activity is prevalent. The amount of mulch incorporated will vary according to the implement used and the number of operations. Soil protection can be achieved by reducing the number of operations and by leaving the soil surface in a rough tilth until just prior to planting. Using tined rather than disc implements will help to maintain mulch. Cultivating on the contour and leaving grassed strips between cultivated areas will also assist in minimising runoff and erosion.



Low-mulch crops
Low-mulch crops such as sesame, mungbean and peanut usually leave the ground exposed at the beginning of the next wet season. Rotating low-mulch crops with high-mulch crops such as sorghum, millet or pasture will increase surface cover and provide more protection at the critical time. No-tilling low-mulch crops into existing vegetation will assist in protecting the soil.

4.2 MULCH AND SOIL SURFACE MANAGEMENT

Mulch is defined as any dead or living vegetative matter which protects the soil from the effects of sun, wind and rain.

Mulch plays a vital role in:

- reducing raindrop impact on the soil surface
- slowing surface water flow and reducing erosion
- increasing infiltration and conserving moisture
- insulating the soil and reducing soil temperatures
- building organic matter, soil structure and fertility
- suppressing early weed growth

Mulch may consist of stubble from previous crops or a combination of pasture remnants, weeds and actively growing vegetation.

Prior to the wet season, mulch is predominantly dead material but live vegetation becomes more prominent as moisture becomes available.

Mulch levels can be described in terms of percentage of soil covered or in tonnes of material per hectare. Over 3.0 t/ha, and as close as possible to 100% soil cover, is desirable in the Top End. Crops such as sorghum, maize, rice and many pastures provide excellent mulch. Mulch allows crops to be established without cultivation and is the key to no-tillage farming. No-tillage without mulch does not work in this environment and usually results in excessive soil temperatures, surface crusting, dramatically reduced water infiltration and erosion. Refer to Figure 4 on page 21.

Managing mulch for soil protection while avoiding planting difficulties is an ongoing process. Too much or too little mulch will pose problems, requiring strategies such as changing grazing pressure, slashing, cultivation or strategic herbicide use. Rotating crops and pastures and integrating with livestock is an ideal way of managing mulch in no-tillage systems.

Mulch management is the key to conservation farming. It is critical for controlling runoff and erosion, conserving moisture and insulating the soil.

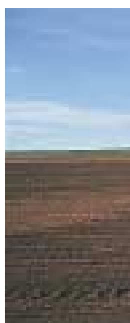
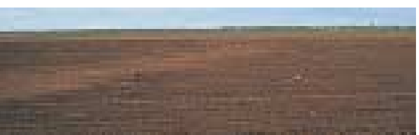


Plate 16a
Once the rains arrive mulch consists of a combination of dead and live vegetation which must be managed to achieve suitable planting conditions.

Plate 16b, c
Cultivated soils without mulch protection are prone to crusting and sealing. This results in poor crop establishment, low water infiltration and high runoff rates.

Plate 17
Mulch can be effectively managed through grazing.



Decisions on mulch management include:

Strategies to Reduce Mulch	Strategies to Preserve/ Increase Mulch
• straw spreading at harvest • slashing or harrowing • baling for fodder • grazing • selective cultivation • strategic herbicide use	• leaving stubble intact • removing livestock • sowing a cover crop or pasture • rotating low-mulch crops with high-mulch crops or pastures

Figure 8
Decision chart for mulch management in conservation farming systems. Mulch management is an ongoing process and should start well before the onset of the wet season.

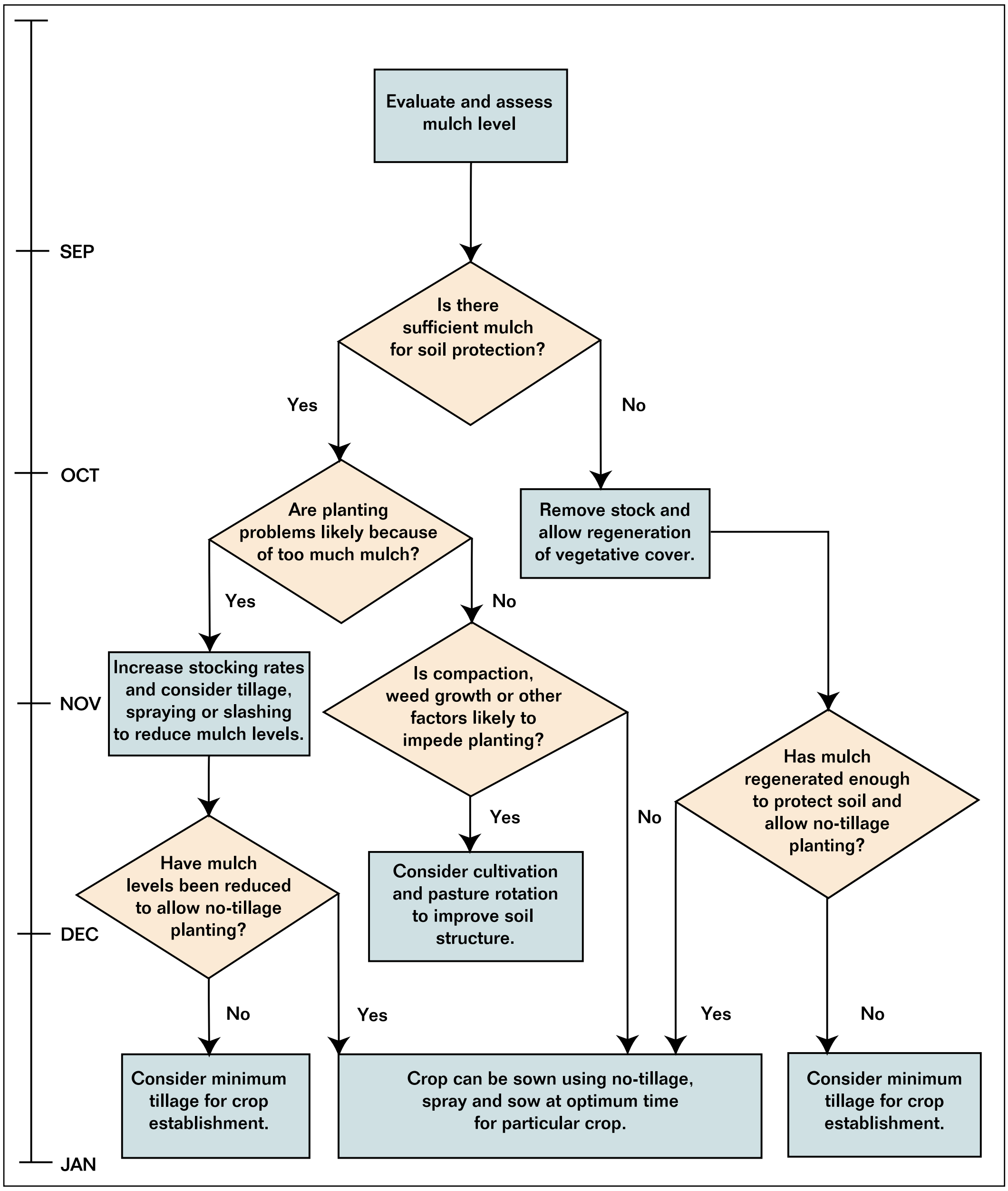
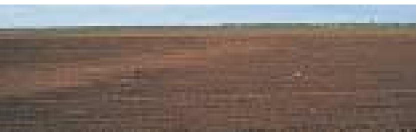
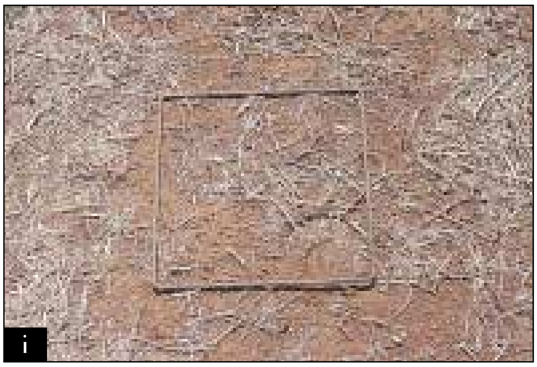
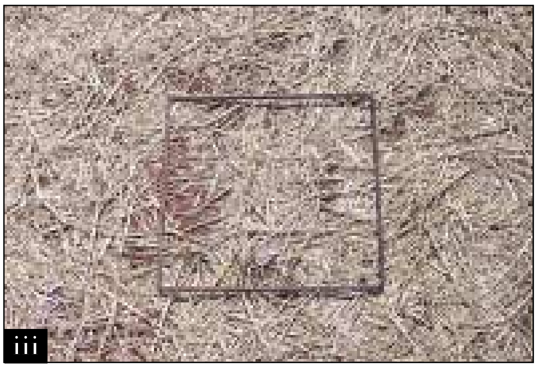


Plate 18a
Different levels of sorghum stubble mulch.

i) 0.6t/ha, ii) 1.6t/ha, iii) 3.0t/ha,
iv) 4.2 t/ha







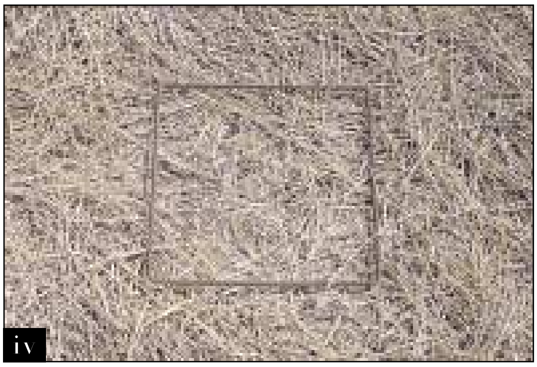
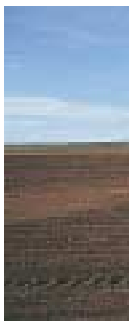


Plate 18b
Different levels of summer grass and Cavalcade mulch.

i) 0.75 t/ha, ii) 2.0 t/ha, iii) 4.5t/ha, iv) 7.0 t/ha



4.3 THE ROLE OF CULTIVATION AND SOIL CONSERVATION STRUCTURES

Cultivation is often beneficial but can cause irreparable damage to soils when over used. Continuous cultivation or heavy grazing can result in soil compaction, sealed and crusted surfaces and "hard pans". Strategic cultivation is used to control many hard-to-kill weeds, open the soil and break up compacted layers, improve infiltration and to incorporate mulch and nutrients.

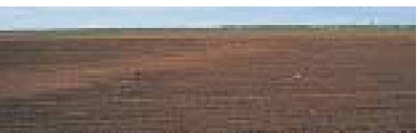
Where soils are compacted and sealed, cultivation is generally the only option prior to crop establishment. An open soil of good tilth will more effectively trap and conserve moisture than one which is compacted. No-tillage does not work on bare compacted soils but minimum tillage will achieve good results under such conditions.

Plate 19
Soils which are sealed and compacted require cultivation to improve the structure and promote moisture infiltration and plant growth.

Cultivation should ideally be carried out along the contour of the land. Contour cultivation involves ploughing and planting along the contour (points of equal height) to slow the flow of water and prevent it running directly down the slope. This allows more time for water to infiltrate and reduces the risk of soil movement.

Situations in which cultivation is beneficial include:

- preparation or developing new ground
- opening up compacted or crusted soils
- breaking up plough layers
- incorporating excessive mulch
- increasing infiltration in low-mulch areas
- unsuitable conditions for application of herbicides
- difficult weed control situations ie. hard-to-kill perennials
- sucker/regrowth control
- incorporating herbicide or fertiliser
- ameliorating previously damaged or eroded land



Tillage implements are designed for specific purposes and vary in the amount of mulch they incorporate. Tined implements such as chisel ploughs and scarifiers leave more mulch on the surface than disc ploughs and are preferred for conservation farming systems.

Implement Type	% mulch lost in each operation
one way disc	50
tandem disc	35
wide-line cultivator (9 cm shank)	35
scarifier (25 cm shank)	30
chisel plough (30 cm shank)	25
sweep plough (0.9 metre)	15
blade plough (1.8 metre)	10

It is the continuous and inappropriate use of cultivation which leads to land degradation.

Physical Structures

Physical structures can be combined with tillage practices to manage runoff and erosion.

Structures include:

- diversion banks
- contour banks
- grassed waterways

Diversion banks
Diversion banks are constructed on higher ground to intercept water and convey it to a designated waterway prior to reaching cropping areas. The size and type of structure will be determined by the volume of water to be diverted. Water must be diverted to a 'safe' area such as a natural storage or designed waterway, otherwise the concentration and velocity of diverted water may cause severe erosion.

Plate 20
Contour banks are important components of conservation farming programs but must be combined with mulch management.

Contour banks
Contour banks are constructed on a slight gradient to the natural contour and are designed to allow the water to travel across the slope at low speeds. Most banks are constructed to cope with a one in 5 or one in 10 rainfall event. Spacing between banks decreases as the slope increases. Water is directed into a waterway or safe drainage area.

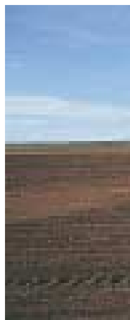


Plate 21a, b
(a) Earthworks must be combined with mulch retention and conservation farming to be effective in controlling erosion.
(b) Earthworks are not always successful in controlling erosion.

Plate 22
Network of contour banks connected by grassed waterway.

Studies in the Daly Basin found that by using no-tillage, spacing between contour banks could be increased to twice that required for conventional cultivation while still reducing soil loss.

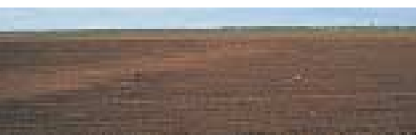
Waterways

Waterways are designed to collect water from diversion and contour banks and deliver it safely to natural water courses, dams or storage areas. They must be well constructed and grassed to cope with large volumes of water.

Physical structures and contour cultivation play an important role in soil conservation but by themselves are inadequate as complete erosion control measures. Erosion between contour banks often occurs under intense rainfall.

If structures are poorly designed or maintained they can concentrate water and lead to significant soil damage. Due to the intensity and amount of rainfall received in the Top End it is often difficult to design structures to adequately cope with water volumes. Physical structures must be combined with soil surface cover to be effective.

Experience has shown that soil cover is more effective than earthworks in reducing erosion in this environment.



4.4 PLANTERS FOR CONSERVATION FARMING

A conservation farming planter or seed drill must be capable of effectively sowing seed through mulch into an unprepared seed bed and achieving an optimum plant stand. It must accurately deliver and place seed at a uniform depth and achieve good seed to soil contact.

Planters need the following characteristics:

- robustness for hard conditions
- effective trash cutting ability
- accurate metering of seed of various sizes
- good penetration in tight soils
- accurate placement of fertiliser
- accurate depth control and seed placement
- flexibility for different row widths

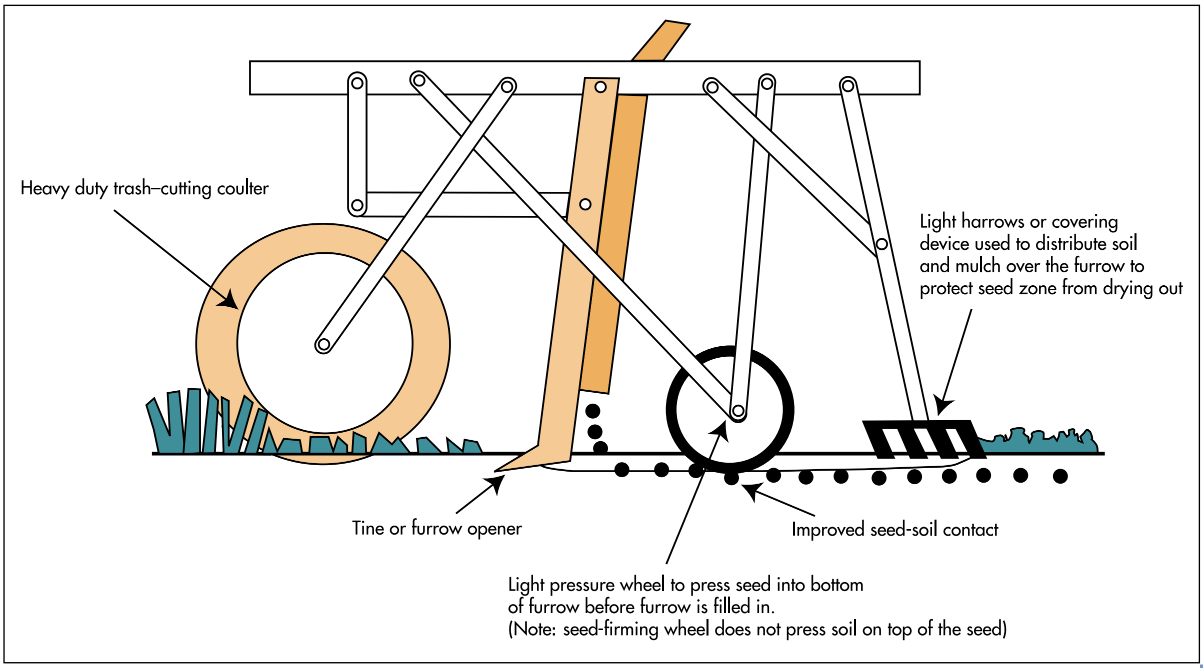
Experience to date suggests that planters need to be fitted with heavy duty coulters, high strength break-out tines, narrow points and suitable presswheels or seed covering devices for conservation farming in the NT.

Planter components

Disc coulters

Disc coulters are essential components and are needed to slice or cut through mulch to allow tines to pass without blockage. Planting without coulters, in light mulch, is often difficult but is practically impossible in heavy mulch. Many types of coulter are available including straight, fluted and twin-inclined coulters which have been designed for specific purposes.

Figure 9
Planter components necessary for successful no-tillage farming in the NT.



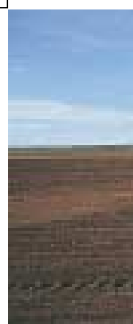


Plate 23a, b
Disc coulters.
(a) Heavy duty self cleaning coulter suitable for NT conditions.
(b) Fluted coulter which has become blocked with mulch and soil. Generally unsuitable for clay loam soils in the NT.

The most common coulter type used, is one with a plain flat, disc measuring about 560 mm in diameter. These coulters, fitted to conventional combines, have performed well in various conditions and soil types in the NT.

Sowing points and furrow openers

Sowing points and furrow openers are critical components as they determine the accuracy with which seed is placed within the soil. Soil openers need to be narrow in profile to reduce soil disturbance, enable efficient soil penetration and create a protected furrow.

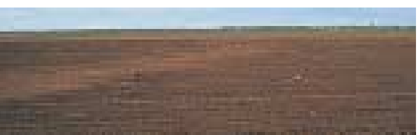
Lucerne points, disc or slot openers are the preferred tools. Several designs are available to suit various conditions and soil types. A recent advance in conservation farming has been the development of a specialised winged opener (the Baker Boot®) which creates an 'inverted T' slot.

This is the only boot specifically designed for conservation tillage and is designed to minimise compaction, create a protected seed zone and provide reliable seed emergence. Its advantage over other openers has not yet been fully confirmed under NT conditions.

Presswheels and seed-firming wheels

Presswheels and seed-firming wheels are designed to improve contact between the seed and soil thereby increasing the availability of moisture immediately around the seed. Many presswheels compact soil over the seed whereas seed-firming wheels are designed to lightly press the seed into the bottom of the furrow. When used correctly and on the appropriate soil types, some presswheels and seed-firming wheels will allow more rapid and higher rates of germination and emergence.

Plate 24a, b, c
(a) Components on a no-tillage row crop planter includes disc coulter, furrow opener and small in-furrow seed-firming wheel.
(b) Twin-inclined presswheels.
(c) Heavy duty in-furrow presswheels may cause compaction and are generally unsuitable for use on Red Earths in the Top End.



Once the seed has been pressed into the soil, the furrow should then be backfilled with loose soil and mulch to protect the seed zone from drying out and allow seedlings to emerge unhindered.

Compacting soil on top of the seed should be avoided especially on heavier soil types and the Red Earths. The clay, when compacted, forms a hard seal on drying, creating a barrier above the germinating seed. This significantly reduces emergence. Presswheels should be chosen to suit specific soil types and conditions.

Covering tools

Covering tools and the nature of the furrow cover have a major impact on seedling emergence. Covering tools are designed to return soil and distribute mulch over the furrow, minimising moisture loss.

Finger harrows, chains, covering discs, presswheels, rollers and tyres have all been used to close or backfill the furrow. Rollers have been successfully used on sandy and gravelly soils but chains or harrows are recommended for heavier soils to prevent compaction above the seed.

Row crop planters versus combines

Row crop planters are precision implements designed to sow crops in row widths of 0.5-1.0 m. They consist of individual planting units fitted with seed and fertiliser boxes on a common tool bar. Row crop planters are usually less robust than combines and are used on land which is free from stumps and stones and where precision is required, as in maize or peanut production.
Combines are suited to a wider range of conditions and are generally more versatile but some may not offer the precision of many row crop planters.

Plate 24d
Incorrect use of presswheels may compact and seal the soil and reduce emergence especially in clay loam soils.

Plate 25a, b
(a) Row crop planter and (b) no-tillage combine.

Plate 26
Conventional combine modified for no-tillage, by removing cultivating tines and adding coulters.

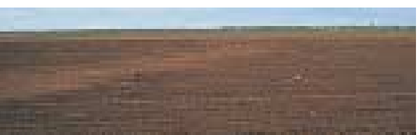
Combines can be used to sow a wider range of crops and pastures including small seeds. The choice of planter will ultimately depend on budget, range of crops and conditions.

Modifying existing planters

Conservation farming machinery is continually being improved as knowledge and experience develops. Farmers regularly modify machinery to suit their specific situations and requirements. Modification is an alternative to buying new machinery when first adopting conservation farming.

Standard combines can easily be modified by carrying out the following procedures:

- removing cultivating tines
- spacing planting tines to appropriate row widths
- fitting narrow points to assist soil penetration
- fitting disc coulters
- adding seed-firming or presswheels
- using a covering device ie. harrow or chain
- increasing tine break-out force



5. HERBICIDES: PART OF A MORE FLEXIBLE SYSTEM!

Agricultural chemicals are a major component of modern farming and have enabled dramatic increases in farm productivity over the past 40 years. Herbicides are the principal weed control agents in conservation farming. They provide more options for weed management and land preparation, have reduced the need for cultivation and can be applied in a fraction of the time it takes to cultivate an equivalent area.

Herbicides such as glyphosate (ie. Roundup® Nufarm Glyphosate CT® etc) are designed to give total control of weeds prior to sowing and allow crop establishment without weed competition. Glyphosate may be applied several days, or immediately, prior to sowing depending upon weather and moisture conditions. In many cases, one application of herbicide is adequate. Spraying and sowing using no-tillage can often be undertaken on the same day resulting in significant time and energy savings.

5.1 GETTING THE BEST FROM HERBICIDES

The performance of some herbicides in tropical environments can sometimes be erratic. This is particularly true of soil-applied herbicides where high temperatures, intense rainfall and low soil organic matter result in rapid breakdown and loss through leaching. High mulch levels also reduce the effectiveness of many soil-applied herbicides.

As a result of heavy rain, some herbicides such as atrazine may be washed into and concentrate in the seed furrow resulting in crop injury.

This effect is more pronounced in sandy soils where the absence of clay permits the herbicide to move freely. Herbicide application rates must be adjusted for soil type and conditions to avoid crop injury. Experience has shown that although many residual herbicides are effective, their activity and persistence is generally shorter under tropical conditions than in temperate climates.

Knockdown and foliar herbicides such as glyphosate are generally more predictable than some soil-applied herbicides. The effectiveness of foliar herbicides is influenced by environmental conditions.

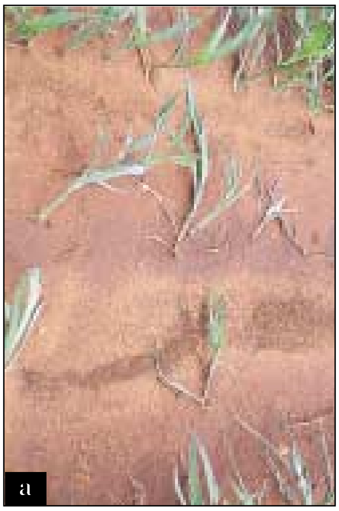


Plate 27a, b
(a) 2,4-D herbicide damage in grain sorghum.
(b) Damaged (club-roots) and undamaged sorghum roots.

Plate 28
Herbicides allow greater flexibility when preparing land for planting and reduce the reliance on cultivation.

Windy or hot dry periods should be avoided when applying such herbicides. Young, actively growing weeds are more easily controlled. Moisture stressed or dusty plants generally do not take up sufficient herbicide to achieve adequate control.

Foliar herbicide is best applied in the early morning when temperatures are moderate, plants are fresh and there is a 3 to 6 km/hr breeze to assist penetration into the foliage. At least 3 to 4 hours should elapse between applying glyphosate and the next rain, to allow sufficient time for uptake. Good quality water must be used as hard or dirty water will reduce effectiveness or may cause complete failure. Various wetting agents and surfactants are available and recommended by chemical manufacturers to increase herbicide effectiveness.

Plate 29
Sabi grass slashed and sprayed with glyphosate before no-tillage planting grain sorghum.

Certain residual herbicides may be added to glyphosate to give extended control of specific weeds. These are recommended by various manufacturers.

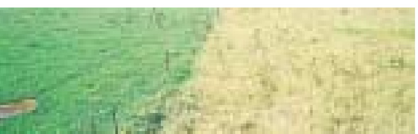
Manipulation of weeds by grazing, slashing or strategic cultivation can reduce the costs and increase the efficiency of herbicides. The older and more mature the weeds, the higher the rate of chemical required for control.

Boomsprays are the main method by which herbicides are applied. Poorly maintained spraying equipment is a major cause of chemical waste and spray failure. Boomsprays should be serviced and calibrated regularly to ensure accurate application.

Boomspray components include:

- quick release nozzles
- anti-drip valves
- inline filter/self cleaning filters
- spray monitors/gauges
- flow meters and sensors
- spray marking systems ie. foam or dye
- self levelling booms
- chemical decanting systems
- additional clean water storage

Plate 30
Foam markers on boomsprays allow greater accuracy when applying herbicides.



5.2 CHEMICAL SAFETY

With agricultural chemicals comes a responsibility to use them wisely. There are two major aspects, operator and environmental safety.

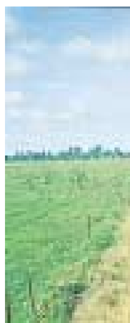
Operator safety

Farm chemicals are labelled according to their uses and toxicity. In general, herbicides are safe and less toxic than many insecticides and fungicides. When used in accordance with label recommendations, herbicides pose minimal risk to the operator. A number of hazardous herbicides, such as paraquat are available but many of the herbicides used and recommended in the Top End have toxicities between that of aspirin and common table salt.

Most poisoning with agricultural chemicals occurs through skin contact but inhalation and accidental oral poisoning have occurred. Full protective clothing in the tropics is often impractical. Gloves, long sleeves, long pants, protective boots, eyewear and face mask will give adequate protection when handling most herbicides.

Clean water and soap should be available to decontaminate splashes or spills. Suction devices on boomsprays eliminate the need to handle the concentrate. Operators have a responsibility to protect others and should store chemicals in original containers in secure areas inaccessible to unauthorised persons or children. Common sense, respect for the chemical, **reading the label and observing safety directions** are essential for operator safety.

Plate 31
Herbicides are an efficient means of controlling weeds just prior to planting.



Environmental safety

Herbicides are broken down by sunlight, biological and chemical action. Some agricultural chemicals may move off-site in runoff or by leaching. The amount lost is determined by the interaction of rainfall, temperature, soil type, organic matter and herbicide type.

Light sandy soils and those low in organic matter are more prone to herbicide leaching. In heavy soils, herbicides are bound to clay particles thereby reducing the amount of chemical leached. Herbicides such as glyphosate are bound strongly to the soil while others like atrazine, dicamba and Velpar® leach readily. Research indicates the highest concentration of chemical is found in sediment, but 75 to 99% of chemical loss occurs in runoff water.

Chemical losses due to leaching may increase in conservation farming systems in some situations, but total losses will be lower due to reduced sediment loss and runoff.

Glyphosate, the main herbicide currently used in conservation farming in the Top End, has a very low toxicity. It is broken down by soil microbes to produce plant nutrients such as phosphoric acid, ammonia and carbon dioxide. Glyphosate poses minimal threat to the environment when used in accordance with recommendations.

Environmental impact can be minimised by using correctly calibrated and maintained equipment, selecting the least toxic chemicals, using all of the chemical for what it was intended, rinsing and recycling containers and minimising spillage or over use. Manufacturers are developing better equipment and more environmentally sensitive products such as recyclable drums, dissolvable bags and ultra low rate chemicals. These should be used where appropriate.

6. CROPS FOR THE TOP END

A range of crops and pastures are available in the Top End allowing considerable scope when choosing farming systems and rotations. These include coarse grains, grain legumes, oilseeds, forage crops and grass and legume pastures.

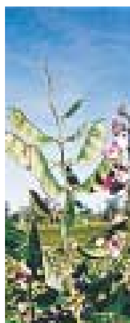
6.1 COARSE GRAINS

Grain sorghum
(Sorghum bicolor)
Grain sorghum has been the major grain crop in the NT in recent times and is used in local stockfeed industries. It can be grown from Darwin to Daly Waters but in the higher rainfall zones sorghum may be subject to head moulds caused by extended wet seasons. Sorghum is suited to a range of well drained soil types including gravelly ironstone soils, Blain sands and Tippera clay loams.

Average yields range from 2-3 t/ha. Paddock yields of over 4 t/ha have been achieved. Sorghum yields have increased significantly with adoption of conservation tillage.

Sorghum cultivars are available for different sowing times and geographical areas. Short season varieties are recommended for lower rainfall areas south of Katherine and longer season varieties for the more reliable areas further north. Sorghum is well suited to a rotation with pasture legumes such as Cavalcade and Bundey, provides excellent mulch for soil protection and the stubble offers valuable dry season grazing.

Plate 32
Grain sorghum.



Maize *(Zea mays)*

Maize is grown for the local stockfeed market. It has a higher yield potential than sorghum but is less tolerant to moisture or nutrient stress. Dryland maize production is recommended for the higher rainfall areas and heavier soil types of the Douglas Daly region and further north. Maize, generally, does not perform well on light soils due to higher soil temperatures, reduced moisture retention and nutritional problems commonly experienced in sandy soils under dryland conditions. The establishment and yield of maize is greatly enhanced by conservation tillage.

Dryland maize yields in the Douglas Daly region range from 1-5 t/ha and average 2 t/ha. Maize has been grown in the Katherine district under irrigation for both grain and silage.

Irrigated maize has yielded up to 9 t/ha of grain and 30-50 t/ha of silage. Maize produces good levels of mulch and the stubble is a useful stockfeed in the dry season.

Rice *(Oryza sativa)*

Rice is grown in the higher rainfall upland areas (over 1200 mm) and coastal floodplains of the NT. Two varieties, NTR 587 and NTR 426 are available. NTR 587 has a higher yield potential and is suited to ponded wet-culture conditions. NTR 426 is a shorter season variety suitable for upland rice production. Commercial yields of 2-4 t/ha from flooded rice and around 2 t/ha from upland rice can be expected.

Construction of low banks to conserve wet season water on the seasonally flooded plains is critical for reliable rice yields.

Plate 33
Maize under centre pivot irrigation and maize cob.

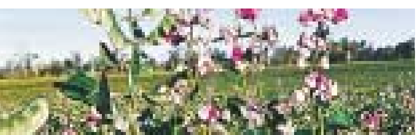


Plate 34
Rice on Top End floodplains.

Rice is a good quality grain and is used in the local stockfeed industries. Rice stubble contains about 6-7% protein, is suitable for hay making and offers valuable dry season grazing.

6.2 LEGUME AND OILSEED CROPS

Mungbean *(Vigna radiata)*
Mungbean is a drought tolerant, quick maturing grain legume. It is suitable for the Douglas Daly, Katherine and Daly Waters regions. Mungbean is adapted to most well drained soils with moderate phosphorus and zinc levels.

Mungbean seed contains about 20-27% protein and is used for human consumption as either bean sprouts or as dhal (splits) in Asian cooking. High quality beans are required for the human consumption market. Low quality beans are used for stockfeed.

Shangtung and Putland are recommended for the NT. Putland is a tall variety and has better weathering and pod shattering resistance than Shangtung. Bean yields of 1-2 t/ha can be expected. Mungbean is relatively cheap to grow and is suitable for a rotation with sorghum and sesame.
It can provide 20-40 kg/ha of nitrogen to a following crop. Mungbean can be sown as an opportunity grain, hay or green manure crop.

Plate 35
Putland mungbean.

Plate 37a, b
(a) Soybean under irrigation in Katherine.
(b) Mature soybean pods.

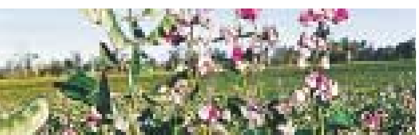
Soybean *(Glycine max)*
Soybean is a sub-tropical grain and oilseed legume. Buchannan and Leichhardt are the main varieties grown in the Top End. Leichhardt is a tropical variety and better adapted to local conditions. Soybean is less drought tolerant and more sensitive to nutrient stress than mungbean and is recommended for the heavier soil types.

It is suitable for a rotation with maize, sorghum, sesame or rice in the higher rainfall areas. Commercial yields of 1-2 t/ha under dryland conditions and up to 4.0 t/ha under irrigation can be expected. Soybean seed has one of the highest nutritive values of any plant and the meal contains between 40 and 50% protein. Sowing soybean into mulch greatly enhances its establishment and performance.

Plate 36a, b
(a) Sesame pods open on maturity and seed losses can be high.
(b) Sesame plant.

Sesame *(Sesamum indicum)*
Sesame, a relatively new oilseed crop to Australia, was first grown commercially in the NT in 1985/86. Sesame seed contains 45-55 % premium oil and 19-25 % protein. The seed is used in confectionary, breads, cereals and tahini paste. Two cultivars, Edith and Yori, are available in the NT.

Sesame is drought tolerant and suited to free draining soils in the 550-1200 mm rainfall areas of the Katherine-Daly Basin.



Commercial yields have averaged 300-500 kg/ha but yields of up to 1 t/ha are possible by using improved harvesting techniques.

Substantial seed loss occurs due to pods opening at maturity and minimising this loss is a major challenge. Headers equipped with air-fronts, extended tables and the use of chemical desiccants can reduce losses considerably. Sesame is well suited to a rotation with high-mulch crops such as sorghum or sabi grass pastures. Sesame stubble provides little mulch or useful animal feed.

Peanut *(Arachis hypogaea)*
Peanut is a high value, high input legume crop suited to the free draining sandy loams of the Daly Basin. It has recently been grown on ironstone gravel soils in the Darwin region. Dryland peanut production is possible in areas with over 1100 mm seasonal rainfall but reliable rainfall is essential for good yields and quality. Dryland yields range from 1.3-3.2 t/ha. Supplementary irrigation is recommended south of Douglas Daly. Peanut can be grown under full irrigation in the dry season. Cultivars available in the NT include Florunner, NC7 and Stretton.

Peanut contributes nitrogen to the system and is suited to a rotation with maize, sorghum or sesame. Timely digging and threshing is critical to ensure good quality and viable recovery of nuts. The NT currently enjoys Peanut Mottle Virus (PMV) free status, allowing a premium for locally produced seed quality peanuts.

Peanut stubble is a good source of animal feed which can be grazed or baled. However, removal of hay takes a significant amount of nitrogen from the system and leaves the soil exposed and prone to erosion.

Plate 38a, b
(a) Peanut field.
(b) Digging peanuts at Douglas Daly.

6.3 FORAGE CROPS

The demand for fodder in the NT is increasing due to the expansion of the live cattle trade with South East Asia. Fodder quality is also becoming increasingly important as the market demands high protein hay for processing.

Plate 39
Fodder production is a major part of Top End agriculture.

Plate 40
Hybrid forage sorghum.

Forage sorghum
(Sorghum x Sorghum)
Forage sorghum hybrids are perennial, high yielding fodder crops suited to wet season or irrigated dry season production. Several hybrid forage sorghums are available which are suitable for either grazing or haymaking.

Digestibility and protein content decrease significantly with maturity, therefore early harvesting is necessary to maintain forage quality. Forage sorghums produce prussic acid, a toxic substance which increases in concentration if heavily fertilised with nitrogen or when suddenly stressed. Grazing under these circumstances may cause poisoning and stock should be removed. Making hay may reduce prussic acid level but will not completely eliminate it.

Forage sorghum will yield 7-15 t/ha per harvest and is generally the most productive grass forage for dry season irrigation in the Top End. Forage sorghum is suited to a rotation with legume pastures as a means of utilising accumulated soil nitrogen and as a break crop for controlling weeds and insect pests.

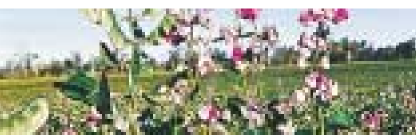


Plate 41
Pearl millet is a productive forage or green manure crop.

Pearl millet
(Pennisetum typhoides)
Pearl millet is an annual, open pollinated forage and grain crop. It produces high yields of forage but quality deteriorates on maturity. It is deep rooted, drought tolerant and has been used as a horticultural green manure crop to recover leached nutrients and to build soil organic matter. The grain is used for stock feed and bird seed.

Cultivars Ingrid and Katherine Pearl are available. Hybrid pearl millets have not performed well under NT conditions. Ingrid flowers 1-2 weeks earlier and produces higher seed yields than Katherine Pearl.

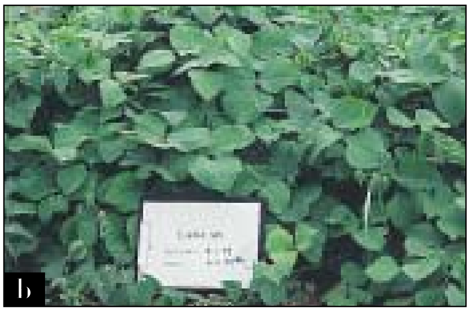
Millet is an alternative to forage sorghum, does not produce prussic acid, is inexpensive to grow and will produce forage yields up to 15 t/ha. Pearl millet is suitable for rotation with legume pastures, will utilise accumulated soil nitrogen, assist in weed control and improve soil structure.

Cowpea *(Vigna unguiculata)*
Cowpea is an annual twining legume suitable as a green manure, fodder or seed crop. Arafura, Meringa and Palmyra are grown in the NT. Cowpea is drought hardy, is suited to a wide range of well drained soils and will tolerate short periods of waterlogging. Existing cowpea varieties flower and mature earlier than lablab. They require moderate phosphorus levels and must be inoculated when grown in new areas.

Cowpea produces dry matter yields of 3-6 t/ha with a crude protein concentration of between 10-20 %, depending upon time of harvest.

Plate 42
Cowpea.

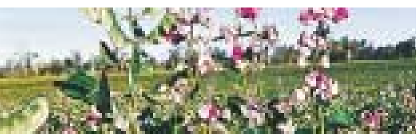
Plate 43a, b, c
(a) Lablab grown in alternate rows with forage sorghum.
(b) Lablab and
(c) flowers and pods of Highworth lablab.



It may be grown with forage sorghum to improve fodder quality. Seed yields range from 200-1000 kg/ha.

Lablab *(Lablab purpureus)*
Lablab is a vigorous, twining, annual legume which is grown for seed, forage or as a green manure crop. Lablab has a longer growing season, higher seed yield, and better tolerance to root and stem rots than cowpea. It matures up to 60 days after cowpea depending on variety. Lablab is drought tolerant but has poor tolerance to waterlogging.

Varieties recommended are Rongai, a white flowered, late maturing variety and Highworth, a blue or purple flowered variety which matures approximately a month earlier. Rongai is suited to the higher rainfall areas and Highworth to Katherine and south. Seed inoculation is recommended when sowing lablab. Forage yields range from 5-7 t/ha and crude protein ranges from 10-22%. Lablab can be grown in conjunction with forage sorghum to improve forage quality.



7. PASTURES IN FARMING SYSTEMS

Farming and grazing systems in the Top End rely on both native and improved pastures. The sustainablilty of agriculture in the NT is dependent upon the productivity, protection and integrated management of these resources.

7.1 NATIVE PASTURES

Native pastures carry most of the livestock in the NT and will remain the mainstay of extensive livestock production in drier areas. They support animal production in areas where the soil has relatively poor natural fertility or where rainfall is low or unreliable. Native pastures are also an integral part of the farming system on many Top End properties.

However, native pastures have a number of limitations. They have short productive periods during the wet season, after which feed quality rapidly deteriorates. They have low production levels and when mature, native pastures are low in minerals, digestible energy and are unable to support any liveweight gain. They generally do not respond to fertiliser, are intolerant of heavy grazing and are easily degraded.

Many producers run their breeder herds on native pastures and use their improved pastures and crop stubbles for growing weaned animals.

Plate 44
Native pastures are an important resource but easily degraded.

Table 1. Average nutrient content of native and improved pastures in the Top End.

Pasture Composition (% Dry Matter)					
	End of Wet (April)		End of Dry (Sep)		Maintenance* Level Req'd
	Native Pature	Improved Pasture	Native Pasture	Improved Pasture	
Crude Protein	3-6	8-10	1-3	4-10	7
Phosphorus	0.03-0.5	0.09-14	0.02	0.04	0.12-18
Digestibility	30-54	41-65	30-43	38-57	approx 50

*Maintenance refers to feed intake which is adequate to prevent loss or gain of tissue

Native pastures can be improved by introducing exotic legumes such as stylos or Wynn cassia and applying phosphorus and sulphur fertiliser to improve legume productivity. However, in most cases it is more efficient to supply phosphorus directly to animals as a mineral supplement rather than applying it over vast areas of native pasture.

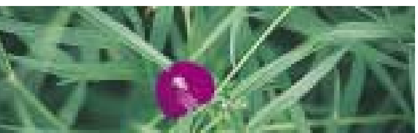
Plate 45
Cattle grazing improved pastures in the Douglas Daly.

7.2 IMPROVED PASTURES

Improved pastures are becoming more important due to the demand for more productive grazing and the increasing fodder requirements of the live cattle trade. In 1996/7 over 20,000 tonnes of hay was produced in the Top End, largely from improved pastures, and a further 40-50,000 tonnes of processed fodder (cubes and pellets) was imported from southern states to meet export cattle needs.

Improved pastures play a major role in enhancing soil fertility and structure and improving animal nutrition and reproduction. The performance, persistence and profitability of any pasture will depend upon soil type, moisture, fertility and management.

Pastures also have a positive environmental role in fixing carbon, reducing erosion, improving the quality of ground water and reducing the activity of many chemical residues.



INTRODUCED PASTURE GRASSES

Sabi Grass
(Urochloa mosambicensis)
Nixon

Nixon sabi grass is a trailing, perennial grass with short rhizomes and erect flowering stems growing to 80 cm. It is suited to a range of soil types in areas with an annual rainfall of 500-1200 mm. It is a popular, productive and drought tolerant pasture suited to the Katherine-Daly Basin. Sabi responds well to early wet season storms but does not tolerate waterlogging.

Sabi grass is palatable, tolerates close grazing, is suitable for mixed pastures and makes good quality hay. Hay yields of 4-8 t/ha with a crude protein of up to 10% can be expected. Sabi grass provides excellent mulch and is ideal for conservation tillage systems. It is easily controlled with glyphosate and crops can be sown into sabi grass pastures using no-tillage. Sabi will re-establish from residual seed after a 1-2 year cropping phase.

Gamba Grass
***(Andropogan gayanus)* Kent**

Gamba Grass is a tall perennial, tussocky grass which forms dense clumps. It is highly productive, palatable and will support high stocking rates (4-5 beasts/ha) during the wet season, if well fertilised.

It is suitable for the Darwin and Douglas Daly regions and is adapted to a range of well drained soils but is intolerant of waterlogging.

Plate 46
Sabi grass.

Plate 47
Gamba (Pangola in foreground) is a free seeding, vigorous and productive pasture but may become a fire hazard if neglected.

Gamba grows to over 4.0 m and forms an impenetrable stand if neglected. Mature stands consist of low quality indigestible dry matter and have high fuel loads which pose a serious fire risk in the dry season. Gamba has been criticised because of its high fuel load, its prolific seeding and its potential to invade conservation areas, roadsides and disturbed areas.

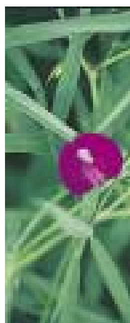


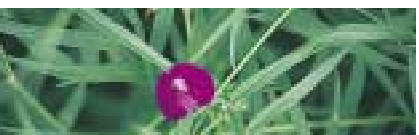
Plate 48a, b, c
(a) Indian bluegrass, growing on infertile ironstone gravel soil, is a hardy species and assists in soil stabilisation.
(b) Signal grass seed head and
(c) Signal grass.

Indian Bluegrass *(Bothriochloa pertusa)*
Indian bluegrass is a creeping, moderate yielding, perennial grass. It produces stolons or horizontal stems which root at the nodes. Foliage grows to 30 cm with erect flowering stems to 65 cm. Crushed leaves and stems have a characteristic scent. It is suited to the Katherine district and further south and will grow on a range of soil types in areas receiving over 500 mm of annual rainfall. Bowen is the main variety grown in the NT. Growth and spread of Indian bluegrass is enhanced by continuous grazing or frequent mowing. Due to its creeping habit, it is a good species for soil conservation in holding paddocks and laneways.

Signal Grass
(Brachiaria decumbens)
Basilisk
Basilisk signal grass is a vigorous, clumping, perennial grass which branches and roots at the lower nodes.
Leaf blades are hairy, up to 20 cm long and 10-15 mm wide. Leaves are commonly dark green during the wet season and yellow-green during the dry season. Foliage grows to 70 cm with erect flowering stems to 85 cm.

Signal grass is suited to a range of well drained soils in areas receiving over 1000 mm of rain but will not tolerate prolonged flooding or waterlogging.
It stays green in the dry season longer than most other species. Signal is palatable to cattle and buffalo but horses may reject it. Signal grass can produce yields of 6-12 t/ha but the hay is usually coarse and of inferior quality.

Koronivia Grass
***(Brachiaria humidicola)* Tully**
Tully is a vigorous, creeping, perennial grass which roots from lower nodes and forms a dense low growing sward. Leaf blades are 11-15 cm long, smooth and taper to an acute point. Tully is suited to a range of soil types in areas receiving over 1000 mm annual rainfall and tolerates waterlogging and shallow flooding.



It may be slow to establish and is generally less palatable as a grazing pasture than other grass species. Stock may accept it better when it is short and well fertilised. Tully produces reasonable quality palatable hay and yields of 5-10 t/ha can be expected. Tully is a useful species for soil stabilisation on earth banks, slopes and areas prone to erosion.

Buffel Grass *(Cenchrus ciliaris)*
American, Gayndah
Buffel is a tussocky, clumping, drought resistant, perennial pasture which grows to about 90 cm. It is leafy when young but becomes coarse when mature. Buffel is suited to a range of free draining soils in areas with 300-1200 mm rainfall but will not tolerate waterlogging. Buffel is well accepted by stock. When horses are restricted to a diet of buffel grass they may develop swelling of the facial bones ("big head") which is caused by a calcium deficiency.

Buffel grass is unsuitable for rotation with annual crops due to its strong tussocky structure. Maintaining a legume in buffel pastures has proved difficult but Milgarra blue pea is a promising companion legume for buffel in the Douglas Daly region.

Birdwood Grass
(Cenchrus setiger)
Birdwood grass is a short, drought tolerant, perennial, tussocky grass, similar to buffel grass but less vigorous. It has a purple seed head with short, stiff spines. Birdwood is suited to the drier areas and well drained soils in the 600-750 mm rainfall zone. It flowers earlier than buffel and tolerates periods of heavy grazing.

Plate 49
Koronivia or Tully is a tough creeping grass for wet areas.

Plate 50
Buffel grass a tough persistent grass for the Katherine-Daly Basin.

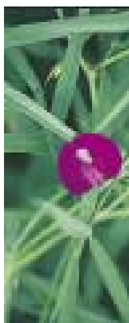


Plate 51
Pangola is a valuable perennial pasture for the higher rainfall areas of the Top End. It must be planted by runners.

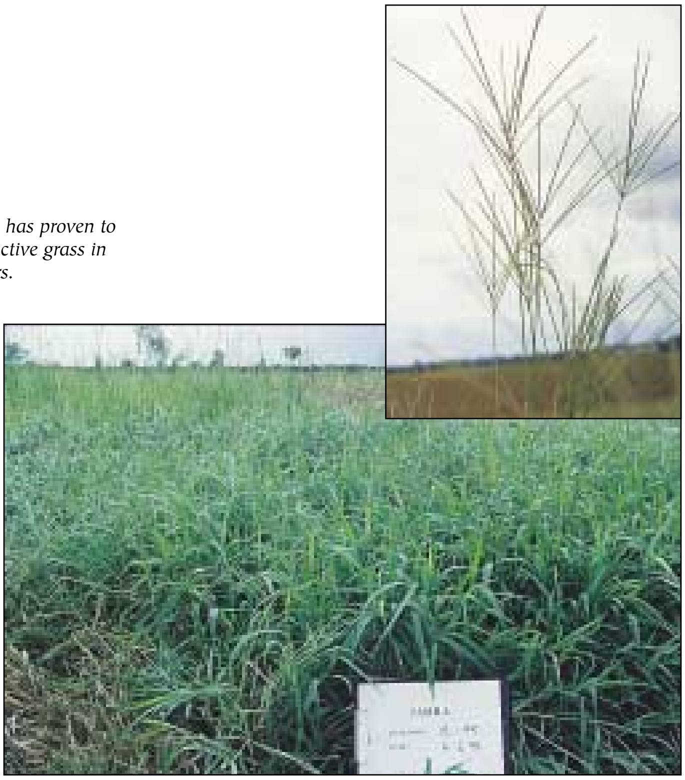


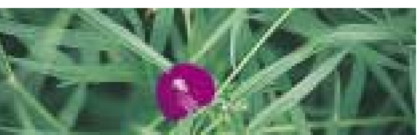
Plate 52
Jarra grass has proven to be a productive grass in recent years.

Pangola Grass
(Digitaria eriantha)
Pangola grass is a low, creeping, perennial pasture which roots at the nodes and forms a dense sward. Pangola has been a popular and productive pasture in the Darwin rural area for over thirty years. It is a fine stemmed grass, suited to a range of soils in regions receiving over 1100 mm of annual rainfall.

Pangola grass tolerates several months of waterlogging but will not persist under continuous flooding.

Pangola grass does not produce viable seed and must be planted vegetatively. It is best used as permanent pasture and once established will persist indefinitely if well managed. It is palatable and makes good quality hay if harvested before the fodder deteriorates. Hay yields in the range of 8-15 t/ha with crude protein levels of around 6-9 %, can be achieved. Higher yields will only be obtained from well fertilised swards.

Finger Grass
(Digitaria milanjiana)
Jarra, Strickland
Finger grasses are perennial species with growth habits similar to pangola. Jarra has broader, hairier leaves and is lighter in colour than pangola. Strickland has a leaf shape similar to pangola but is also blue-green in appearance.



Both cultivars produce viable seed. Jarra roots at the nodes and can creep several metres in a season. Jarra is suited to a range of soils in areas receiving over 1000 mm of rainfall and is a potential pasture for the Katherine area.

Finger grass can withstand waterlogging but not prolonged flooding. It is palatable as green or standing dry feed or hay.

Jarra grass can be grown as a dryland or irrigated hay crop and produces yields similar to pangola (8-15 t/ha). It has not yet been evaluated as a component of a mixed farming system.

Finger Grass
(Digitaria swynnertonii)
Arnhem
Arnhem finger grass was released in the NT in 1997. It differs from Jarra and Strickland in being smooth and hairless. It does not produce creeping stems or stolons but has a tussocky more erect growth habit. Arnhem is a strong, free seeding grass which tolerates continuous grazing and grows on a range of soils.

Dry matter yields of up to 17 t/ha have been recorded under experimental conditions at Berrimah Agricultural Research Centre in Darwin.

Trials indicate that Arnhem may tolerate higher rates of set-stocking for longer periods than many other grasses resulting in higher total liveweight gains per hectare.

Arnhem may prove to be a viable alternative to Kent Gamba grass in pasture improvement programs.

Guinea Grass
(Panicum maximum)
Common, Hamil
Guinea grass is a tall, perennial tussocky grass with long, flat, broad leaves. Flowering stalks can reach 4 metres. Cultivars Common and Hamil are adapted to 1100 mm and higher rainfall areas on deep well drained soils of medium to high fertility.

Plate 53
Guinea grass.

Guinea grass is palatable and moderately drought hardy. It tolerates short periods of heavy grazing but prolonged grazing pressure may permanently deplete the stand. Guinea grass is suitable as a permanent pasture and good quality hay can be made from well fertilised swards.

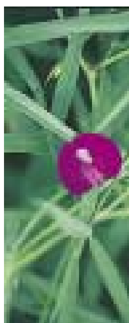


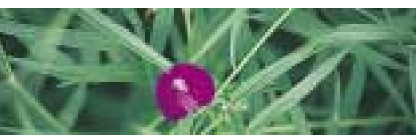
Plate 54
Kazungula setaria is adapted to the wetter soils of the high rainfall areas of the Top End.

Setaria *(Setaria sphacelata)*
Kazungula
Kazungula setaria is a robust, tussocky, perennial grass which spreads by short underground stems or rhizomes. It grows to 2 m and has light, bluish-green leaves. Kazungula is adapted to a range of soils in areas receiving over 1100 mm rainfall. It performs best on waterlogged soils or shallow floodplains which stay moist during the dry season.

It is palatable and can withstand periods of heavy grazing once established. Kazungula may contain oxalates toxic to horses, lactating or hungry cows. It is not recommended as a pasture for horses.

Silk Sorghum *(Sorghum spp.)*
Silk sorghum is an open pollinated, short lived, perennial forage sorghum. It grows to over 3 m and is suited to deep, well drained soils in areas receiving between 900 and 1300 mm of rainfall. Silk is suitable for grazing, may be combined with pasture legumes or grown as a hay crop. Silk sorghum generally produces less dry matter than many commercial forage sorghum hybrids, however Silk sorghum seed is less expensive. Silk may contain prussic acid if suddenly stressed and appropriate grazing management is necessary.

Plate 55
Silk sorghum.



Introduced Pasture Legumes

American Jointvetch
(Aeschynomene americana)
Glenn, Lee
Jointvetches are vigorous, annual or perennial shrub legumes growing to 2 m. Glenn has green stems and mauve flowers whereas Lee has reddish stems and bright orange flowers. Glenn flowers in mid-April while Lee flowers in early to mid-June. Both cultivars generally behave as annuals in the Top End.

Jointvetch will grow in wet or waterlogged soils where rainfall exceeds 1100 mm and is best suited to waterlogged soils and the floodplains of the Top End. Plants become woody at maturity so early grazing is preferable. Where grazing is deferred due to flooding, Lee is the preferred cultivar as it maintains its leaf and nutritional quality for longer into the dry season.

Roundleaf Cassia
(Chamaecrista rotundifolia)
Wynn
Wynn is a semi-erect, short lived, perennial legume which grows to 70 cm. It is adapted to a range of conditions but prefers sandy surfaced soils. Wynn is grown from Darwin to Daly Waters, is a prolific seeder and spreads rapidly.

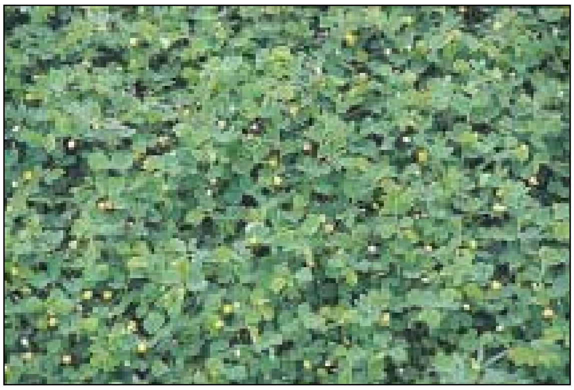
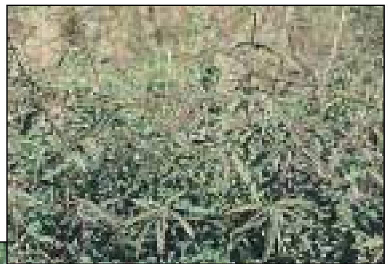
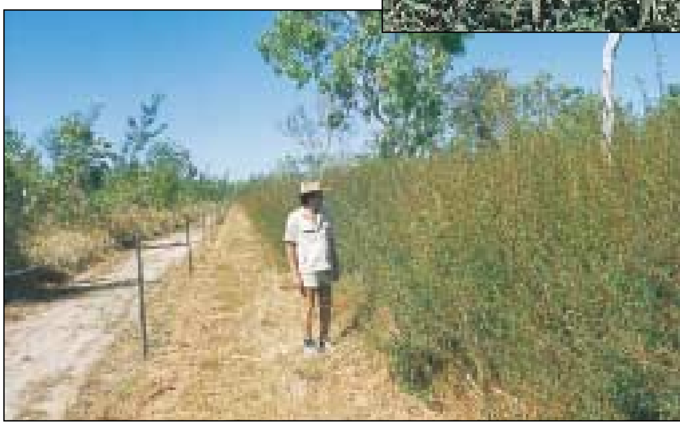


Plate 57
Wynn cassia is a free seeding legume of relatively low palatability.

Wynn has low palatability during the wet season which often results in stock over-grazing other pasture species. It is generally rejected by horses at all stages of growth. Wynn is a valuable legume in a mixed pasture but grazing management is required to keep it in balance. Application of phosphorus may increase its palatability but may also increase its vigour. Hay containing up to 50% Wynn has been well accepted by stock in feeding trials. Wynn cassia can be used as a component of fully improved pastures or introduced into native pastures.

Plate 56
Jointvetch is a legume adapted to the higher rainfall areas and floodplains of the Top End.





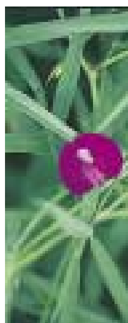


Plate 58a, b
(a) Cavalcade hay crop at Katherine.
(b) Cavalcade flower.

Centurion
(Centrosema pascuorum)
Bundey, Cavalcade
Cavalcade and Bundey are prostrate, twining, annual legumes. Leaves are trifoliate and have large showy crimson flowers. Cavalcade flowers in mid-March while Bundey flowers a month later. Bundey is recommended for areas with extended wet seasons such as the sub-coastal areas and Darwin and Daly regions. Cavalcade is recommended for the Katherine area; however, both species grow on a range of soil types and will tolerate periods of waterlogging and seasonal flooding.

Bundey and Cavalcade are highly productive species and make up over 90 % of the legume hay produced in the Top End. Fodder yields of 6-10 t/ha can be expected and hay contains 12-15 % crude protein. Both species are suitable for processing as cubes or pellets for the live cattle market.

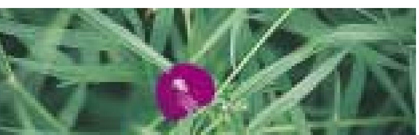
In a feeding trial at Berrimah Agricultural Research Centre Cavalcade cubes produced equivalent animal weight gain to that of lucerne pellets.

Bundey and Cavalcade pastures can contribute 50-200 kg N/ha/year to the soil and are suitable for a rotation with cereal crops. Bundey and Cavalcade mulch is ideal for no-tillage systems. However, weed control in Centrosema pastures and hay crops is a major management consideration.

Centro
(Centrosema brasilianum)
Oolloo
Oolloo is a new, short lived, perennial centrosema cultivar released in the NT in 1997. Leaflets are oval in shape, 3-4 cm long, flowers are large, showy and purple in colour.

Oolloo is a climbing, twining cultivar which produces roots from its stems when conditions are favourable. It forms a prostrate sward when grown alone but climbs vigorously with tall companion grasses.

Plate 59
Oolloo centro, a new vining perennial legume that will climb companion grasses.



It is suited to a range of soil types and conditions and will grow in most locations in the Top End. It has the ability to persist under heavy grazing when given the opportunity to set seed and produces dry matter yields of 3-4 t/ha.

Plate 60
Blue pea, a productive perennial legume adapted to a range of soil types throughout the Top End.

Blue Pea
***(Clitoria ternatea)* Milgarra**
Milgarra blue pea is a perennial legume with an erect woody base and fine twining stems. The attractive flowers are large, blue or, occasionally, white. It is suited to a range of soils including well fertilised sandy soils and heavy clays where rainfall exceeds 600 mm.

Milgarra is palatable and produces good quality hay with up to 19% crude protein. It drops some of its lower leaves as it matures which may reduce yield and quality. Blue pea is a vigorous species when established and is regaining popularity as a companion legume in perennial grass pastures such as buffel.

Its tolerance to heavy grazing is doubtful but it shows potential as a ley pasture for Top End farming systems.

Plate 61
Maldonado is a vining legume.

Llanos Macro
***(Macroptilium gracile)* Maldonado**
Maldonado is a twining, short lived, perennial legume. Leaves are trifoliate and flowers are grey-orange in colour. Flowering commences in mid to late April. It is suited to a range of soil types in areas receiving over 1100 mm of rainfall and has performed well in demonstration sites at Katherine.

Maldonado tolerates waterlogging and seasonal flooding. It is well accepted by stock as green feed or hay and is a promising pasture for rotation with grain crops.

Carribbean Stylo
(Stylosanthes hamata)
Verano, Amiga
Verano and Amiga stylos are similar in appearance and both are annual or short lived, perennial, herbaceous legumes. They have a branched, semi-erect habit and grow to 75 cm with small yellow flowers. Stylos are drought hardy, suitable for a range of soil types in regions receiving over 600 mm rainfall.

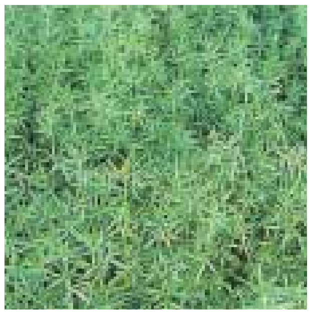


Plate 62
Verano stylo, a legume suitable for intensive pasture improvement or oversowing into native pastures.

Stock will generally accept stylos well after becoming familiar with them but palatability can be enhanced by applying phosphorus fertiliser.

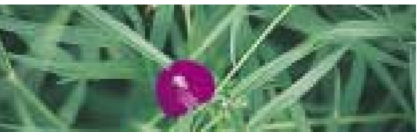
When grown under adequate nutrition, stylos can fix about 130 kg N/ha/year for use by subsequent crops in a rotation. Verano and Amiga make good quality hay and yields of 5-10 t/ha are possible.

Shrubby Stylos
(Stylosanthes scabra)
Seca, Siran
Shrubby stylos are vigorous, erect, perennial shrub legumes which can grow to 2 m. The stems and leaves are sticky and have a distinct aromatic odour when crushed. Flowering commences in late April and continues into the dry season. Seca and Siran are suited to a range of soil types in areas receiving over 500 mm of rainfall. They tolerate burning, drought stress and limited waterlogging. Shrubby stylos are used in mixed pastures or for oversowing into native pastures. They are generally unsuitable for hay production because of their stalky, woody nature.

Plate 63
Seca stylo, ideally suited to extensive pasture improvement programs.

Calopo
(Calopogonium mucunoides)
Calopo is a vigorous, free seeding, annual legume which was sown in the 1970s and early 1980s but is no longer recommended. It is a sprawling, vining species forming dense swards. It climbs trees, shrubs and fences and may become a weed on small blocks, in horticultural situations and reserves. Calopo is relatively unpalatable when young but may contain up to 16% crude protein. Stock will graze it when hayed off in the dry season. Once established it is difficult to eradicate as it is a prolific seeder and it responds to increased soil phosphorus levels.

Plate 64
Calopo climbing up gamba grass. Calopo is relatively unpalatable and is now rarely sown.



Forage Peanut
(Arachis glabrata)
Forage peanut is a potentially new species currently being evaluated for tropical Australia. It is a high quality perennial legume suited to free draining soils. *A. glabrata* produces little or no seed and must be propagated vegetatively. Once established it will persist indefinitely and is a good competitor with vigorous grasses. It has potential as a high quality perennial hay crop, mixed or ley pasture in cropping systems and as a horticultural cover crop.

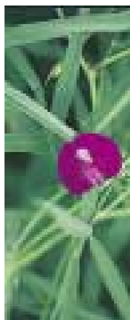
Leucaena
(Leucaena leucocephala)
Cunningham, Peru, Tarramba
Leucaena is a perennial, deep rooted, shrub or tree legume which produces high quality fodder. It can grow to 10 metres but is maintained as a shrub for grazing purposes. Leucaena is suited to well drained soils in areas receiving over 750 mm annual rainfall.

Irrigated leucaena has given liveweight gains of over 1.0 kg/head/day or over 1000 kg/ha/year in the Ord River area. New shoots are 75% digestible and contain 20-25% crude protein. Leucaena contains mimosine, a toxic amino acid.

Animals require specific rumen bacteria to detoxify the mimosine and these can be acquired from contact with other stock or by inoculation. Leucaena has proved difficult to establish under dryland situations in the Top End. Protection from wallabies is essential in young plantations. Supplementary irrigation may be required initially to establish leucaena, which should then remain productive without irrigation for many years.

Plate 65
Forage peanut is a perennial legume which produces high quality fodder.

Plate 66
Leucaena produces the highest quality feed of any tropical legume.



7.3 MAINTAINING PASTURE PRODUCTIVITY

GRASS PASTURES

Maintaining pasture productivity is a major challenge. Productivity declines as nutrients run down, weeds invade and plants lose vigour. Nitrogen is the most important nutrient in grass production. Animal productivity is largely determined by feed intake and digestibility. When soil N declines or is tied up in organic matter and becomes unavailable, grass growth, digestibility and feed intake are dramatically reduced. A 50% reduction in available soil N will generally result in a 50% decline in pasture growth.

Tropical grasses are high in indigestible fibre and this proportion increases with age and declining N levels. Young grasses with a digestibility of 70-80% can fall below 30% on maturity. Stock must have access to new growth to benefit from grazing tropical grasses.

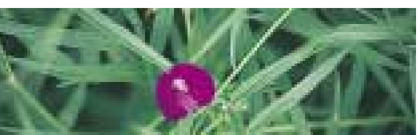
Nitrogen fertiliser is required to stimulate new pasture growth and will increase liveweight gains or carrying capacity. In the Top End, application of 100-200 kg N/ha on various grass pastures allowed stocking rates to be increased from 2 to 4 head/ha without reduction in liveweight gain per animal. Similarly, 75-150 kg N/ha applied to pangola grass late in the wet season gave a 3 to 4 fold increase in dry matter production over unfertilised pasture. High inputs of N fertiliser applied to grasses will result in high production and good animal weight gain but such systems require significant investment and are not necessarily the most economically or ecologically sustainable.

MIXED AND LEGUME PASTURES

Legumes play a vital role in improving soil fertility, increasing pasture quality and animal productivity. Legumes are higher in protein, more digestible than grasses and require no N fertiliser. At low to moderate stocking rates, the productivity from legume based pastures should be similar to that of grass pastures fertilised with N but at a lower cost. Mixed pastures containing compatible legumes and grasses are often more productive and ecologically stable than either pure grass or pure legume pastures.

Pure legume pastures are difficult to maintain and as nitrogen accumulates, pastures succumb to weed invasion within 2-3 years. Standover legume forage also deteriorates sharply in nutritive value and acceptability with the onset of rain. See Figure 10, page 70.

This results in lower intake and animal weight loss until new growth is available.



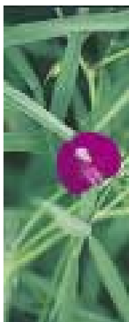
Perennial grasses grown with legumes will provide more rapid regrowth, assist in maintaining pasture quality and reduce the period of weight loss.

However, maintaining legumes in mixed pastures can be difficult as many are intolerant of heavy grazing and are generally less competitive than perennial grasses. Some legumes may persist for only 2-3 years when sown with vigorous grasses such as buffel, Tully or pangola. Declining legume content significantly reduces fodder quality and studies have shown that liveweight gain decreased by up to 64% when legumes were lost from the pasture. This would equate to a production loss of up to 96 kg/head/year in situations where stock gained 150 kg/head/year with access to legumes. Legume persistence can be extended by strategic grazing, fertilising and weed control.

Reducing grazing pressure at the end of the wet season to allow seed set is important for annual legumes. Phosphorus and sulphur are necessary to promote growth, root development and nodulation of legumes.

Plate 67
Cattle grazing mixed pastures (Wynn cassia/Kazungula setaria) at Coastal Plains Research Station.

Plate 68a, b
(a) Blue pea/buffel grass mixture.
(b) Blue pea and buffel grass in the left paddock, showing more vigour than the buffel grass alone in the right paddock.



Some Attributes of Improved Pastures

Perennial Grass Pastures	Legume Pastures
• persistent and productive under good fertility	• productive, palatable and highly nutritious
• effective competitors with weeds	• less competitive and subject to weed invasion
• tolerate periods of high stocking pressure	• less tolerant to high grazing pressure, less persistent than most grasses
• build organic matter and soil structure	• build N fertility and soil structure
• regenerate quickly at the start of the wet season	• annual legumes slow to regenerate at the start of the wet season
• tolerant to many herbicides, ie. more weed control options	• susceptible to many herbicides, fewer weed control options
• require nitrogen fertiliser in absence of legumes	• do not require N fertiliser
• can become unproductive or 'run down' and tie up nitrogen	• require renovation and reseeding to remain productive
	• may accelerate soil acidity due to N leaching

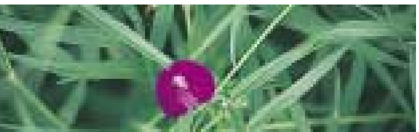
Phosphorus application of 20-25 kg/ha at establishment and 10 kg/ha annually (ie. 250-312 kg/ha single superphosphate initially plus 125 kg/ha annually) should provide optimum dry matter production in most legume based pastures in the higher rainfall areas.

Fertiliser rates may need to be varied depending on grazing enterprise and market considerations. Maintenance fertiliser of 5-10 kg/ha/year may be appropriate to achieve optimum economic return in many grazing situations. Potassium and trace elements such as zinc and molybdenum are required for highly productive legumes such as Cavalcade and Bundey and where hay is being produced.

Pasture productivity may, in the future, be determined by the ability to manage soil acidification. Leaching of calcium, magnesium, potassium and the mineralisation of organic N from legume pastures may result in soils becoming progressively acidic. If this takes place, management of pastures and crops may involve the application of lime to maintain an acceptable soil pH.

When pastures become rundown and unproductive, a combination of cultivation, re-seeding, herbicide and fertiliser application may be necessary to restore pasture vigour. Cropping phases can reduce the weed burden, use accumulated N and improve soil conditions for subsequent pastures.

Pasture quality is the foundation for successful and profitable livestock production systems.



8. LEY FARMING SYSTEMS

Ley farming is a system of rotating crops with legume or grass pastures to improve soil structure and fertility and to disrupt pest and disease lifecycles. It has been practised in many parts of the world for centuries. The concept has considerable application in the Top End.

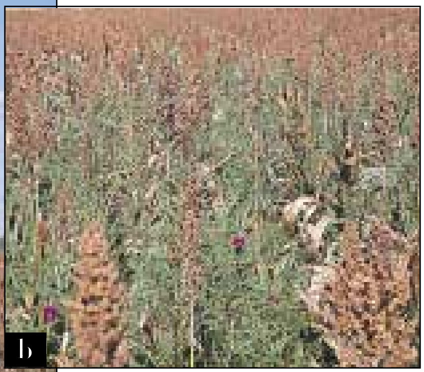
Benefits include:

- improved soil fertility and structure
- reduced erosion and land degradation
- more efficient use of natural resources
- improved weed, insect and disease control
- more reliable crop and animal production
- increased options and flexibility

Ley farming systems are particularly important in the Top End due to the N provided by legume pastures. Legumes supply varying amounts of nitrogen depending on existing soil N levels, growth of the legume, seasonal conditions and effectiveness of nodulation.

Contributions up to 200 kg N/ha/year have been measured in legume swards. Experiments have shown that the N requirement of a sorghum crop can be supplied by a 2-year ungrazed Cavalcade pasture. In commercial practice, Cavalcade can supply up to 25-40 kg N/ha or 30-50% of a dryland grain crop's N requirement. 1 and 2-year grazed stylo pastures have contributed 25-45 and 35-75 kg N/ha, respectively, to sorghum crops.

Plate 69a, b
(a) Harvesting sorghum undersown with Cavalcade.
(b) Cavalcade in mature sorghum.



8.1 LIVESTOCK INTEGRATION IN FARMING SYSTEMS

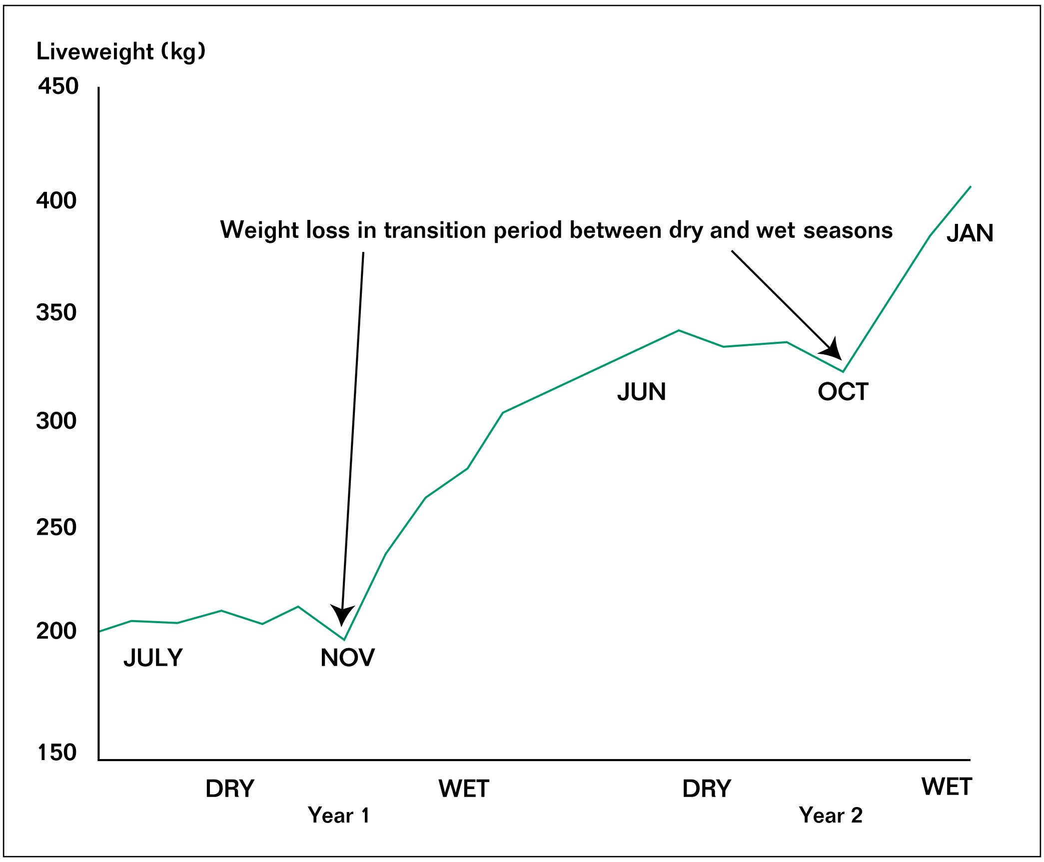
In other studies at Katherine it is estimated that 1 and 3-year stylo ley pastures increased the uptake of N in cereal crops by 30 and 50 kg N/ha, respectively.

Grass pastures increase organic matter, improve soil structure and are effective in suppressing many broadleaf weeds. Buffel, pangola and Tully are best used as permanent pastures; however, sabi grass is compatible with many legumes and is suitable for rotation with annual crops. Sabi and Cavalcade grow well together and both have the ability to regenerate after a 1 or 2-year cropping phase.

The major challenge in animal production systems in the Top End is providing a continuity of feed and minimising weight loss during the dry season. Regardless of pasture type, ie. native or improved, weight loss occurs during the transition period from the late dry to the early wet season. See Figure 10.

Native pastures can provide liveweight gains of 50 to 120 kg/head/year at low stocking rates (1 head/16 to 40 ha) with the larger gains being achieved with mineral supplementation. However, throughout much of the dry season, weight loss occurs. See Figure 11a, b.

Figure 10
Seasonal weight loss in cattle during the transition period between the dry and wet season as feed deteriorates in quantity and nutritive quality. Stocking rate decisions must account for this period to minimise losses.



Losses of 0.25 kg/head/day have been measured on native pastures in the Katherine district.

On improved pastures and crop stubbles, stock usually maintain or gain weight through most of the dry season until the dry feed deteriorates with the onset of rain. In trials on improved pastures at Katherine, Douglas Daly and CPRS, liveweight gains of 120-200 kg/head/year were obtained at stocking rates of 1 head/ha.

Rice and sorghum stubbles have provided weight gains of 0.5-0.7 kg/head/day at 1-2 beasts per hectare, during the early to mid-dry season.

Plate 70
Steers grazing sorghum stubble after harvest at Katherine.

At Katherine, 3 steers/ha (average weight 200 kg/head) on sorghum stubble and legume understorey gained an average of 0.46 kg/day for 99 days in the main part of the dry season.

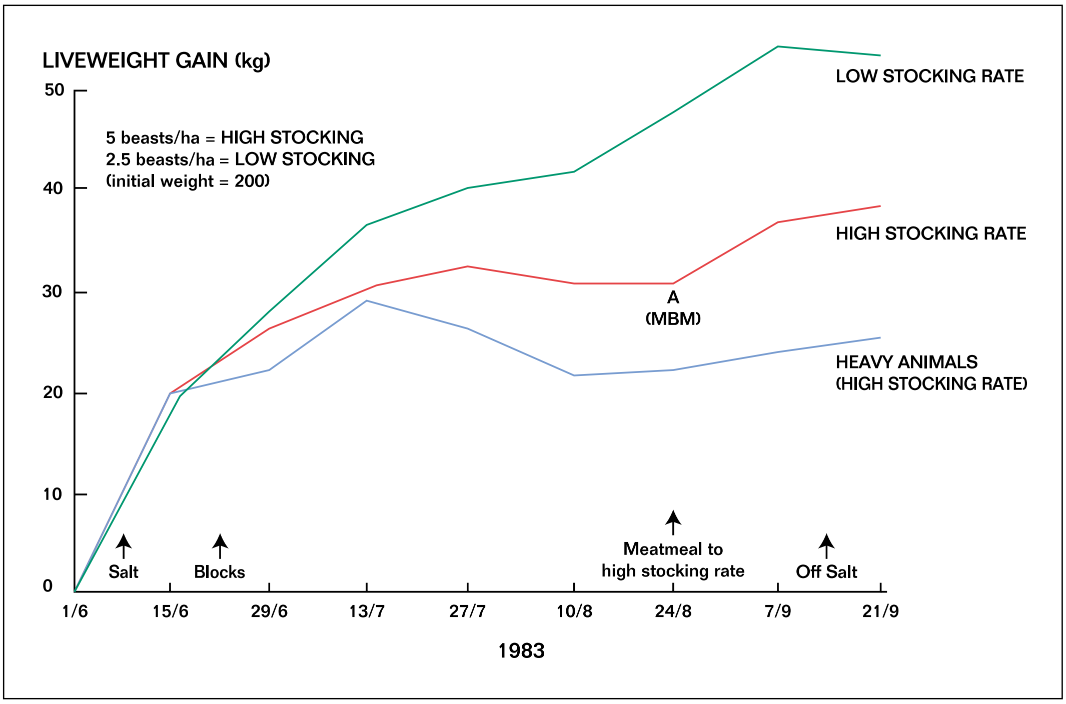


Figure 11a
The effect of different stocking rates and supplementation on liveweight gain of steers grazing rice stubble at Tortilla Flats Research Station in 1983. The low SR produced almost 70% (20 kg) more liveweight per animal, while the high SR with supplementation produced a 40% (50 kg extra/ha) increase in per hectare liveweight gain.

Plate 71
Cattle on buffel grass in the Douglas Daly region.

In another study, similar steers at 2 head/ha which were supplemented and implanted with a synthetic growth promotant, gained an average of 0.6 kg/head/day from mid-April to mid-July while grazing a combination of sorghum stubble, Cavalcade and Maldonado pastures.

At Douglas Daly, unsupplemented steers at 1.5 head/hectare gained up to 60 kg/head over three months (July-Sept) on sorghum stubble.

In some experiments cattle weight gain was higher on crop stubbles, ie. maize, sorghum and rice, than on improved pastures during the latter part of the dry season, illustrating the benefit of integrating cattle and crop production.

Combining native and improved pastures with crop stubbles allows more flexible management, greater animal productivity and more rapid turn-off.

Table 2 shows the performance of steers under various grazing systems in the Top End. Animal production varies considerably depending on season, location, stocking rate, class of animal and the type and duration of grazing.

Stocking rate decisions must be based on the feed required per animal, its quality, availability and anticipated grazing duration.

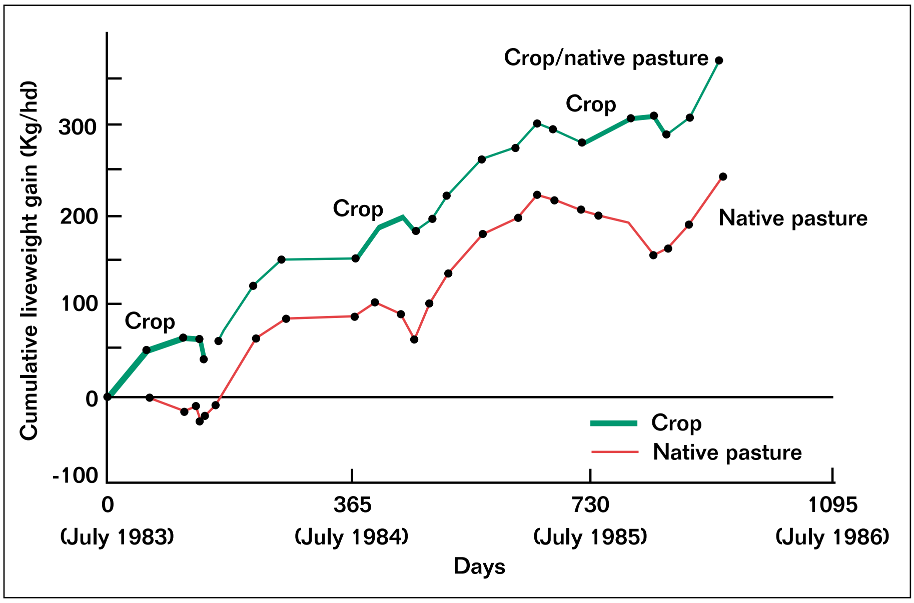


Figure 11b
Animal liveweight gain achieved on a combination of crop stubbles in the dry and native pastures in the wet, versus cattle grazing native pastures only.

Table 2.
Liveweight Gains and Losses Under Different Grazing Systems.

Grazing situation	Stocking rate (beasts/ha)	Grazing period duration (days)		Weight gain or loss (kg/head/day)	Weight gain or loss for grazing period (kg/head)	Weight gain or loss for grazing period (kg/ha)
Native Pastures[1] [KM1] (unsupplemented)	1 per 16 to 40 ha	Wet season	140	+0.30 to +0.50	+40 to +70	+1.0 to +4.4
		Main dry	163	-0.24 to -0.39	-40 to -64	-2.5 to -4.0
Native Pastures[1] (supplemented*)	1 per 16 to 40 ha	Wet season	140	+0.42 to +0.86	+60 to +120	+1.5 to +7.5
		Main dry	163	-0.24 to -0.39	-40 to -64	-4.0 to -2.5
Improved Mixed Pastures[1,2,4] (supplemented*)	1.0 per ha	Wet season	134	+0.75 to +0.88	+100 to +118	+100 to +118
	1.0 per ha	Main dry	163	-0.10 to +0.25	-16 to +40	-16 to +40
	0.75 per ha	Full season	365	+0.34 to +0.46	+127 to +170	+95 to +125
	1.0 per ha	Early dry	84	+0.40 to +0.83	+34 to +70	+34 to +70
	1.0 per ha	Late dry	84	-0.21 to +0.10	-18 to +9	-18 to +9
	1.0 per ha	Full season	365	+0.34 to +0.54	+125 to +200	+125 to +200
Legume based pasture (Cavalcade/ Maldonado[1])	2 per ha	Early dry	86	+0.60	+51.6	+103
Sorghum stubble[2]	1.5 - 2.0 per ha	Main dry	84	+0.15 to 0.72	+12.7 to +60	+18.7 to +120
Sorghum stubble & Cavalcade understorey[1] (P,S, No supplementation)	2 per ha	Main dry	120	+0.10	+12	+24
	3 per ha	Main dry	99	+0.46	+45.5	+136
Rice stubble[3]	2.5 per ha	Main dry	56	+0.5	+28	+70
	5.0 per ha	Main dry	113	+0.22	+24	+120

Figures from various grazing trials at Katherine[1], Douglas Daly[2], Tortilla Flats[3] and Coastal Plains[4] since 1985.

* supplemented - animals provided with mineral supplementation (ie. non-protein N in dry season, P in wet season).

8.2 SUSTAINABLE STOCKING RATES

Stocking rate (SR) is the single most important management factor in grazing systems because it determines animal productivity and performance and persistence of pastures. SR must ensure that adequate feed is available for livestock needs and that pastures remain productive. This is achieved through mating and weaning management, sale of stock, fertiliser application and, if necessary, supplementary feeding.

Both over-grazing and under-grazing will reduce productivity and economic return. Over-grazing will permanently damage pastures while under-grazing results in poor feed utilisation and low overall productivity as plants eventually become rank, indigestible and intake is subsequently reduced.

Plate 72
Over-grazing leads to permanent pasture damage and soil degradation.

At low SR, the performance per animal will be high because animals can select the most nutritious feed; however, overall productivity and pasture utilisation may be lower than optimum. As SR is increased up to a point, weight gain per hectare will increase despite decreases in individual animal performance. When SR is set to achieve maximum production per hectare, liveweight gain per animal will be reduced significantly. Optimum SR is usually somewhere between that which provides maximum production per animal and maximum production per hectare. Optimum SR will vary considerably throughout the year and the challenge is to match stock numbers with seasonal feed supply. Estimating optimum SR can be difficult because carrying capacity depends on seasonal conditions, pasture quality, class of animal and grazing duration.

Exceeding the optimum SR increases competition for feed, reduces individual intake and will eventually reduce productivity. Continued overstocking will result in pasture decline and land degradation. SR decisions are further influenced by market and economic considerations. The more productive the system, the more dynamic and complicated its management becomes.

Table 3. The effect of stocking rate on productivity per animal and per hectare on a sabi grass pasture at DDRF.

Liveweight Gain per animal and per hectare on Sabi Grass Pasture at DDRF		
animals/ha	kg/animal	kg/ha
1.0	100	100
1.5	75	112.5
2.0	60	120
2.5	40	100
3.0	25	75

Note: 2 head/ha provides the maximum per hectare weight gain. However, at this SR pastures are heavily utilised and there is a 20% and 40% reduction in individual animal performance compared to 1.5 and 1 head/ha, respectively. Stocking at 1 to 1.5 head/ha is a more sustainable option as individual and total liveweight gain is maintained and pastures are less likely to be degraded. (Initial weight 180-200 kg, animals unsupplemented)

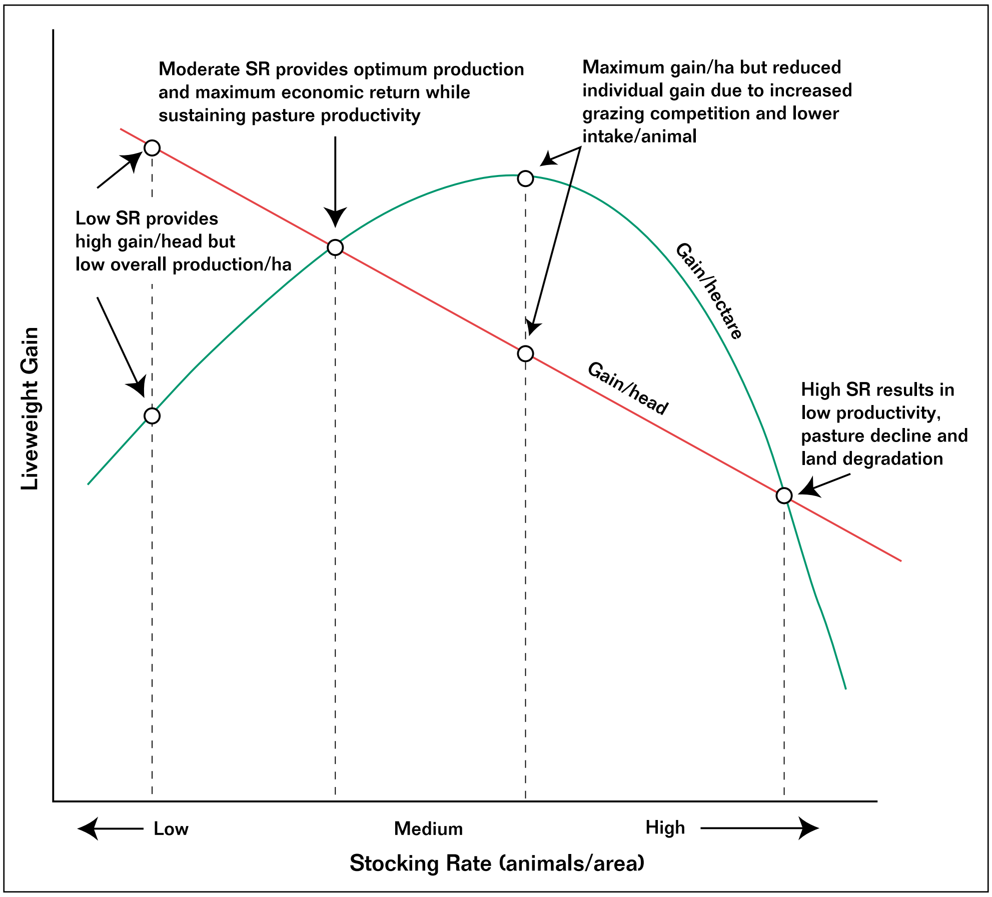


Figure 12
The relationship between liveweight gain per head and per hectare as influenced by stocking rate. SR will determine the productivity and the profitability of grazing enterprises.

The basic question pastoralists must answer is, how profitable and sustainable is it to have many animals achieving relatively low weight gain versus fewer animals with higher productivity and reaching target weights earlier.

Stocking rates must balance optimum economic return with the need to protect pastures for the long term. Producers need to calculate how many head they can run on a given area of pasture while meeting market specifications within a specified time frame. Considerable experience and knowledge of animal requirements, pasture productivity and the effects of seasonal conditions is needed to effectively manage SR.

A rule of thumb estimate of forage requirement for young growing stock is that animals require between 2 and 3% of their body weight in dry matter (DM) intake each day.

Plate 73
Over-utilisation of stubbles exposes the soil to raindrop impact, runoff and erosion.

Using an example of 200 kg steers at a SR of 2.0 head/ha, the daily feed required for both animals would be:

Daily feed required/animal =
Animal Liveweight (LW) by 2.5 %

Daily feed required for 2 animals =
Animal LW by 2.5 % x 2

Total daily feed required =
200 x 0.025 x 2 = 10 kg dry matter/day

Knowing that the combined DM intake must be approximately 10 kg, the animals would need to consume 28 kg of pasture/day to satisfy their requirement. This is because the pasture contains 60-65% moisture which is not contributing to their overall nutrition. In reality, significantly more feed needs to be available to allow for pasture growth and maintenance, trampling losses and spoilage.

In any grazing situation pastures are not totally utilised. Utilisation (grazed or trampled etc.) rates will vary but in most cases only 30 to 60% of the available pasture dry matter is used. The remainder is maintained for soil protection and to ensure continual regrowth and pasture persistence.

Plate 74a, b, c
(a) Brahman cows on native pasture at Kidman Springs, in the Victoria River region.
(b) Swamp/Riverine cross cows at Coastal Plains, part of a buffalo improvement program in the Top End.
(c) An imported Riverine buffalo bull used in a cross-breeding program.

Assume a paddock of 5-6 t/ha of sorghum stubble and legume understorey is available for grazing in the dry season and the aim is to have a 50% utilisation rate. Stock can, therefore, utilise 2.5-3 t/ha of the feed on offer before being removed.

Stocking rate is the single most important management factor in grazing systems. It determines profitability, animal production, persistence of pastures, and extent of erosion.

Using the above example of 2 animals/ha consuming 28 kg/ha/day, there would be less than 90 days grazing available before the desired utilisation rate is exceeded.

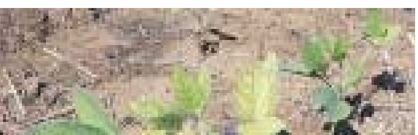
Extending the grazing beyond this period would result in loss of soil cover and reduced animal performance due to increasing competition. This crude example illustrates how forage availability and stock requirement can be used in calculating safe stocking rates.

9. CROP AND PASTURE NUTRITION

Sixteen elements are essential for good plant growth. *Carbon, oxygen and hydrogen are obtained from water and the atmosphere. Other elements are supplied in fertiliser and obtained from the release and recycling of nutrients in the soil and organic matter. Plant nutrients are divided into two groups, the major nutrients and trace elements. Major nutrients such as nitrogen, phosphorus and potassium are required in the largest quantities. Trace elements such as zinc, copper and iron are equally important but are required in smaller amounts.

Essential Plant Nutrients		
Major nutrients	***Symbol***	***Role and function in the plant***
Nitrogen	**N**	*The most important element for plant growth, and is usually taken up in the largest quantities. N is the key building block of protein and is required for vigorous growth, yield and quality*
Phosphorus	**P**	*The second most important element and essential for photosynthesis. Required for early root growth, cell division and seed and grain formation.*
Potassium	**K**	*Often taken up in a similar quantity to that of N. Required for cell division, the formation of sugars and the control of water within the plant. Promotes plant health and disease resistance.*
Sulphur	**S**	*Essential part of plant proteins and is taken up in a similar quantity to that of phosphorus.*
Calcium	**Ca**	*Required for cell wall formation, cell growth and promotes the uptake of other nutrients.*
Magnesium	**Mg**	*A component of chlorophyll and needed for efficient photosynthesis.*
Trace elements		
Zinc Copper Molybdenum	**Zn** **Cu** **Mo**	*Trace elements are used by plants in minute quantities and are essential for many functions in the plant. They are activators in many enzyme systems and are essential for vigorous growth which is, in turn, required for viable production and animal health.*
Iron	**Fe**	*Iron, zinc and copper are often the most deficient trace elements in the Top End.*
Magnesium Manganese Boron	**Mg** **Mn** **B**	*Iron is required for efficient photosynthesis. Zinc promotes stem elongation. Molybdenum is required by* Rhizobium *spp. which are essential for efficient nodulation and legume nutrition.*

**Chlorine (Cl), cobalt(Co), sodium(Na) and silicon(Si) are required and taken up in minute quantities by some plants; however, their exact role in plant nutrition is not yet fully understood. Cobalt, sodium and other elements have a significant role in animal nutrition.*



The Law Of The Limiting Nutrient!

The law of the limiting nutrient states that plant growth can be no greater than that allowed by the most limiting plant nutrient. If any one element is unavailable or absent, production cannot be increased until the specific deficiency is corrected. Once a specific nutrient deficiency is remedied, another deficiency may be induced if other nutrients are in short supply.

Optimum plant growth depends on balanced nutrition and the availability of all nutrients in sufficient quantities. Tissue and soil tests are used to estimate nutrient requirements and when calculating fertiliser inputs.

Grain and, particularly, hay crops remove large amounts of nutrients and these must be replaced to maintain production. Under grazing many nutrients are recycled and remain in the system for longer periods.

Plate 75a, b
(a) Plants on the right are suffering from a nitrogen deficiency which results in reduced growth, delayed maturity and low yields.
(b) Effective nodulation of legumes is essential for nitrogen fixation.

Table 4. Nutrients Removed in Crop and Pasture Production

Crop	Yield	N	P	K	S	Cu	Zn
	t/ha	kg/ha				g/ha	
Maize (grain)	9.5	150	27	37	11	60	170
Maize (stubble)	11.0	110	19	135	16	55	300
Soybean (grain)	3.4	210	22	60	9	140	193
Peanut	3.4	220	45	120	25	17	30
Grain Sorghum (total)	4.5	130	20	110	19	13	162
Rice (grain)	2.8	184	20	18	18	N/A	42
Grass pastures (hay)	10.0	100	10	100	10	60	250
Legume pastures (hay)	6.0	120	9	90	9	36	150

Aspects Of Soil Fertility In The Top End

Top End soils have low levels of natural fertility but are also subject to high rates of nutrient (ie. N, K, S, Ca and Mg) leaching. Nitrogen is also lost to the atmosphere from waterlogged soils.

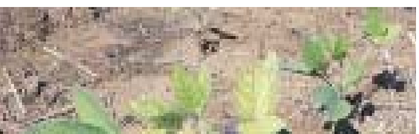
Plant nutrition is determined by the complex interaction of natural fertility, soil texture and structure, pH, organic matter levels, climatic conditions and management practices.

Plate 76a, b
(a) Iron chlorosis and zinc deficiency in soybean, a disorder common in many crops on light textured soils, especially under irrigation.
(b) Phosphorus deficiency in maize.

Aspects of Plant Nutrition and Soil Fertility in Top End Agriculture

Aspect	Comment
Natural fertility	Top End soils are inherently low in fertility. All major and most trace elements are deficient for intensive production. Sandy surfaced soils are less efficient in retaining nutrients and frequently have greater nutritional problems than heavier soils. Many crops have specific nutritional requirements.
Soil texture and structure	Determines how well moisture and nutrients are retained. Well structured soils composed of appropriate proportions of sand, silt and clay are generally more easily managed and provide a good store for plant nutrients. Top End soils are poorly structured and easily compacted by cultivation. Conservation tillage and rotations will improve soil structure.
Soil pH	A measure of how acidic or alkaline a soil is. A pH of 7.0 is neutral, lower values are progressively more acid and values above 7.0 are alkaline. Many nutrients are 'tied up' if soil is either very acid (pH 4-5) or very alkaline (pH 8-9). Most plant nutrients are available in the range pH 6.5 to 7.5. Fertiliser and irrigation practices may change soil pH. Soil acidification may occur under intensive management and legume pastures. Lime application may be required to reduce acidification and to maintain productivity.
Organic matter (OM)	OM breaks down rapidly under tropical conditions and cultivation further accelerates OM loss. OM helps bind soil particles and improves structure, aeration and drainage. OM enhances moisture holding capacity and acts as a reservoir for nutrients such as nitrogen, phosphorus and sulphur. Conservation farming, pasture rotation and green manuring will increase OM.
Environmental conditions	Dictate moisture availability, release and loss of nutrients, soil temperature and the degree of erosion. Heavy rain and high temperatures break down OM, leach nutrients and may lead to acidification. Environmental conditions cannot be changed but the adverse effects can be reduced by using conservation farming and associated practices.
Management practices	Management practices can influence soil fertility and structure, pH, OM levels and productivity. Conservation farming, mulch retention, rotations and good agronomic and grazing practices will improve soil health and conditions for plant growth. Over-grazing and continuous cultivation reduce fertility, OM levels, and leads to land degradation.

Crops are generally more sensitive to nutrient deficiencies than pastures and even short-term deficiencies can significantly reduce grain yields.



Perennial pastures have a longer period in which to grow, are more efficient in extracting nutrients and are generally more tolerant than crops to lower levels of nutrition.

Conservation farming and especially no-tillage systems may result in an increase in organic matter in the top layer of the soil. This rich source of organic nutrients is not immediately available to plants and can immobilise or 'tie-up' N, resulting in poor initial crop growth. The degree of N immobilisation depends on climatic conditions and the quantity and type of mulch.

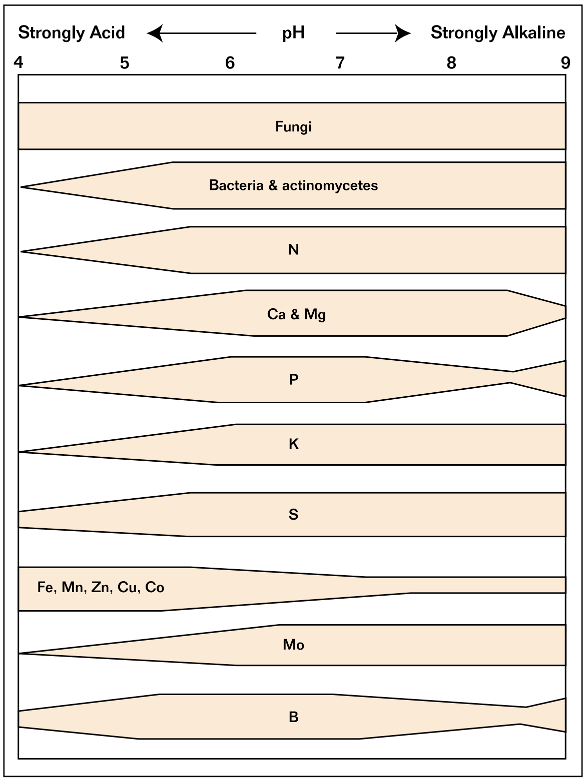


Figure 13
The effect of soil pH on the availability of plant nutrients and activity of soil microbes. Most nutrients are available at pH 6.5 to 7.5.

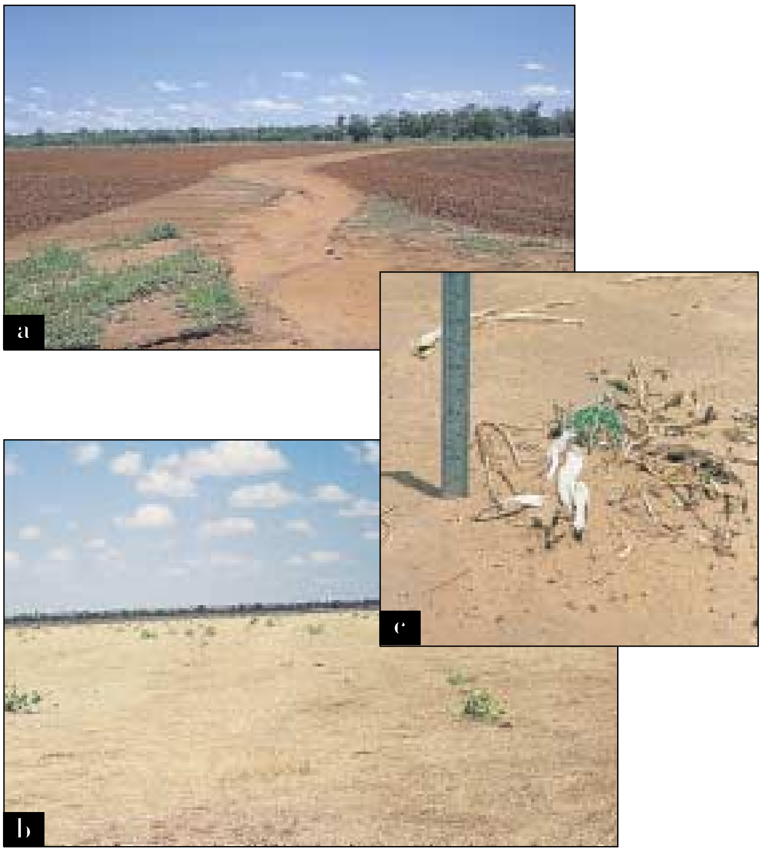


Plate 77a, b, c
(a) Erosion results in significant nutrient and productivity losses.
(b) Maintaining mulch is the best way of building fertility and protecting the soil.
(c) Exposed soils can lose up to 100t/ha of top soil per year.

Grass mulches or crop stubbles will immobilise N for a longer period than legume mulches. Cultivation prior to planting will assist in breaking down the organic matter and releasing some of the N. Banding N fertiliser beneath or beside crop seed (not in contact with the seed) will ensure crops have access to N from the earliest growth stages.

Practices such as maintaining mulch, fertilising to meet crop requirements, rotations and pasture phases will assist in managing soil fertility. Selecting crops and pastures for specific soil types will also enhance crop nutrition and performance.

Conservation farming and crop rotation are the most effective ways of improving and maintaining soil structure and fertility.

10. FIELD CROP IRRIGATION
IN THE TOP END

Irrigation of field crops is largely undeveloped in the Top End but there is increasing interest in producing maize, sorghum, soybean, peanut, fodder crops and high value seed crops under irrigation.

Plate 78a, b, c
(a) Centre pivot irrigation in the Top End.
(b) Cotton is currently being evaluated as a possible irrigated crop for the Top End.

There is an interest in cotton production in the NT and investigations are being jointly funded by a number of organisations. By comparison, irrigated horticulture is relatively well advanced with rapidly expanding mango, banana and exotic fruit and vegetable industries.

Water And Soil Resources

Unlike the Ord Irrigation Area in northern Western Australia which is on deep Cununurra clays with an abundance of gravity fed water, irrigation in the Top End currently relies on water from individual bores or rivers.

The Katherine and Daly River systems offer considerable potential for irrigation and certain areas within the Daly Basin, Sturt Plateau and Darwin region have good ground water resources. Water in these areas is supplied by large limestone and dolomite aquifers, some of which are high in calcium and magnesium carbonates. Bore capacities over 80 litres/second (L/s) are possible but average flow rates for most irrigation bores are around 20-30 L/s. Estimating underground water resources is an inexact science and resource surveys are continually undertaken.

Strategic water harvesting and conservation of wet season river flows hold considerable potential but have not yet been undertaken. On-farm storage of water may be possible in specific cases but is impractical in many situations due to high evaporation rates and the porosity of many soils.

Aspects For Consideration

Soils in the Top End are sandy or clay loams, have low water holding capacities, high percolation rates and are suitable only for sprinkler irrigation and other non-flooding systems. Exceptions are the undeveloped sub-coastal clay soils of the Darwin region, isolated black and grey soil plains throughout the Top End and the Keep River Plain near the WA border. Large areas of uniform soil type close to water sources are difficult to find in the Top End. Variation in soil type presents management difficulties in relation to irrigation scheduling and nutrient management.

Evaporation is high throughout the dry season with rates of 7, 8 and 10 mm/day during August, September and October, respectively. Although exact water requirements and costs for irrigated crops in the NT have not been fully ascertained, maize and peanut grown from April to July will require 4-6 million litres/ha (ML/ha). Crops grown during July to October may require over 8 ML/ha. Water costs will vary but using electricity to pump water from 70-metre bores for centre pivot irrigation may be over $75 per ML.

Irrigation is a high input system which requires intensive and often specialised management. All aspects from land type, water source, irrigation system, agronomy, marketing and economics must be considered. Irrigated crops have a high requirement for nutrients and deficiencies are often amplified.

Plate 78c
Irrigated maize grown for the local stock feed market.

Due to the poor buffering capacity of many soils, alkaline water often increases soil pH, resulting in a 'tie up' of nutrients and inducing Zn, Cu and Fe deficiencies. See Figure 13.

Increased insect and disease pressure occurs under irrigation. The provision of a continuous moisture and food supply allows pests to continue breeding throughout the year. Sorghum midge, rarely a problem in dryland crops, can cause considerable damage in irrigated sorghum.

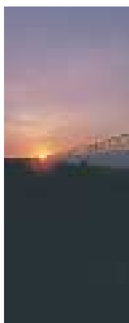


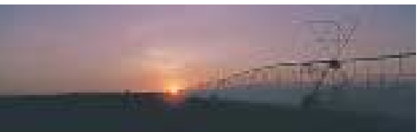
Plate 79
Changes in soil type can significantly alter crop performance, nutrient uptake and water use as seen in this irrigated peanut crop.

Leaf diseases such as Cercospora leaf spot in peanut and other plant diseases thrive in irrigated environments.

Many tropical crops and pastures which are adapted to high wet season temperatures do not respond to dry season irrigation (ie. Cavalcade and many tropical pastures) or have reduced growth rates due to lower dry season temperatures. In the coolest months of May, June and July the growth of many tropical crops is retarded.

There is considerable potential for irrigated field crops in the Top End but more knowledge on crop selection, water use, nutrition, pest management and economics is required before significant expansion takes place.

Irrigation is a high input system which requires specialised agronomic, financial and marketing management.



11. WEEDS - A MAJOR THREAT

TO AGRICULTURAL SYSTEMS

Weed infestation is a major form of land degradation in the Top End. Weeds cost the Australian economy approximately $3 billion per year. They reduce productivity, increase production costs, degrade and devalue land.

Agricultural weeds are defined as: *Plants that are competitive, persistent and damaging and interfere with human activities, agricultural and natural processes and, as a result, are undesirable.*

Weeds:

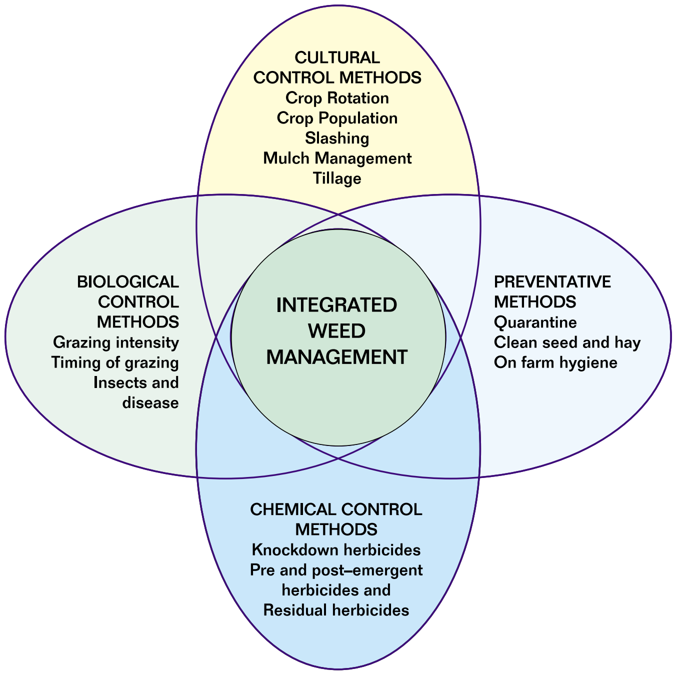
- contaminate and reduce the quality and quantity of produce
- restrict the production of certain crops
- rob moisture and nutrients from crops and pastures
- interfere with, and damage harvesting equipment
- increase fire risk
- interfere with mustering and stock movements
- act as hosts for insect pests and disease
- cause animal and human health problems through toxic properties
- contaminate and obstruct waterways and aquatic resources
- reduce aesthetic and property values
- damage and interfere with natural ecosystems

Weeds directly affect production through competition for nutrients, light and moisture. The degree of competition depends upon weed type, time of emergence and many other factors. The effect of weed competition is greatest when the crop or pasture is young. Weed competition can reduce crop yields to below economic levels and render pastures virtually unproductive. Weeds reduce the quality of hay, grain or pasture. Contamination of sesame or mungbean, either by plants or weed seed, can reduce the price or cause rejection of the crop.

11.1 INTEGRATED WEED MANAGEMENT - THE ONLY SOLUTION

Unfortunately, weeds are a fact of life and integrated control is the only effective management strategy. This involves a combination of *preventative*, *cultural*, *chemical* and *biological* control methods.

Figure 14
Integrated weed management involves bringing all the elements of weed control together into a combined management program to reduce the spread and impact of weeds.



Good farm hygiene, strategic cultivation, herbicides, crop rotation and grazing management are all required to minimise the spread of weeds.

Preventative Weed Management

Prevention is the first control measure. Any implement, animal, product or vehicle entering the farm from another area is a potential source of weeds. Isolated weeds can rapidly become heavy infestations. Stands of senna (*Senna obtusifolia*) can produce over 10,000 seeds per square metre which can remain viable for over 10 years.

Don't buy weeds!

Hay and pasture seed contaminated with weed seed is a major cause of weed introduction and spread. In the NT, the Government may issue a notice restraining a person from selling hay or animal fodder containing noxious weeds or seeds. Failure to comply can result in a fine.

Seed should always be analysed for purity, germination and weed seed content before purchase. A seed analysis report should be available with all seed sold. Certified seed is the best option, but the quality of any seed should be confirmed prior to sowing. Buying 'cheap' seed of unknown quality may result in poor establishment and a lifetime of costly weed control.

Plate 80a, b
(a) Pennisetum is a serious weed in crops and improved pastures.
(b) Heavy infestation of Hyptis in Cavalcade.

Most hay contains some weeds but the level of contamination can vary from less than 1% to nearly 100%. Buyers should insist on the cleanest hay possible and be aware of its origin and content prior to purchase. Demanding clean hay, buying from reputable producers and using hay in confined areas can help to minimise weed spread.

Contaminated seed and hay are major sources of weed introduction. Insist on clean hay and demand a seed analysis before purchasing.

Beware of stock and farm machinery!

Introducing stock or machinery from other areas almost always carries the risk of introducing a variety of weeds. Livestock distribute weed seeds in their dung and spined seeds such as Noogoora burr stick to their tails and hides. Hard seeds such as senna can pass through the digestive system undamaged. To minimise the spread of weeds, stock introduced from other areas should be inspected or confined until all foreign matter has passed through the digestive system.

Vehicles, farm machinery and earth moving equipment can introduce and spread weeds. Washing machinery prior to use on new country will minimise the risks of introduction.

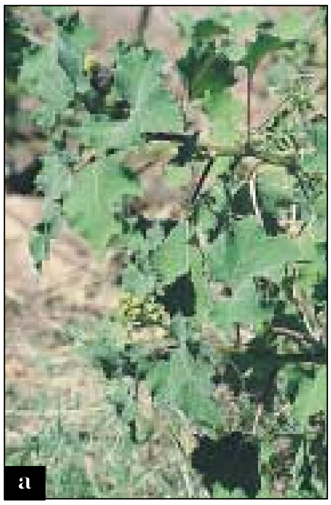
Spined weeds like caltrop pierce tyres, while sida, hyptis, senna and pennisetum are carried on vehicles and farm machinery. Farm quarantine and restricting vehicle access will help reduce the introduction and spread of weeds.

Cultural Weed Management

Tillage

Tillage is an effective form of weed control. It is used when conditions are unsuitable for herbicides and for the control of perennial and woody weeds. Deep ploughing inverts soil, buries seed and reduces emergence of some weeds. Shallow tined cultivation brings weed seeds close to the surface and stimulates germination, allowing control with subsequent tillage or herbicides. Cultivation relies on drying of the soil surface to kill weeds, but if soils remain moist due to regular rainfall cultivation may be ineffective and may simply transplant weeds. Herbicides can be used to assist in weed control in such situations.

Plate 81a, b, c
(a) Noogoora burr is introduced on the hides and tails of livestock.
(b) Caltrop, an increasing problem under irrigation is spread on machinery and farm vehicle tyres.
(c) Many weeds seeds such as senna species are ingested by stock and then spread over wide areas.



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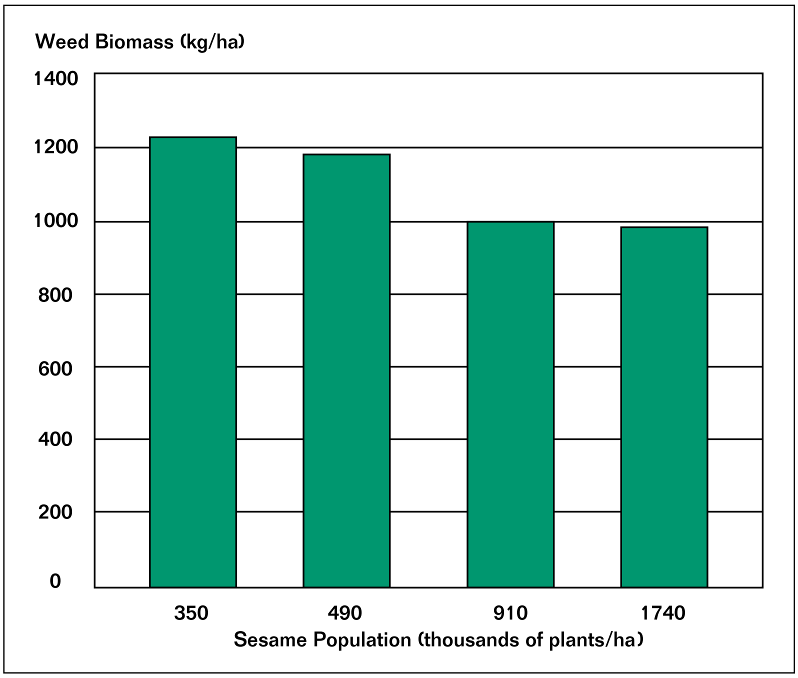


Figure 15
The effect of sesame population on weed biomass 8 weeks after sowing. With optimum plant populations weed growth is suppressed resulting in less competition for the crop.

Crop and pasture agronomy

A healthy, vigorous crop or pasture is an effective competitor with weeds. Growing crops in narrow rows results in earlier canopy closure, which suppresses weeds and will help reduce the need for post-emergent herbicides. Research in other countries on narrow row corn and soybean has shown significant improvement in weed control and crop yields.

Grazing management largely determines how quickly weeds spread. Continuous heavy grazing exposes the soil and creates opportunities for weed invasion. Maintaining adequate ground cover conserves early moisture allowing pastures to re-establish rapidly and compete more effectively with weeds.

Research has shown that mulch cover also suppresses early weed emergence, possibly by changing the light, temperature and moisture conditions at the soil surface. Complete rejuvenation of pastures is often the only way of managing and reducing heavy weed infestations.

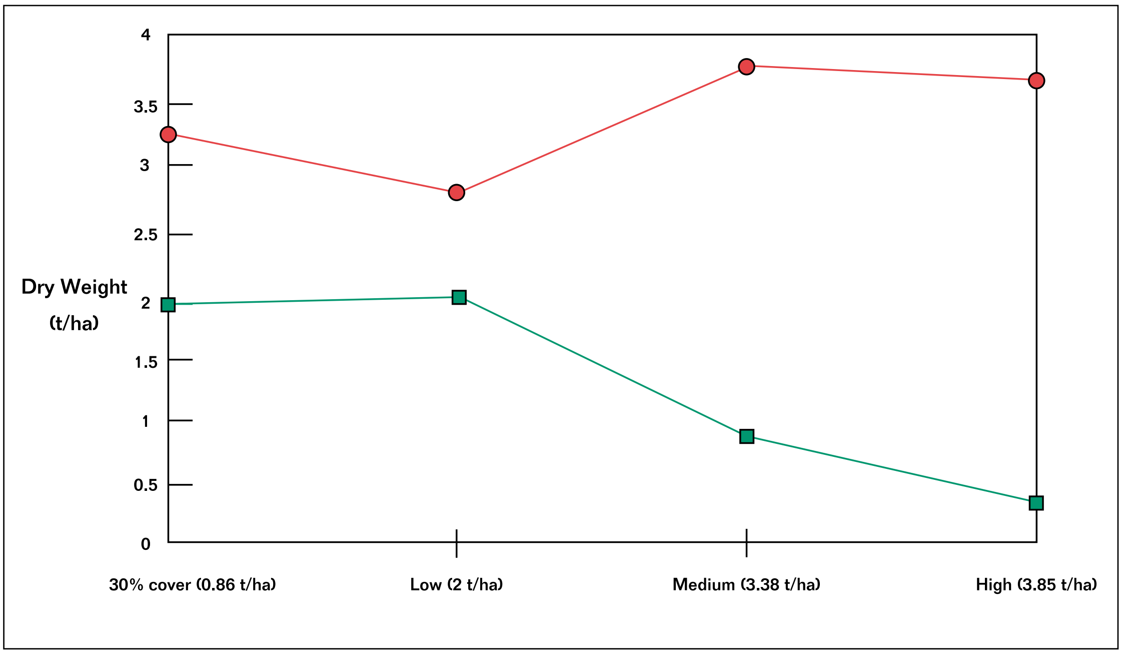
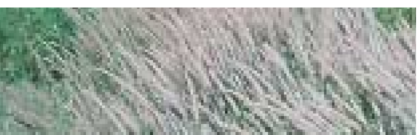


Figure 16
The effect of mulch quantity at sowing time on sorghum yield and weed biomass at harvest. In this experiment high mulch levels at planting resulted in reduced weed competition and better crop performance, indicating the potential of mulch in suppressing early weed growth.



Slashing

Repeated slashing of weeds will reduce seed production and plant vigour but, in most cases, will not eradicate them. Seed produced after slashing weeds, late in the wet season or in the early dry season, often has lower viability and subsequent weed seedlings have less vigour.

Slashing along boundaries and fence lines will minimise seed set and is also an effective means of manipulating vegetation prior to herbicide application. A combination of slashing and herbicide use will be more effective in most situations than relying on a single method of weed control.

Chemical Weed Control

Herbicides allow greater flexibility and offer a range of management options for weed control. There are herbicides which are active on all vegetation, ie. glyphosate or paraquat while others are highly selective and will control specific weeds, ie. grass herbicides. Herbicides are grouped into categories according to **active ingredient, mode of action, type of formulation, and application method and timing**.

Plate 82
Weeds are more effectively controlled with herbicides when young and actively growing. These are sida (left) and hyptis seedlings.

The broad groups used in farming systems in the NT are:

Herbicide Type and Activity

Non-selective/non-residual knockdown	Controls most vegetation, used as an initial knockdown prior to planting or total vegetation control, no residual effect, various *glyphosate* formulations. ie. *Roundup CT®, Nufarm Glyphosate®* etc. *Spray Seed 250 Herbicide®, Basta®.*
Selective and residual	Controls certain weeds in specific crops and pastures for extended periods, applied pre or post-planting, residual for weeks or months. ie. *atrazine, Dual®, Treflan®, Spinnaker®.*
Selective non-residual	Controls certain weeds in established crops and pastures such as grass weeds in legumes or broadleaf weeds in grasses, little or no residual activity. ie. *Sertin®, Fusilade®, Verdict®, Basagran®, Starane®.*
Non-selective and residual	Used as spot applications for difficult weeds, fence lines and non-crop purposes, long-term residual action. ie. *Velpar®, Residone®.*

Chemical weed control in crops and pastures

Weed control prior to planting is the best management strategy as it enables crops and pastures to establish without competition. In conservation farming, a single application of glyphosate at 2.5 to 3.0 L/ha will adequately control most weeds prior to planting. If weed growth is prolific, two separate herbicide applications, one to two weeks apart, may be necessary for adequate control. Certain selective and residual (soil acting) herbicides may be added to glyphosate to give longer control over specific weeds in certain crops.

Controlling weeds after crop or pasture establishment is often costly and in some situations may be impossible. Selective post-emergent herbicides are available but are expensive and must be applied to small weeds to be effective. These include herbicides for broadleaf weeds in grass crops, broadleaf weeds in legumes, grass weeds in legume crops and grass weeds in crops such as maize and sorghum. Weed control is more easily achieved when herbicides are applied to young, actively growing weeds.

Herbicide rollers and rope-wick applicators

Herbicide rollers and rope-wick applicators are designed to apply herbicide to weeds growing above the crop or pasture canopy. Herbicide rollers consist of a rotating, ground driven drum covered with a chemically impregnated material. Rope-wick applicators work on the same principle but use a rope-wick to carry the herbicide. Herbicide is physically 'wiped' or 'rolled' onto the stems and leaves of the weeds using approximately one sixth of boomspray application rates.

Biological Control

Biological weed control involves the use of insects or disease organisms to reduce the spread of weeds. As most weeds have been introduced from other countries, bio-control agents are usually obtained from the country in which the weed originated. Biological control is a slow process requiring several years of research to identify suitable agents.

A number of bio-control agents have been released in the NT, including the insects *Cyrtobagous salviniae* and *Calligrapha pantherina* which are assisting in the control of salvinia and spinyhead sida, respectively.

A number of bio-control agents are currently being evaluated for mimosa control, including the carmenta stem boring moth and two disease organisms.

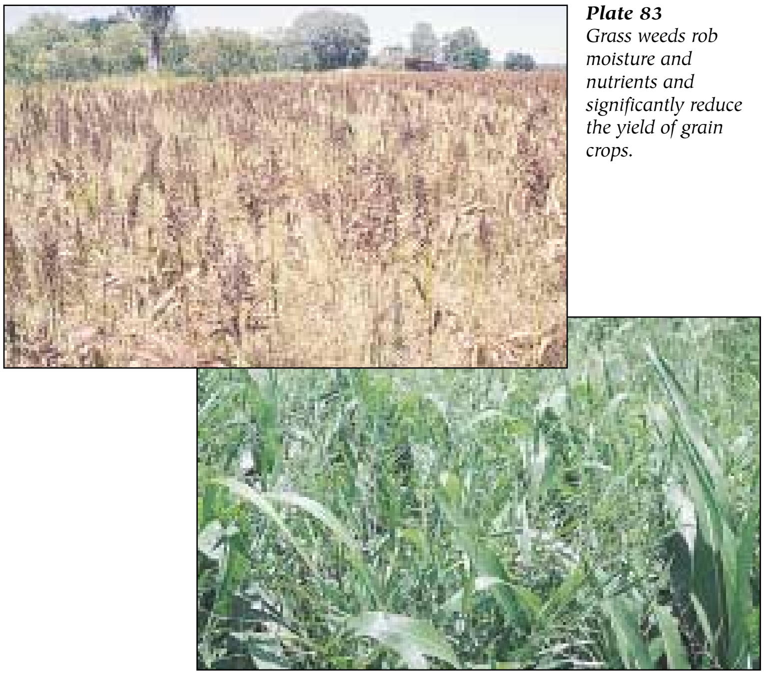


Plate 83
Grass weeds rob moisture and nutrients and significantly reduce the yield of grain crops.

Plate 84a, b
(a) Herbicide rollers allow tall weeds to be controlled in pastures.
(b) Weeds in pasture controlled by a herbicide roller.

11.2 NOXIOUS WEEDS – A CAUSE FOR CONCERN!

The major noxious weeds in the Top End include mimosa *(Mimosa pigra)*, salvinia *(Salvinia molesta)*, hyptis *(Hyptis suaveolens)*, senna *(Senna spp.)*, noogoora burr *(Xanthium occidentale)*, bellyache bush *(Jatropha gossypifolia)*, and parkinsonia *(Parkinsonia aculeata)*. Others such as Siam weed *(Chromolaena odorata)* and rubbervine *(Cryptostegia grandiflora)* pose a serious threat if introduced to the NT.

Noxious weeds infest pastoral and farming properties, small rural blocks, National Parks, Aboriginal and Crown lands. Landholders are responsible for the control of noxious weeds within their boundaries but co-operation between landholders, the community, councils and government agencies is required to effectively manage weeds. The Northern Territory Noxious Weeds Act is aimed at preventing the introduction and spread of noxious weeds. An outline of the Act and a list of noxious weeds appear in appendix 1.

Plate 85a, b, c
(a) Senna (Senna obtusifolia) is a major weed in Cavalcade and Bundey hay and seed crops.
(b) Mimosa, a major weed of the Top End floodplains, is a target for biological control..
(c) Senna seedling.
Early identification of weed seedlings is essential for effective control.

Weed Problem or Source of Contamination	Options for Control and Management
Introduction into new country or new crops and pastures	• Inspect and clean all machinery prior to use • Purchase certified/clean seed • Hand pull or spot spray small outbreaks to minimise spread
Introduction through purchased hay/fodder	• Purchase clean fodder • Isolate areas where fodder is used • Control weeds as they emerge • Grow own fodder
Introduction through livestock	• Hold cattle in 'quarantine' area on farm until digestive tract is emptied • Control weeds in quarantine area • Avoid stock from known noxious weed areas
Introduction from surrounding areas	• Isolate and treat initial outbreak • Slash, spray borders and fence lines • Plant competitive pasture around perimeter of property • Co-operate with neighbours in controlling boundary weeds • Fence property to prevent entry by wildlife which carry weeds (option for small blocks only)
Build-up of weeds in pastures or crops	• Good grazing management • Application of selective and or residual herbicides • Application of non-selective herbicides with herbicide roller or rope-wick • Spot spraying and hand pulling isolated areas • Slashing or cultivation where desirable • Complete pasture renovation ie. re-seed, fertilise and apply selective and or residual herbicides. • Rotation with alternative crops or pastures

12. INSECT PEST AND DISEASE MANAGEMENT

Conservation farming promotes a diversity of insect life, influences pest populations and also favours many beneficial insects. The beneficial insects which act as natural control agents help to create a more stable agricultural system.

Reducing cultivation and maintaining a mulch provides a more favourable habitat for certain soil dwelling insect pests and disease organisms. A range of pests including caterpillars, beetles, grasshoppers, foliage feeders and sap-sucking insects occur in all crops and pastures and will require control from time to time.

12.1 INTEGRATED PEST MANAGEMENT – THE LONG-TERM SOLUTION

Pest management will be achieved only by a long term commitment to integrated control practices. Integrated pest management (IPM) involves the strategic use of rotations, resistant varieties, beneficial insects, cultural measures and selective pesticides. IPM requires an understanding of the interaction between pests, plants and the environment. IPM will ensure that chemical use and pest control is optimised, environmental contamination is minimised and production is maintained.

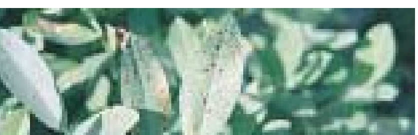
Integrated pest management involves:

- rotating crops and pastures to disrupt pest lifecycles
- selecting varieties resistant to pests and disease
- using strategic cultivation to disrupt the development of pests
- eradicating plants which harbour insect pests or disease
- monitoring crops to determine pest and beneficial insect activity
- encouraging and protecting beneficial insects
- applying pesticides only when pests approach economic injury level
- using selective or 'soft' pesticides which target pests only

Common Insect Problems

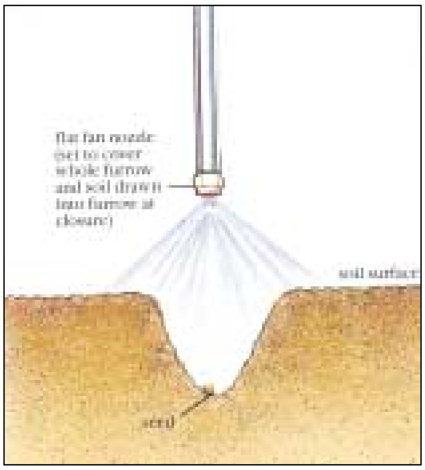
Insect Pests and Crop Establishment

Soil dwelling pests such as earwigs, scarab beetles, false wireworms, wingless cockroaches and cutworms are active in or on the soil particularly under high mulch levels. They feed on the roots and shoots of emerging seedlings. Insect numbers and damage levels will vary from year to year according to seasonal conditions.



False wireworm is the most common and damaging insect pest of crops and pastures at establishment. Damage is caused by the larval or immature stage feeding on germinating seeds but adults may also feed on seedlings.

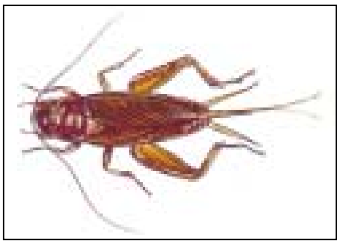
Some soil dwelling insects can be detected prior to planting by placing baits of pre-soaked sorghum grain at several sites throughout the field. Baits are dug up and inspected after the seedlings emerge. The number of insects found gives an indication of expected populations and one or more per bait usually indicate that control may be necessary.



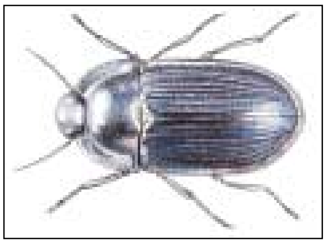
In-furrow application of insecticide for soil dwelling insect control.

Plate 86
Courtesy of DowElanco. Soil dwelling insect pests can cause significant damage to establishing crops.

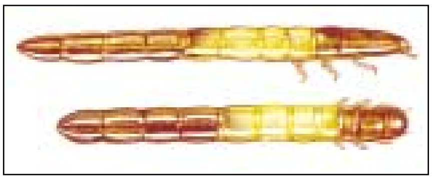
Control of soil borne pests involves seed treatment with an appropriate insecticide or an in-furrow insecticidal spray or granule at planting. A commercial bait is available for the control of surface insect pests. Presswheels or seed-firming wheels will allow more rapid germination and may help restrict the movement of insects through the soil.



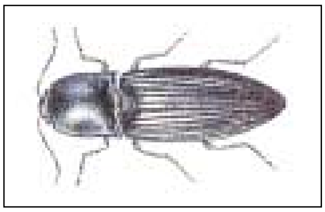
Field cricket. The adults and immature stages, feed at night on the leaves and stems of seedlings and young plants. They also feed on the flowers, developing fruits and seeds mature plants.



(1) Pie–dish beetle (adult false wireworm) Length 16–19mm.

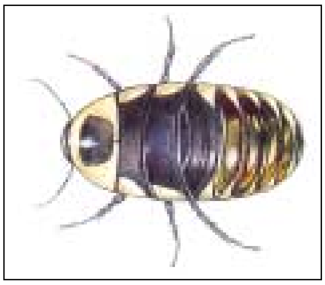


(2) False wireworm have hard, round bodies with a pointed, upturned tail segment (pie-dish beetle larvae). Length about 3.5cm when fully grown.

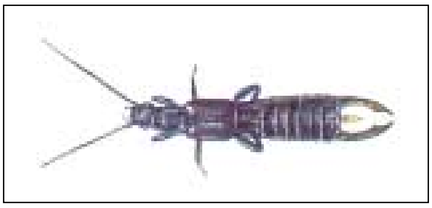


(1) Click beetle (adult true wireworm) Length 9–13mm.

(2) A wireworm with soft, semi–flattened body and a forked tooth–edge tail segment. Length up to 2cm when fully grown.



Wingless cockroach. These insects are most active during the summer months causing crop damage at night by chewing seedlings off at ground level.



Black field earwig. These insects feed on the germinating seed and roots of young plants, killing or weakening them. This damage can continue until the plants are 60cm high and can result in severe crop lodging. Damage mostly occurs in areas with heavy black soils.

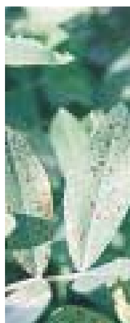



Plate 87a, b
(a) Yellow winged locusts.
(b) Damage to a sorghum crop.

Grasshoppers, yellow-winged locusts and various caterpillars have occasionally damaged sorghum and maize crops at establishment. Problems may arise in no-tillage areas where immature hoppers move from the dying mulch to emerging crop seedlings. Damage at this stage is swift and monitoring is essential to identify the problem. Armyworm caterpillars have also caused sporadic damage to young sorghum crops in some seasons.

Foliage feeders, sap suckers, pod and grain pests

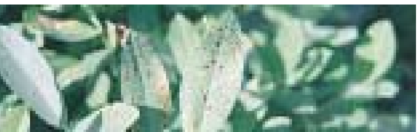
Grasshoppers, beetles, caterpillars, flies, aphids, plant hoppers and pod-sucking bugs attack the foliage, flowers, pods and seed of crops and pastures. Some insects are specific and feed on only one type of plant while others attack a wide range of crops.

Helicoverpa caterpillars (formerly heliothis) attack several crops, including sorghum, maize, peanut, sesame and most grain and pasture legumes. Sorghum midge is a specific pest of grain sorghum.

The most common insect pests are *Helicoverpa spp.*, other caterpillars and pod-sucking bugs such as the green vegetable bug, red-banded shield bug and *Riptortus spp*. Pod-sucking bugs are particularly damaging to legumes such as mungbean, soybean and Cavalcade and Bundey seed crops.

Monitoring Pests and Deciding on Control

Crops vary in their tolerance to insect attack depending on the type of damage and stage of growth. Seedlings have little tolerance to insect attack and relatively small numbers can cause economic damage. Most crops can withstand considerable insect pressure in the vegetative stage but considerably less damage at critical growth stages such as establishment, flowering, grain fill and pod maturity. Monitoring and management during these high risk periods is essential to minimise economic loss.



The first step in managing pests is to establish which insects, and how many are present. Monitoring involves regular inspection of crops. Insect pests are usually present but, in most instances, in numbers too low to cause economic damage or warrant control. Monitoring avoids unnecessary use of pesticides and allows informed decisions to be made based on actual pest numbers and damage levels, rather than guesswork. Monitoring involves counting insect numbers in a given area (ie. 5 m of crop row) at several sites throughout the field. Guidelines regarding insect tolerance levels have been established for most crops.

Beneficial insects such as predators and parasites are important natural control agents and play a major role in reducing pest numbers. Only when natural control is absent or pest numbers grow beyond the capacity of natural agents, do other control measures become necessary. Beneficial insects are a vital part of integrated pest management and include beetles, bugs, ants, wasps, spiders, earwigs, flies, mantids, lacewings and damselflies.

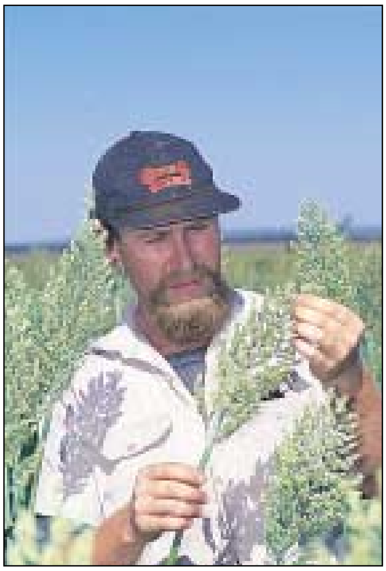


Plate 88
Monitoring crops, especially at flowering, is essential for effective pest management.

Identifying the pests, their damage and knowing when they are likely to attack the crop is essential for effective insect management.

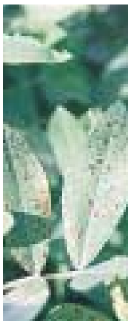
Plate 89a, b
Beneficial insects such as
(a) the Predatory shield bug and
(b) Assassin bug play a major role in reducing insect pest numbers. Both predators are feeding on heliothis.

Plate 90a i, ii
(i) Red-banded shield bugs and
(ii) Green vegetable bugs are serious pests of grain and pasture legumes.

Plate 90b i, ii
(i) Heliothis caterpillars on sorghum head and
(ii) Northern armyworm is a sporadic pest, while heliothis are a frequent pest of most crops of the Top End.

Plate 90c i, ii
(i) Riptortus feed on pasture seed crops and grain legumes and
(ii) Crusader bug (with a straight proboscis, characteristic of plant-sucking bugs).

Plate 90d
Grain sorghum damaged by sorghum midge.
The insect is usually prevalent in irrigated crops.



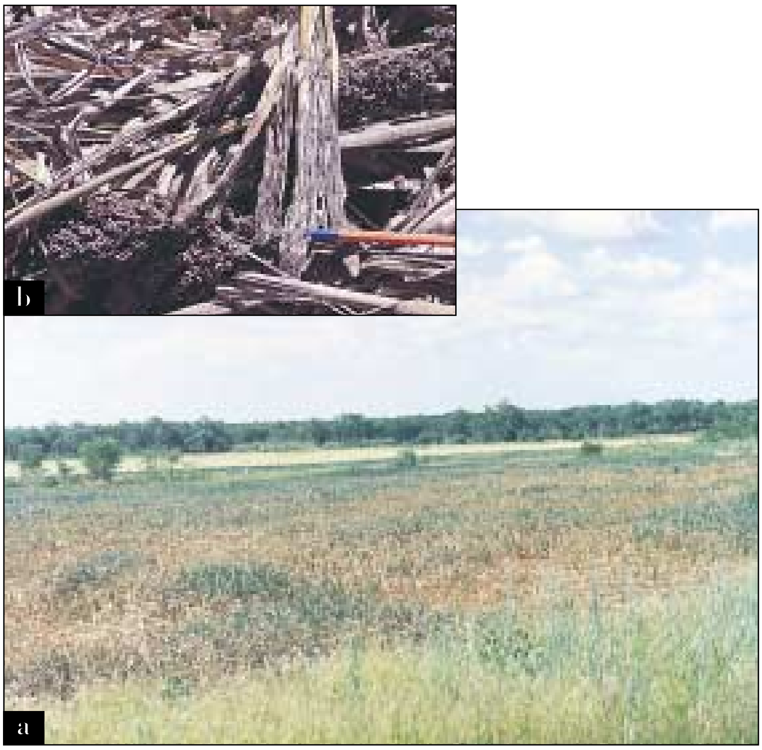
12.2 DISEASE IN CROPS AND PASTURES

Plant diseases include many species of fungi, bacteria, mycoplasmas, viruses and nematodes. Some diseases are transmitted by vectors such as insects, fungi or nematodes. Development of disease depends upon a number of factors and if one or more of these are absent, disease will not develop or will be reduced in severity.

Disease development depends upon:

- Susceptibility of the crop or pasture to disease
- The presence of a virulent disease organism
- Environmental conditions favourable for infection and disease development

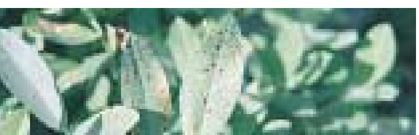
Plate 91a, b
(a) Sorghum affected by charcoal rot (Macrophomina phaseolina).
(b) Stem disorder caused by the disease.



Townsville stylo (*Stylosanthes humilis*), a legume similar to Verano and Amiga stylo, which was planted over vast areas of the NT and north Queensland was devastated by anthracnose (a leaf and stem disease caused by the fungal pathogen *Colletotrichum gloeosporioides*) in the mid-1970s. Large areas of stylo pasture were wiped out, illustrating the damage which can be caused by a virulent plant disease.

New species with better disease resistance have since been released but there is still a threat that a new race of anthracnose may develop and infect one or more of the current stylos. To combat this threat, it is recommended that a number of stylos (ie. Seca, Siran, Verano and Amiga) be sown in a mix so that if one should succumb to disease the others will persist and remain productive.

The retention of mulch may favour the build up of certain disease organisms which cause leaf spots and stem and head rots. These can damage crops when conditions are favourable. Burning crop residues to reduce disease has been practised in other agricultural areas in Australia but current experience suggests this practice is undesirable in the Top End due to the negative impact of reducing soil surface cover.



Conservation tillage can reduce the incidence of certain diseases by improving the conditions for crop growth and thereby increasing resistance to infection. Fungal diseases such as charcoal rot (*Macrophomina phaseolina*) and stalk rot of grain sorghum (*Fusarium moniliforme*) are accentuated by high soil temperatures and moisture and nutrient stress. Maintaining mulch, good nutrition, weed control and resistant varieties will reduce the incidence of such diseases.

Disease management, like all pest management, requires an integrated approach and strategies include:

- crop rotation
- use of resistant and adapted varieties
- correct planting time and agronomy
- insect vector control
- adequate soil fertility and appropriate pH
- use of fungicides and seed dressing
- management of mulch levels
- strategic tillage
- quarantine to prevent disease entry
- farm and machinery hygiene

Plate 92
Wallaby-ear virus transmitted by a leafhopper insect in irrigated maize.

Common Plant Diseases

The most common diseases in crops and pastures are foliar and stem diseases. Head and grain moulds in sorghum may occur in prolonged wet weather but are of minor importance. Seed and seedling rots can occur but are largely controlled by fungicide treated seed.

Leaf spots, blights and rusts thrive in prolonged wet weather and high temperatures. Cercospora leaf spot in peanut and blast in rice can be particularly damaging in certain seasons. Leaf spot survives in seed and old peanut debris. Control involves crop rotation to reduce inoculum, sowing non-infected seed and applying fungicides immediately the disease is evident. Rice blast is a leaf and stem disease which survives on rice stubble. Burning stubble will reduce inoculum levels but resistant varieties and rotation offer more sustainable long-term control.

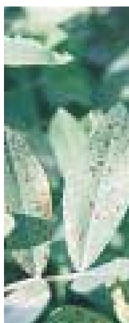


Plate 93
Cercospora leaf spot is a serious disease of peanut and builds up on successive crops.

Many soil borne organisms infect plants when conditions favour their development. Such diseases include charcoal rot of sorghum and stem blight of mungbean, sesame and soybean caused by *Macrophomina phaseolina*. Plant diseases occur sporadically and although not of major economic importance in the Top End at present, the potential for disease will increase as farming and irrigation intensifies.

Conservation farming systems will have no more and possibly less insect and disease problems than conventional farming.

Plate 94
Powdery mildew on mungbean grown under irrigation in the dry season.

13. ECONOMICS OF CONSERVATION FARMING

Conservation farming influences both the short and long-term economics of farm production. Short-term issues relate to farm costs, returns and yields. Long-term economic factors are concerned with natural resource protection, maintaining soil chemical and physical fertility and minimising land degradation and environmental pollution. Long-term viability will largely be determined by short-term practices which in turn determine the health and productivity of the land.

Although conservation farming has been practised in the Top End for a relatively short time, there are clear indications that crop yields are at least equal to those of conventional farming methods and significantly higher in seasons with below average rainfall. See Figure 17.

Conservation farming reduces labour and machinery costs but, in some cases, herbicide expenses may increase. Over the longer term, conservation farming should result in greater flexibility, lower production costs, more reliable yields and better protection of natural resources. See Figure 6, page 25.

Figure 17
Benefits arising as a result of adopting conservation farming in commercial grain sorghum on Carbeen Park at Katherine. From 1990/91 to 94/95 conservation farming increased crop yields on average by 75% (0.8t/ha) over earlier conventional crops and all yields in this period were better than break-even.

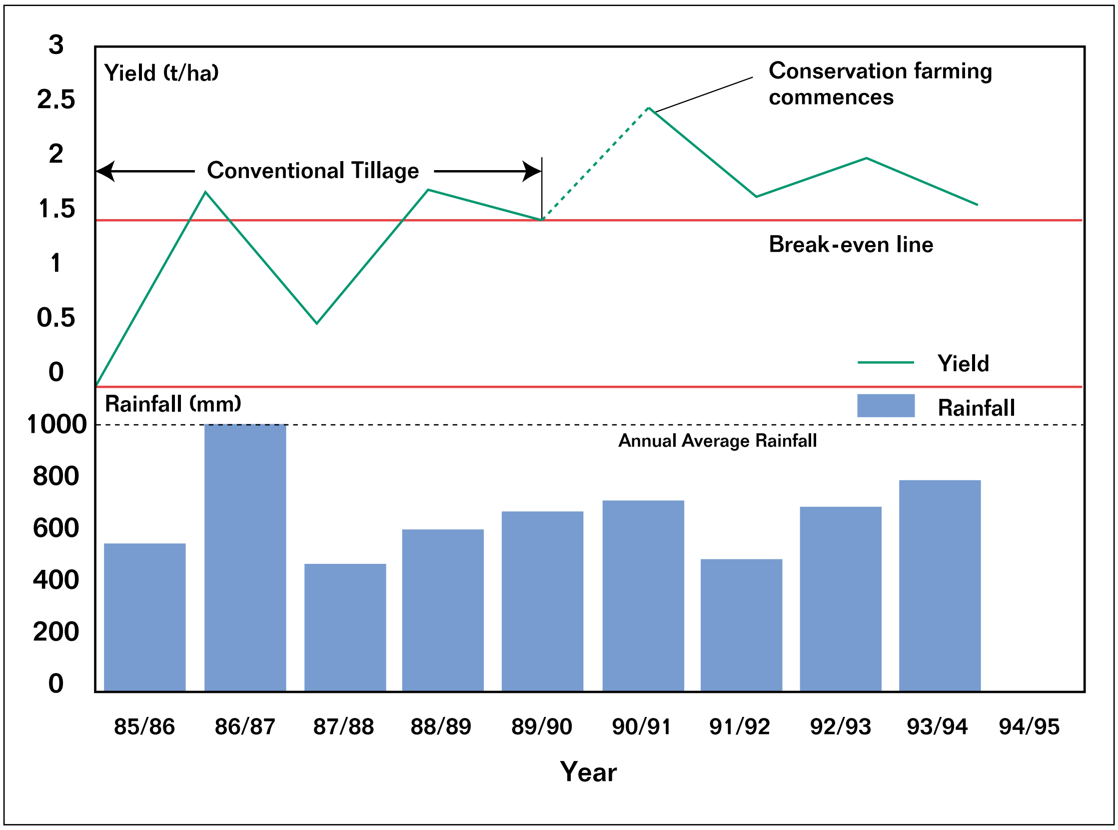


Table 5. Comparison of likely gross margins for grain sorghum under no-tillage and conventional tillage at Katherine, NT.

	Conventional tillage	No-tillage
Yield (t/ha)	2.0	2.5
Price ($/t)	275	275
Gross income	550	687
Land preparation	13	20 (herbicide)
Land prep. labour	5	2
Planting, seed	38	38
Fertiliser	169	169
Post-planting weed control	19	19
Harvesting	24	24
Transport/marketing	94	118
Total variable costs	364	392
Gross margin per hectare	186	295

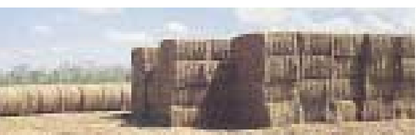
Assumptions:
All fertiliser requirements supplied, ie. no residual fertility.
No–tillage crop receives 2 L/ha of glyphosate 450g/L a.i.
Both crops receive post-emergent herbicide.
GM yields based on historical information.

Markets and Profitability of Crops and Pastures

A comparison of gross margins per hectare, based on short-term data show that crop and pasture rotations are less profitable than continuous grain or legume hay at current prices. Computer simulation showed that while continuous legume hay production is the most profitable enterprise it will present problems in terms of weed and pest management. Rotating pastures with grain crops is one option to maintain profitability while managing weeds and other pests.

At present the demand for coarse grain for the local stock feed industry is approximately 10,000 tonnes. Sorghum, maize and rice are grown locally for this market but in most seasons, a shortfall in local supply has required imports of grain from the Ord Irrigation Area or Queensland.

The existence of a local market for coarse grains will depend on the continuation and growth of the pig, poultry and horse feed industries and possibly on NT government policies.



The use of processed feed for the live cattle trade, the establishment of local feed lots or the development of overseas niche markets could stimulate further demand for these commodities.

Good market prospects exist for peanut, sesame, mungbean and a range of fodder crops. In 1993, the world trade in sesame seed was 486,000 tonnes and Australia currently imports about 10,000 tonnes of seed and sesame product annually. NT sesame is recognised as high quality and up to $1000/t has been paid for local sesame which meets market specifications.

There is a strong Australian market for peanut. Peanuts are graded and priced according to kernel size and quality and confectionary peanuts (nut in shell) can range in price from $400 to $800/t.

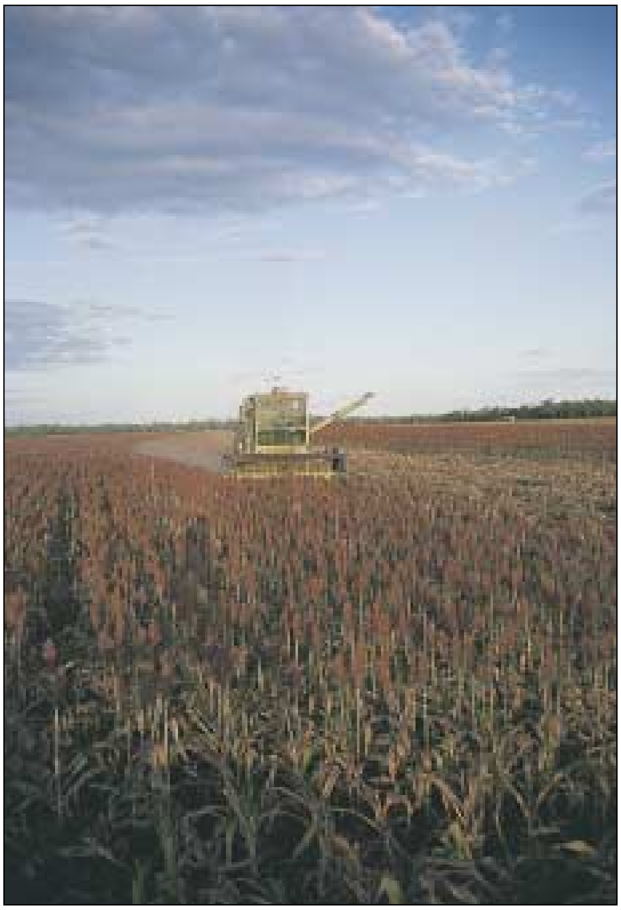


Plate 95
Sorghum demand has never been satisfied by local production.

Plate 96a
Sesame is used in a wide variety of confectionary and culinary products.

There is also a significant domestic and international trade in high quality mungbean seed for human consumption but markets vary considerably depending on seasonal production in Asia. Tropical pasture seed is potentially a lucrative enterprise but markets vary considerably from year to year and specialised machinery and knowledge is often required.

Historical records on crop yields in the Top End show that grain sorghum has the highest gross margin and least risk when compared to other crops. Sorghum is generally less risky than maize and has produced better overall yields. Sesame has shown to be high risk mainly due to seed losses at harvest time. The adoption of no-tillage, crop rotation, improved harvesting techniques and better agronomy will significantly reduce many of the risks.

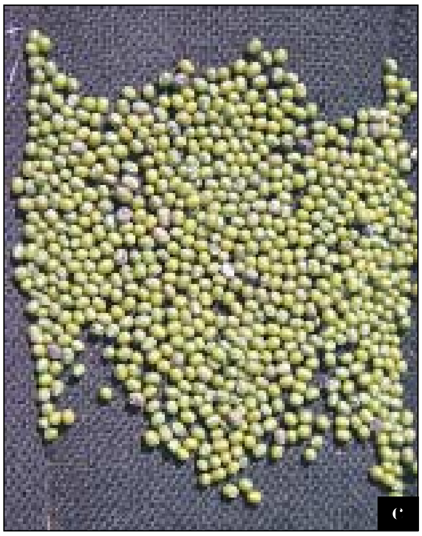


Plate 96b, c
(b) Close-up of unprocessed sesame seed.
(c) There is a good market for high quality mungbean.

Plate 97
Peanut is a crop with good potential under irrigation in the Top End.

Table 6. Gross margins for selected field crops in the Katherine-Daly region, NT, 1995/96.

Crop Gross Margins	Dry season Peanut (Full Irrigation)	Wet season Peanut (Supp. Irrig)	Rice	Cavalcade Hay	Sesame	Sorghum	Maize	Mungbean
Yield (t/ha)	4.0	4.0	3.0	7.0	0.6	2.7	3.0	1.0
Price/t ($)	700	700	280	170	1000	275	280	500
Income ($/ha)	2800	2800	840	1190	600	742	840	500
Enterprise Costs ($/ha)								
Land preparation	37	37	34	16	20	20	20	20
Sowing	321	321	54	94	12	38	140	33
Fertiliser	317	317	221	138	169	169	194	106
Inter-row cultivation	11	11	0	0	0	0	0	0
Weed control	134	134	138	50	0	19	55	0
Disease control	142	142	0	0	0	0	0	0
Insect control	53	53	45	0	24	0	0	46
Irrigation	392	168	0	0	0	0	0	0
Desiccation	0	0	0	0	59	0	0	0
Harvesting	150	150	77	99	37	24	37	36
Marketing	360	360	90	0	123*	81	90	183*
Total Enterprise Cost ($/ha)	**1917**	**1693**	**659**	**397**	**444**	**351**	**536**	**424**
Gross Margin ($/ha)	**883**	**1107**	**181**	**793**	**156**	**391**	**304**	**76**

Assumptions :
All crops are supplied with entire fertiliser requirements ie. soil fertility is ignored.
Fertiliser freight subsidy ($95/t) has not been accounted for in GM.
* Current cleaning and grading charges ($150/t) should be reduced in the future.
Prices and costs based on 1977 data, labour not included.
Peanut prices will vary according to quality grades.
All crops sown no-tillage except peanut and rice.
Cavalcade GM is based on sowing seed, in subsequent years Cavalcade may be self–sown.
Returns from grazing/hay have not been included in crop GM.

Table 7. Gross margin for export steer production (post-weaning) on improved pastures at Douglas Daly.

Steer Production System on Improved Pastures.	
Income ($/ha)	
1.4 x 300 kg steers @ $1.20	**504**
Enterprise Costs ($/ha)	
Weaners purchased @ $1.20/kg* av. wt 160kg @ 1.4 steers/ha	269
Livestock husbandry (5 in 1 vaccine, Avomec®, botulism)	6
Supplements (eg. Uramol® and Phosrite®)	31
Pasture maintenance (75kg super/ha/yr)	30
Marketing (5% commission)	25
Enterprise Costs ($/ha)	**361**
Gross Margin ($/ha)	**143**

Assumptions:
Data based on experimental results from grazing trial on Gayndah buffel grass at Douglas Daly Research Farm over 4 years.
Stocking rate is 1.4 steers/ha, equivalent to 224 kg liveweight/ha at the start of the dry season. Stock turned off from January to May as steers reach 280-320kg.
Mustering costs not included.
Mortalities not included (usually less than 1%).
Freight not included.
Prices paid for weaners may vary considerably and may be dearer per kg than sale price.

Pasture and Fodder Production

The increase in the live cattle trade with South-east Asia has prompted a swing away from annual cropping towards grazing and fodder production. Hay has recently been one of the most profitable enterprises in the Top End and is closely linked to the fortunes of the live cattle trade.

Plate 98a, b
(a) Pellets processed locally for the live cattle trade.
(b) Forage production is an important agricultural industry.

Processed feed is required for stock prior to, and during, shipping and this has led to the establishment of a number of cubing and pelleting plants and a significant expansion in legume hay production in recent years.

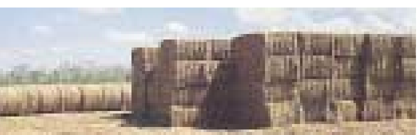
Should there be a temporary or extended decline in live cattle exports, (as seen in the 1997/98 Asian currency crisis), there could well be an over-supply of hay.

The local stockfeed market will absorb some of the higher quality produce but lower quality hay may be difficult to sell. Alternative markets for fodder need be developed to reduce the risks of relying on a single market.

The growing demand on pastures for grazing and agisting may lead to pasture decline and land degradation. This will have long-term financial implications for the industry. Pastures and fodder crops must be well managed to maintain productivity and this will ultimately increase production costs. The quality, as well as the yield of pastures and fodder crops will largely dictate the long-term viability of many enterprises.

The Vagaries of Production and Markets.

Market fluctuations and unforseen events are traits of all agricultural industries. In late 1997 the buoyant live cattle trade suffered a sudden downturn. Economic problems in South-east Asia sparked a dramatic devaluation of many countries' currencies. Indonesia, the largest market for live cattle, lost 70% of the value of its rupiah, while the Philippine peso lost 25% of its value. As a result, exports to Indonesia practically stopped in early 1998.



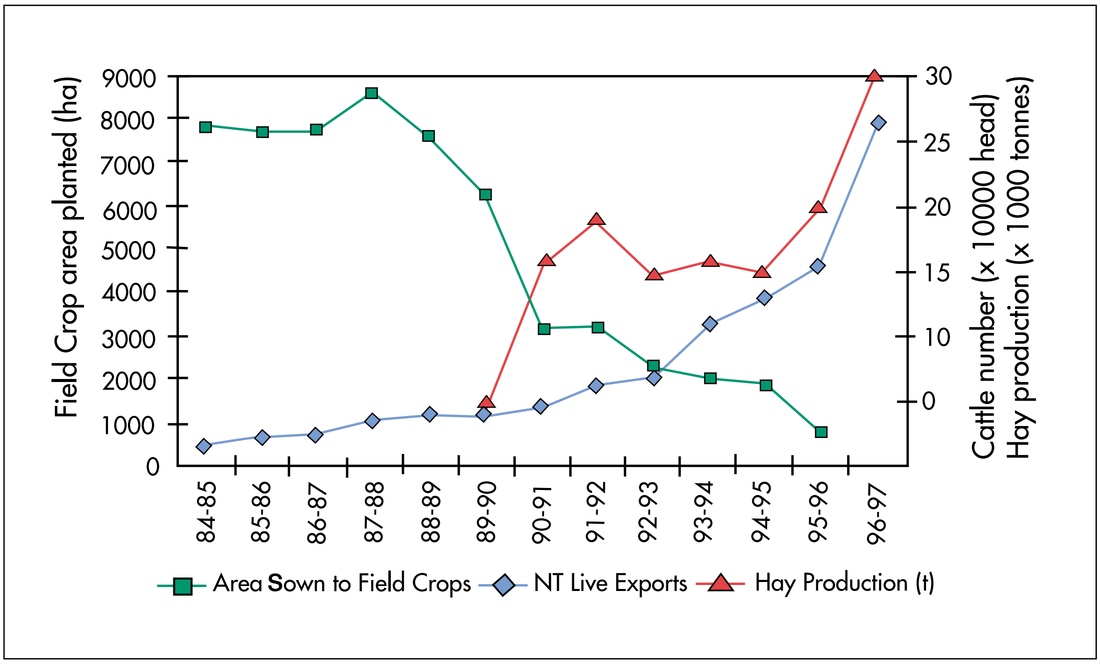


Figure 18
Growth in live cattle exports from the NT from 1985 to 1997 and the corresponding growth in hay production and decline in cropping area.

Despite this, NT cattle exported to the Philippines almost doubled from 4,350 head in Jan 1997 to 8238 head in Jan 1998.

The Cattle Council of Australia estimated that only 40 to 60% of the 1997 tally of 440,000 cattle would be exported to Asia in 1998 due to the currency slide. The severity of the decline was unforseen by most but it highlights the risks associated with relying on a single commodity and largely a single market.

Other events can cause unforseen problems and impact heavily on any agricultural industry. A cyclone, flood, an outbreak of disease or the introduction of a new pest may have serious implications in terms of lost production, quarantine, market restrictions and costs of control or eradication. The appearance of an exotic fruit fly in the Darwin region in late 1997 which threatened NT horticultural exports is an example.

Relying on a single commodity and market is a business decision. However, the associated risks and financial implications should be well understood. Having a fall-back position when markets suffer a downturn is an important aspect of whole farm planning. Mixed farming systems and diversification are possible ways of reducing or spreading the risks associated with livestock production and farming in the Top End.

Plate 99
Management of pastures will dictate the profitability of grazing enterprises.

Economics of Integrating Crops and Pastures

Financial and production information on farming systems in the NT is insufficient to allow detailed investigation of various enterprise combinations. Economic analysis using available data suggests that crop and pasture rotations become more profitable as the frequency of cropping increases.

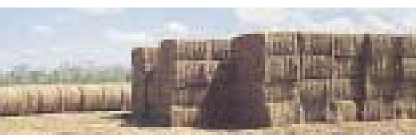
Returns per hectare for livestock grazing enterprises on improved pastures are considerably lower than for grain or fodder cropping. However, many producers perceive annual grain cropping as high risk. Integrating hay crops, grazing and grain production using conservation farming reduces the risks and offers a more sustainable combination.

Profitability of agricultural enterprises depends on many factors, notably the existence and accessibility of markets and the ability to produce commodities efficiently. Unfortunately, even then, success is not guaranteed and many variables must be considered when evaluating the most profitable mix of enterprises.

Attitude to risk, finances, skills, infrastructure and personal preference as well as market trends and environmental constraints are factors which will determine profitability.

The Top End is in a unique position in that it is isolated from the major centres of southern Australia, has a small population base and therefore a small local market for many agricultural products. However, our proximity to Asia and consequently our advantage in marketing and transporting products offers opportunities, as the live cattle trade has shown.

The viability of agriculture in the Top End will ultimately depend upon the adoption of sustainable production techniques in line with the development of sustainable long-term markets. Additional markets need to be developed for a wider range of products so that the risks and vulnerability associated with relying on a single commodity can be reduced.



14. SUMMARY

Intensive agriculture in the Top End is still relatively new. Although much information and expertise has been developed over the past 20 years there is still much to learn. Farming in the tropics is extremely challenging and risks are forever present. Mother Nature has an exquisite ability to undo our best efforts and more so in this environment than in others.

Success will depend on a thorough understanding of the physical environment and skills in agronomy, animal husbandry, finance and marketing. Farming systems must be flexible enough to allow producers to adapt to changing market circumstances and production technology, while protecting the natural resources.

Conservation and ley farming practices will greatly reduce the risks in this environment. Integrating crops, livestock and pastures into a flexible system allows greater utilisation and better management of resources. If agriculture is to develop and prosper in the Top End, it must do so in a manner which works with the environment. Conservation farming principles and practices will play an increasing role in the development of sustainable farming systems in the NT.

The ultimate success of conservation farming will have more to do with how farmers perceive it and their willingness to try it, than any deficiency in the system.

Plate 100
No-tillage sorghum at Katherine.

14.1 WHAT PRODUCERS HAVE SAID

The following is a selection of comments on farming and grazing management, taken from producers in the Top End.

"My observations throughout these years was that the areas with good mulch at planting time were always successful whilst those which were bare or over-grazed would only produce good results when rain was very favourable." **Colin Stopp, Katherine.**

"After three years of conventional cultivation it became obvious that erosion was increasing each season and it was evident that the contour banks were insufficient in preventing inter-bank rilling. If dryland farming was to be viable in the NT a better farming system had to be formulated… in the 1990/91 season we trialled zero-tillage for the first time and I was amazed by the efficiency gain in terms of man-power and tractor time."

"..with the introduction of zero-tillage it has really cut the erosion to an absolute minimum in comparison to what we were suffering before…"
Brian Sellars and Stuart Wheal formerly of Carbeen Park, Katherine NT

"All you need to look at is a cultivated paddock and get rain for a week, you can't access it, it crusts and then look at a paddock with grass or good mulch and see the difference!"

"..conservation farming is the only way to farm here…the more mulch you have the better the little seedlings get away….we're putting in 200 hectares of maize this year and its all going in no-till into cavalcade mulch."
Martin and Don Williams of Williams Quality Hay & Seed.

"Conservation farming is a way of getting the seed in the ground on time and spending less time on the tractor. The benefits in terms of soil protection go without saying !" **Greg Symes, Contract Forage Manager, Carbeen Park, Katherine.**

"I may be wrong but I think no-till or minimum till is the way to go and helps get away from erosion,…at the time of year when you're farming the ground gets so hot, a little mulch cover gives you better establishment and plants get off to a better start….but I learn something new every year…."
Roy Townsend, Labelle Station

"…the bottom line is watch your carrying capacity all the time, or suffer the consequences of over-stocking,… it's a constant balancing act."
Ian McBean, (ex Bradshaw Station) Bonalbo, Douglas Daly

"...Don't start off too big because the first year or two is a steep learning curve. I'm sure now when I look back to those dry years we would have had a crop had we been using conservation tillage because in the last few years our yields went from about 2 t/ha to nearly 4 t/ha, it virtually doubled the yield ."
Spencer and Paul Denniss, formerly Dry River Station, Katherine

"... the secret to farming here is to travel slowly, consolidate, learn and don't be too ambitious until you get established....and the key for improved pastures is not to look at increasing the stocking rate so much, but more so to improve individual animal performance and weight for age and increase reproduction.
Brian Gough, General Manager Tipperary Export Division

"....the weather is whats gets you, too much rain or not enough and when it comes it all comes at once, so you've got to be ready. Zero-tillage is excellent because of our country and it seems to be better in a drier year. It seems to work for two years in a row and then we need to do a ploughing.
Rod and Beth Beament, "Kumbychants", Douglas Daly

"Its false economy and detrimental to the country to think improved pastures in the Top End is a means of running unlimited cattle...because the soil structure is so fragile every effort needs to be made to keep the soil in pristine condition, so running fewer cattle, reaching higher weight gain while retaining good ground cover should be paramount..."
Jim McAdam, Manager, Kalalla Station, Daly Waters

"....In developing or maintaining a sustainable and economic pastoral enterprise, a sensible stocking rate, relative to available waters, and land systems, coupled with regular spelling of paddocks is essential.

Use of improved pasture, not a method of drastically increasing stocking rates as a whole, but as a tool aiding weight for age weaning, good holding areas creating flexibility for market variations and delays, and hardy species to reduce the severity of sacrifice areas.

Prepare financially and mentally for the costs of distance, delay and apathy.
Mike Harding, Gorrie Station.

AUTHOR'S NOTE

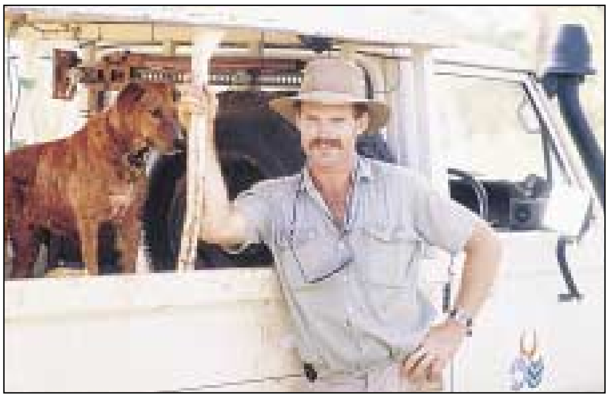


Plate 101
Fergal O'Gara.

The need for awareness about the condition of our planet has never been greater and the challenges we face rival any in history. If we are to protect and preserve our environment we must do our part as nations, families and as individuals.

Just as there is an urgent need to protect our air, rivers, lakes, forests and oceans for future generations, it is also critically important we protect the vitality and productivity of our grazing and crop lands. These natural resources, on which our survival depends, can no longer be looked at in isolation. They are all inter-connected and part of the one great system, called earth. We must find better ways of protecting and managing the whole system. This will require new ways of thinking, much learning and co-operation.

Sustainable agriculture, new age agri-chemicals, precision farming and genetic manipulation are promoted as solutions to many of our agricultural and land management problems.

However, these advances will not be enough unless there is a corresponding change in our attitudes and values. Unless we change the way we think and act we will continue to make the same mistakes. Along with new technology, we must adopt a new and more enlightened approach to our relationship with the land.

We must seek better management alternatives and respect the land as we respect any finite resource. Conservation farming is one alternative which will work only when we understand why we need to use it. I hope this book, provides some impetus and ideas for a better way of thinking about and managing the land in northern Australia.

Fergal O'Gara is a graduate of Wagga Wagga Agricultural College (Charles Sturt University), Queensland Agricultural College, and the University of Western Sydney. He has spent ten years with the Northern Territory Department of Primary Industry and Fisheries developing and extending conservation farming and mixed farming systems in association with producers of the Top End.

GLOSSARY OF TERMS

Acidic soil •
Soil with a pH value less than 7.0. In highly acid soils some nutrients and elements become toxic, while others are unavailable resulting in poor plant growth.

Acidification •
The process by which soils become increasingly acidic due to leaching of minerals such as Ca, Mg, K and nitrate nitrogen.

Alkaline soil •
Opposite to acidic. Soils with a pH value greater than 7.0.

Amelioration of soil •
To correct or improve the condition of the soil through some practice such as liming or cultivation etc.

Annual •
A plant that completes its lifecycle within one year and then dies.

Arable land •
Land which is capable of the production of cultivated crops.

Available water •
Portion of water in the soil which can be used by plants.

Beneficial insects •
Insects which are natural enemies of crop and pasture pests and thus play a role in reducing pest populations.

Biological control •
The use of naturally occurring insects or disease organisms to assist in control of pests in crops and pastures.

Boomspray •
Mechanical device consisting of chemical tank, pump, boom and nozzles designed to apply agricultural chemicals.

Buffering capacity •
The capacity of a soil to resist changes in pH.

Build-up (climate) •
A term used to describe the period that coincides with the early part of the wet season when the temperature and humidity increase prior to the onset of the monsoon.

Calibrate (chemical) •
Accurately measure the output per unit area of chemical from a boomspray or other application device.

Carrying capacity •
The ability of a unit of land to adequately support a given number of livestock without degrading the resource.

Combine •
A planter designed sow a range of crops and pastures in narrow rows, usually less than 500 mm.

Compaction of soil •
Compression of the soil surface or sub-soil through the movement of stock or machinery leading to reduced water infiltration and restricted root growth.

Conservation farming •
A broad term referring to a combination of farming techniques designed to conserve soil and water. Usually involves mulch retention and reduced tillage.

Contour •
An imaginary line connecting points of equal height over the land.

Contour bank •
A soil conservation bank constructed at a slight gradient to the contour to direct runoff water across the slope at low velocities.

Contour tillage/farming •
A system where tillage or farming is carried out on or near the contour of the land to slow the flow of surface water.

Conventional cultivation •
A term referring to traditional practices where several tillage operations are carried out and plant residues are incorporated prior to planting.

Coulter •
A disc used on conservation tillage planters to cut surface mulch and allow tines or furrow openers to pass without blockage.

Cover crop •
A quick growing crop used specifically as mulch to protect the soil.

Crust •
A hard soil surface layer that is compacted and which restricts the entry of water and the emergence of seedlings.

Cultural management •
The use of agronomic practices to disrupt the lifecycle of pests and disease, such as rotations, cultivation and resistant varieties.

Cyclone •
A tropical low pressure system associated with rising warm air and clockwise air circulation which generates high velocity winds and heavy rain.

Dhal •
De-husked, split legume seed used in Asian cooking.

Degradation of soil •
Physical damage or a reduction in the soil's productive capacity due to processes such as erosion, acidification, salinisation or weed infestation.

Desiccant •
Chemical applied to crops to hasten the dry down period; enables earlier harvesting and reduces seed loss.

Digestibility •
The percentage of the total plant which can be digested or absorbed by the grazing animal for its metabolism and growth.

Diversion bank •
Soil conservation bank designed to divert water before it reaches a designated site or cropping area.

Dry matter •
The portion of plants or vegetation which is not water.

Dryland farming •
Rain-fed production of crops and pastures.

Erosion •
The wearing away of the land surface by the action of wind and/or water.

Evaporation •
The conversion of water to vapour and its subsequent loss from free water bodies or the soil surface.

Floodplain •
Practically level land situated close to a channel which is subject to overflow or flooding.

Foliar herbicide •
Herbicide which is applied to the foliage of plants and is taken up through the leaves.

Furrow •
A slot or depression created by the passage of planter tines into which the seed is placed. Furrows are also created by cultivation.

Glyphosate •
Translocated non-selective herbicide used in conservation farming systems.

Green manure crop •
Crop grown for the purpose of improving soil fertility and structure and which is returned to the soil.

Growth promotant •
Synthetic hormone administered to livestock to enhance feed conversion and growth rates.

Hardpan •
A compacted and hardened layer of sub-soil which impedes water flow and root growth.

Herbicide •
Chemical which is biologically active and is used to kill or control the growth or emergence of specific plants and weeds.

Hybrid •
Plant or animal resulting from a cross between parents which are genetically different.

Immobilisation of nitrogen •
The conversion of N to an organic form in microbial or plant tissue which is unavailable for uptake or use by plants.

Improved pastures •
Introduced or exotic pasture species with superior nutritional or growth characteristics to native pastures.

Infiltration •
The rate at which water is taken into the soil, usually measured in mm/hr.

Inoculum (plant disease) •
The disease organism or its parts that contact the plant and cause the infection.

Integrated pest management (IPM) •
Pest management systems which incorporate a range of practices to keep pests below economic injury levels. IPM includes chemical, cultural, biological, physical and quarantine controls.

Ironstone gravel •
Gravel nodules high in iron oxides found in many soils in the Top End

Kaolinite clay •
Hydrous, non-expanding clay mineral containing aluminosilicates and having 1:1 crystal structure.

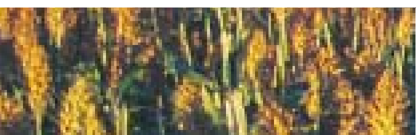
Lateritic soil •
Soils of various textures containing (10-50%) ironstone gravel in the surface layers or within the profile.

Leaching •
The downward removal of nutrients and chemicals in solution through the soil.

Legume •
A member of the Leguminosae or pulse (beans and peas) family most of which use *Rhizobium spp.* associations to fix atmospheric nitrogen.

Legume inoculation •
Coating legume seed with a specific culture of *Rhizobium* bacteria to promote effective nodulation and enhance nitrogen fixing.

Legume understorey •
Legume pasture grown in conjunction with an annual crop.



Ley/Ley farming •
Refers to the practice of rotating legume pastures with annual crops to improve soil structure and fertility and to provide grazing for stock. The pasture phase is the ley phase.

Liming •
Application of lime (calcium oxide CaO) or similar neutralising material to reduce soil acidity.

Liveweight gain •
Increase in animal liveweight when measured from a specific point in time.

Major elements or nutrients •
Chemical elements required in the largest quantities for plant growth, ie. nitrogen, phosphorus, potassium.

Mimosine •
Toxic amino acid found in the foliage of leucaena (*Leucaena leucocephela*).

Mineralisation of nitrogen •
The conversion of N from an organic form to an inorganic form as a result of microbial decomposition. It can then be utilised by plants.

Minimum tillage •
A system where tillage is reduced to the minimum required to achieve a suitable environment for plant establishment.

Micro-nutrient •
Nutrients or elements required in minute quantities but essential for plant growth ie. zinc, copper, iron.

Monitoring •
Regular inspection of crops to identify insect and disease activity in order to determine whether control measures are necessary. Monitoring is an integral part of integrated pest management.

Mulch •
A natural layer of plant residue or live vegetation on the soil surface. Mulch may also be artificial, ie. plastic, paper.

Native pastures •
Natural pastures consisting of original plant species.

Nematode •
Microscopic wormlike organism some of which are parasites of crops and pastures.

No-tillage •
A system of establishing crops and pastures without prior cultivation. Specialised planters are used and weeds are controlled using herbicides.

Node •
Slightly enlarged portion of the stem where leaves, buds or roots arise.

Nodulation •
The process by which legume roots are colonised by *Rhizobium* bacteria and nodules are formed.

Non-selective herbicide •
A herbicide which is non-specific and controls most vegetation to which it is applied. Glyphosate is an example of a non-selective herbicide.

Noxious weed •
Any plant which is deemed harmful, damaging or causes a loss in production or intrinsic values may be declared noxious. Its control will be determined by relevant legislation.

Nutrient •
Element which is taken up and used by plants for growth and reproduction.

Organic farming •
Farming without the use of chemical fertilisers and pesticides.

Oxalates •
Oxalic acid found in many plants causing gastroenteritis or hypocalcaemia (low blood calcium levels) in livestock. Kazungula, buffel and other pastures may contain oxalic acid. Horses are particularly susceptible to oxalic poisoning.

Pasture decline •
A gradual process of productivity decline associated with nutrient immobilisation or loss of productive species.

Pasture utilisation •
The proportion of total pasture dry matter consumed by livestock. Usually expressed as a percentage of the total.

Percolation •
The downward movement of water through saturated soil.

Perennial •
A plant which continues to grow from year to year.

Permeability of a soil •
The ease with which water enters and passes though the soil.

Pesticide •
Term used for any chemical used for the control of weeds, insects or disease in crops and pastures.

pH of soil •
A numerical scale indicating the degree of acidity or alkalinity of a soil with pH 7.0 being neutral.

Pod-sucking bugs •
Insect pests of the *Hemiptera* family which have sucking mouth parts and feed on the sap of immature pods and seeds.

Podsolic soil •
Soils with texture profiles which change from light surfaced to bleached, heavier clay layers at depth. Usually poorly drained and subject to waterlogging in the wet season.

Presswheel •
Device used on planters to assist in covering the furrow, improving seed to soil contact and enhancing emergence.

Proboscis•
Piercing, needle-like mouth parts of plant-sucking bugs and predatory shield bugs.

Prussic acid •
Hydrocyanic acid (HCN) formed in sorghum plants as a result of stress or rapid growth. Causes poisoning in livestock.

Red earth •
Class of soils which are the massive structured red clay loam and sandy loam soils of the Top End.

Reduced tillage •
Synonymous with minimum tillage

Rejuvenation of pastures •
Renovation of 'run-down' pastures by undertaking weed control, reseeding, fertilising or other practice to improve productivity.

Residual herbicide •
Herbicide which is soil-acting and controls germinating weeds over an extended period.

Rhizobia •
Bacteria which colonise the roots of legumes and are capable of fixing atmospheric nitrogen for the benefit of the plant.

Rhizome •
Underground stems formed by many plants as a means of vegetative spread.

Rilling (erosion) •
Small intermittent channels only centimetres deep which usually occur as a result of runoff on newly cultivated land.

Rotation •
A management system where crops and pastures are grown in alternate years, to control weeds, insect pests and diseases and maintain soil structure and fertility.

Row-crop planter •
A precision planter designed to sow crops in discrete rows of 0.5 to 1.0 m. Usually used in maize, cotton and peanut production.

Runoff •
Rainfall in excess of the infiltration rate which is lost as surface flow.

Sediment •
Suspended soil particles which are carried away in runoff water and are deposited further down the slope.

Seed-firming wheel •
A term given to a specific type of presswheel which presses the seed lightly into the bottom of the furrow rather than compacting soil on top of the seed.

Seed inoculation •
Application of a specific *Rhizobium* culture to legume seeds to induce nodulation and nitrogen fixation.

Selective herbicide •
A herbicide which controls a specific group of plants but is inactive against others, ie. grass herbicides.

Semi-arid tropics •
A term given to a tropical area in which there is a distinct dry period which severely limits plant growth.

Soil microbes •
Beneficial and harmful species of bacteria, fungi and other microscopic organisms which are a part of the soil's ecology.

Soil structure •
The physical arrangement of soil particles into units or aggregates.

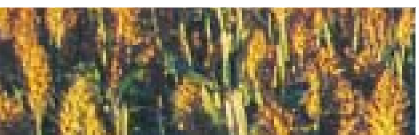
Sowing point •
The part of the planter which physically engages the soil creating a furrow into which the seed is placed.

Stocking rate •
The number of stock units run on a particular area of land.

Strip cropping •
Growing crops in an arrangement of strips that serve as protection against wind or water erosion.

Stubble •
Plant residue left over from a crop.

Supplemented cattle •
Cattle which are provided with mineral or fodder supplementation to overcome temporary deficiencies in nutrition.



Surfactant •
Chemical additive which improves the dispersion, spreading and wetting action of herbicides or other chemicals.

Sustainable •
Term used to describe agricultural practices which allow continued and viable production without degrading natural resources.

Tahini •
Paste made from sesame seed.

Tillage •
Cultivation or mechanical working of the soil.

Tilth •
The physical condition of the soil as related to ease of tillage, fineness of seedbed and impedance to seedling emergence.

Tindall clay loam •
Class of sandy clay loam and clay loam red earth soils with structured B horizon. Agriculturally important and found in the Katherine-Daly Basin.

Tippera clay loam •
Similar soil type to Tindall but has a massive hard structured B horizon.

Top End •
Northern-most area of the Northern Territory (above 16°S) in which the production of dryland crops is possible during the wet season.

Trace elements •
Also called micro-nutrients. Elements required by plants in minute quantities but essential for healthy plant growth.

Trafficability •
Refers to the ability to travel or drive over the land in order to carry out some operation, ie. cultivating, spraying or sowing.

Transition period •
The period between the dry season and the onset of the wet season when sporadic storms cause spoilage of dry feed.

Trap-cropping •
The practice of growing a sacrifice crop to encourage insect pests which may later be chemically or physically controlled.

Tropics •
Geographical regions between the tropics of Capricorn and Cancer.

Tine •
Shank on a planter or cultivator to which sowing or cultivating points are attached.

Vector •
Insect, fungus, nematode or other organism which transmits disease.

Water holding capacity •
The amount of water a soil can hold and make available for plant use. Sands and clays have low and high water holding capacities, respectively.

Waterlogged •
Saturated with water. Conditions detrimental to plant growth. Common problem in some soils during the wet season.

Waterway •
A structure designed to collect runoff water from diversion and contour banks and carry it safely to a discharge area or natural water course.

Wetting agent •
Synonymous with surfactant.

Appendix 1 – NOXIOUS WEEDS

Northern Territory Noxious Weeds Act and list of noxious weeds.

The Northern Territory Noxious Weeds Act is aimed at preventing the introduction and spread of noxious weeds. A plant may be declared noxious, over the whole or part of the Territory.

Landholders can be issued with a notice to eradicate or control a Class A or B noxious weed. Persons in possession of hay or animal fodder containing seeds of noxious weeds may be issued with a notice not to sell and to destroy hay or fodder by specified means.

Failure to comply with a notice can result in a penalty, conduct of the work by authorised persons and cost recovery action. Assistance in the form of materials, equipment and labour may be provided to persons issued with a notice.

There are three classifications recognised under the Act.

Class A: To be eradicated.
These are weeds which pose a significant threat but occupy a relatively small area and there is a good chance of eradication.

Class B: Growth and spread to be controlled.
These weeds are widely distributed but prevention of further spread is desirable. Eradication may be possible if they occur in geographically isolated areas.

Class C: Not to be introduced into the Northern Territory.
This class includes weeds which are not known to exist in the Territory but could pose a significant threat if introduced. It also includes all Class A and B weeds, as further introductions of these would aggravate existing problems.

CLASS A NOXIOUS WEEDS - to be eradicated

COMMON NAME	BOTANICAL NAME
Cutch tree	*Acacia catechu*
Prickly acacia	*Acacia nilotica*
Onion weed	*Asphodelus fistulosus*
Baleria	*Barleria prionitis*
Ornamental rubber vine	*Cryptostegia madagascariensis*
Dalbergia	*Dalbergia sissoo*
Longspine thornapple	*Datura ferox*
Paterson's curse	*Echium plantagineum*
Water hyacinth	*Eichhornia crassipes*
Physic nut	*Jatropha curcas*
African boxthorn	*Lycium ferocissimum*
Devil's claw	*Martynia annua*
Mimosa, giant sensitive plant	*Mimosa pigra*
Parthenium weed	*Parthenium hysterophorus*
Salvinia	*Salvinia molesta*
Chinee apple, Indian jujube	*Ziziphus mauritiana*

CLASS B NOXIOUS WEEDS - growth and spread to be controlled

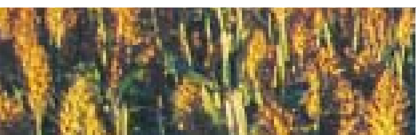
COMMON NAME	BOTANICAL NAME
Star burr, goat's head	*Acanthospermum hispidum*
Khaki weed	*Alternanthera pungens*
Mexican poppy	*Argemone ochroleuca*
Rubber bush	*Calotropis procera*
Saffron thistle	*Carthamus lanatus*
Mossman River grass	*Cenchrus echinatus*
Spiny emex	*Emex australis*
Hyptis	*Hyptis suaveolens*
Bellyache bush	*Jatropha gossypifolia*
Common lantana	*Lantana camara*
Creeping lantana	*Lantana montevidensis*
Lion's tail	*Leonotis nepetifolia*
Mimosa, giant sensitive plant	*Mimosa pigra*
Common sensitive plant	*Mimosa pudica*
Prickly pears	*Opuntia* spp.
Mission grass	*Pennisetum polystachion*
Water lettuce	*Pistia stratiotes*
Parkinsonia	*Parkinsonia aculeata*
Mesquite, algaroba	*Prosopis limensis*
Castor oil plant	*Ricinus communis*
Salvinia	*Salvinia molesta*
Candle bush	*Senna alata*
Sicklepod	*Senna obtusifolia*
Coffee senna	*Senna occidentalis*
Spinyhead sida	*Sida acuta*
Flannel weed	*Sida cordifolia*
Paddy's lucerne	*Sida rhombifolia*
Snake weeds.	*Stachytarpheta spp.*
Tamarisk, Athel pine	*Tamarix aphylla*
Grader grass	*Themeda quadrivalvis*
Caltrop	*Tribulus cistoides*
Caltrop	*Tribulus terrestris*
Noogoora burr	*Xanthium occidentale*
Bathurst burr	*Xanthium spinosum*

CLASS C Noxious weeds - not to be introduced to the Territory

COMMON NAME	BOTANICAL NAME
Creeping knapweed	*Acroptilon repens*
Mistfower	*Ageratina riparia*
Alligator weed	*Alternanthera philoxeroides*
Annual ragweed	*Ambrosia artemisiifolia*
Perennial ragweed	*Ambrosia psilostachya*
Groundsel bush	*Baccharis halimifolia*
Siam weed	*Chromolaena odorata*
Rubber vine	*Cryptostegia grandiflora*
Thornapples	*Datura* spp.
Dense waterweed	*Egeria densa*
Canadian pondweed	*Elodea canadensis*
Harrisia cactus	*Eriocereus martinii*
Knobweed	*Hyptis capitata*
Lagarosiphon	*Lagarosiphon major*
Giant sensitive plant	*Mimosa invisa*
Mesquite	*Prosopis* spp.
Johnson grass	*Sorghum halepense*
Burrs	*Xanthium* spp.

WEED THREATS TO THE NORTHERN TERRITORY

COMMON NAME	BOTANICAL NAME
Siam weed, Christmas bush	*Chromolaena odorata*
Spindletop	*Cleome rutidosperma*
Barnyard grass	*Echinochloa glabrescens*
Sprangletop	*Leptochloa spp.*
Yellow sawah lettuce	*Limnocharis flava*
Mile-a-minute	*Mikania micrantha*
Small rat's ear	*Mucuna pruriens*
Salvinia	*Salvinia cucullata and Salvinia natans*
Fireweed	*Senecio madagascariensis*

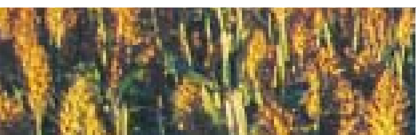


Appendix 2 – COMMON INSECT PESTS OF CROPS AND PASTURES

INSECT	CROPS AFFECTED	IMPORTANT COMMENTS
Wireworms & False Wireworms	Sorghum, maize, pastures and legume seed crops	Damaging at establishment and seedling stage. Determine numbers & activity with bait. Use seed treatment or in-furrow chemicals. Presswheels reduce pest mobility.
Earwigs	Range of crops and pastures	Damaging at establishment period & seedling stage.
Scarab beetles	Range of crops and pastures	Occur at establishment period & seedling stage.
Locusts and Grasshoppers	Sorghum, maize, legumes and pastures	Young hoppers damage establishing crops. Adults damage vegetative and maturing crops.
Helicoverpa (heliothis) caterpillars	Wide range of crops and pastures	Active all season, particularly damaging at flowering, grain and pod development. Chemical control if at damaging level.
Armyworms and various caterpillars	Wide range of crops and pastures	Sporadic pests of vegetative parts. Large numbers will damage crops.
Bean pod borer	Mungbean, soybean and other legume crops	Feed on flowers and the maturing pods. Difficult to control when inside the pod. Early detection necessary for control.
Sesame leaf roller	Sesame	Feed on leaves, flowers and maturing pods.
Sorghum midge	Grain sorghum	Feed on florets and immature seeds preventing development of grain. Resistant varieties are available. Chemical control at flowering. Not serious in dryland but damaging in irrigated crops.
Plant hoppers, aphids, thrips and mirids	Range of crops and pastures	Damage crops by sucking sap and transmission of plant diseases..
Pod suckers ie. green vegetable, Riptortus & other shield bugs	Grain legumes and legume pastures	Suck sap from immature pods and seed. May cause significant damage to grain and pasture legumes. Must be detected at flowering and early pod stage for effective control.
Stem borer moth	Rice	Larvae chew through and feed within the stem damaging head & reducing grain fill.
Leaf roller	Rice	Larvae eat and roll leaves into tubes in which they later pupate.
Caseworm moth	Rice	Feed on leaf surface

Appendix 3 – COMMON DISEASES IN CROPS AND PASTURES

DISEASE	CROPS AFFECTED	IMPORTANT COMMENTS
Charcoal rot	Sorghum.	Occurs under moisture stress in susceptible varieties. Crops lodge as a result. Use tolerant varieties and reduce stress with mulch.
Stem rots and blights	Sorghum, maize, legume crops and pastures.	Occur under moisture stress and high temperatures. Can kill seedlings. Use tolerant varieties and maintain mulch.
Crown rots	Peanut.	Favoured by excessively wet conditions and plant injury. Improve drainage and avoid plant damage.
Damping-off, ie. seed and root rots	Most crops and pastures.	Damage seed or roots of seedlings under prolonged waterlogged conditions. Improve soil drainage, use rotations and fungicidal seed treatment.
Head and grain moulds	Maize, sorghum, millet.	Occur in prolonged moist conditions after grain maturity. Sow at correct time and use open-headed varieties.
Leaf spots and blights	Most crops and pastures. Serious in rice and peanut.	Organisms survive in infected volunteer plants and stubble. Use crop rotation and resistant varieties. Apply fungicides to high value crops like peanut. Control volunteer plants.
Bacterial leaf blights	Most crops and pastures, serious in legume crops.	Diseases survive in infected seed and plant material. Favoured by rainy weather. Use resistant varieties and crop rotation.
Viral diseases	Maize, peanut and most crops and pastures.	Spread by sap-sucking insect vectors such as aphids, white fly and leafhoppers. Control insects and use virus-free seed.
Little leaf	Most legume crops and pastures.	Spread by insect vectors such as aphids, white fly and leafhoppers. Control insects.
Rusts	Sorghum, maize, legume crops and pastures.	Minor diseases at present. Controlled by crop rotation, cultural practices.
Powdery mildew	Mungbean & other crops.	Minor but damaging to susceptible varieties in the dry season under irrigation.



Appendix 3 continued.

Common and scientific names of plant diseases

Grain Sorghum

Grain mould	*Aspergillus flavus.*
Assoc. head mould	*Fusarium* sp. *Penicillium* sp., *Curvularia* sp. *Drechslera* sp.
Leaf spot	*Bipolaris sorghicola, Drechslera sp.*
Tar spot	*Phyllachora sacchari*
Grey leaf spot	*Cercospora sorghi.*
Upper stalk rot	*Fusarium moniliforme.*
Charcoal rot	*Macrophomina phaseolina.*
Bacterial leaf streak	*Xanthomonas campestris pv. holcicola.*
Bacterial leaf spot/streak	*Pseudomonas* sp.
Rust	*Puccinia purpurea*
Red stripe	*Johnsongrass mosaic virus.*

Sesame

Leaf spot (small)	*Cercospora sesami. (Mycosphaerella sesami).*
Pod/stem/leaf sopt	*Corynespora cassiicola.*
Ashy stem blight	*Macrophomina phaseolina.*
Leaf spot (large)	*Pseudocercospora sesami. (Mycosphaerella sesamicola).*
Powdery mildew	*Oidium* sp.
Little leaf	*Tomato big bud phytoplasma.*

Mungbean

Leaf spot	*Cercospora cruenta.*
Wet rot, blight	*Choanephora cucurbitarum.*
Ashy stem blight	*Macrophomina phaseolina.*
Damping-off, stem rot, base rot and leaf blight	*Rhizoctonia* sp., *Sclerotium rolfsii.*
Powdery mildew	*Sphaerotheca fuliginea (Oidium* sp.).
Bacterial leaf spot	*Xanthomonas campestris pv. phaseoli.*
Little leaf	*Tomato big bud phytoplasma.*
Zonate leaf spot	*Undet. (Agonomycetales).*

Centrosema species

Leaf spot	*Cercospora* spp.
Stem rot	*Macrophomina phaseolina.*
Leaf blight	*Rhizoctonia solani.*

Soybean

Purple stain of seed	*Cercospora kikuchii.*
Pod lesion, leaf spot	*Cercospora* sp.
Mould	*Choanephora cucurbitarum.*
Flower blight	*Colletotrichum truncatum.*
Seed rot	*Fusarium compactum.*
Seed contaminant	*Fusarium proliferatum.*
Ashy stem blight, pod and stem lesions	*Macrophomina phaseolina.*
Rust	*Phakopsora pachyrhizi.*
Bacterial wilt & blight	*Pseudomonas* spp.
Stem rot	*Pythium sp., Sclerotium rolfsii.*
Bacterial pustule	*Xanthomonas campestris pv. glycine.*
Little leaf	*Tomato big bud phytoplasma.*

Peanut

Kernel mould	*Aspergillus flavus.*
Crown rot	*Aspergillus niger.*
Early leaf spot	*Cercospora arachidicola.*
Leaf spot	*Cercosporidium personatum.*
Stem rot	*Macrophomina phaseolina.*
Bacterial wilt	*Pseudomonas solanacearum.*
Rust	*Puccinia arachidis.*
Wilt	*Pythium myriotylum.*
Stem rot	*Sclerotium rolfsii.*

Maize

Southern leaf blight	*Bipolaris maydis.*
Grain mould	*Fusarium chlamydosporum.*
Grain mould	*Fusarium proliferatum.*
Java downy mildew	*Peronosclerospora maydis.*
Tropical rust	*Puccinia polysora.*

Maldonado

Blight, patch death	*Rhizoctonia solani.*

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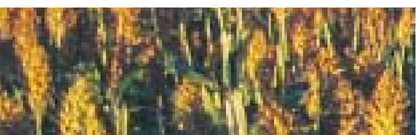

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