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Mosaic irrigation for the northern Australian beef industry

An assessment of sustainability and potential

Synthesis Report

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OVERVIEW

This is a synthesis of a more comprehensive technical report[1], prepared by CSIRO for the Office of Northern Australia, addressing the prospects for using mosaic irrigation to produce forage to enhance beef production on northern Australian pastoral properties. Irrigation mosaics are "irrigation schemes in which small patches of irrigation occur within a region rather than irrigation of one large contiguous area" (Cook *et al.* 2008[2]). In relation to the northern beef industry, mosaic irrigation involves small-scale irrigation developments that produce feed for cattle and are scattered within a matrix of unirrigated, generally native or naturalised, pastures. This project focussed on that part of the continent north of the Tropic of Capricorn, but excluded the eastern flowing catchments, east of the Great Dividing Range in Queensland (Figure 1).

This synthesis presents a series of key messages about the opportunities for establishing and operating mosaic irrigation for beef production, analysing prospects at enterprise, industry and regional levels. These key messages are followed by brief summaries of the nine chapters of the technical report.

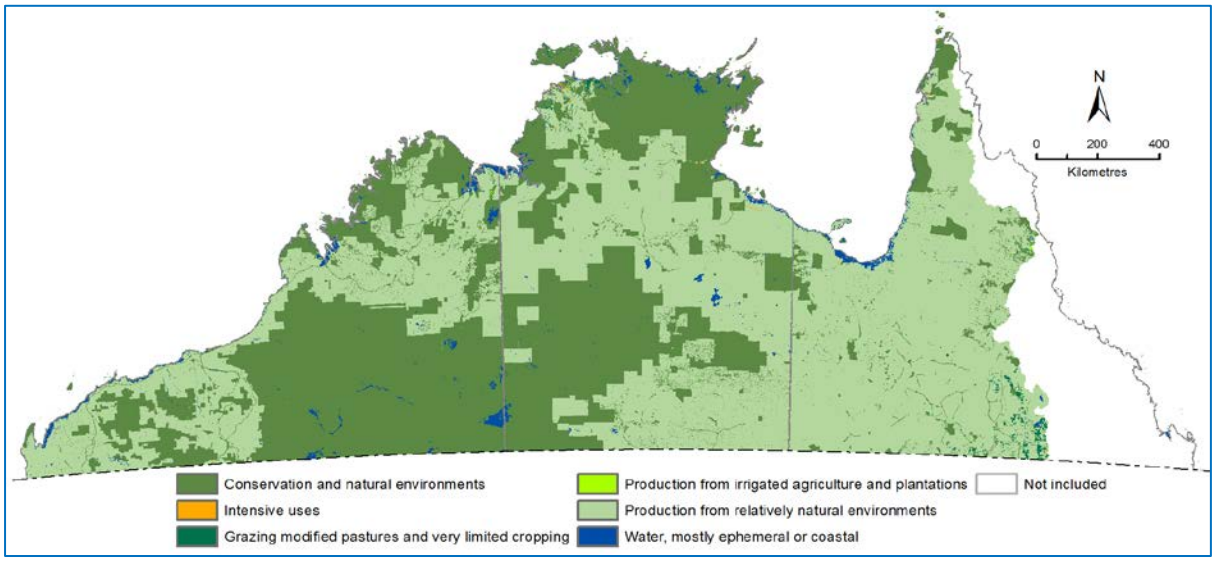
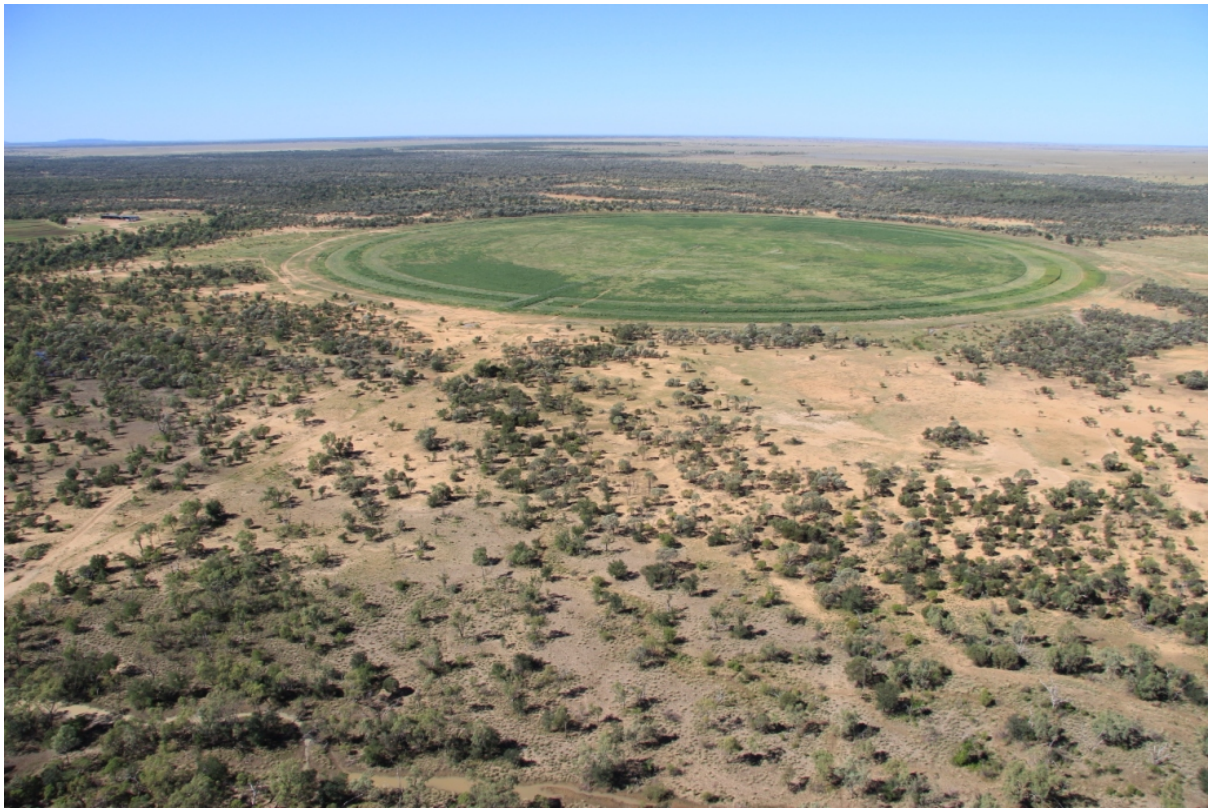


Figure 1. Land use within the project area.

[1] Grice AC, Watson I and Stone P (2013) Mosaic Irrigation for the Northern Australian Beef Industry. An assessment of sustainability and potential. Technical Report. A report prepared for the Office of Northern Australia. CSIRO, Brisbane.

[2] Cook, F. J., Xevi, E., Knight, J. H., Paydar, Z., and Bristow, K. L., (2008). 'Analysis of biophysical processes with regard to advantages and disadvantages of irrigation mosaics.' CRC for Irrigation Futures Technical Report No. 07/08; CSIRO Land and Water Science Report 14/08. (CSIRO, Land and Water Australia, National Program for Sustainable Irrigation, CRC for Irrigation Futures and the Governments of Australia: Queensland, Northern Territory and Western Australia).



Source: Heinz Buettikofer (CSIRO Land and Water)

KEY MESSAGES

1. Northern Australian groundwater resources provide opportunity to increase beef production via irrigation.
2. Mosaic irrigation to support northern Australian beef enterprises has the potential to become more commonplace over the next decade.
3. A high proportion of northern Australia's pastoral properties may have enough suitable soils and water for small-scale irrigation.
4. Ready availability of forage grown on property could drive positive change to beef production systems and boost productivity at the enterprise scale.
5. Mosaic irrigation to enhance the beef industry is not dependent on large scale public investment in infrastructure.
6. The environmental impacts of mosaic irrigation development will be small compared with those of the cattle industry itself and other land uses.
7. Mosaic irrigation promises modest benefits to northern beef enterprises provided systems are carefully designed, constructed and managed.
8. While they are small compared with the size of pastoral stations, mosaic irrigation units may constitute a high proportion of the capital value of the entire enterprise.
9. There is renewed and new impetus for the diversification of pastoral enterprises in northern Australia.
10. Constraints to the development of mosaic irrigation on beef cattle enterprises are largely institutional, social and economic, rather than biophysical.
11. Lack of data can obstruct sound decision-making.
12. Graziers planning mosaic irrigation must access specialist advice and carefully select where irrigation units are placed on their properties in order to maximise the chances of success.
13. The likely scale and distribution of mosaic irrigation suggest major regional impacts are unlikely.
14. Mosaic irrigation developments require an immediate return on investment.
15. Environmental risks must be managed strategically.
16. Mosaic irrigation is unlikely to transform landscapes or the northern beef industry, but it has potential to transform some businesses/enterprises.

1. NORTHERN AUSTRALIAN GROUNDWATER RESOURCES PROVIDE OPPORTUNITY TO INCREASE BEEF PRODUCTION VIA IRRIGATION

The limited data available suggest that 600 GL/year of extractable groundwater could be available to irrigate between 50,000 and 120,000 ha in northern Australia, depending on the type of crop (which dictates water requirements) and irrigation efficiency. This represents less than 0.08% of pastoral land and 0.05% of the entire project area.

The 600 GL/year is primarily derived from three basins:

(i) the central Daly-Wiso and Georgina;
(ii) the coastal section of the Canning basin; and
(iii) the Great Artesian Basin

Each has estimated extractable groundwater volumes of over 100 GL/year.

The remainder of the Daly-Wiso and Georgina and the inland portion of the Canning basin have estimated extractable groundwater volumes of between 10 and 100 GL/year.

Under favourable assumptions, this water could add as much as 10% ($200 M) to the value of beef production from pastoral lands in the project area or 6% across all of northern Australia (northern Western Australia, all the Northern Territory and Queensland). Estimates are based on the degree of uptake of available water, water use, forage yield per unit area, and cattle prices. Under modest assumptions, mosaic irrigation is likely to add 5% ($100 M) or less to the value of beef production in the project area. A 10% increase in the value of beef production would require an estimated capital investment by the industry of between $350 M and $1.32 B.

It is possible that a significant proportion of the available groundwater will be allocated to irrigation schemes or precincts that do not conform to a mosaic irrigation model, in which case water is used for production of crops rather than for cattle forage. An example is the Katherine-Douglas-Daly-Area which was developed by the Northern Territory government in the 1990s from what were pastoral properties.

There are around 300 pastoral properties in the project area in Western Australia and the Northern Territory. This sets an upper limit to the number of properties suitable for mosaic irrigation, and is a constraining factor in utilising the available water. However, the introduction of productive mosaic irrigation could make smaller properties more viable and allow subdivision of large properties. Very large properties could potentially establish multiple irrigation units.

2. MOSAIC IRRIGATION TO SUPPORT NORTHERN AUSTRALIAN BEEF ENTERPRISES HAS THE POTENTIAL TO BECOME MORE COMMONPLACE OVER THE NEXT DECADE

A significant proportion of northern Australian beef properties have the necessary physical resources, of water and suitable soils, to capitalise on mosaic irrigation. Whether the practice becomes commonplace will depend on the willingness of governments to provide practical support, the economics at the farm scale and an entrepreneurial spirit amongst graziers. This will need to be matched by their willingness to plan carefully and develop skills of their own in irrigated agriculture in remote environments, or partner with others who have them.

Practical support can be provided by governments by:

- streamlining the various approval processes under land tenure, planning, vegetation management, water resources, cultural heritage, and other legislation to facilitate mosaic irrigation or other diversification;
- progressing water resource planning in Western Australia, the Northern Territory and Queensland;
- water resource planning that explicitly favours many, dispersed, small water licences rather than a few, large licences or many licences but geographically aggregated;
- providing and supporting research, development and extension that delivers farming and irrigation systems adapted to the northern Australian environment;
- investing in the acquisition and analysis of higher resolution, better attributed data, including the use of newer techniques such as digital soils mapping and proving groundwater resources;
- encouraging a diversity of collaborative arrangements between commercial farming interests and graziers to overcome any shortfall in skills;
- facilitating connections between northern beef producers and investors from Australia and overseas;
- encouraging co-ordinated approaches across jurisdictions and departments by establishing collaborative links between relevant departments

While economic analysis suggests that growing forage for use on-property provides only a marginal economic return, this may change for the better due to altered economic circumstances such as a fall in the Australian dollar and improved beef markets or due to changes in opportunity such as a new abattoir in northern Australia.

Our evaluation is based on one representative property in each region and there will be some individuals who will inevitably get better economic performance than our assessment suggests due to their entrepreneurial spirit and innovation.

3. A HIGH PROPORTION OF NORTHERN AUSTRALIA'S PASTORAL PROPERTIES MAY HAVE ENOUGH SUITABLE SOILS AND WATER FOR SMALL-SCALE IRRIGATION

While there are a few areas that have sufficient water and suitable soils for scheme-scale irrigation, many properties in the north, even in areas of generally low overall prospectivity, are likely to have enough water and suitable soil for small-scale irrigation developments. This could be based on surface or groundwater, including localised groundwater resources which cannot be mapped with current knowledge. These localised water resources may be more variable and less reliable.

The resolutions of currently available water and land suitability maps are insufficient to identify prospective areas at property scale. Soil and water maps may show areas as not being prospective, when in fact they are.

4. READY AVAILABILITY OF FORAGE GROWN ON PROPERTY COULD DRIVE POSITIVE CHANGE TO BEEF PRODUCTION SYSTEMS AND BOOST PRODUCTIVITY AT THE ENTERPRISE SCALE

Improvements in the quality and/or reliability of forage supplies could drive significant changes to northern beef production enterprises and strengthen their financial position. This could occur through on-property production of quality forage under irrigation leading to increased total beef

production, more rapid turn-off, the production of higher quality animals and/or increased reproductive rates. Increased reproductive rates are the single biggest driver of increased profitability in the northern beef industry.

For example, 16 ha of irrigated forage could be used to feed 100, 30-month-old, 450 kg Brahman steers in order to have them reach 560 kg live-weight in 3 months. This yields an average net return of approximately $15,900 per annum or a marginal annual return of approximately 12% on capital investment. Average projected returns on investment in irrigation under a range of northern Australian scenarios varied from -5% for forage sorghum production to 44% for tropical perennial grass in the Kimberley. These returns do not account for capital outlays or interest payments – annual average returns of 20% before tax are generally considered marginal. The most favourable results are predicted for scenarios where forage production is high quality or available for an extended period of the year.

Early weaning was consistently raised by producers as having potential benefits. It allows the cow to recover condition in order to get in calf again and ensures the weaned calf is able to grow rapidly to sale weight, assuming sufficient feed is available. Studies show that early weaning is one of the best ways to improve beef enterprise performance. Simulations of early weaning suggested increased productivity of case study enterprises by allowing cows to produce more calves in their lifetime.

5. MOSAIC IRRIGATION TO ENHANCE THE BEEF INDUSTRY IS NOT DEPENDENT ON LARGE SCALE PUBLIC INVESTMENT IN INFRASTRUCTURE

Development of the infrastructure required for mosaic irrigation will be focused at the property, rather than regional, scale. The widely dispersed nature of mosaic irrigation units and the fact that the forage produced will mostly be used on-property means that public investment in regional infrastructure is not necessary. This does not, on its own, preclude public investment in infrastructure. However, public investment may be justified should an externality such as a new abattoir in the north, an associated feedlot, or a new market for northern beef arise. Additional labour to support the more intensive production will also be widely dispersed and unlikely to require further public investment in social infrastructure, such as schools or hospitals.

6. THE ENVIRONMENTAL IMPACTS OF MOSAIC IRRIGATION DEVELOPMENT WILL BE SMALL COMPARED WITH THOSE OF THE CATTLE INDUSTRY ITSELF AND OTHER LAND USES

The proportion of northern Australia's pastoral lands that are likely to come under mosaic irrigation is of the order of less than 0.08%. However, because irrigation mosaics are likely to be in areas of high environmental value, point scale environmental impacts may still be significant and all irrigation developments will need to consider both on- and off- site environmental impacts.

7. MOSAIC IRRIGATION PROMISES MODEST BENEFITS TO NORTHERN BEEF ENTERPRISES PROVIDED SYSTEMS ARE CAREFULLY DESIGNED, CONSTRUCTED AND MANAGED

Establishment of mosaic irrigation units will require substantial capital investment with costs varying depending on circumstances. The initial capital outlay for a 100 ha irrigation unit would be at least $700,000 and it could be as high as several million, including design and survey, land clearing and preparation, water supply and the purchase of machinery. Running costs will also be substantial. An enterprise must be able to service any debt associated with capital investment in mosaic irrigation and manage any risks involved.

For many producers, growing forage as a by-product of a cash cropping enterprise may be a more viable financial option than just growing forage species though this will depend upon the marketing options available. The case for justifying investment in mosaic irrigation for beef production must incorporate consideration of the opportunity costs involved.

Acquiring and/or hiring the skills required to establish and operate irrigation systems will be critical if traditional northern extensive beef enterprises are to transition to include small-scale irrigation developments.

Success in enhancing northern Australian cattle enterprises with mosaic irrigation will depend not simply on growing more cattle but on producing a higher grade of animal that attracts premium prices, is sold into a higher value market or reaches turnoff weight more quickly than from grazing native pastures. Irrigation would strengthen the capacity of northern beef enterprises to finish cattle rather than sell only store cattle.

Specialist expertise will be crucial at all stages of development and operation of a mosaic irrigation unit. There is no single recipe for irrigation development on northern Australian beef properties and each development will have its own challenges.

Production in any one year may be vulnerable to climatic and other exigencies so producers must be financially buffered to withstand these failures due to environment.

8. WHILE SMALL COMPARED WITH THE SIZE OF PASTORAL STATIONS, MOSAIC IRRIGATI0N UNITS MAY CONSTITUTE A HIGH PROPORTION OF THE CAPITAL VALUE OF THE ENTIRE ENTERPRISE

Mosaic elements would typically constitute much less than 0.1% of the area of a property. However, a large mosaic irrigation development on a lower-priced property might constitute up to one-half of the capital value of the property. Management must be sound in order to ensure adequate return on that capital

The capital investment required to establish 50 ha or more of mosaic irrigation from scratch will be anywhere from $350,000 to several million. This is a large investment compared with the capital cost of beef cattle enterprises typical of northern Australia and, almost certainly, will require borrowed money. The return must be sufficient to warrant such an investment. There is likely to be little room for the effects of poor management or significant set-backs due to severe climatic or other environmental events. The imperative to manage irrigated production well will have profound effects on the operation of the beef enterprise. Irrigation should not be thought of as peripheral or subsidiary to the beef enterprise but as integral to it, requiring financial, labour and management skills of a calibre at least equal to that of the beef operation.

9. THERE IS RENEWED AND NEW IMPETUS FOR THE DIVERSIFICATION OF PASTORAL ENTERPRISES IN NORTHERN AUSTRALIA

Social, political and regulatory developments in northern Australia have improved the prospects for diversification such as irrigated agriculture. While pastoral holdings have traditionally been considered suitable for livestock grazing only, shifts in the attitudes of industry, government and the broader community have increased expectations for this region.

There are three broad groups of drivers for this change:

1. Changes in land use over the last few decades across the northern pastoral estate have seen a large number of properties no longer running commercial cattle herds. These properties have been bought for both private and public nature conservation, mining companies, tourist and "lifestyle" operators and Indigenous organisations.
2. Many graziers see diversification playing a major role in helping secure the future of northern Australia's grazing industry, enabling them to broaden their income stream and allow their businesses to better manage changing market conditions and market shocks to the cattle industry. The diversification options being considered include cash crops and forage cropping that will enable beef enterprises to have cattle reach turn-off weights sooner, meet markets with higher specifications, turn-off at times of year when prices are higher, and/or facilitate increased reproduction from first and second calf heifers, so broadening their market access.
3. The governments of Western Australia, the Northern Territory and Queensland each have strategies to substantially increase agricultural production in the next few decades. They have actively sought to facilitate this increase through land tenure reform, water resource planning and a range of development activities aimed at intensifying agricultural land use in the north of each jurisdiction.

The Northern Australia Beef Industry Working Group, convened through the Northern Australian Ministerial Forum, has produced an action plan for the northern beef industry. This working group is comprised of industry and Indigenous advisory groups as well as Western Australia, Queensland, Northern Territory and Commonwealth government agencies. These government agencies are actively removing barriers to diversification and providing support to the beef industry to develop a more profitable and resilient business model. Many cattle producers are on the public record as supporting diversified uses for their pastoral properties and there is a correspondingly high demand for diversification permits and water licences across the northern cattle industry. Land tenure reform is one good example of where government, the pastoral industry and a range of other stakeholders are attempting to change the current system to facilitate the use of pastoral lands for purposes other than the grazing of extensive, mostly native, pasture.

10. CONSTRAINTS TO THE DEVELOPMENT OF MOSAIC IRRIGATION ON BEEF CATTLE ENTERPRISES ARE LARGELY INSTITUTIONAL, SOCIAL AND ECONOMIC, RATHER THAN BIOPHYSICAL

The water and soil resources of northern Australia are sufficient to allow the development of small-scale irrigation units in many regions. A few regions could reliably yield large amounts of ground or surface water but many smaller, local, sources also exist. Many northern properties would have at least some land that is topographically suitable and has irrigable soils.

In all jurisdictions there is land tenure, water resource and other legislation that controls whether and how mosaic irrigation might be implemented. There have been recent efforts to make legislation relating to diversification on pastoral leases more flexible, but some further changes may be helpful in facilitating the development of small-scale irrigation systems on beef properties. In particular, streamlining approval processes under current legislation would be valuable.

Prospective developers of small irrigation systems in the north need to be cognisant of legislation relating to clearing of native vegetation, biosecurity threats, conservation of flora and fauna, Native Title and cultural heritage. Small irrigation units in a mosaic format are unlikely to have more than a localised impact on many of these issues, especially because less than 0.1% of the landscape is likely to come under irrigation. However, introduced weeds pests and diseases do present regional risks.

Construction and management of even small irrigation units for the production of forage require skills in addition to those typically held by northern Australian beef producers. Successful operation of an irrigation unit will require labour input in addition to that normally associated with extensive pastoral properties. Suitably skilled labour may not always be readily accessible in remote areas, especially given the seasonal nature of the labour demand.

Mosaic irrigation has the potential to provide some employment opportunities including for Indigenous people in relatively remote areas.

11. LACK OF DATA CAN OBSTRUCT SOUND DECISION-MAKING

There are limited data available on the water, soils and other resources of many parts of northern Australia. Information on the environmental assets and values of northern Australia also varies in quality and intensity across the region. In some cases the data are grossly depauperate. Soil maps have been produced at very coarse scales so that small, but useful areas of soil suitable for irrigation are likely to exist though they do not show up at this resolution. This is particularly critical for mosaic irrigation developments where areas of, say 100 ha, may be sufficient to provide for a viable irrigation unit. Across large areas of Australia, data on key soil attributes are not available.

To maximise chances of success it will be important to make decisions based on sound information. Investment in data acquisition and analysis will be important. To really explore the prospects for mosaic irrigation in particular locations, higher resolution and more detailed data are necessary. This needs to occur at property and regional levels.

12. GRAZIERS PLANNING MOSAIC IRRIGATION MUST ACCESS SPECIALIST ADVICE AND CAREFULLY SELECT WHERE IRRIGATION UNITS ARE PLACED ON THEIR PROPERTIES IN ORDER TO MAXIMISE THE CHANCES OF SUCCESS

Specialist advice will be required during design, construction and operation of mosaic irrigation units. This will be important for tailoring the approach to each particular situation but also for maximising the chances of success.

Typically, pastoralists do not have all the skills necessary for constructing and operating irrigation systems and irrigation specialists are not commonly available in many northern areas. Collaborative arrangements (e.g. share farming, accessing consultants) with producers and others from outside the region may benefit pastoralists considering mosaic irrigation. Such models have worked elsewhere.

Graziers will need to “pick the eyes” out of the soils to ensure maximum productivity and minimise the risk of problems arising from soil-related factors. They will also need to ensure the reliability of their water supply, that it can yield the amount of water required, at the times it is required, and that water extraction will not lead to unacceptable environmental consequences.

13. THE LIKELY SCALE AND DISTRIBUTION OF MOSAIC IRRIGATION SUGGEST MAJOR REGIONAL IMPACTS ARE UNLIKELY

Major changes at a regional scale are unlikely to be generated by the economic and social activity arising from a relatively small number of widely dispersed irrigation units on beef cattle properties.

Unlike large-scale irrigation schemes that concentrate physical and economic activity, mosaic irrigation is, by definition, too dispersed to generate the same type and scale of positive and negative impacts.

Social impact would be more significant should development warrant secondary industries such as meat processing and feedlotting. In addition to the change in performance of beef enterprises, impacts will be felt through labour demands, changing town populations, and a range of flow on effects.

The northern beef industry is regarded as a key opportunity for sustainable wealth creation for Indigenous communities, through direct employment and business ventures. Although there is the potential to improve productivity within current operations, Indigenous pastoral enterprises are heavily exposed to another challenge, the live export trade. The loss of live export markets could lead to further decline in viability of Indigenous properties. Mosaic irrigation potentially addresses this risk through opportunities to adjust production to meet other marketing opportunites. Mosaic irrigation could also promote development of Indigenous industry if viewed as a new training opportunity that offers options beyond those pastoral activities that are traditional for Indigenous people.

14. MOSAIC IRRIGATION DEVELOPMENTS REQUIRE AN IMMEDIATE RETURN ON INVESTMENT

Economic analysis suggest that the development of mosaic irrigation must provide a return on investment from the start and failure to do so in the first few years may put the whole beef enterprise at risk. Furthermore, irrigation and soil management must be first class from the beginning because many soils in northern Australia are prone to rapid structural decline, the repair of which requires sophisticated management involving considerable time, money and lost opportunity.

Many beef cattle enterprises in northern Australia are suffering financially and carry large debts. Many northern producers are struggling with maintaining repayments and banks are very wary about lending large amounts for development. Most producers would need to borrow the funds for mosaic irrigation development. They would need an immediate return on an investment in order to maintain repayments.

Graziers without experience in irrigation are likely to make mistakes in the first few years as they acquire the necessary skills and learn to manage their unique bio-physical circumstances. Some of these mistakes will have financial consequences, possibly dire consequences. Others will have bio-physical consequences such as salinity problems or soil structural breakdown. Addressing each of these problems will require considerable time and other inputs.

15. ENVIRONMENTAL RISKS MUST BE MANAGED STRATEGICALLY

Strategic rather than ad hoc management of environmental risks is essential. Addressing these risks will require careful planning and implementation to suit the circumstances of individual properties (e.g. carefully selecting water sources to minimise salinity risk). On-site, off-site, local and regional issues must be addressed. These include properly managing tail water from flood irrigation systems, minimising the risk of contaminants making their way into water bodies downstream and spread of pest plants and animals. Hydrological change, especially of river flows or waterholes that are sustained by groundwater during the dry season, is one of the more likely off-site effects of mosaic irrigation. Measures would also be required to minimise biosecurity risks.

Irrigation developments radically alter natural systems but small developments are unlikely to have major environmental repercussions beyond the immediate area under irrigation or associated infrastructure. The scale and extent of impacts will depend upon the size of individual irrigation units, the number of irrigation units in a district or region and the natural values of the immediate area.

Irrigation developments have the capacity to have impacts on flora, fauna and communities that are restricted in their distributions. Careful placement of irrigation developments should minimise the risk of these impacts.

It is possible that the best sites for mosaic irrigation on a property may coincide with areas of extremely high natural value, such as threatened ecological communities or habitat for rare and threatened species. Such a situation would invoke obligations under state or Commonwealth legislation.

16. MOSAIC IRRIGATION IS UNLIKELY TO TRANSFORM LANDSCAPES OR THE NORTHERN BEEF INDUSTRY, BUT IT HAS POTENTIAL TO TRANSFORM SOME BUSINESSES/ENTERPRISES

Transformation of the local industry is possible where multiple enterprises within a district adopt mosaic irrigation, particularly if it is congruent with other industry developments such as a nearby abattoir.

The scale of development (<0.1% of the pastoral area) is unlikely to transform the environment at the landscape scale though there will be some landscape effects at the point scale and there may be some off-site impacts.

Given current knowledge, uncertainties about the size of the groundwater resource and the jurisdictions' natural (and appropriate) caution about over-allocation and over-extraction, mosaic irrigation is unlikely to transform the northern beef industry.

If a number of graziers in proximity to each other adopted mosaic irrigation there may be some transformation of a local area (but probably less significant than, say, off-farm income through mining etc).

Individual beef enterprises will almost certainly be transformed. The scale of investment required ($350,000 to several million) will by definition alter the beef enterprise and once that investment is made will need to be worked intensively to provide an acceptable return.

Source: Heinz Buettikofer (CSIRO Land and Water)

REPORT SUMMARY

INTRODUCTION

In recent years there has been increasing interest in how the natural resources of northern Australia might be further developed, with a particular focus on its water resources. There have been several important initiatives in this regard. In 2004 the National Water Initiative (NWI) was established to help increase the productivity, efficiency and sustainability of Australia's water use. Under that initiative, in 2012 the National Water Commission (NWC) released a position statement on water management in northern Australia[3]. That statement encouraged the relevant states and territories, as well as the Commonwealth Government, to apply five principles including adoption of the NWI water reform framework, planning for effective water management, building understanding based on science and socio-economic information, recognising indigenous interests and strengthening cross-jurisdictional collaboration.

The nature of pastoral leasehold tenure in northern Australia has been recognised as constraining opportunities for diversification in the pastoral industry. This led to a report that raised questions about the extent to which the existing pastoral lease arrangements were the most appropriate means of fostering rural and regional development opportunities[4]. This report and other pressures prompted an active process of land tenure reform in Western Australia, the Northern Territory and Queensland with a view to lowering the barriers to non-pastoral uses on pastoral leasehold land.

In 2009 the Northern Australia Land and Water Taskforce presented a report to the Commonwealth Government on the sustainable development of northern Australia[5] which was defined in that document in terms of surface and ground water systems within the Timor Sea and Gulf of Carpentaria drainage divisions and the portion of the North East Coast drainage division north of Cairns. It pointed to groundwater as the providing the best prospects for new consumptive uses of water, irrigated agriculture being an obvious option for using northern Australia's water resources. The Northern Australia Land and Water Taskforce report[5] suggested that there were potentially 600 GL of renewable groundwater available in the north and proposed that this volume of water could irrigate 40,000-60,000 ha of intensive agriculture. The Taskforce report also suggested that mosaic agriculture was a model for agricultural development in northern Australia that warranted further consideration.

The beef industry is a major part of the economy, culture and landscape of northern Australia and inextricably linked with its future[5]. It utilises around 60% of the land area of northern Australia (as defined by the NALWT[5], carries about 30% of the nation's cattle but produces 80% of Australia's live cattle exports, worth about $300–400 million a year. In 2012 the Northern Australian Beef Industry Working Group, which was established by the Northern Australian Ministerial Forum (NAMF),

[3] NWC (National Water Commission) (2012). 'Water management in northern Australia.' Position Statement. Available at: http://www.nwc.gov.au/__data/assets/pdf_file/0020/22097/Northern-Australian-Position-Statement-May-2012.pdf (Accessed 22 November 2013).

[4] Productivity Commission (2002). 'Pastoral Leases and Non-Pastoral Land Use.' Commission Research Paper. (AusInfo: Canberra, ACT).

[5] NALWT (Northern Australia Land and Water Taskforce) (2009). 'Sustainable development of northern Australia.' (Department of Infrastructure, Transport, Regional Development and Local Government, Commonwealth of Australia: Canberra, ACT).

released a report on strategic directions for the northern Australian beef industry[6]. This document pointed to the importance of the northern beef industry and to its potential for growth but recognised that while costs have been rising in recent decades there have not been comparable increases in productivity or prices. There is a glaring need for productivity gains across the northern beef industry. Beef production in northern Australia has been largely based on the exploitation of extensive native and naturalised pastures. "The application of mosaic-style irrigated agriculture has the potential to support intensification and diversification of production and generate greater value across the supply chain" [6], thus drawing a link between the needed reform of the northern beef industry and the further development of the region's water resources. The principal means by which mosaic irrigation might enhance the viability of the northern beef industry are by lengthening the seasonal window for fattening cattle and as a precursor to developing a more integrated supply chain[7].

Irrigation mosaics have been defined as "irrigation schemes in which small patches of irrigation occur within a region rather than irrigation of one large contiguous area" [2]. In contrast to large-scale irrigation schemes, mosaic irrigation involves the development and operation of relatively small scale units of irrigation scattered within a broader matrix of other land-uses. In relation to the northern beef industry, mosaic irrigation involves small-scale irrigation developments that produce feed for cattle and are scattered through a matrix of unirrigated, generally native or naturalised, pastures. "Small scale irrigation precincts…based on the concept of irrigation mosaics" have been highlighted as a future development opportunity for the north of Western Australia[8]. Chilcott raised the prospect that irrigation units for forage production could be integrated into current cattle production systems, accepting that pastoralism remains the dominant land use in the region. The principal benefit of mosaic irrigation for the beef industry is likely to be via improvements in the amount, quantity and timeliness of feed supplies[5]. Such advances would enable beef enterprises to have cattle reach turn-off weights sooner, meet markets with higher specifications, turn-off animals at time of year when prices are higher, and/or facilitate increased reproduction from first and second calf heifers.

Mosaic irrigation is seen as "... logically attractive, but largely untested"[9]. This report seeks to investigate the idea in more detail and delivers on a project, funded by the Office of Northern Australia, to assess the prospects for mosaic irrigation to enhance production and profitability of the northern beef industry, building on some of the key points emerging from earlier work[5]. This project focuses on the Australian mainland north of the Tropic of Capricorn and west of the Great Dividing Range. This report analyses the main constraints and drivers relating to the development of irrigation mosaics and describes the principal factors that need to be considered in evaluating the prospects of using them to enhance beef enterprises and the beef industry in northern Australia.

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[6] NABIWG (Northern Australia Beef Industry Working Group) (2012). 'Strategic directions for the Northern Australia beef industry.' A Joint Government and Industry Action Agenda developed for the Northern Australia Ministerial Forum. (Queensland, Northern Territory and Western Australia). Available at: http://www.regional.gov.au/regional/ona/files/20121129-strategic-directions-for-northern-australia-beef-industry.pdf (Accessed 22 November 2013).

[7] Gleeson, T., Martin, P. and Mifsud, C. (2012). 'Northern Australian beef industry. Assessment of risks and opportunities.' ABARES report to client prepared for the Northern Australia Ministerial Forum. (Department of Agriculture, Fisheries and Forestry: Canberra, ACT).

[8] Chilcott, C. (2009). Growing the north – opportunities and threats to developing agriculture in the north of Western Australia. *Farm Policy Journal* **6,** 11-17.

[9] Webster, T., Morison, J., Abel, N., Clark, E., Rippin, L., Herr, A., Taylor, B. and Stone, P. (2009). Irrigated agriculture: development opportunities and implications for northern Australia. *In: '*Northern Australia Land and Water Science Review'. Pp 10.1-10.53.

BACKGROUND

The beef industry is an important part of the economy, culture and landscape of northern Australia. The industry is based on extensive grazing of mostly native and naturalised pastures and by area it is the dominant commercial land use in the north.

This project examined the prospects for sustainably integrating into the northern beef industry the production of forage crops produced under mosaic irrigation. Irrigation mosaics involve irrigation of small discrete patches of land dispersed across the landscape rather than concentrated in irrigation schemes or precincts. In focusing on mosaic agriculture, the project did not consider the prospects for such schemes or precincts. Neither did it consider the production of cash crops using mosaic irrigation on beef cattle properties or the large scale production of fodder for abattoirs or feed pellets for live export but rather focused on forage to feed cattle to enhance individual beef enterprises.

The project's geographical focus is that part of the continent north of the Tropic of Capricorn, but excluding the eastern flowing catchments that are more densely settled, that support a number of large urban centres and where there is considerably more intensive agriculture.

Most of the larger towns and cities in northern Australia are outside the project area which supports a human population of around 340,000. Most of the region has a very low-density of people.

The climate of the project area is characterised by a strongly seasonal climate with most rain falling during the hot summer. This climate drives temporal and spatial patterns of availability in soil water, surface water and groundwater. Particularly during the long dry season, losses through evapotranspiration are high.

The economy of northern Australia relies strongly on primary industries, including mining, but pastoralism for beef production is the primary commercial land-use in terms of area occupied. Pastoral lands, including both leasehold and freehold tenure, occupy about 59% of the project area. Indigenous lands, not including Indigenous-held pastoral leases occupy a further 20% while other Crown Land and land held for nature conservation purposes covers about 5%. The vast majority of the beef cattle enterprises in the north are in Queensland. .

Northern Australia has many areas of high natural and cultural value and these are also important to the north's tourism industry. Natural ecosystems, while they have been subject to some disturbance, are more intact than those in much of southern Australia.

The northern beef industry faces a number of challenges including declining terms of trade and exposure to market shocks. Irrigated forage production has been widely advocated as one means whereby the productivity of the northern beef industry may be increased by enabling beef enterprises to have cattle reach turn-off weights sooner, meet markets with higher specifications, turn-off at times of year when prices are higher, and/or facilitate increased reproduction from first and second calf heifers. While the idea is logically attractive, it remains largely untested.

WATER RESOURCES

Adequate supply of suitable quality water underpins the development and operation of all irrigated agriculture. Irrigation may be based on the use of either groundwater or surface water. In northern Australia, the characteristics of these two general water sources are strongly influenced by geology and patterns of climate. The high seasonality and inter-year variation in rainfall are particularly important in dictating patterns of river flow and groundwater recharge and discharge. High evaporation rates mean that much of the rainfall never makes its way into streams or recharges aquifers. Using a Gulf river in north Queensland as an example, only about 5% of the rain falling on a catchment discharges as stream flow. Only about 1% recharges groundwater.

Groundwater systems are complex and dynamic. Reliable evaluation of groundwater resources requires information on the extent of the aquifers, including their spatial variability, how water moves through them, temporal patterns of recharge and discharge, their interactions with surface waters and assessments of water quality. Much of the information that is currently available is based on estimates and is at coarse scales. In particular, data on groundwater yields are lacking.

Northern Australian groundwater resources are highly variable in time and space due to variation in geology and climate and are currently not thoroughly described. However, compared with surface water resources, groundwater may provide opportunities for larger developments because of the capacities of some aquifers and their lower susceptibility to inter-year variations in rainfall. The aquifers in which the water is held can be roughly classed as either shallow local-scale unconfined aquifers or deep regional-scale confined aquifers. In some locations, shallow aquifers overlie deeper ones and interactions may occur. Interactions between surface waters and shallow and deep groundwaters are important in the hydrology and ecology of northern Australia though many of these interactions are not well understood. Focused multi-disciplinary research is required to make more informed decisions about sustainable yields of water and potential impacts of development for specific locations.

Shallow aquifers are highly responsive to recharge from the current year's rainfall; in coastal regions of the far north they are recharged during the wet season but discharge to rivers, creeks, wetlands and springs during the dry season. This pattern is less common in aquifers located further inland as rainfall becomes more erratic. Shallow aquifers offer widespread opportunities for small-scale irrigation developments but the quality and quantity of water available from each of these sources is variable. These shallow water resources are not well documented and their sustainable yields are not reliably known. However, they may provide opportunities to individual graziers. Deep aquifers are more extensive, have greater storage capacity than shallow aquifers and they are less susceptible to variation between years in the amount of recharge. The amount of groundwater extractable at a given location is affected by the thickness, hydraulic conductivity and storage characteristics of the aquifer. For example, in some cases an aquifer may have high storage capacity but low transmissivity so that effective rates of extraction are limited. Yield data are lacking for most of the aquifers in the north and detailed evaluation of groundwater resources is required. This would aim to characterise the system in terms of recharge locations and rates, aquifer flow paths and flow rates, and discharge locations and rates. Sufficient understanding of these mechanisms will assist the sustainable allocation and management of groundwater resources.

Current maps of groundwater resources are based on low resolution data and inadequate knowledge of important characteristics and problems are compounded by the fact that aquifers of different characteristics overlay one another. The new map of groundwater prospectivity produced for this report is based on three sources of information: estimated groundwater recharge rates, groundwater productivity and groundwater flow systems. Three basins, (i) the central Daly-Wiso and Georgina, (ii) the coastal section of the Canning basin and (iii) the Great Artesian Basin each have

estimated extractable groundwater volumes of over 100 GL/year. The remainder of the Daly-Wiso and Georgina and the inland portion of the Canning basin have estimated extractable groundwater volumes of between 10 and 100 GL/year. These figures suggest that, based on the limited data that are available, there may be 600 GL/year of extractable groundwater available in northern Australia.

There are potentially exploitable surface water resources in northern Australia but the supply is highly variable in time and space. The temporal variability in surface water resources means that surface water storage is a prerequisite if it is to be regularly used for irrigation though there are relatively few opportunities for large scale surface water storages in the north and these would not be compatible with widely dispersed small scale irrigation on beef properties.

Widespread flooding of coastal areas and floodplains, as well as localised flooding in many northern catchments, presents a risk to irrigation development and operation in many locations where the availability of arable soil and sufficient water might suggest good locations for mosaic irrigation. While the percent of the pastoral lands at flood risk is between 5 and 10% it is these floodout areas that often have high quality alluvial soils. This project has provided a map of inundation duration and extent based on data from 2000 to 2011. The floodplains of the Fitzroy catchment in Western Australia, the Roper catchment in the Northern Territory and the Gulf Rivers in Queensland especially the Flinders are particularly prone to inundation by floodwaters, sometimes for prolonged periods.

Extraction of surface or groundwater for irrigation can have hydrological effects that have ecological consequences, particularly for so-called groundwater-dependent ecosystems (GDE). Extraction of water from shallow aquifers may reduce the permanence of waterholes and the reliability of river flows. Extraction from deeper aquifers is less likely to have direct impacts on stream flows and waterhole persistence but the risk of base-flow reductions should be considered in any development. Irrigation of soils over shallow water tables may also lead to rising water tables and consequent water-logging or secondary salinisation. Obtaining location-specific information to predict and minimise the risk of adverse hydrological and soil condition effects is important as a prelude to mosaic irrigation developments. This will require specialist expertise.

LAND AND SOIL RESOURCES

Production systems based on irrigation require soil and land conditions suitable for the purpose. The topography must be suitable for the establishment and operation of the irrigation system and use of an appropriate harvesting system. The terrain must not present unacceptable risks in terms of soil erosion and soils must be of suitable texture and depth. The availability of soils and terrain suitable for irrigation must be considered in relation to its proximity to water, necessary infrastructure, existing property layouts and operation, environmental assets and flood risk. The financially modest benefits of irrigated pasture in much of northern Australia will drive the development of irrigation mosaics toward areas of the very best soil. These are likely to be found more frequently on alluvial soils, often on floodplains. These parts of the landscape are the ones most prone to flooding.

Spatial information on the soils of northern Australia is largely based on land systems as a surrogate rather than analysis of the soils themselves. This does not provide sufficient precision to identify specific locations that have soils suitable for irrigation. In addition, many Australian soils are relatively poor in terms of depth, texture, structure, nutrient value, alkalinity and salinity. In spite of these factors it is clear that northern Australian has soils that are suitable for irrigated crop or pasture production.

Many of the better soils are in alluvial areas, often on floodplains, making them (and the irrigated agriculture infrastructure, including transport access) potentially vulnerable to flood damage and prolonged inundation, leading to issues such as waterlogging, salinisation and nutrient leakage.

The distribution of suitable soils, along with the spatially and temporally heterogeneous availability of water, will drive irrigation developments toward a mosaic approach rather than large irrigation schemes. Areas of suitable soils are relatively small and discontinuous. Within most northern Australian pastoral properties there are likely to be some areas with soils and terrain suitable for irrigation. Many of these areas are likely to be mapped as low suitability given the coarse resolution of available data. The soils must be supported by available water resources, transport and other infrastructure and have good vehicular access.

It is important to take into account the particular traits and limitations of a soil and its behaviour under irrigation to ensure long term sustainable production and maximum yield under cropping whilst minimising development risks, management costs, land degradation and off-site impacts. Soils of low or moderate suitability can still be productive but require intensive agricultural practices and the input costs may be too high to make the development viable. There is also a consequent requirement for managing off-site impacts, particularly in the deeper, sandy soil systems.

Irrigation developments in northern Australia will have to consider the fact that most Australian soils are old, highly weathered, low in nutrients and prone to structural decline under cultivation. Poor management practices may lead to soil structural decline and so productivity losses over a period of years and the kinds of problems that could emerge will be difficult to redress. Irrigation *per se* has the capacity to increase mineral weathering, leach materials through the soil profile, change soil structure and raise the water table, with the possibility of increasing salinity levels. While it may be possible to modify critical soil characteristics to make them more suitable for irrigation, these modifications come at some cost, reducing the economic margins of an irrigation system.

The climate of wet-dry annual cycles typical of much of northern Australia, combined with periodic occurrence of intense rainfall events, means there is a high prospect of wind and water erosion on soils cleared for agriculture. This may be the case even on quite shallow slopes. The development of perennial pastures systems may go some way toward militating against the risk of erosion once an irrigation production unit has been established.

Specialist advice relating to soils should be sought prior to the development of an irrigation unit. This should involve soil testing at fine scales to help decide the best locations and devise management plans for getting the most out of the available soils.

New approaches to soil mapping and attribute estimation, such as those recently used in the Flinders and Gilbert catchments of Queensland, have the potential to provide more cost effective methods of soil and land suitability assessment, for agricultural purposes, than those traditionally used.

BEEF PRODUCTION SYSTEMS

The predominant economic use of northern Australian grazing lands is for beef cattle production from unimproved native vegetation under extensive grazing systems. That part of Australia north of the Tropic of Capricorn and east of the Great Dividing Range supports around 7.7 million cattle, almost 30% of the national beef herd. Historically, the northern beef industry was characterised by low inputs, low efficiency and low return production and marketing systems.

Most northern beef properties have either no or very limited areas of developed pastures or cropping land. Enterprises produced older cattle on large holdings with limited development of pastures and infrastructure. Substantial changes over the last 60 years have seen increases in herd productivity, major shifts in cattle breeds, infrastructure developments and new markets, including the emergence of the live export trade through the 1990s. However, northern beef enterprises have long been challenged by a cost price squeeze due to costs rising more rapidly than prices, the terms of trade declining by approximately 2% per annum. Recently there have been problems associated with the live export trade and the number of animals sold into this market having peaked at 970,000 animals in 2002-2003.

Climate, nutritional opportunity and distance to viable markets determine the type of enterprises that are run in different parts of the north with markets for various classes of sale stock segmented according to their type, age, weight and finished size. Enterprises are mostly characterised by self-replacing breeding herds producing male progeny for on-selling as either store or finished animals but they may also turn-off a mix of female aged breeders, culled cows, and/or heifers that are not required to maintain the desired herd size and make-up.

Mosaic irrigation for forage production is a mode of development that could be used to address productivity challenges faced by the northern beef industry. Only a small proportion of northern Australian is currently under irrigation but the predominant use of land that is irrigated is for pasture production and haymaking. Given the scale of most northern beef enterprises, mosaic irrigation is unlikely to be used to provide forage for the entire herd of a property. Any benefits likely to derive from mosaic irrigation will be associated with the provision of quality feed for particular classes of animals so that they meet market specifications of a given market at an earlier age or out of season, so attracting market premiums.

Establishment of irrigation units require a substantial capital investment. Estimates of the outlay required range from $7,000 to $11,000 per hectare. This includes costs of removing standing vegetation, ground preparation and purchase and installation of the irrigation system. If an individual producer has to make this capital investment, particularly if that requires borrowing money, it would have a significant impact on the economic returns that would be expected. An estimate of operating costs is approximately $70 per tonne of forage produced, with irrigation costs of approximately $20 per tonne.

Mosaic irrigation units could be used to produce forage from either perennial tropical grasses, annual grasses or annual or perennial legumes. These forages could supplement current beef production systems in various ways: for overcoming seasonal shortages in quality or quantity, for use during drought or for feeding at critical stages in an animal's development. Forage produced under irrigation is likely to be of greatest benefit when used during the late dry and early wet seasons. Simulation models suggest that annual dry matter production from legumes (e.g. lablab), annual grasses (e.g. forage sorghum), and tropical perennial grasses are likely to be of the order of 12, 18-20 and 30-35 tonnes per hectare, respectively. Harvesting of 10 tonnes of dry matter, for example as hay, would require replacement of around 150 kg/ha of nitrogen, 20 kg/ha of phosphorus and 12 kg/ha of sulphur. Modelling indicates that, under a scenario in which 100, 30-month-old, 450 kg Brahman steers are fed irrigated forage in order to have them reach 560 kg

liveweight in 3 months, 16 ha of irrigated pasture would be required. This yields an average net return of approximately $15,900 per annum or a marginal annual return of approximately 12% on capital investment. These returns do not take capital outlays or interest payments into account.

Computer simulation case studies in the Barkly region of the Northern Territory, north Queensland and the Kimberley region of Western Australia indicate that there is considerable scope for productivity gains from mosaic irrigation developments as higher quality forage is made available at critical times of year. However, predicted economic returns vary greatly depending on the scale and cost of the development. Average projected returns on investment in irrigation ranged from -5% for forage sorghum production in the Kimberley to 44% for tropical perennial grass in the Kimberley. These returns do not take capital outlays or interest payments into account. The most favourable results are predicted for scenarios in which the forage produced is high quality or when forage is available for an extended period of the year.

Under favourable circumstances, the estimated 600 GL of ground water that could be extracted per annum in the project area (Chapter 3) could be used to produce 2.4 million tonnes of forage under irrigation, assuming the use of 5 ML of water per hectare and a forage yield of 20 tonnes per hectare. This could potentially be used to turn off over 200,000 cattle per annum with a market value of around $219 million ($1000 per head). Our most conservative scenario, using estimates of 12 ML of water, producing 15 tonnes of forage per hectare and a sale price of $600 per head, yielded a turn off of 68,000 cattle with a market value of $41 million.

Many factors will influence the financial outcome of small scale irrigation developments. This includes the nature of the irrigation unit, the outlays required to construct and operate the unit, its productivity in terms of the quality and quantity of feed produced, how the feed is utilised and the marketing opportunities that are available for the class of animals that are turned off.

Simulations suggest that at least some developments not involving irrigation are likely to deliver greater returns on investment than mosaic irrigation developments, for example, broad-scale pasture development or increasing the number of watering points.

SOCIAL FACTORS

The beef industry has long played a major role in the shaping the economy, culture, and social and physical landscapes of northern Australia. The north as a whole, and beef industries and enterprises in particular, are facing some critical adjustment pressures. However, there remains a general expectation that the north will continue to support viable communities, that it will play an expanding role in the nation's food production and that the beef industry will be an important part of that expansion. Access to irrigation for forage production has been identified as one critical means of adjustment and growth for the northern Australian beef industry.

The development and operation of irrigation can have major socio-economic consequences for enterprises, industries and regions. Development of large, centralised irrigation schemes can cause rapid and significant social change, having both positive and negative impacts for communities. However, mosaic irrigation developments, consisting of relatively small-scale and widely dispersed irrigation units within a matrix of non-irrigated pastoral land use are not expected to result in the same social impacts as these larger schemes but there will be some effects, both positive and negative.

The extent of social impact arising from mosaic irrigation will be highly dependent on the specific development context. The extent of land use change in a region associated with mosaic irrigation development, its contribution to the value of production, both at farm and aggregated scales, and the employment generated, both directly on farm, elsewhere in the supply chain (e.g. meat processing) and indirectly (e.g. new regional economic development) will be important. They, in turn, will be influenced by factors such as the amount and reliability of the water supply, the type and use of irrigated crop/forage, the investment needed in infrastructure, the net economic benefit or cost to the beef enterprise and access to markets for output.

At the farm scale, mosaic irrigation can bring benefits in the form of increased incomes and improved risk management. On the other hand, water reliability and production variability are significant issues affecting the profitability of an investment in mosaic irrigation and bring added risk to the enterprise, particularly in the early years of operation. An initial run of low or negative returns will impair the short-term performance of an investment in irrigation, even if it is profitable over a longer term. Increased farm business debt as a result of an investment in irrigation development may, at least in the short term, lead to greater economic vulnerability, rather than more resilient businesses. Again, at the enterprise level, particular skills are required to develop and use irrigation efficiently and effectively. This includes expertise and advice regarding regulatory and legal matters, specialist technical irrigation expertise, agronomy services, equipment suppliers and repairers, and input suppliers. In northern Australia there is likely to be a shortage of expertise in these areas and yet the need for it is great given the level of experience in irrigation held by current pastoral producers.

At the regional scale, the distributed and small-scale nature of mosaic irrigation would be unlikely to require the movement of a large amount of skill and labour to any one region and appear to prejudice against the development of critical industry and community infrastructure. If development occurs at sufficient scale to warrant secondary industries emerging (e.g. meat processing, feedlotting), then social impact can become more significant. In addition to impacts arising directly from change in performance of beef enterprises, others will also be felt through labour demands, which can change the population of a town, with a range of flow on effects related to construction of infrastructure and provision of services.

The northern beef industry provides an opportunity for sustainable wealth creation for many Indigenous communities in northern Australia, through both direct employment by non-Indigenous enterprises and establishment of business ventures by Indigenous groups and individuals. Currently,

Indigenous pastoral operations are heavily exposed to challenges associated with the live export trade. The loss of live export markets could lead to further decline in viability of Indigenous properties. Mosaic irrigation potentially addresses this risk by providing opportunities to shift production to meet other marketing opportunities. It could also benefit Indigenous industry development if viewed as a new training opportunity offering options beyond traditional pastoral opportunities for Indigenous people.

Negative impacts on Indigenous interests include the potential to exacerbate a skills disadvantage on Indigenous pastoral lands, and exacerbate inequalities in performance within the pastoral sector. Beyond risks to Indigenous pastoral operations, other impacts of mosaic irrigation relevant to the general Indigenous community may include threats to water and cultural heritage sites.

In assessing the social factors associated with mosaic irrigation, the multiple interests in the land and water resource should be noted. These include but are not restricted to pastoralists, Aboriginal traditional and contemporary interests, conservationists, tourism entrepreneurs, developers, statutory organisations and agencies of federal, state and local governments. Recognising multiple interests also brings multiple values into the decision-making process including food-production values, Indigenous aspirations, preserving biodiversity and natural landscapes, and promoting distinct styles of tourism and recreation.

Mosaic irrigation is dispersed in its implementation, and diffuse in its impacts. Unlike large-scale irrigation schemes, which concentrate economic activity, mosaic irrigation is too dispersed to generate the same type and scale of positive and negative social impact. Social impact is more likely to be experienced as small-scale benefits and disadvantages.

LAND TENURE, WATER RESOURCE AND NATIVE TITLE

There are few impediments to the development of small scale irrigated agriculture, as an adjunct to existing beef enterprises, from legislation dealing with land tenure, water resources or Native Title. The impediments are much higher in the case of proposals for large scale developments in which irrigation rather than grazing *per se* would become the dominant contributor to the enterprise instead of grazing.

Approval for small scale irrigated agricultural developments for forage production on beef cattle properties is possible under current land tenure systems. This applies to pastoral leasehold land in Western Australia, the Northern Territory and Queensland and on freehold land in Queensland. Approval is granted relatively freely.

All three jurisdictions have begun land tenure reform, although it is not clear whether this reform will have much impact on the ability of graziers to develop small areas that are complementary to their beef enterprises, given that mechanisms already exist for this to happen. It may, however, provide greater security of access to resources, allowing graziers to more easily raise finances for the development. Reforms may also streamline the approval process.

The process for applying for water allocations is relatively straightforward but water allocation may not be easy to obtain. There are mechanisms in place in Western Australia, the Northern Territory and Queensland to grant water allocations to graziers for small scale irrigated agriculture for forage production. In reality however, it can be very difficult to obtain a water allocation because either water in existing water resource plans may already be fully allocated or knowledge of the resource is insufficient for the government authority to make an informed decision.

Water reform is taking place at both the national and state and territory jurisdictional levels. The demand for water allocations is rising, partly as a result of the northern development agenda. The Western Australian, Queensland and Northern Territory governments are all investing in water planning processes to meet this demand. Water resource planning follows the National Water Initiative process whereby diverse and competing water uses are taken into account.

While large scale developments do need to consider Native Title, small scale irrigated agriculture development for forage production on beef cattle properties is possible without affecting native title because in almost all cases it is not considered a ‘future act’.

INFRASTRUCTURE

The current availability and condition of northern Australian infrastructure relevant to the development and operation of mosaic irrigation is highly variable.

Development of mosaic irrigation units requires a substantial investment in infrastructure. The investment required is strongly affected by the extent of land clearing and land preparation that is required, the type of irrigation system to be used, the source of the water and any requirement for water storage. Capital costs per ha range from about $7,000 per ha to about $11,000 per ha so that a 100 ha development may cost between $700,000 and $1,100,000.

Mosaic irrigation requires on-property investments above that necessary for an extensive cattle grazing enterprise. Some investment in regional infrastructure may improve the viability of a mosaic irritation development.

Establishment of a mosaic irrigation unit are will incur various costs. The cost of land preparation, including clearing of vegetation and levelling, will vary with the density of the vegetation and topography. Provision of water requires expenditure on drilling to access groundwater resources and diversionary works for surface sources. Pumps will be needed to extract water from underground sources and, depending on the circumstances, to divert water from surface sources. Surface storage of water requires a major investment though this will not always be necessary - water storage facilities serve to buffer water availability against the variability of supply that may result from variable rainfall, and so river flows, or limits to the rate at which water can be extracted from an underground source.

Water reticulation infrastructure, either channels or pipes, will be necessary so that the closer the water source to the site at which the water will be used, the better. The cost of infrastructure required to irrigate will depend upon application system that is used; this may be by flood irrigation, overhead irrigation or centre-pivot.

There will also be significant running costs. These include pump operation, maintenance of plant and equipment, advisory services, insurances, wages, sowing costs (especially relevant for annual forages, fertilizer, harvesting and transport of product. Water licenses will also come at a price. Costs associated with each of these items may vary considerably with circumstances.

The distribution of export and processing facilities is such that, for most enterprises, long-distance road transport of cattle is required. The road network away from main highways is generally not sealed and therefore prone to road closures in the wet. Long distance road transport is expensive and animals can lose condition, and so market value. Proximity to abattoirs or port facilities is a potentially important issue and close proximity can greatly reduce costs in some cases.

ENVIRONMENTAL FACTORS

The annual cycle of wet and dry seasons and, in many regions, a high inter-year variation in rainfall, is the major driver behind the flora and fauna characteristic of northern Australia.

Native species are highly adapted to these rainfall patterns and associated temperature regimes and respond to annual and inter-annual variation by changing behaviour with the seasons or migrating to locations that suit them.

Many species and communities are dependent on particular conditions at different times of the year and phases of a longer-term "drought" cycle. While all rely on water in some way, they vary greatly in terms of the sources and amounts of water they require, each being adapted to particular spatial and temporal patterns of availability. Changes to the spatial and temporal patterns of resources availability inevitably influence the composition, structure and function of plant and animal communities and the capacity of individuals of different species to meet their resource requirements.

Any agricultural or pastoral development will have environmental impacts. Irrigation developments, including mosaic irrigation developments designed to support beef enterprises in northern Australia will have both direct and indirect effects on the environment during both construction and operation.

The most extreme environmental impacts will be on the sites at which irrigation actually takes place. Other effects will be incurred as a result of associated infrastructure away from the irrigated land and flow-on effects through changes in the quality, quantity and spatial and temporal patterns of resource availability.

The development and operation of irrigation mosaics can impact on the northern Australian environment through:

- Removal of native vegetation, with flow-on effects on the fauna that is dependent on it, would have its greatest impact at the immediate site of an irrigation development
- Disturbance of soil in association with irrigation mosaics could increase the risk of wind and water erosion, especially during a development phase. There is the potential for off-site effects as eroded material is deposited with the possibility of reduced quality of surface waters. Soil and vegetation disturbance may also facilitate plant invasions and the proliferation of certain weeds.
- The deliberate or accidental introduction of novel species, some of which could be problematic for particular land-users
- Changes to resource availability, perhaps most importantly to changes in water quality, quantity and spatial and temporal patterning, but also through nutrient addition due to the use of fertilisers
- Release of pesticides and chemicals into the environment
- Increased risk of salinity problems in soils and water
- Changed hydrological function directly through depletion of natural surface or underground water bodies or addition of surface waters, or indirectly due to surface-groundwater interactions.

Relevant legislation includes:

- Commonwealth and State/Territory government legislation relating to vegetation management, water resources, land and soil management, biosecurity and threatened

species and ecosystems is relevant to the impacts of irrigation mosaics on the northern Australian environment.

- The Commonwealth government has obligations relevant to the development and operation of irrigation mosaics as a result of Australia's ratification of international agreements and conventions relating to biodiversity, World Heritage Areas, National Heritage Places, migratory species and threatened species and communities.
- The Environment Protection and Biodiversity Conservation (EPBC) Act is the primary Commonwealth legislation relating to the environment. It is designed to protect and manage nationally and internationally important flora, fauna, ecological communities and heritage places. The EPBC Act also recognises Key Threatening Processes including land clearing, degradation by invasive animals and loss of native species due to plant invasions.
- The Commonwealth Native Title Act makes provision for recognition of the rights of Indigenous people, including in relation to native species and impacts of proposed activities.

Western Australia, the Northern Territory and Queensland each have legislation governing environment and natural resources. Various Acts relate to the clearing of native vegetation, exploitation and management of water resources, threatened species and ecological communities, environmental pollution and biosecurity (weeds, pests and diseases). Legislative arrangements and obligations vary between the states and territories and each does not always align neatly with Commonwealth legislation.

The scale and density of irrigation units together dictate their impact but the relationship between scale, density and impact will vary with specific circumstances. Generally, multiple irrigation units will have a summative effect on environmental assets.

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