final report

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Student Undergraduate Program:
Geographic Information System (GIS) dataset for the Australian Feedlot sector

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Executive summary

An extensive study was undertaken to determine the status of the Australian Feedlot Industry. This study used Geographic Information System (GIS) software to analyse the current situation, with additional potential of becoming a tool to select future sites for this industry. The base for a feedlot dataset was an amalgamation of known data on feedlots from various sources. The sources of feedlot data was from the licensing authorities in each State, known feedlots through FSA Consulting's work, industry magazines and through the list of the National Feedlot Accreditation Scheme (NFAS). NFAS list provided the bulk of the information, but it was not a complete list, due to the NFAS not being a compulsory body.

This database then needed to be georeferenced (giving each feedlot a spatial location of *latitude* and *longitude*), to allow the data to be displayed in the GIS. This process utilised Google Earth to go to localities and search for a known feedlot within that area. If a feedlot could be located and identified as the feedlot that was sought, it was given a georeference quality of “Good”. If it had either poor resolution, could not be found or identified successfully then it was given a “Poor” quality. 882 feedlots were located and assigned quality using this method.

National guidelines and industry texts provided the basis for the industry survey. An out-of-date text was used to compare 1990 industry statistics with the current results. These guidelines and texts provided parameters to set up site suitability criteria. Accompanying these parameters was an Objectives-Oriented Comparison (OOC) method that allows industry consultants to weight criteria that were used in the broad-scale site selection. Three methods of broad-scale site selection were attempted. Method 1 (Reduction) locating only areas that are acceptable to all of the site selection criteria, Method 2 (Weighted used weightings to rank criteria on their individual importance to the site selection, and Method 3 (Non-Weighted) was similar to the weighted method, however it did not utilise the OOC weights. The Non-Weighted Method was added when additional criteria was deemed necessary for the project, after the OOC survey had been completed These methods were compared and validated to their relevance to the current feedlot locations throughout Australia.

Results from the industry survey showed that the Australian Industry has grown heavily via expansion of individual feedlots. However, the data within this report was not a complete representation of smaller feedlots. Thus, growth reported seems heavily expansionistic, when in reality, with a complete list of feedlots, this growth may seem be both through addition of new feedlots and through expansion.

Central Queensland and parts of Western Australia were the only new regions that had opened up to feedlots, and some areas had closed to feedlots. The survey resulted in the current numbers of feedlots within Australia were at 882 with a total capacity of 1,180,848 head. Utilising specific thematic maps to analyse changes over the years between locations of feedlots in relation to annual rainfall areas and seasonal rainfall, revealed how the Australian feedlot sector has adapted to these environmental factors. From the results areas over 750mm of annual rainfall were a limiting factor in the development of new feedlots, with little growth within these areas. However, the seasonal rainfall distribution did not seem to be a limiting factor for the feedlot industry.

The site selection methods brought three results of areas suitable for feedlots. The first, the reduction method, gave 4% of Australia as being suitable. The current feedlots did not validate this result, with only 25% of individual feedlots within this area and 26% of total capacity within this area. The Weighted Site Selection Model and Non-Weighted Model used five ranks to determine suitability. These are “Not Suitable”, “Low Suitability”, “Medium

Suitability", "High Suitability" and "Very High Suitability". This project deemed the ranks of "High Suitability" and "Very High Suitability" as regions that were suitable. The Weighted Model found that 29% of Australia was suitable. The result of 91% of individual feedlots, and 94% of total capacity being contained in suitable areas, successfully validated this method. The Non-Weighted Method resulted in labelling 21% of Australia as suitable. With 92% of individual feedlots, and 95% of Australian capacity being located within these areas, meant this method was successfully validated.

Due to a slightly larger amount of individual feedlots and total capacity being within its areas, and within a smaller area, that the Non-weighted model was the best representative of the commercial reality of the feedlot sector within Australia. The Weighted model held some merit; however, more work including input from feedlot managers for the weights to more closely correspond to the reality of this industry. The Reduction model is not a suitable method to conduct site suitability within the feedlot sector.

This project demonstrated the growth within the Australian Feedlot Sector, and portrayed the relevance and potential that GIS has for the Australian Feedlot Industry.

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1 Acknowledgements

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- FSA Consulting for gather the many sources of information that enabled this project to have an amalgamation of feedlot information are from a large number of sources.

1.1 FSA Consulting

FSA Consulting is a professional consultancy providing agricultural, environmental and engineering services to intensive livestock industries, broad acre farmers, abattoirs and industry. The company was founded in early 1994.

FSA's vision is to provide ethical, independent, high quality, innovative and practical solutions that enable their clients to improve their profitability through more efficient and sustainable use of natural resources. The mission is to consistently provide all clients with high-quality outputs representing value for money, in a timely manner and through the development of practical and innovative solutions.

A multi-disciplinary team includes highly qualified agricultural and environmental engineers and agricultural and environmental scientists with diverse experience. Staff hold the following accreditations:

- Registered Professional Engineer
- Certified Practicing Engineer
- Certified Practicing Agriculturist
- Certified Professional Soil Scientist

Staff members belong to the following professional organisations:

- Institution of Engineers
- American Society of Agricultural Engineers
- Society for Engineering in Agriculture
- Australian Institute for Agriculture and Technology
- Australian Soil Science Society Inc.
- Australian Association of Agricultural Consultants
- Association of Professional Engineers, Scientists and Managers Australia

FSA Consulting is a partner in the National Centre for Engineering in Agriculture, a corporate member of the Australian Water Association and an associate member of the Australian Lot feeders Association.

Their main work areas include:
- Intensive livestock
- Environmental
- Natural resource management
- Irrigation design

2 Background

2.1 The Australian Red Meat Industry

The Australian Red Meat Industry is a significant player on the world meat market. It is also an important part of the Australian economy, exporting over $5.4 billion dollars worth of product in 2005 (MLA, 2006). The Australian Red Meat Industry comprises of cattle, sheep and goat meat. In 2005, the Australian Red Meat Industry produced over 27.78 million head of cattle, and around 101.1 million head of sheep. (MLA, 2006). Australia is one of the world's most efficient producers of cattle and the world's second largest exporter of beef, exporting 65% of beef produced (MLA, 2006). The Australian Red Meat Industry holds its world market share using the many assets that the Australian environment offers.

The quality and integrity of Australian meat makes the Australian Red Meat Industry known on the world market. Being an island, Australia benefits from isolation. This contributes to the prevention of many diseases spreading into the Australian Red Meat Industry. Industry standards protect the Australian industry through a proactive approach in prevention of disease. Proactive work ensures that consumer enjoy quality, safety and integrity of the product they buy. These standards extend from on-farm accountability to feedlot and processing standards, and finally to exporting standards monitored by the Australian Quarantine Inspection Service. Throughout this whole process, a compulsory National Livestock Identification Scheme (NLIS) enables traceability from the plate back to the farm.

The production of meat from Australian farms involves three components: grazing, lot feeding and processing. Grazing utilises large areas of land, with cattle feeding mainly on a grass diet. Lot feeding, however, uses a controlled diet of grain with cattle confined in pens. The processing component delivers a safe and quality product through the abattoir. Each component contributes to a quality product reaching both the domestic and international markets. Each must meet strict standards to allow integrity of the final product.

Feedlots are an important component of the Australian Red Meat Industry because they are able to produce a specialised uniform product year round. This constant production of cattle means that consumers are able to locate a reliable source of beef at an expected quality. Feedlots utilise large amounts of grain and other agricultural products to maintain the continual growth of the cattle within their care. In June 2006, cattle on feed made up 3% of the national cattle numbers (MLA, 2006).

2.2 The Australian feedlot industry

2.2.1 What is a feedlot?

"A feedlot is a confined yard area with watering and feeding facilities where cattle are completely hand or mechanically fed for the purpose of production." (ARMCANZ, 1997). Production occurs year round and provides a reliable source of meat for both export and domestic markets. The feedlot sector exists to increase the size and therefore the market value of cattle. Feedlot cattle begin as grazed cattle. They are on feed from 80 to 200+ days. There were about 940,000 cattle on feed in the June quarter of 2006 (MLA, 2006).

Figure 1 shows the intended destination of Australian cattle on feed in June 2006 (MLA, 2006). The feedlot sector is a rapidly expanding industry within Australia. This intensive industry produces many economic and environmental impacts.

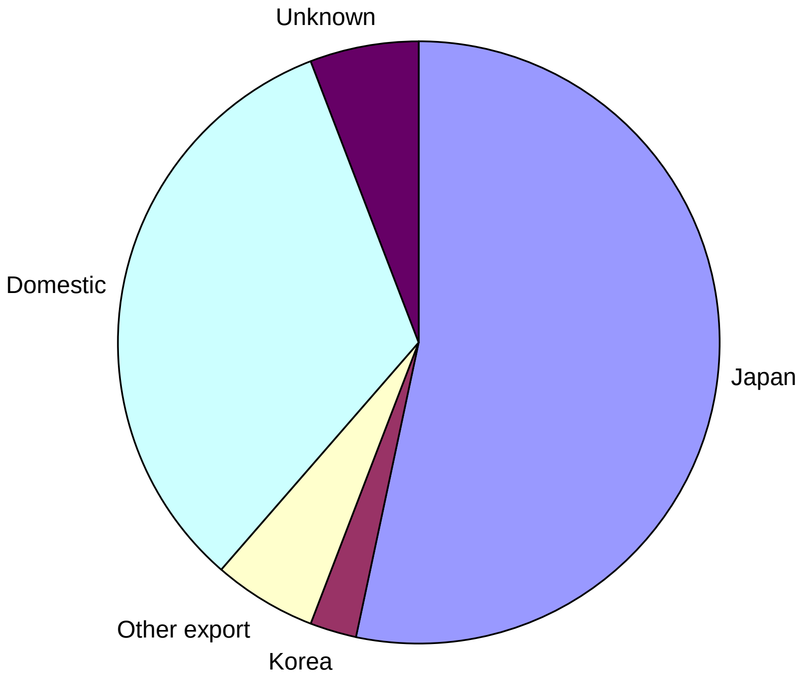


Figure 1 - Destination of Australian Cattle on Feed - June quarter 2006 (MLA, 2006)

2.2.2 Economic impacts of feedlots

The economic impacts of feedlots reach further than the feedlot themselves. A study on "*The impact of the feedlot industry on the Australian economy"* published 2003 (MLA, 2003), saw many economic benefits that feedlots put back into local and regional communities. A feedlot development delivers flow-on effects to the economy at a regional, State and national level (MLA, 2003). It estimated that the total value added to the economy by feedlots was $806 million (MLA, 2003). This production of a specialised product, which benefits local to national economies, requires several components that are similar to all feedlots.

2.2.3 Geographic distribution of feedlots

Production of lot fed cattle requires several components to be in place in feedlots. Feedlots need access to large amounts of grain to sustain the cattle's diet. This means that feedlots today are found in regions that are able to produce this grain. Hence, they are mainly in the grain growing areas of Australia with Queensland and New South Wales being the major players. Feedlots also need access to other components of the cattle ration, shown in Table 1. Access to store cattle is another factor. Access to input resources determines the geographic distribution of feedlots

Table 1 - Commonly Used Components for Feedlot Rations (Tucker, et al., 1991; Watts and Tucker, 1994; Forster, S.J., 2006)

Ingredients	Percent of Ration	Common Types
GRAINS	71%	Wheat, Barley, Sorghum
PROTEIN	9%	Cottonseed, Lupins
ROUGHAGE	2%	Hay, Cotton by-products
FATS	2.50%	Vegetable Oil
SUPPLEMENTS	4.50%	Mineral/Vitamin
SILAGE	9%	
MOLASSES	2%	

2.2.4 Current information on the feedlot sector

The Feedlot Sector is a vital part of both the export and domestic markets in Australia, producing a specialised product in an intensive and specialised operation involving the investment of millions of dollars. However, there is currently no complete register of feedlots in Australia so it is difficult to accurately quantify the size of the feedlot sector. There are a number of sources of data but all have their shortcomings. Some databases represent voluntary registration schemes while other databases are regulatory and State-based. The National Feedlot Accreditation Scheme (NFAS) is a voluntary register of feedlots throughout Australia. It is mandatory for those feedlots wishing to export meat as grain fed. However, being voluntary, it is not complete. As cattle feedlots have a potential environmental impact, each state licences feedlots under environmental protection legislation. Furthermore, local authorities require land use consent for feedlots. Hence, in most states, State and local government agencies regulate cattle feedlots. Individual states have feedlot registers. Different states have different regulatory systems. There are differences in regulations and licensing thresholds between states. Therefore, there is no standard regulatory database for feedlots in Australia.

2.2.5 Growth of the feedlot sector

The Feedlot Sector has grown from humble beginnings and continues to grow today. The Australian feedlot industry began on the Darling Downs in the early 1960's (Tucker et al., 1991). It has grown to having about 940,000 cattle on feed in June 2006 (MLA, 2006). Figure 2 shows the growth over the past 10 years. The growth within this industry is due to feedlots producing a specialised product. For the same reason further growth in this industry will continue to occur. Throughout this growth, there is a constant need to see a current picture of this industry and constant monitoring will be required.

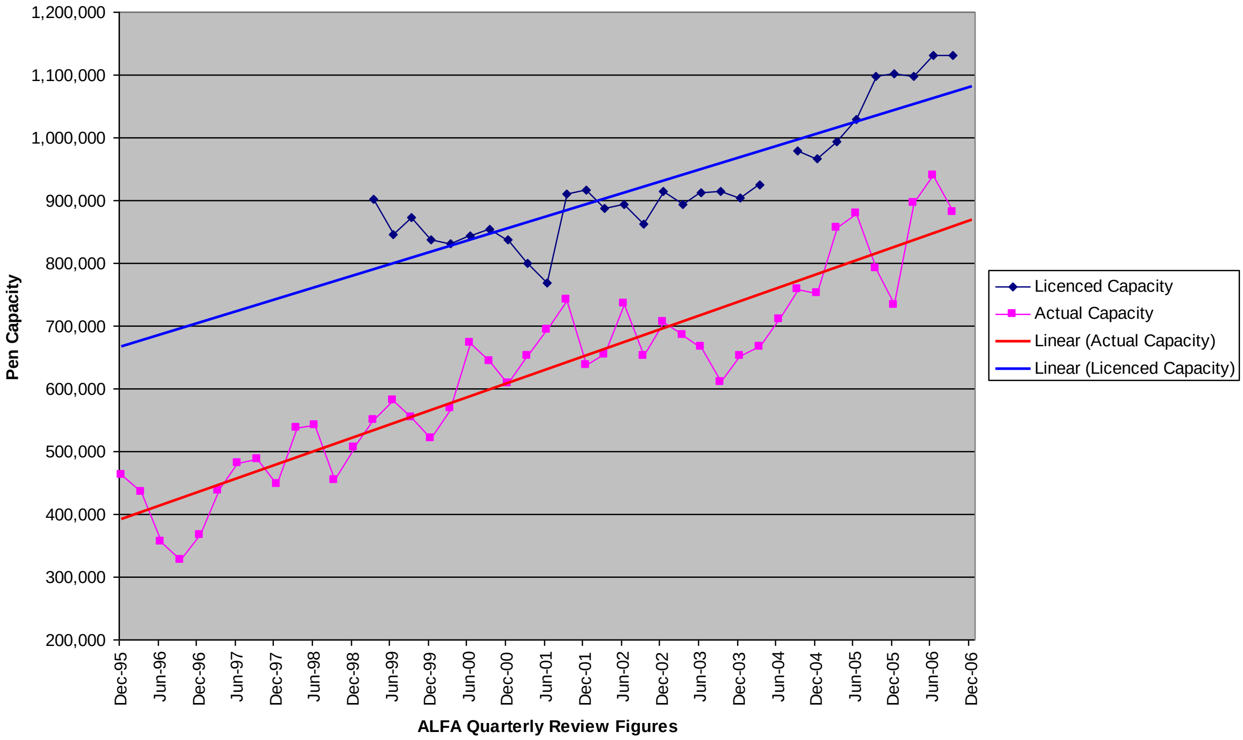


Figure 2- Growth of Feedlot Capacities from the December Quarter 1995 to September Quarter 2006 (MLA, 2006)

The feedlot industry continues to grow. Figure 2 shows this growth from 1995 to 2006 (MLA, 2006). Both licensed capacity and pen capacity has doubled in this period. The information in Figure 2 is only information from feedlots that are a part of NFAS. Hence, numbers given in Figure 2 are not a complete representation of the total feedlot sector. However, as evident by the actual capacity trend line the growth is 43,000 head per year over this period, This growth, coupled with the fact that intensive farming such as feedlots have environmental and social impact issues, means that work has to be done now for the future development of this industry. Gathering feedlot information from throughout Australia would provide a better picture of many of the impacts that this intensive farming style has. Sound industry statistics will also assist with economic growth. Any big picture must look at the feedlot sector's impact from local environments to catchment, State and National level issues.

2.2.6 Economic development of the feedlot industry

There is a need for effective forward planning for this sector to allow it to increase production into the future. Currently production of feedlot cattle is limited to various regions. The planning of the industry needs information to be able to guide this industry into new areas and regions that may be suitable for lot feeding. The current growth of this industry means that to sustain this growth work needs to be done now to allow for future growth. If an estimate of economic benefits of feedlots in 2002 gave $806 million as the total economic impact on the Australian economy, then the actual economic impact can be assumed higher in light of the growth that occurred between 2002 and 2007. It is vital for further economic development that future planning be undertaken. This requires a survey of the current lot-feeding in Australia and the various impacts.

2.2.7 Environmental impacts of the feedlot industry

Environmental impacts are a concern due to the intensive nature of this industry, often limiting applications for new developments. Feedlots are large producers of manure, and resultant greenhouse gases such as methane. The manure can also contribute large amounts of nitrogen, potassium and phosphorus to the surrounding environment. Methods are required to deal with the potential impact of the high nutrient levels contained in the manure. Effluent ponds contain and reduce the amount of nutrients leached from the waste into the local environment. These use both anaerobic and aerobic bacteria culture conditions to utilise nutrients, filtering the impact on the environment. However, this can become an issue as periods of large amounts of rainfall can potentially wash these nutrients into the surrounding environment. All these factors influence the management and site selection criteria of feedlots. These can also be limiting factors for future developments, which need to be able to sustain the environments surrounding the feedlot. The economic cost of environmental compliance was in development 4-6% of total cost per 600kg animal exiting the feedlot, and $2.35 per 600kg animal exiting the feedlot annually to stay compliant with environmental regulations (MLA, 2003).

2.3 A Geographic Information System Dataset for the Australian feedlot sector

2.3.1 What is a Geographic Information System?

Geographic Information System (GIS) is an amalgamation of geographical referenced data with an information system for an analysis of that same data. It is a powerful tool for the capture, storage, retrieval, management, analysis and display of data. It also provides the interrogation tools to extract spatial information based on criteria inputted by the user. The basis for a GIS program is to translate real world features into representation on the computer screen. It does this by representing real world features as points, lines and polygons. ArcGIS 9.1 is a Geographic Information Systems (GIS) software package produced by the Environmental Systems Research Institute (ESRI). ArcGIS can provide quickly and easily a feedlot industry snapshot, once the necessary data is within the program in a useable format.

2.3.2 Applications for a GIS Dataset for the Australian feedlot industry

A GIS dataset of the Australian feedlot sector would provide many benefits to lot feeding. Feedlot information throughout Australia would be able to be easily updated and maintained. Information such as size, capacities and new feedlot applications could all be stored to quickly give an up to date picture of the feedlot sector when required. The three major advantages that a GIS dataset could provide are the economic planning, environmental assessment and disease outbreak response for the feedlot sector.

1) Economic Planning GIS could provide data on the size and capacities of feedlots, broken down into State, regional and local divisions. It also has further applications such as the potential to provide direction for future growth. Using GIS software, there is potential for site selection using economic indicators as well as cost benefit analyses of potential sites that may not be in a region considered as having potential for feedlots. An example would be an investigation whether feedlots could survive in regions without a ready supply of grain, in accessing grain through low cost importation.
2) Environmental Assessment A GIS Dataset of all feedlots in Australia can assist national, State and local assessments of the environmental

impacts of feedlots. Environmental regions could be the basis for these assessments, e.g. catchments or climatic zones.

3) <u>Disease Outbreak Response</u> A GIS Dataset would assist rapid response for the industry in the case of disease outbreak. With an up-to-date picture of all feedlots in Australia, in the event of a disease outbreak, GIS could provide details on all nearby feedlots within minutes. Armed with further access to current National Livestock Identification Scheme (NLIS) information, cattle movements in these surrounding feedlots can pinpointed, perhaps aiding the location of the initial outbreak of disease.

A GIS dataset of the Australian feedlot sector is more than an industry survey. It is an effective management tool. This tool can be sharp and efficient, or blunt, depending on the data that is supplied to it.

2.4 Project objectives

There is great potential for the utilisation of GIS software to perform an industry snapshot and assist with future growth. This implies two project objectives:

1) Provide a dataset for the feedlot industry
2) To assess GIS as a basis for future site selection.

These objectives were adapted from a project brief obtained before starting this project. This brief can be found in Appendix A.

2.4.1 Objective 1 - Provide a dataset for the Australian feedlot industry

In 1991, *Lot Feeding in Australia: A survey of the Australian Lot Feeding industry* (Tucker et al., 1991) attempted to provide a survey of the industry. This text, while now grossly out-of-date, will provide a basis for comparison of statistics. The data reported in Tucker, et al., (1991) will be updated and the details from the initial survey data will report on the change from 1991 to 2006. A recommendation would be for this dataset also to be updatable to handle future applications for this industry.

The statistics used to analyse the Australian Industry in Tucker et al. (1991) and the basis for this industry summary are:

- feedlot numbers by State and capacity
- feedlot numbers by Shire and capacity
- feedlot capacity versus the feedlot size
- geographic changes between 1991 and 2006:
    - Australia wide
    - Queensland
    - South East Australia
    - South East Queensland
- feedlot number per catchment and sub-catchment
- feedlot position vs. annual rainfall distribution
- feedlot position vs. seasonal rainfall distribution

New Indicators can be produced from the 2006 data

- Heat Stress indicative potentials using a combined map of :
    - climate zone
    - cooling degree day
- growth of individual feedlot numbers on Statistical Local Areas (SLA) basis

2.4.2 Objective 2 - To assess GIS as a basis for future site selection

GIS can be used to undertake a more rigorous site selection for new feedlots, taking into account economic and environmental factors. These factors fall into three main streams: economic site criteria, climatic criteria and environmental criteria. Successful site selections have been based on these criteria in the past with management costs, animal welfare, social implications and future expansions in mind. The benefit of using GIS is the ability to interrogate large amounts of spatial data quickly and easily. However, GIS needs to have the data in a format that it can recognise. This is often where the largest amount of time is spent. The data also needs to be accurate and reliable. Therefore, current site selection criteria need to be translated into a format that is understood by GIS and that can allow GIS to give a result.

Site selection criteria can be specified based on guidelines developed by State and National bodies. To be effective in modelling site selection in GIS, the results must be applicable to a real-world scenario. Hence, the GIS must take the guidelines and turn them into applicable criteria. For example, with the criterion of proximity to grain, the GIS modified criterion might be *within 250km to grain*, or *within the grain belt*. Similarly, if the criterion asked for proximity to an abattoir, then the GIS criteria may be that feedlots need to be in *within a 250km radius from an abattoir* or *within 500km of three abattoirs*. Through the development of these GIS criteria, the goal must be to provide a result that is commercially relevant to the industry.

The new GIS criteria can be broken into “hard” (mandatory) and some “soft” (optional). The hard criteria are site selection criteria that are vital to the relevant site selection and cannot be adapted to new situations. An example could be that a feedlot cannot be placed within a declared national park, thus ruling out that area. The soft criteria provide a recommended criterion to be used in the selection of a site. However, this can be worked around if a site is otherwise suitable. An example of this could be access to a 3-phase electricity grid, which could be satisfied through the purchase of a generator.

In using GIS, site selection needs to occur on two levels. These levels are a regional scale and a local scale. A regional scale has GIS using certain criteria to select a general region for the site to be located. A local scale uses further criteria to continue to break down the pre-selected region into smaller suitable sites. Through this method, suitable sites are able to be located.

3 Literature review

3.1 Australian feedlot industry information

Information holds value to individuals and organisations only in certain contexts. Take information on feedlots for example. A registry of the feedlots in one scenario may need information on feedlots that are over a certain size threshold. Therefore, only that information on feedlots over these size requirements has value to that scenario due to the context of the requirements. This context gives priority to gathering information of those feedlots that satisfy these requirements. The need or value of gathering information on the feedlots that are outside these requirements is nil. A dataset of the entirety of Australian feedlots, however, has immense value to the economic planning of future sites and analysing environmental impacts of the feedlot industry. Hence, gathering information on all feedlots is of value in this context. This literature review will outline the data that is currently available about the industry to the industry itself from the following sources:

- National Feedlot Accreditation Scheme (NFAS)

- Regulatory Bodies (State)
- Information from Industry Magazines and Consultants.
- Data from an industry survey in 1990 (Tucker, et al., 1991)

3.1.1 National Feedlot Accreditation Scheme (NFAS)

The National Feedlot Accreditation Scheme is a voluntary self-regulatory quality assurance scheme. The scheme was initiated by Australia Lot Feeders Association (ALFA) and is managed by the Feedlot Industry Accreditation Committee (FLIAC). An accredited feedlot operator within this scheme must

- have documented procedures in place, specifically for the feedlot, which meet the requirements of the industry standards;
- maintain records showing that these procedures have been adhered to for all cattle prepared at the feedlot; and
- undergo a third party audit of these procedures, records and facilities at the feedlot.

Being a part of NFAS is mandatory for feedlots for the export of grain fed beef.
(AUS-MEAT website, 18/12/2006).

This scheme has a mandatory component for the ability to export grain-fed beef. However, within the past 5 years, the composition of cattle fed for specific markets has moved from 20% domestic/80% export, to 40% domestic/60% export (MLA *Lotfeeding*, 18/12/06). Figure 1 showing the destination of feed cattle in the June Quarter, 2006 also demonstrates that there is a domestic market available for grain-fed beef. Therefore, the NFAS can never gather a complete overview unless it becomes compulsory for all feedlots. However, the mandatory requirement of being a part of NFAS in order to export helps NFAS accredit a large proportion of the Australian capacity. It is mostly smaller feedlots that are not part of the scheme.

3.1.2 Regulatory bodies

Currently the regulatory bodies in Australia are State-based departments. These enforce the States' environmental legislation and regulations. Table 2 presents the licensing and regulatory requirements from each State and the minimum licensing capacity thresholds for each State body. Tasmania and the Northern Territory are not included in this list as each only has one known feedlot. It is these requirements that give context to the information they require in their feedlot registers.

Table 2 - Regulations Regarding Feedlots in Australia

Regulatory Body	Requirements	Licensing Capacity
Victorian Code for Feedlots 1995		
Victorian Department of Agriculture & Minerals	Agricultural Approval	below 1000 head submit to feedlot proposal
Victorian Department of Agriculture & Minerals	Agricultural Approval	above 1000 head require planning permit
Victorian Environmental Protection Agency	Works Approval	above 5000 head
West Australian Guidelines 2004		
West Australian Department of Environmental Protection	Licence	above 500 head and less than 100m to water
	Registration	above 500 head and more than 100m to water
South Australian Guidelines 2006		
South Australian Environmental Protection Agency	Approval	Above 500 head or
& Primary Industries		Above 200 head within water protection area
Queensland Reference Manual 2000		
Queensland Department of Primary Industries	Licence	above 1 head
Environmental Protection Regulation 1998		
New South Wales Environmental Protection Act 1997		
New South Wales Environmental Protection Agency	Licence	above 1000 head

Feedlots with capacities smaller than 500 head miss registration in all other states except Queensland.

The data on feedlots found within a compilation of state regulatory bodies' registers skews toward Queensland due to large numbers of smaller feedlots in these data sources. The complete registration of Queensland feedlots causes this. A complete list will shrink averages in certain states, giving those states with a complete list a false impression of a higher number of smaller feedlots.

3.1.3 Industry magazines and consultants

FSA Consulting has had 16 years experience in providing services to the feedlot industry. This relationship between a firm and an industry gives the staff an understanding and knowledge of various locations and operations of feedlots not seen in other registers. Access to other consultants adds to this information, and clients may give information about feedlots known to them. Industry magazines also give access to further information.

3.1.4 1990 Industry survey

In 1990, Tucker et al. (1991) undertook one of the first geographical surveys of the Australian feedlot industry. Unfortunately, little of the original data set remains today. It was possible to generate data on the location of individual feedlots in 1990 but pen capacity data has been lost. Hence, it is not possible to regenerate the analyses presented in Tucker et al.

(1991) using the original data. Nevertheless, data on the geographical location of individual feedlots in 1990 is useful data.

The 1990 data suffers the same limitations as the current data. That is, it is based on a voluntary national registration system (AUSMEAT) and incomplete state regulatory databases.

3.1.5 Current data summary

Establishing a list or registry of the current feedlots within Australia is vital to understand the implications of the feedlot industry. This would begin as a compilation from known information sources and develop from adding further information. However, even with these sources compiled, there are still a number of feedlots that will not be counted, because they are not present on any list. There should still be an attempt to create a database of all the feedlots within Australia. This would use the simple definition of a feedlot, without the requirement of size or capacity. This list needs to be relevant to the industry with the ability to be updated. This database also needs a spatial component to allow for use within a GIS.

3.2 Basis for site selection

The location of an intensive livestock production will affect the future management, environmental and social impacts that the operation will have. Feedlot site selection needs to be based upon effective planning and selection criteria to be effective in the triple bottom line of economic, ethical and environmental impacts. With the current expansion in the Australian industry, future feedlots need more sites that are suitable. This literature review will focus on several key elements:

- Compile a list of key site selection criteria
- The use of GIS in site selection for other intensive agricultural activities
- The history of selecting sites for feedlots in Australia

Several states of Australia have developed guidelines for feedlots and these are in various levels of currency.

3.2.1 Key site selection criteria

Currently the expansion of the feedlot industry has occurred with feedlots being placed where they suited and abiding by certain constraints placed on the industry's development at various times. Feedlots have closed under certain constraints imposed with new legislations and the industry has opened to new opportunities (using different management and site design to maximise on grain availability in Western Australia, while coping with the less suitable winter dominant rainfall patterns.)

Tucker et al. (1991) explained the process of site selection in 1990 "*to date, most feedlot sites have been selected on the basis of economic factors and site features with lesser consideration of environmental factors. Hence, most feedlots are located close to the major grain growing belts and to supplies of store cattle and processing plants*." However, this is no longer the case. Since the early nineties, various states have produced environmental management guidelines used in the selection of sites of feedlots. These guidelines include developmental constraints based on environmental concerns. In 1994, South Australia produced guidelines which planning principles required "*Cattle feedlots should not create any significant adverse impact, including … pollution of the environment*" (SA EPA, 1994). The Victorian code for Cattle feedlots (Vic DAE&M, 1995) has as one of its two main purposes to "*provide a set of environmental standards which will allow the development and operation of the cattle feedlot industry in such a way that community expectations of* *environmental production are achieved."* In 2002, the Western Australia Department of Agriculture produced the "*Guidelines for the Environmental Management of Beef Cattle Feedlots in Western Australia*" (WA D Ag, 2002). All of these codes, requirements and guidelines require this industry to take a new approach in the selection of new feedlots, emphasising current environmental constraints. Understanding the current situation is pertinent to understanding the future.

In the Australian industry, there are numerous publications on site selection requirements. Selection criteria need to be relevant to Australian conditions and therefore cannot be adapted from those of other countries. The current guidelines from National (ARMCANZ, 1997) and State regulatory bodies (NSW EPA, SA EPA & DPI, VIC DPI, WA DEP& DPI and Qld DPI) and industry texts (Tucker et al (1991) and Watts and Tucker (1994)) are used to compile a list of the current site selection criteria. This uses three categories found in Tucker et al. (1991). These categories are:

- Economic Features
- Site Features
- Environmental Features

Table 3 shows the various selection criteria divided into two columns. The first is criteria common to most of the guidelines, and the second is a State specific criteria.

These are suggested criteria based upon an ideal site. While the selection of a site with one or more unfavourable environmental parameters is not encouraged, overcoming or reducing some recognised site disadvantages can be achieved by appropriate engineering works or superior management practices (QDPI, 2000).

Table 3 – State Guidelines in Site Selection for Feedlots

General Criteria	State Specific Criteria
Economic Factors	
proximity to store cattle	
proximity to grain	
availability of other feedstuffs	
proximity to abattoirs	
proximity to sale yards	
availability of labour	
Site Features	
suitable topography	
source of gravel and other construction materials	
250hd/ha for pens and associated facilities	
10 head/ha for manure and effluent utilization	
suitable agronomic soils for waste disposal	
proximity to good roads	
proximity to major roads	
availability of water (quantity and quality) allow per animal 5L per 50kg live weight/day	
proximity to 3 phase electricity	
temperate climate (not too hot or cold)	Provision of Shade or cooling if temperature exceeds 30^{o}C annual greater than 750 hours
	temperature not greater than 35^{o}C for prolonged periods
proximity to railways	
Clay suitable for dam construction. Good agricultural soils	
buffer from existing or future residential development	
constraints, significant landscapes, aboriginal sites, vegetation clearance	
Environmental Factors	
rainfall less than 750mm per annum	Climate as rainfall, wind, humidity and temperature affect cattle welfare
high evaporation, low rainfall	
summer dominant rainfall	
adequate separation from surface waters	buffer from water to external runoff
	200m boundary of wetland vegetation around estuaries and lakes
	200m conservation wetlands
	100m banks of streams rivers & 100m bores
	50m to intermittent water courses
away from flood prone areas	above 1 in 100 year flood if known
adequate separation from groundwater	1.5m to wet season ground water level
avoidance of major faulting zones or permeable soils (groundwater)	
adequate separation from neighbouring houses, towns, etc.	5000m residential areas, 1000m isolated residences
	50m property boundary
visual screening from public view	buffered by natural hill

3.2.2 The history of site selection in Australia

The Feedlot Industry began in the 1960s, and started expanding in the 1970s as access to the Japanese market opened (Tucker et al., 1991). Growth halted when access to this market closed for a year in 1975. With the reopening of the market in 1976, the industry grew steadily. The onset of dry season in the late 1980s (Tucker et al., 1991) and increased access to the Japanese market in 1988 and the Korean market (Food Victoria, 1995) led the growth of the Feedlot Industry to date. The industry has grown due to drought seasons and the ability to produce beef year round in these conditions. Markets shares held by Japan and Korea meant there was a demand for feedlot beef. Estimations put the capacity of the feedlot industry in 1991 at 631 feedlots with a total capacity of 485,000 head (Tucker et al., 1991). Figure 2 shows in Section 2.2.5 the growth in capacity from 1995 to 2006. MLA and ALFA estimate a current capacity of 940,000 head (MLA, 2006) on around 598 accredited feedlots (AFLA industry survey, 2002).

There have been major pushes in Australia driving the site selection of feedlots. Initially it was proximity to a number of requirements, such as access to grain, cattle and water. Through the development of the industry, however, the odour generating capabilities of these feedlots in the 1980s generated a social component from surrounding communities (Tucker and Watts (eds.), 1994). Recently, the basis of being environmentally sound was the driving force for site selection. Regulatory bodies demonstrate this in the guidelines by including environmentally sound criteria.

The future issues for site selection are access to water, as water licences become more difficult to obtain. The potential for transporting grain longer distances is an option potentially opening up wider areas. Grain also may be able to be imported opening up areas surrounding ports. Climate change will potential affect this industry by affecting the climatic patterns in Australia.

3.2.3 The use of GIS in site selection of intensive agricultural activities

Site selection for feedlots is a process involving many variables. Its goal is to make decisions about where a feedlot is best situated. The first large scale feedlots in Queensland were established on the Darling Downs from the early 1960s (QDPI, 2000). However, it was not until 1989 with the publication of *Queensland Government Guidelines for Establishment and Operation of Cattle Feedlots* by Queensland Department of Primary Industries, that a published guide was available on the operation and site selection criteria for feedlots. Since the Queensland Guidelines were established, other States followed, producing guidelines fuelled by expansions of the feedlot industry in their respective States.

The process of site selection is done on a case-by-case basis. The question remains of the ability for a GIS to produce similar results to those of an experienced lot feeder or consultant. The advantages of a GIS would be the time saved by interrogating large amounts of data in a short period. This would give a generalised area of suitable land for lot feeding. GIS software could perform a broad-scale analysis for a suitable site.

Kizil and Lindley (2005) were able to perform spatial evaluation of feedlots regarding water quality in North Dakota. 478 feedlot operations were mapped using a feedlot database with coordinates of each operation and GIS software. Using national and State legislation on the site selection criteria, they were able to distinguish between feedlots that were within current legislation and those that were outside of it. They looked at GIS interrogation capabilities in slope analysis, runoff and soil type on each individual feedlot. Inaccuracies from GPS data created problems with site selection criteria. GPS placed known feedlots that are near a waterway, away from that waterway. However, despite problems in GPS accuracy, Kizil and

Lindley developed a state wide GIS feedlot dataset. Future broad scale site selection is improved due to the foundational work established in their study.

McLeod et al. (2002) evaluated the use of GIS on a national level in the application of site selection for the intensive agriculture of shrimp farming. Site selection for aquaculture planning is a complex task involving the identification of areas that are economically, socially and environmentally suitable, available to aquaculture and commercially available (McLeod et al., 2002). Analysis was conducted through a two-step process of a coarse national scale assessment and then a finer local scale assessment. McLeod et al. (2002) used this technique to optimise the use of data and processing time. This study demonstrated that the use of buffering provides an effective method of bridging between two scales. It allowed the importation of coarse scale results into fine scale analysis without a large increase in spatial error (McLeod et al., 2002)

Coarse-scale pre-selection used the following parameters:

- Mainland Australia above 32^{o}S latitude and within 10km of the coast,
- distance to water <2km,
- elevation <20m,
- slope <5%,
- not mapped as wetland,
- not within 3km of built-up area.

Fine-scale selection involved:

- pre-selection of the study area,
- current tenure,
- parcel area,
- finer elevation,
- finer-scale slope,
- distance to water,
- current zoning,
- strategic plans,
- agricultural land class
- sugarcane suitability.

Criteria weighted the finer scale results and ranked them accordingly. A 470 m buffer enabled a transition between two scales by adding it to the broad-scale pre-selection. The following formula calculates the large-scale buffer spatial error at 470 m using:

Equation 1 - Spatial error calculation

Spatial error = square root (sum of (layer x spatial resolution)^2 +(layer y spatial resolution)^2+ …)

This two-step process is an effective national scale method of site selection adjusting for errors in resolution.

Basnet, et al., (2001) in 'Selecting suitable sites for Animal Waste Application', performed another broad-scale site selection. This project used a raster data model to weight site selection criteria over the Westbrook sub-catchment, Toowoomba Australia. The relative importance ranking of input factors was determined by making an objectives-oriented comparison (OOC) that required valuing each factor in terms of achieving the desired objectives of the site suitability analysis (Basnet et al., 2001). The objectives were ranked by interview of catchment stakeholders (farmers, local shire councils, government departments, and university academics). The weights on the site suitability criteria then allowed the software to identify suitable land for the disposal of animal waste from within the sub-catchment.

3.2.4 Summary

To summarise, site selection criteria of feedlots are dependent on economic factors, state regulations (environmentally and socially), local government planning, a proximity to resources for the feedlot and the climatic features of Australia. Once built, a feedlot cannot be relocated. There is a need for a clear site selection package to produce broad scale site selection based on Australian known climatic conditions, economic, site and environmental criteria. A GIS software package could perform broad-scale site selection on hard criteria from the site selection process. Further criteria can allow for a finer scale site selection, locating feedlots in a local context.

4 Methodology

4.1 ArcGIS 9.1

There are different GIS software package available at present with differing levels of complexity and performance. At present, there is no single industry standard. For this project, ArcGIS 9.1 was used.

ArcGIS 9.1 is a Geographic Information Systems (GIS) software package produced by the Environmental Systems Research Institute (ESRI). It is a powerful tool for the capture, storage, retrieval, management, analysis and display of data. Geographic Information System is an amalgamation of geographical referenced data with an information system for an analysis of that same data. ArcGIS can provide quickly and easily a feedlot industry snapshot, once the necessary data is within the program in a useable format. It also provides the interrogation tools to extract spatial information based on criteria inputted by the user. The basis for a GIS program is to translate real world features into representation on the computer screen. It does this by representing real world features as points, lines and polygons.

4.2 Construction of the feedlot database

Combining Feedlot Industry data from various sources gives the potential for a correct industry geographical representation. Even with the total compilation of the available data, some feedlots can still be missing, as they are not listed on any register. This process began with compiling the NFAS database with other databases of state regulatory bodies. Then further feedlot information was added to that found by searching FSA Consulting industry magazines and talking with other consultants. This then created the FSA Feedlot Database (FSAFLdB). The FSAFLdB records each feedlot's capacity in two formats, "Licensed Capacity" and "Actual Capacity."

"Licensed Capacity" is the capacity of the feedlot (in either SCU or head depending on the regulatory system) approved for that site.

"Actual Capacity" is the currently constructed pen capacity. This may be less than Licensed Capacity if the feedlot is still under development.

4.3 Confirmation of feedlot capacity

A brief telephone call to the major feedlots was performed of current data. For this analysis of the feedlots, the 80-20 rule was used, checking 80% of known capacity, to ensure that accurate data for the “Actual Capacity” was current for 80% of known feedlot capacity.

4.4 Georeferencing feedlot database

GIS requires spatial information for its analysis and map building functions. The data collection phase, due to the nature of information, is an ongoing operation. This will continue until the time at which the report is due, or the feedlot data is complete. Georeferencing takes a real world location and gives it spatial attributes such as coordinates. This was necessary as none of the feedlots in the FSAFLdB had a spatial reference of any sort. The software Google Earth, a 3D satellite imagery program, allowed photos from satellites and aircraft to be used to locate feedlots. These images are pictures taken throughout the last three years. This gives a combination of low resolution (15 m pixel size) and high-resolution images (one-metre pixel size) (Google Earth, 2006). Using Google Earth in combination with known areas of localities in the FSAFLdB, the actual position of feedlots were located and recorded. The FSAFLdB then records the *latitude* and *longitude* coordinates of these positions in decimal degrees.

The way that feedlot sites were located was performed on a ranked order. Larger capacity feedlots were located first, as they were easier to find. Then the search focused on feedlots that were any size and that had higher resolution imagery. Street addresses provided additional aid in locating feedlots on both high and low resolution imagery. Finally, the search began for low-resolution imagery areas and smaller feedlots. Not every feedlot was successfully located. However, given the scale of this project, an Australian industry snapshot, georeferencing with the locality of the feedlot was sufficient. Hence, the higher priority of establishing a total industry picture overruled the need for absolute accuracy.

To distinguish between the feedlots that have been georeferenced accurately and those that have not, uses another ranking system. This helps also to distinguish between known feedlot sites and other sites that need further information to establish a more precise location. In taking a national scale picture, the requirement of a total picture of all known feedlots to FSA Consulting was greater then the need for accuracy. Therefore, the two categories are as follows:

- Good - The point position is accurate on a known location of a known feedlot. The feedlot can be clearly identified on Google Earth. This category does not to need to be updated.

- Poor - The Poor category is made up by any of the following scenarios. This category does need to be updated.
  - The feedlot is too small and cannot be found so the point position is located on the town of its postal address and can be assumed to be within a 30km radius of the actual point
  - The resolution is too large to see it clearly so again the point position is located on the town of its postal address and can be assumed to be within a 30km radius of the actual point
  - When a feedlot is found in an area of many feedlots, a guess is hazarded on which feedlot is actually is. Feedlot size is usually the basis for these guesses.

The "Poor" category does leave inaccuracies within the map, but these are insignificant due to national scope of the study

Table 4 - A Comparison of "Good" versus "Poor" Georeferenced Feedlot Locations

Size Capacity	"Good" Count	%	"Good" Capacity	%	"Poor" Count	%	"Poor" Capacity	%	Total Count	Total Capacity
Less than 400	61	12.8%	7,006	11.5%	416	87.2%	54,070	88.5%	477	61,076
400 to 999	37	17.6%	26,430	20.3%	173	82.4%	103,566	79.7%	210	129,996
1000 to 4999	56	39.7%	130,552	48.7%	85	60.3%	137,817	51.4%	141	268,369
5000 to 9999	21	77.8%	148,155	81.3%	6	22.2%	34,000	18.7%	27	182,155
over 10000	26	96.3%	523,623	97.5%	1	3.7%	13,500	2.5%	27	537,123
Grand Total:	**201**	**22.8%**	**835,766**	**70.9%**	**681**	**77.2%**	**342,953**	**29.1%**	**882**	**1,178,719**

Currently the georeferenced feedlots within the FSAFLdB represent around 99.8% of known current feedlot capacity and 99.2% of total known feedlots (See Section 5.1). The FSAFLdB references the locations of 882 feedlots.

4.5 Creating a GIS dataset

ArcGIS 9.1 was able to import feedlot positions once the FSAFLdB had spatial references. Feedlots used the Geographic Coordinate System using the Geocentric Datum of Australia to place point positions. A list of other GIS data sourced for this project follows:

Table 5 - Data Sources and Currency

Description of Data	Source of Data	Current as of
Digital Topographic Maps	Geosciences Australia	2001
Climatic Data	Bureau of Meteorology	2006
Statistical Local Areas	Australian Bureau of Statistics	2001
Agricultural Statistics	Australian Bureau of Statistics	2001
Catchments	Geosciences Australia	1997
Population Statistics	Australian Bureau of Statistics	2001

The project used a spatial standard into which everything was converted or projected. This standard was:

Data at the National Level

Map Datum — Geocentric Datum of Australia 1994 using the Geographic Coordinate System
Semi-Major Axis: 6378317.000000
Flattening: 298.257222

4.6 Data design interrogation methods

Data manipulated for a spatial analysis uses these general steps.

Step One – Locate the thematic map of Australia displaying the feature of which analysis is required.

Step Two – Merge this data with the Feedlot Database data, and the feedlot attributes are assigned a location marker based upon which type of theme they fell, i.e. in the State thematic map, feedlots assigned the State that they were in to the FSAFLdB, i.e. Queensland.

Step Three – Generate reports using groupings that were outlined by the theme (States) using Crystal Reports XI that was packaged with the ArcGIS software, exported to Microsoft Excel in table form from which the information can be used in Microsoft Word.

The following sections identify individual procedures needed for each theme mapped or statistic produced. Throughout these procedures quotations marks represent actual processes in ArcGIS that perform the required operation i.e. "Select by Attributes." For detailed explanation on the operation used, consult Appendix . Appendix also contains a generalised flow diagram of this process.

4.6.1 Current pen capacity

The current pen capacity analysis was completed using the combined resources of the FSAFLdB. The FSAFLdB contains details of feedlots from the NFAS, individual State authorities and licensing agencies, magazines, other consultants and feedlot design and application work completed by FSA Consulting. Generating one report on the capacity and count of the feedlots within the database gives the totals of the FSAFLdB.

To demonstrate the amount of information that has been georeferenced is to query the FSAFLdB based on data that has been georeferenced and that data that has not been georeferenced. This data then forms a figure graphically demonstrating the coverage of the dataset, and the information that forms the basis of the GIS reports.

4.6.2 Major Australian feedlots

The data for the major Australian Feedlots uses the top current pen capacities in Australia to demonstrate the geographic location and relative capacities to the overall feedlot sector. "Select by Attributes" selects feedlot with a capacity of 12,000 head or greater. This was then "clipped" to form a stand-alone point position map. To create a point position map of the data sourced in 1990, a text file was created separating field using commas; this file is located in Appendix . A National map created summaries of the years 1990 and 2006 with points of the major feedlots in those years. This demonstrates the geographical changes in location of the major feedlot over the past 16 years.

4.6.3 State-based analysis

The production of a state-based analysis using GIS software was as follows. A 1:1,000,000 scale digital topographic map of Australia and the FSAFLdB added feedlot positions. The goal was to identify feedlots within state boundaries. This was completed by running "Select by Attributes" selecting an individual State. This selected State boundary was then "clipped," forming a layer comprising of only that State. Then using "Select by Location" with feedlot locations as the input data, all feedlots that "are completely within" the individual State were selected. On these selected feedlots' attribute table an operation of "Add a field" was performed to create a new field for the State information to be stored. "Calculate values" operation entered data into the new field of only the currently selected attributes. This new value is the individual State's name. This was repeated for each State.

4.6.4 Analysis of feedlot capacities versus feedlot size

This analysis used ArcGIS to interrogate the FSAFLdB on capacities of various size ranges of feedlots. The Tucker et al. (1991) size ranges are the basis for those selected in this study. An additional two ranges of 5000 to 10000 head, and 10000+ head ranges were included to reflect the nature of the 2006 data. This was performed by "Selecting by Attributes" individual size categories, "Adding a Field" into the FSAFLdB to record these size categories. These were then exported using all the feedlots that have a spatial reference, into Crystal reports, grouping them into various size categories. A table is used to record and summarise this information. A national scale map shows the relative location of each size range on a national scale.

4.6.5 Geographic location

Geographic location maps produced use point position to represent feedlot distribution of the entire feedlot sector at national scale. Additional maps highlight regions of importance to the industry. Unfortunately, due to the scale of the national view it gives a limited description of the actual distribution in certain areas i.e. from a national level the feedlots in South East Queensland appear 'clumped'. Therefore, the following maps are needed to clearly represent the spatial distribution of feedlots:

- National Level
- Map of Queensland
- Map of South-East Australia extending from NSW border down to Tasmania, from the East Coast to the Middle of South Australia
- Map of Western Australia's South Western corner.
- Map of South-East Queensland.

Each map was a comparison of the 2006 feedlots against a 50 km area buffer around known 1990 feedlot points.

A further analysis performed was the growth of feedlot numbers based on certain regions. A national scale that breaks Australia down into further regions is the Australia Bureau of Statistics Statistical Local Areas (SLA). For this analysis, each SLA needs to be given the number of feedlot locations within its borders. Using "Join on spatial location" and summarizing the feedlot incidence by count in each area, SLA boundaries can be associated with the number of individual feedlots within each individual SLA region. The 2006 and 1990 data both underwent this procedure. These joins are then in turn "Joined" to create another SLA boundary layer having both the 2006 and 1990 count. "New Field" created a new field labelled "Growth." The operation "Calculate Values" used an arithmetic operation of the 2006 count of individual feedlots minus the 1990 count of individual feedlots, giving the value recorded in each SLA boundary. This field is then symbolised on its values. Negative numbers show that some of the 1990 feedlots have disappeared, and positive numbers show a growth from 1990 figures in that region.

4.6.6 Catchments

The first process of turning the catchment data into usable dataset was to extract the catchment boundaries. A national coverage map displayed the 12 major catchments in relation to the feedlot location data. Maps of individual catchments were created by selecting the individual catchment boundaries, and clipping them from the map of Australia. These catchments used the "Select by Location" function, with the selection being each feedlot within a particular catchment. The "Add Field" option added a field to the Feedlot database and "Calculate values" gave each of the selected feedlots within a catchment that catchments name as the identifier in the new field. This data generated a report, showing feedlots grouped by Catchments.

Further analysis was required to break down two major Catchments into sub-catchments. The procedure was identical to that performed to break Australia into catchments. However, in this procedure, the sub-catchments used were those with feedlots within them. Each sub-catchment regions made an individual layer. An additional field was added to record into which sub-catchments the feedlots fell.

4.6.7 Annual rainfall

A Bureau of Meteorology map of annual rainfall, and feedlot locations stored within FSAFLdB allowed ArcGIS 9.1 to perform an analysis of the distribution of feedlots over rainfall zones. “Select by Attributes” operation selected individual isohyets. Only the isohyets from 600mm to 800mm were selected because few feedlots are in zones with much less than 600 mm and most guidelines recommend that feedlots are not located in areas with more than 750 mm of annual rainfall. By then using “clip” these individual isohyets formed a new map. “Select by location” selected feedlot occurrences that were completely within isohyets. “Add field” created a new field for the feedlot database and “Calculate values” added values to the database that established in which isohyets each feedlot occurs. A report generated using the feedlots with a geographic reference, showed feedlots grouped on the rainfall isohyets classifications.

4.6.8 Seasonal rainfall

A report outlining the analysis of the distribution of feedlots in these seasonal rainfall zones used another thematic map sourced from the Bureau of Meteorology, classifying seasonal rainfall zones and the FSAFLdB. The seasonal rainfall zones represent summer dominant and winter dominant rainfall zones across Australia. “Select by Attributes” selected individual seasonal zones; and multiple “Clip” operations of individual zones formed layers of seasonal rainfall. “Selecting by location” selected all feedlot occurrences that were completely within the area outlined by the individual seasonal rainfall zone. An “Add field” process added another field to individual records within the feedlot database to which the feedlot database recorded the seasonal rainfall zone. This data generated a report, reporting only on the data that has a point position.

4.6.9 Potential heat stress zones

Heat stress has been an issue that has undergone considerable research in the past few years. Formulae to indicate when heat stress is likely to occur have been developed. There are several versions of Heat Load formulae and most use data not readily available from the Bureau of Meteorology (e.g. daily wind speed). Nevertheless, an analysis was undertaken to show the potential for GIS to map areas where high heat stress might be expected.

An analysis of the distribution of feedlots throughout the potential heat stress zones in Australia was performed by creating a map with potential heat stress zones classified on it. The map was created by the union of a climatic zones map of Australia and a map of cooling degree-days zones within Australia. The climate map showed areas of high humidity. The cooling degree-days showed the accumulation of degrees Celsius above a base temperature in a year areas are subject to. As an example, for this analysis, a cooling degree-day map with a base temperature of 18^{o}C was selected. Areas that had more than an accumulation of 1000^{o}C over the base temperature throughout a year were selected. The union created multiple areas of variations of humid and temperature, which were the heat stress zones. A “Select by Attribute” operation identified a single heat stress zone, which was then “clipped” from the rest of the map to form its own layer. Then using “Select by location” all feedlots within that climatic zone had a field added to each record giving each feedlot location an identifier on which climatic zone it inhabits. This was repeated for all zones. A report grouped on climatic zones then gave a count and capacity of all the feedlots in a particular zone.

4.7 Site selection criteria

The methodology used in the site selection of feedlots is an adaptation of the method of using a broad scale to a finer scale analysis cited in Section 3.2.3 by McLeod et al. (2002). McLeod et al. (2002) eliminated a large portion of the Australia continent that would not be suitable and then performed the finer scale analysis on the remaining areas. The Australian Feedlot Sector could have this method as a basis for a feedlot site selection. As outlined in Section 2.4.2, a method of regional and local site selection criterion needs to be established. This allows for the formation of the components for the broad-scale and the fine-scale site selection. Utilising the current summary of the site selection guidelines (Table 3) and McLeod et al. (2002), the guidelines were translated to create the relevant GIS criteria. Table 6 displays the summary of these criteria. The broad-scale site selection criteria are labelled “regional” in the scale column. The fine-scale site selection criteria are labelled “local.”

These criteria then provide a basis for additional spatial data that is needed to perform the site selection. Additional categories of mandatory and optional allow the site selection method to rank potential areas of suitability. Mandatory criteria are immovable constraints while optional criteria are constraints that can be worked around using different management or design methods.

Table 6 - Site Selection Criteria

Site Selection Criteria				
Type	**Scale**	**Mandatory/Optional**	**Criteria**	**Solution to missing Criteria**
ECONOMIC/RESOURCES				
Proximity to Grain	Regional	Optional	within Grain Belt	Good transport route - beside railway line
				Importation of Grain/near ports
Proximity to Cattle	Regional	Optional	Within 1500 km of Breeding Zone	Back-grounding
Proximity to Abattoir	Regional	Optional	within 250km	Preferred location
		Optional	Within 800km	Possible location with economic costs
Staff - 1 per 750-1000head	Local	Optional	within 50km to town	onsite accommodation
				International workforce
Road Access	Regional	Optional	within 50km to Main (State) Road	build own access road
Power – Electricity	Local	Optional	access to 3 phase power grid	onsite generator
Water Supply - Bore, Surface	Regional	Mandatory	24ML/1000head capacity	Great Artesian Basin Licence
Topography	Local	Optional	2-4% slope	earthworks
CLIMATE				
Rainfall	Regional	Optional	< 750mm annual	better design/management/greater buffer
Heat Stress	Regional	Optional	Temperature/Humidity	Shade/Cattle Type (*Bos Indicus*)
ENVIRONMENTAL				
Odour	Local	Mandatory	adequate distance separation	Better design/management
Ground Water Quality	Local	Optional	Deep or no ground water	Good pen construction
				Pond lining
				Nutrient balance avoid leeching
Surface Water Quality	Local	Optional	separation from surface waters	large ponds - nutrient balances
		Recommended	avoids 1 in 100 year flood plain	Levee banks
Soil Agronomic Land	Local	Optional	Land available for disposal of waste	
			Effluent -	evaporation ponds - only in certain climates
			Solid Manure-	off site sale
Community Amenity	Local	Mandatory	Buffer to sensitive areas - Nat. Parks, etc	
Remanent Vegetation	Local	Mandatory	All ready cleared or clearing allowed	

4.8 Prediction of feedlot site locations

Three methods of performing a broad scale site selection were attempted. All aimed to produce a broad-scale site selection and all used the same input data. However, the difference was the how the GIS interpreted the data used. The methods that are used were adapted from methods used in the literature review. All methods used the same resulting translation of the selection criteria to GIS compliant criteria.

4.8.1 Translation of site selection criteria into GIS compliant criteria

To perform a site selection, the first process required was one to adapt all maps to be compliant with the GIS criteria. This involves taking the spatial data and rendering to a point that it will either be accepted or rejected by the site selection criteria. Then the criteria can be used in the GIS. For example, if the site selection criterion was to place feedlots in areas with less than 750mm of rain annually, any areas above 750mm of annual rainfall would be rejected and all the areas below accepted. Thus, this criterion can be used in the GIS. Alternatively, another example would have the site selection criterion to locate feedlots within areas of 250 km to an abattoir. The area within this range was accepted. Those outside of this range were rejected. To do this, information was needed to translate the individual criterion into an accept/reject basis for the GIS. A summary of each criterion and how it was translated into an accept/reject statement for GIS is displayed in Table 7. A brief explanation of each criterion follows:

Proximity to Grain was defined as being within the “Grain Belt.” The “Grain Belt” criteria was selected from the SLA regions that produced over 10,000 tonnes of grain in the 2001 Australian Bureau of Statistics (ABS) data. To allow for the option of bringing grain to a feedlot outside of the Grain Belt, a 100 km “Buffer” was performed around the railway lines of Australia. A buffer gives an area that is a nominated distance surrounding certain locations in a GIS.

Water Access was created from maps of aquifers and major rivers. While this does not give a guarantee of water for a feedlot, this gives areas where water is available. This was all that was needed for the GIS. A “Select” operation was performed to create a new layer of only aquifers with a “High” level of production. “Select” was also used to create a new layer of only major rivers. A “buffer” of 10 km was applied to give an area surrounding these rivers. These layers were then joined using “Union” to keep the individual attributes.

Proximity to Cattle was a “Select” function based on the SLA regions of 10,000 calves or higher in ABS data.

Road Access was a 50km buffer surrounding all the major roads in Australia. From the Topography map, “Select” was used to create a layer of only major roads. On this a 50 km buffer operation was performed, selecting an area of 50 km surrounding the major roads.

Table 7 - Translating the Site Selection Criteria into GIS Selection Criteria (Accept or Reject basis)

Type	Data Source	Criteria	GIS criteria
ECONOMIC/RESOURCES			
Proximity to Grain	ABS data 2001	within Grain Belt	SLA regions with grain production of >= 10,000 tonnes in 2001 ABS data
			100 km Buffer to Railway lines
Proximity to Cattle	ABS data 2001	Within 1500 km of Breeding Zone	Any SLA that produced over 10,000 calves in 2001 ABS data
Proximity to Abattoir	Georeferenced locations	within 250 km	250k Buffer based on large beef Abattoir locations
		Within 800 km	A Buffer of only 250 – 800 km surrounding Abattoir locations
Road Access	Topography Map of Australia	within 50km to Main (State) Road	50 km to Dual Carriageway, Major and Secondary Road
Water Access	Map of Aquifers	24ML/1000hd capacity	Union of only select those aquifers with HIGH permeability
	Topography of Major Rivers		10 km buffer to major rivers
CLIMATE			
Rainfall	BOM data annual rainfall	< 750mm annual	Select only those areas of less than 750mm annually
Heat Stress	BOM data cooling degree days (CCD)	no humidity, cooler regions	Union of areas that are an accumulation of over a 1000 ^{o}C over 18^{o}C per annum
	BOM data seasonal classification		areas that are known to have hot humid summers

Table 8 - Additional Site Selection Criteria Translated into GIS Selection Criteria (Accept or Reject basis)

Type	Data Source	Criteria	GIS criteria
ECONOMIC/RESOURCES			
Proximity to Populated Centres	ABS 2001	within 50 km of Town	within 50km buffer of populated centre over 3000 people
Density of Abattoirs	Georeferenced locations	enough abattoirs close by for competition on cattle prices	within 250 km of 5 or more large beef abattoirs

Proximity to Abattoirs was created from a layer of abattoirs that was georeferenced from a database using Google Earth, known localities and street addresses. This database had added to it several new columns that recorded the Google Earth quality of each abattoir, the relative size of its production, and whether it was a beef abattoir. Buffers were performed to generate areas surrounding each of 250 km and 800 km. The 800 km buffer had the 250 km buffer removed from its centre so that it only represented the 250km to 800km area. Those within the 250 km of an abattoir were multiplied by a factor of 0.75 and those in the range 250 – 800km multiplied a factor of 0.25. The addition of the figures of 0.25 and 0.75 were an attempt to reflect the preferable distance to abattoirs of under 250 km. These distances of 250 km and 800 km were used to represent the preferable distances in economic cost of transport as well as distances that will not be detrimental to the animal.

The *annual rainfall* criterion of feedlots being preferred placement in areas of less than 750mm per annum, was translated into GIS criteria by using a annual rainfall map divided into 50mm isohyets, allowing GIS to “Select” only those that were less than 750mm and produce a new layer.

The *heat stress* criterion was hard to define in terms of GIS criteria, due to the areas that were sought after are those that do not fit this criterion, i.e. the criterion found heat stress areas, and the ideal feedlot positions were outside of these areas. Work has been performed in calculating levels of heat stress over the past several years in terms of predicting potential events based upon climate data. Katestone Environmental developed a weather forecasting system to assist in warning feedlot operators of cattle feedlots of impending adverse weather conditions that could lead to excessive heat loads for feedlot cattle (Katestone Environmental, 2005). This site provides a service using a Heat Load Index (HLI) as an indicator of the environmental heat load placed on cattle (Katestone Environmental, 2007). The best indicator would be to spatially adapt current meteorological models into a format that would represent the HLI in regional classifications. These would be ranked using the potential number of days that Heat Stress poses a threat. However, due to lack of data, an adaptation using only BOM data of humid zones and high temperatures provides, as an example, some insight. The spatial data for humid zones was selected from a map of climate zones, with areas that are classified as humid. These were “Selected” to create a new layer of only humid areas. The temperature was taken from a BOM map of cooling degree-days with 18^{o}C as a base temperature. Areas with over 1000 hours per annum of temperatures above 18^{o}C were “selected” to create a new layer. Both these were joined using “Union” to form an area of perceived high levels of Heat Stress occurrence. Again, due to the available data, the heat stress model is an example only and does not reflect HLI type models. However, it can provide insight on what might be possible with access to the necessary data.

This process had additional criteria added after some consultation with a feedlot manager. An additional criterion of proximity to towns with a population greater the 3000 was added to allow for both staff and tradesmen who are required for the economic viability of a feedlot. Proximity to abattoirs had additional criteria added to further allow this process to represent the commercial reality of feedlots. This was proximity to a number of abattoirs to allow for the commercial viability of competition between the abattoirs for the feedlot cattle. However, this variable was not subject to the object-oriented weighting due to being discovered as significant late in the project and thus is not included in Table 7 or Table 9.
Their relevant site selection criteria translated into GIS criteria is found in Table 8.

Proximity to towns with a population greater than 3000 was performed through the process of finding population data, joining it to a 1:250,000 scale topography map of Australia so that only populated places with a population of higher than 3000 are shown. A 50 km buffer is then performed on these points to give a map of areas within a 50 km radius of major centres.

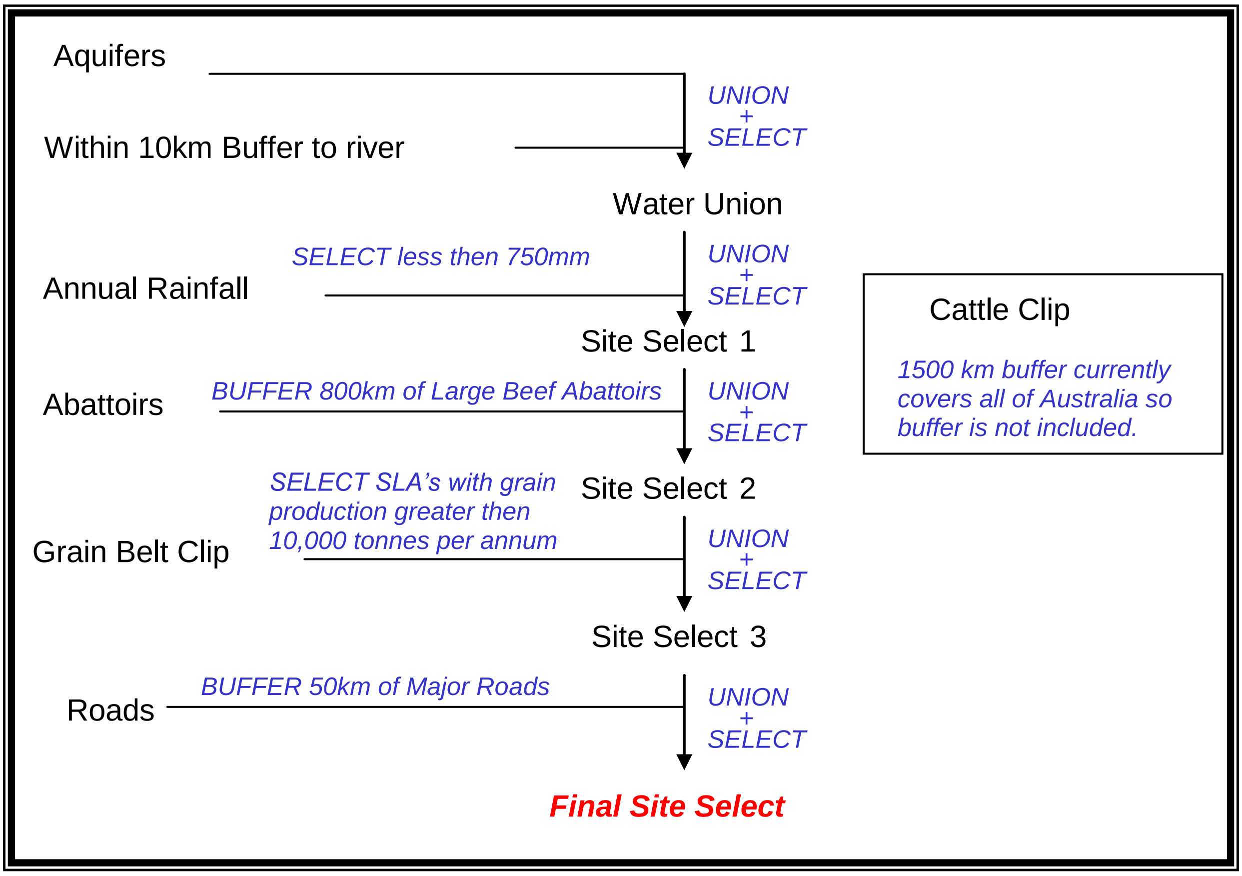
Density of Abattoirs was an adaptation of the proximity to abattoir map performed previously. The buffer of 250 km was used and then "joined on spatial location" with large beef abattoirs. As a result, the count of abattoirs within each 250 km buffer is shown. Only those buffers with five or more abattoirs within 250 km were selected to create another map of the density of abattoirs.

4.8.2 Method 1 - The reduction method of site selection

The first method reduced the area that is regarded as suitable, selecting only those areas that have given an accepted result. The process involved taking all the criteria that have been translated to GIS criteria, amalgamating this to form one map, and selecting only those regions within the amalgamation that is acceptable to all the criteria. This uses several processes to form the amalgamated map. The result is obtained by selecting only areas that are accepted in the GIS and the area that results gives a general area that is suitable for feedlots. McLeod et al., (2002) used this method in the broad-scale selection of potential sites for aquaculture.

Performing the amalgamation of the maps was the main task in this method. It was necessary to perform this in stages due to limits on the amount of data the GIS could run a "Union" operation for at one time. Flow Chart 1 outlines the process for the selection of the criteria for this method. The italics indicate processes used.

Flow Chart 1 – Diagram of the Process used to select suitable sites using the Reduction Method.



4.8.3 Method 2 - The weighted method of site selection

The second method is adapted from work done by Basnet et al., (2001). In this method, a map of Australia was divided into 30915 rectangles or cells of 16.6 km long and 14.6 km wide. These dimensions are due to the process used to create these rectangles, using decimal degrees as a unit. Due to the process of breaking Australia into these rectangles, complete coverage of Australia was not possible, with rectangles missing some parts the coastline. This was due because these cells that contained more ocean then land being labelled as ocean. Data is then attached to these cells, again based again on the premise of accepting or rejecting the GIS criteria. In this case, however, the criteria to accept an area of suitable sites are not solely one that is able to accept all the criteria. A ranking system was used to allow areas to be displayed based on the number of criteria they accept. This allows for the adaptation of potential solutions to problems faced in feedlot developments in areas of some unsuitability. The relative importance ranking of input factors was determined by making an Objectives-Oriented Comparison (OOC) that required valuing each factor in terms of achieving the desired objectives of the site suitability analysis (Basnet et al., 2001). Basnet et al. (2001), developed this process. These criteria were weighted using the experience in the site selection application of the staff at FSA Consulting, using a survey. Copies of all the surveys are included in the Appendix. Five consultants at FSA Consulting gave input giving a score to each criteria ranking the criteria on levels of importance. The corresponding scores were “1” is “High Importance”, “2” is “Medium Importance” and “3” was “Low Importance”. The results of the survey are in Table 9.

Table 9 - Results of the Objectives-Oriented Criteria Survey from FSA Consulting

	Criteria A	Criteria B	Criteria C	Criteria D	Criteria E	Count	Weighting
High Annual Rainfall *	2	3	3.5	4	1	19.5	0.223
Low Annual Rainfall*	0.5	1	2	1	1.5		
Water Access	3.5	3.5	3	2	5	17	0.194
Under 1500 km to Cattle**	0.5	2.5	1	0	2	15.5	0.177
Over 1500 km to Cattle**	0.5	4	3	0	2		
Proximity to Grain	1	4.5	3	0	3	11.5	0.131
Heat Stress Factors	2	2.5	3.5	0.5	1.5	10	0.114
Access to Major Road	2.5	2.5	0.5	0.5	2	8	0.091
Proximity to Abattoirs	0.5	3.5	1	0	1	6	0.069
					Total	87.5	

*Notes: Fields with either * or ** are joined in the weighting that is given, they were separated for the purpose of the survey.*
The additional criteria of density of abattoirs, proximity to populated centres and proximity to grain-exporting ports were not included in the OOC survey.

Criteria Used in Table 9:

A	*Economic importance in initial capital costs*
B	*Economic importance to continuing costs*
C	*Increased level of management*
D	*Environmental Impacts*
E	*Necessary for Site*

These weightings were then applied throughout the map of Australia, giving each cell a value and ranking based on its spatial position. This was achieved by using the “selection by location” operation. After criteria has been transformed into an accept/reject proposition in the GIS, all the cells within this region are given the number “1” in the cell to represent that it was a positive result. All criteria outside of this area were given a “0.” After this was completed, a “New Field” was added to calculate and display the site suitability results. The calculation for this value was to simply multiply the scores of each cell by the OOC weighting and add all the scores together. The exception to this was the value of *Heat Stress* that was subtracted from the total once multiplied by its weighting. The higher the number of the result, the more suitable a site that cell was for feedlots.

The formula used for this calculation is:
((Water Access * 0.194) + ((Proximity to Grain * 0.131) + (Proximity to Cattle * 0.177) +(((0.75 * Abattoir less 250 km) + (0.25 * Abattoir from 250km to 800km) + Density of Abattoirs) * 0.069) + (Annual Rainfall less than 750mm * 0.223) + (50km buffer to Main Roads * 0.091) + (50km to a Population of greater than 3000 * 0.100)- (Potential Heat Stress * 0.114)) = Weight of individual cell.

Because the additional criteria were not part of the OOC survey, provisions were made. The density of abattoirs was weighted by the corresponding abattoir weighting. Proximity to towns was assigned a weighting of 0.100.

4.8.4 Method 3 - The non-weighted method of site selection

Due to the additional information received from feedlot managers, a need arose to further reflect the commercial viability of feedlots in selecting future potential areas. The Non-Weighted method used the same base map as Weighted Method. However, instead of weighting the scores of each of the selection criterion, the method was to calculate the score of acceptable results each cell. This better accommodated the criteria that were not originally in the OOC survey.

4.9 Validation of site suitability methods

An important part of the site suitability procedure is to test whether a seasoned professional within the feedlot industry would come to the same conclusion about where to place feedlots. A relevant test is to compare the prediction of suitable feedlot sites to where current feedlots are found. Therefore, the broad scale site selection results were compared with the extent of current feedlots. A result was given on the proportion of feedlots that occurred within the suitable areas to those that occurred outside. If there was a higher proportion of feedlots outside of the suitable areas suggested by the GIS, then this method was not successful. However, if there was more feedlots inside the selected areas then the method was successful.

5 Results of the Australian feedlot industry survey

5.1 Current pen capacity

The Australian Feedlot Sector is made up currently by feedlots ranging in size from less than 50 head on feed to the current largest capacity of 53,000 head on feed. According to the industry survey, there are 882 feedlots with a total current pen capacity of 1,180,868 head. The current point locations (*latitude* and *longitude*) within this database cover 99.2% of the total feedlots and 99.8% of the industry’s total capacity. Feedlots that were not included in the point position were due to a lack of location data (very little information was supplied), or that they were yet to be built. Estimations put the capacity of the feedlot industry in 1991 at 631 feedlots with a total capacity of 485,000 head (Tucker et al., 1991). Therefore, a growth from 1990 to 2006 is clear.

5.2 Major Australian feedlots

5.2.1 2006 Major Australian feedlots

The current top 22 feedlots were included in this summary of Australia's major feedlots. The top 22 were chosen as the 1990 major feedlot list had 22 entries. Half of the current major feedlots in this list were on the 1990 Major Feedlot List. Table 10 shows the 2006 major feedlots alongside their respective pen capacity if they were operating in 1990.

Table 10 – Major Australian Feedlots 2006 with Respective Capacities from 1990

Feedlot Name	Locality	State	Commenced	1990 Current Pen Capacity	2006 Current Pen Capacity
Rockdale Beef Feedlot	YANCO	NSW			53,333
Whylla	TEXAS	QLD	1989	20,000	50,000
Prime City	TABBITA	NSW			35,000
Rangers Valley	GLEN INNES	NSW	1988	12,000	30,000
Beef City	AUBIGNY	QLD	1975	25,000	26,500
Caroona	QUIRINDI	NSW	1972	15,500	24,000
Peechalbah	WANGARATTA	VIC	1973	17,000	22,000
Brindley Park	ROMA	QLD			21,000
Myola	TOOWOOMBA	NSW			20,000
Killara	QUIRINDI	NSW	1975	6,500	20,000
Charlton Feedlot	CHARLTON	VIC	1970	18,000	20,000
Smithfield	PROSTON	QLD			18,500
Goonoo	BRISBANE	QLD			17,500
Jindalee	STOCKINBINGAL	NSW		9,000	17,000
Sandalwood	DALBY	QLD	1986	5,000	15,290
Miamba	BEENLEIGH	QLD			15,000
Aronui	DALBY	QLD	1964	10,000	15,000
Ravensworth	HAY	NSW			15,000
Mundindi	MUNGINDI	QLD			14,000
Yambinya	DENILIQUIN	NSW			13,500
Tasmania Feedlot	PERTH	TAS			12,500
Lillyvale	CONDAMINE	QLD	1972	5,300	12,000
Other 1990 Feedlots				76,500	
	Grand Total			**219,800**	**487,123**

The 2006 major feedlots make up 41% of the Australian industry's total current pen capacity

5.2.2 1990 Major Australian feedlots

The remaining major feedlots from 1990 taken from Tucker et al. (1991) are as follows. Included is whether that feedlot closed in the last 16 years. Five feedlots have closed.

Table 11 – Major Australian Feedlots 1990 (Tucker et al, 1991)

Feedlot Name	Locality	State	Commenced	Closed	1990 Current Pen Capacity
Burdekin Valley Beeflot	HOME HILL	QLD	1987	Y	12,000
AMH	BEAUDESERT	QLD	1970	Y	12,000
Caroona	MUNGINDI	QLD	n/a		10,000
Gunnee	DELUNGRA	NSW	1982		8,000
Crown Beef	STAWELL	VIC	1975	Y	6,000
Wide Bay	KILKIVAN	QLD	1972		5,000
Gurley	MOREE	NSW	1969	Y	5,000
Perenc	YASS	NSW	n/a		5,000
Balgowan	ACLAND	QLD	1985	Y	5,000
CRM	WAGGA WAGGA	NSW	n/a		4,500
Kurrawong	QUINALOW	QLD	1987		4,000
			Grand Total		**76,500**

5.2.3 Comparison between 1990 and 2006

Figure 3 compares the locations of 1990 feedlots to the 2006 feedlots. New South Wales growth is evident with five of the additional major feedlots having started operations in New South Wales, and only two stopping production since 1990.

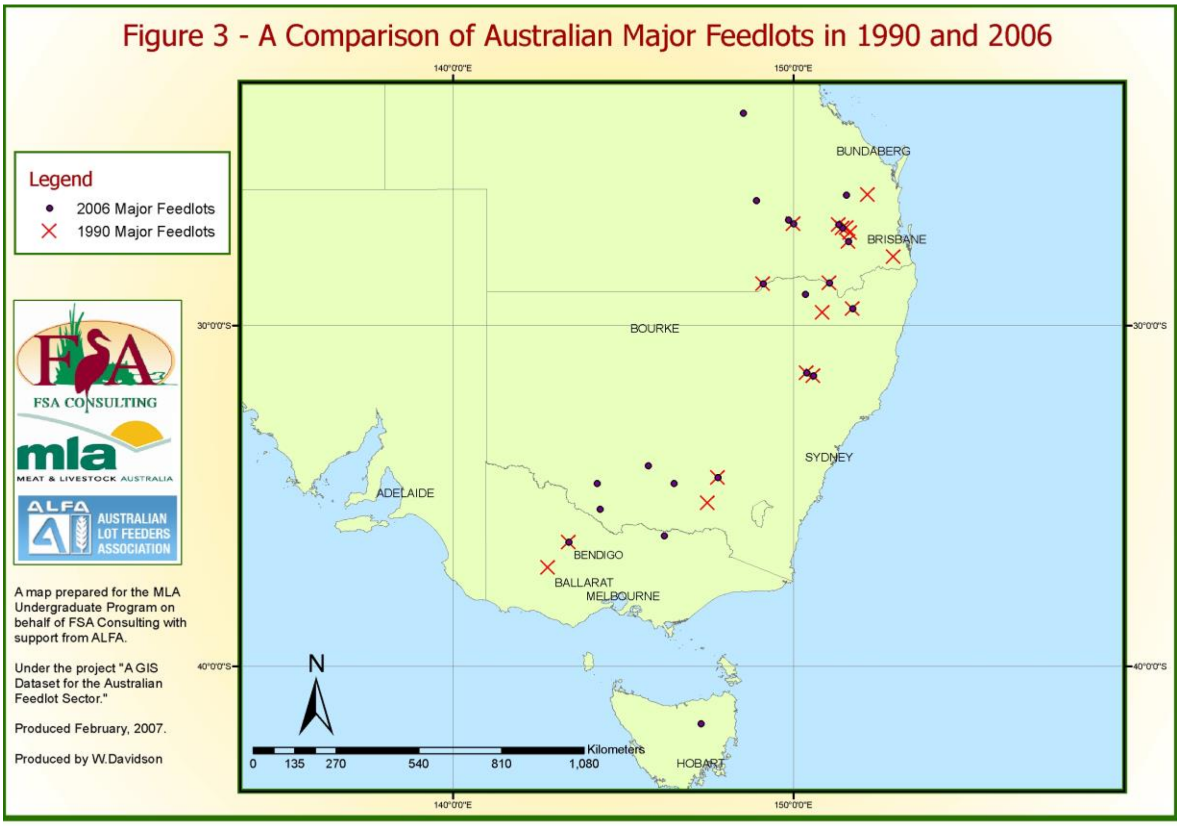


Figure 3 - A Comparison of Australian Major Feedlots in 1990 and 2006

5.3 State distribution

5.3.1 2006 Analysis

An analysis of the current distribution of Feedlots by State gives the results shown below:

Table 12 - Distribution of Current Feedlots by State

	Number of Feedlots	%	Average Capacity	Current Pen Capacity	%
QLD	592	67.1%	1,011	598,680	50.8%
NSW	95	10.8%	3,847	365,486	31.0%
WA	100	11.3%	997	99,711	8.5%
VIC	20	2.3%	3,316	66,325	5.6%
SA	73	8.3%	384	28,017	2.4%
TAS	1	0.1%	12,500	12,500	1.1%
NT	1	0.1%	8,000	8,000	0.7%
TOTAL	882	100.0%	1,336	1,178,719	100.0%

Currently Queensland has the most feedlots by count and capacity. Although New South Wales and Western Australia both have a similar count (95 and 100 respectively), their capacities are significantly different (365,486 and 99,711). This is reflected by New South Wales' average being almost four times greater than the average of Western Australia. In terms of average capacity, (disregarding both Northern Territory and Tasmania both with a count of one), New South Wales and Victoria are the highest, while Queensland and Western Australia average are mid range, while South Australia has the lowest average. However, these high averages of New South Wales and Victoria are potential results of not finding all the smaller feedlots in these states. By having only their larger feedlots included in this survey without corresponding smaller feedlots, their averages are distorted. With known amount of South Australian feedlots having zero head of current pen capacity this lower average may be the result of a number of South Australian feedlot being opportunistic and thus not operating constantly, or potentially a result of not having the current pen capacities of all the feedlots, which accounts for its low average.

5.3.2 1990 Analysis

An analysis of the 1990 distribution of Feedlots by State gives the results shown below:

Table 13 - Distribution of 1990 Feedlots by State (Tucker et al, 1991)

	Number of Feedlots	%	Average Capacity	Current Pen Capacity	%
QLD	471	74.6%	557	262,200	54.1%
NSW	90	14.3%	1,343	120,865	24.9%
WA	34	5.4%	992	33,720	7.0%
VIC	7	1.1%	6,120	42,840	8.8%
SA	27	4.3%	836	22,560	4.7%
TAS	1	0.2%	2,000	2,000	0.4%
NT	1	0.2%	700	700	0.1%
TOTAL	631	100.0%	768	484,885	100.0%

The differences in the State distribution are that all average State capacities have increased except for the average of Victoria that has fallen by almost half from 6,120 to 3,316. All relative percent capacities have increased between 1990 and 2006 bar Queensland, South Australia and Victoria that decreased their respective percent capacities, by around 5%, 2%

and 3% respectively. All individual feedlot percentages have increased except for Queensland and New South Wales falling around 7% and 3% respectively.

Table 12 and Table 13 also demonstrate that it seems that growth has occurred via expansion of current feedlots of the industry, or that the general life expectancy of many feedlots is not long term, and feedlots are continual being built to replace those that have finished up. The expansionistic growth could potentially is a misrepresentation of the large expansions that larger feedlots have undertaken, and does not represent the smaller feedlots, or indeed the industry. Smaller feedlots however may have a shorter feedlot life expectancy and the higher turnover, which is not potentially true of smaller feedlots. In Queensland, a State that has an assumed complete list due to the requirements of the State regulations, its industry has grown from 471 individual feedlots in 1990 to 592 in 2006. However, in this same period, the State feedlot current pen capacity has grown from 262,200 head to 598,680 head. This results in the average feedlot capacity increasing from 557 to 1,011 in this period.

However, this expansionistic growth appears to be apparent in New South Wales data. In 1990, New South Wales had 90 feedlots with a capacity of 120,865 head. In 2006, New South Wales has 95 feedlots with a total current pen capacity of 365,486 head. Thus, New South Wales average has tripled from 1,343 to 3,387. This view of expansionistic growth could potentially be skewed by not having a complete list of the New South Wales feedlots. Table 3 showed that New South Wales only needed to hold a licence with numbers over 5000 head. Due to this being the only list available of feedlots exclusively from New South Wales, there is a high probability of not having all of New South Wales feedlots within this FSAFLdB.

Western Australia has tripled in both individual feedlots and the total industry capacity, meaning that the average has stayed relative during this period (992 head to 997).

Victorian individual feedlots numbers grew from 7 to 20 with current pen capacity growing from 42,840 head to 66,325 head. This has meant that the average feedlot size has dropped considerably from 6,120 to 3,316 head on each feedlot, which is potentially the result of knowing more of the locations of smaller feedlots in Victoria in 2006 than in 1990.

South Australia has grown from 27 to 73 in its count of individual feedlots; however, this has only increased its current pen capacity from 22,560 to 28,017 head. Thus, South Australian average has dropped from 700 head per feedlot in 2006, to 384 head per feedlot in 1990. Due to the large number of zero capacities from this state in this survey, this may influence the results, and not give a true representation of the South Australian feedlots industry.

Both Northern Territory and Tasmania feedlots industries have grown due to expansion; as both only have one feedlot, but both increasing capacities.

5.4 Analysis of feedlot capacities versus feedlot size

5.4.1 2006 Feedlot capacities versus feedlot size

Table 14 – 2006 Analysis of Individual Feedlot Size of Capacity

	Number of Feedlots	%	Average Capacity	Current Pen Capacity	%
below 400	477	54.1%	128	61,076	5.2%
400 to 999	210	23.8%	619	129,996	11.0%
1000 to 4999	141	16.0%	1,903	268,369	22.8%
5000 to 9999	27	3.1%	6,746	182,155	15.5%
10000 +	27	3.1%	19,893	537,123	45.6%
Summary of above 5000	***54***	***6.1%***	***13,320***	***719,278***	***61.0%***
Grand Total:	882	100.0%	1,336	1,178,719	100.0%

Table 14 shows the distribution of distinction of feedlots by size:

This analysis reveals that currently 22% of feedlots (1000 head +) are currently contain 84% of the capacity of feedlot cattle. Applying a cut on feedlot size of 5000 head and above reveals that around 6% of feedlots represent around 61% of capacity. Figure 4 to Figure 8 shows the 2006 feedlots broken into the size rankings in Table 14.

5.4.2 1990 Feedlot capacities versus feedlot size

Table 15 - 1990 Analysis of Individual Feedlots by Capacity (Tucker et al, 1991)

	Number of Feedlots	%	Average Capacity	Current Pen Capacity	%
below 400	424	67.2%	116	49,350	10.2%
400 to 999	106	16.8%	535	56,705	11.7%
1000 to 4999	79	12.5%	1,966	155,310	32.0%
5000+	22	3.5%	10,160	223,520	46.1%
Total	631	100.0%	768	484,885	100.0%

Applying the same distinction as in the 2006 data, 16% of feedlots (1000 head +) are producing 78% percent of production and feedlots with 5000 head or more 3.5% of feedlots produce 46% of capacity.

This shows that the Australian Feedlot Industry has grown over the last 16 years in both the number of larger feedlots as well as the larger feedlot capacities. This also reveals a tendency away from smaller feedlot size with a drop from 67.2% of the industry under 400 head in 1990, to only 54.1% in 2006, with the relative capacity of the industry dropping from inputting 10.2% in 1990 to 5.2% in 2006. This is potentially because this database does not have data on the smaller feedlots, and this means in a drop in the smaller size capacity representation. The highest growth is the number of feedlots with a size of 5000 head or greater. In 1990, the number was around 3.5% contributing 46.1% of the industry's total capacity. In 2006, this has grown to be a higher proportion of individual feedlots, rising to 6% producing over 61% of the total industry capacity. This is due to this being the best known area of feedlots. It is safe to assume that the data of feedlots with a capacity of greater than 5000 head is well represented within this database.

The results for size category of less than 400 head records a growth in individual feedlots from 424 (67.2%) to 477 (54.1%) while the current pen capacity grows from 49,350 (10.2%) to 61,076 (5.2%) head. The average feedlot size for this category in 1990 was 116 that grew to 128 head by 2006, meaning an expansion of capacity in these categories. This loss of capacity is due to not have enough data on these smaller feedlots within this database

The results from the 400 to 999 head category doubled between 1990 to 2006 in both number of individual feedlots and their capacities. Their average capacity increasing from 535 head per feedlot in 1990 to in 2006, 619 head per feedlot reflects this growth.

The 1000 to 4999 category grew from 79 (12.5%) to 141 (16%) individual feedlots, the current pen capacity did follow this same growth, however only growing from 155,310 (32%) to 182,155 (22.8%) head capacity. This resulted in a decline in the average size of feedlots in this category from 1990's average of 1966 to 2006's average of 1903.

Growth in the above 5000 head size category was most pronounced. The individual feedlots grew from 22 (3.5%) to 54 (6.1%) between 1990 and 2006, meaning the 2006 figure is 2.5 times the 1990 figure. The capacity grew from 223,520 (46.1%) head in 1990 to 719,281 (61%) head in 2006 tripling the 1990 figure. The average size feedlot for this category grew from 10,160 to in 2006, 13,320 head per feedlot.

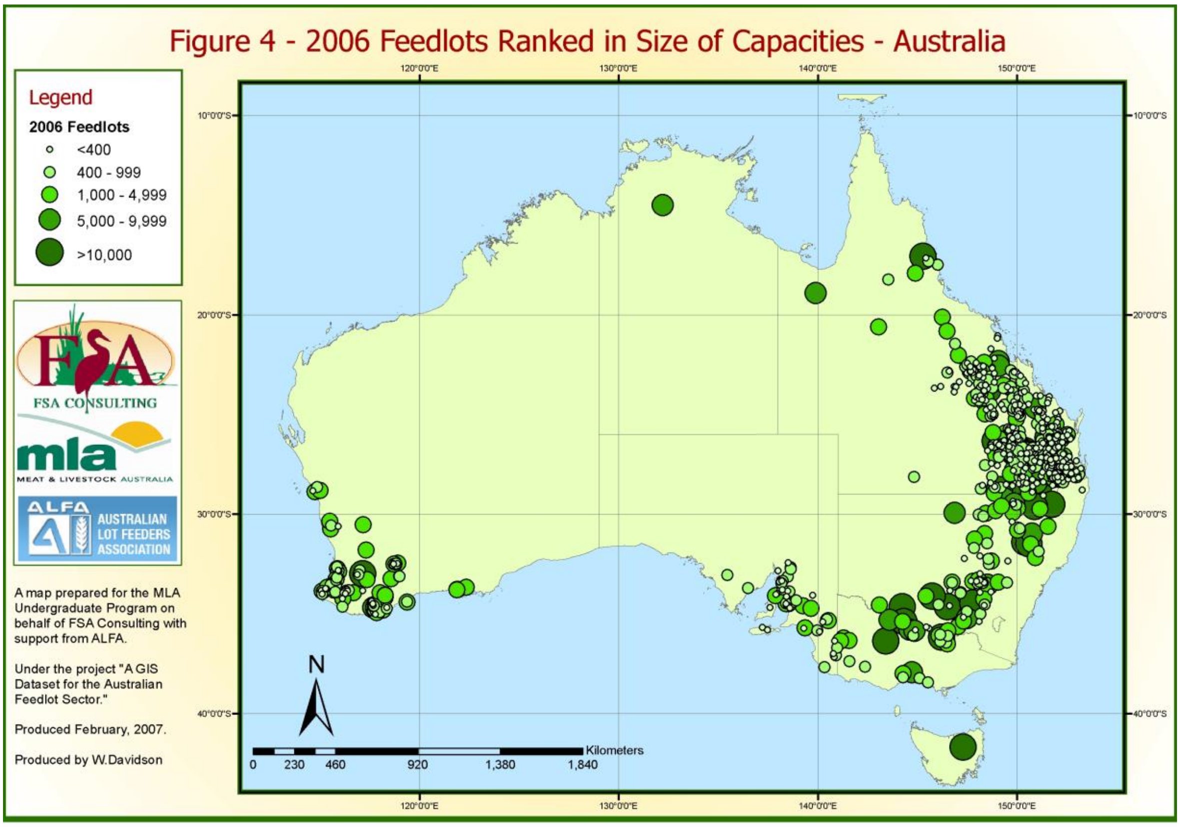


Figure 4 - 2006 Feedlots Ranked in Size of Capacities – Australia

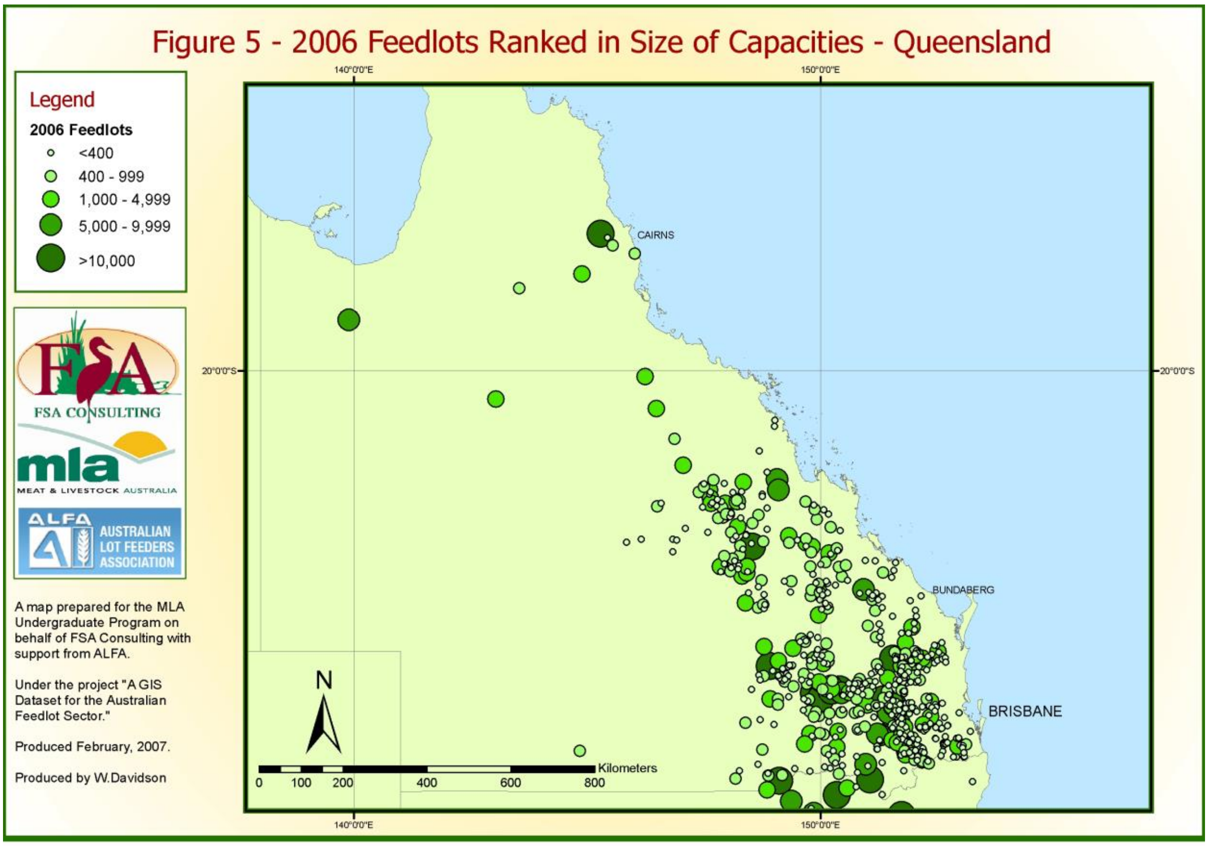


Figure 5 - 2006 Feedlots Ranked in Size of Capacities – Queensland

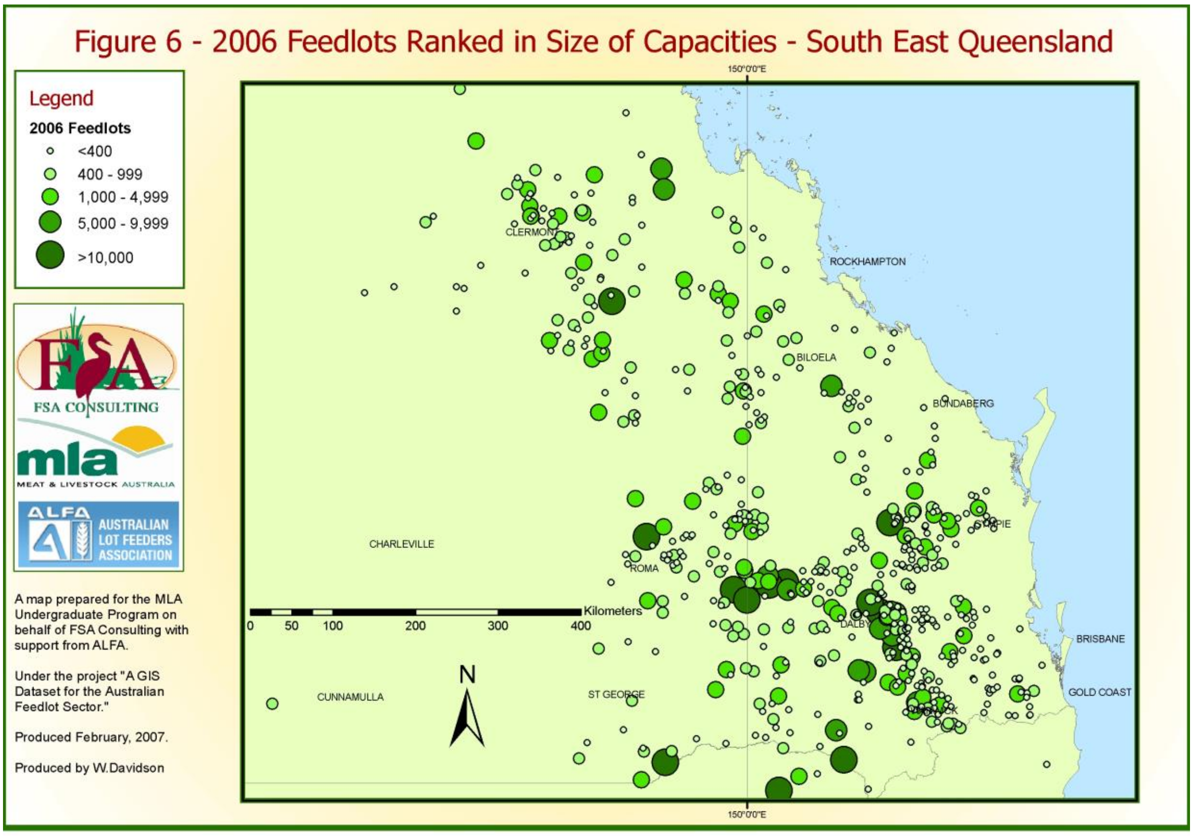


Figure 6 - 2006 Feedlots Ranked in Size of Capacities - South East Queensland

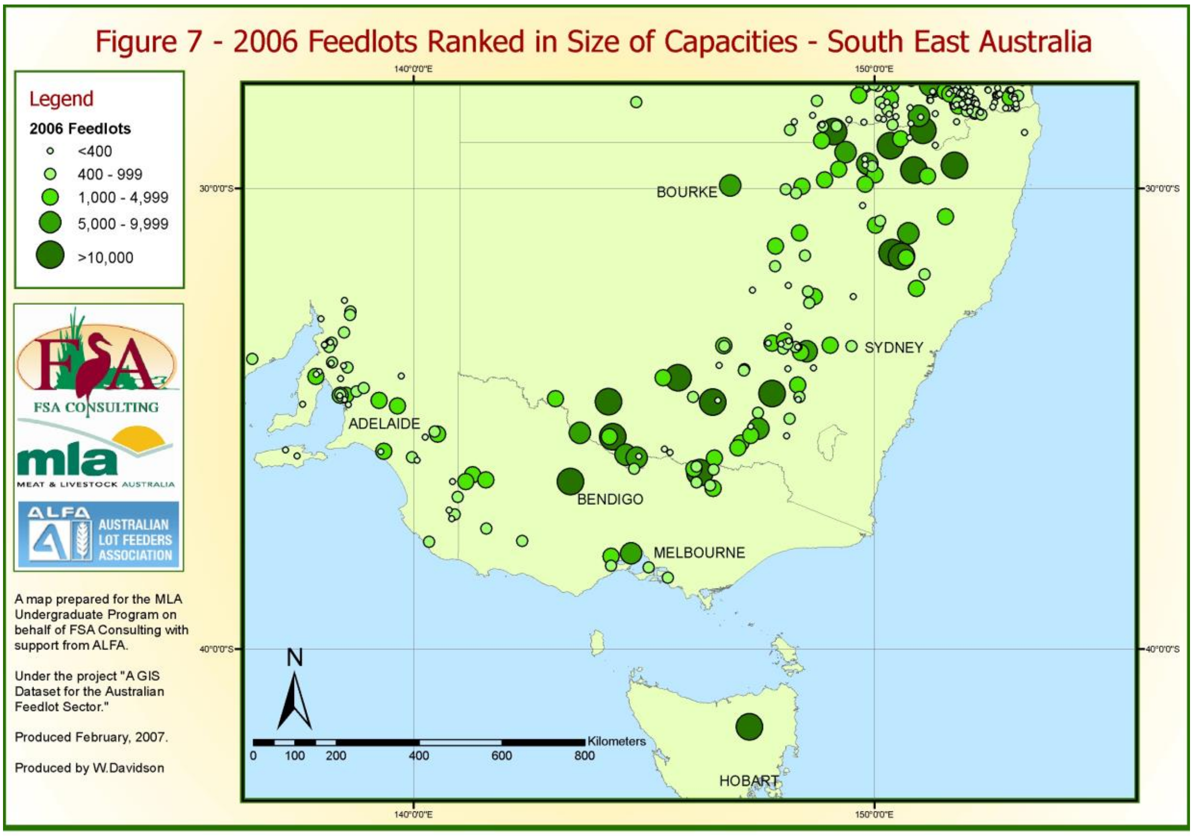


Figure 7 - 2006 Feedlots Ranked in Size of Capacities - South East Australia

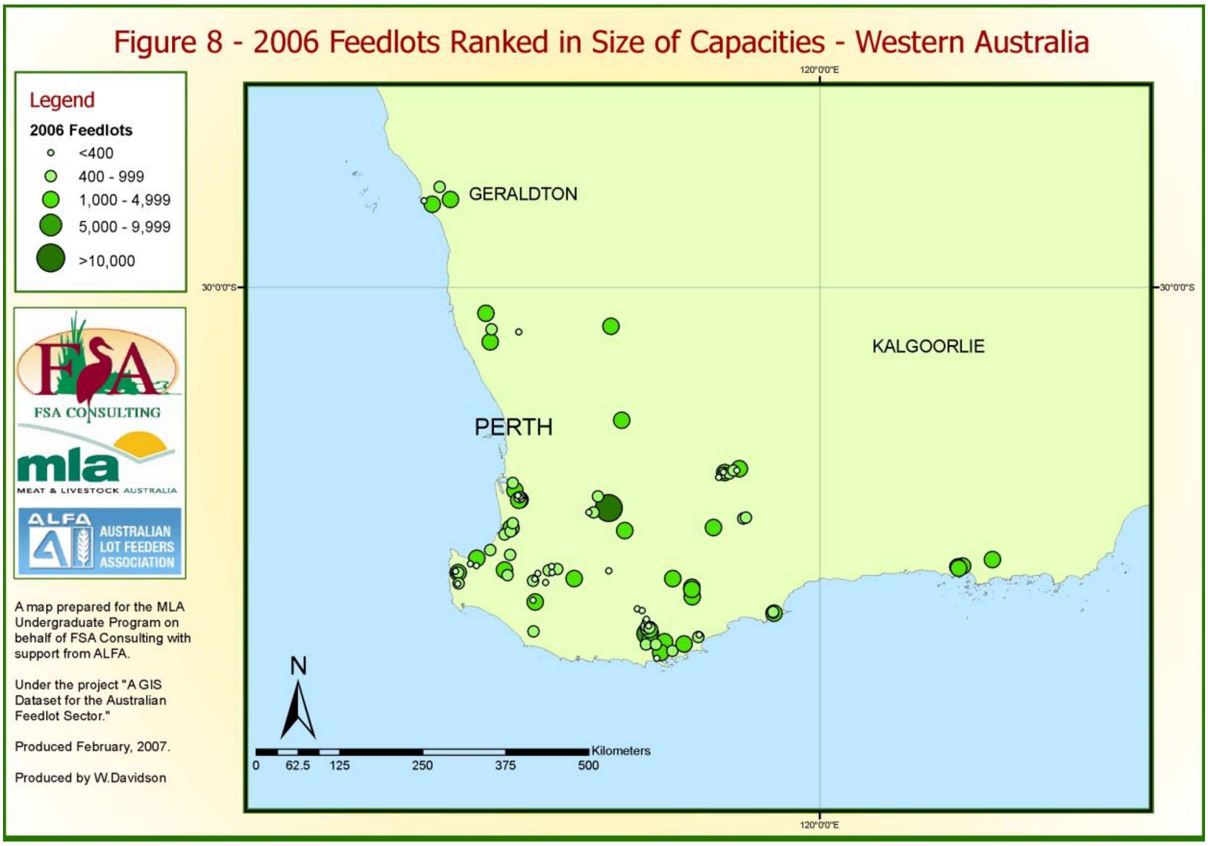


Figure 8 - 2006 Feedlots Ranked in Size of Capacities - Western Australia

5.4.3 State Based Analysis of Feedlot Size versus Feedlot Capacity

An analysis was also conducted on the Size versus Capacities of individual States.

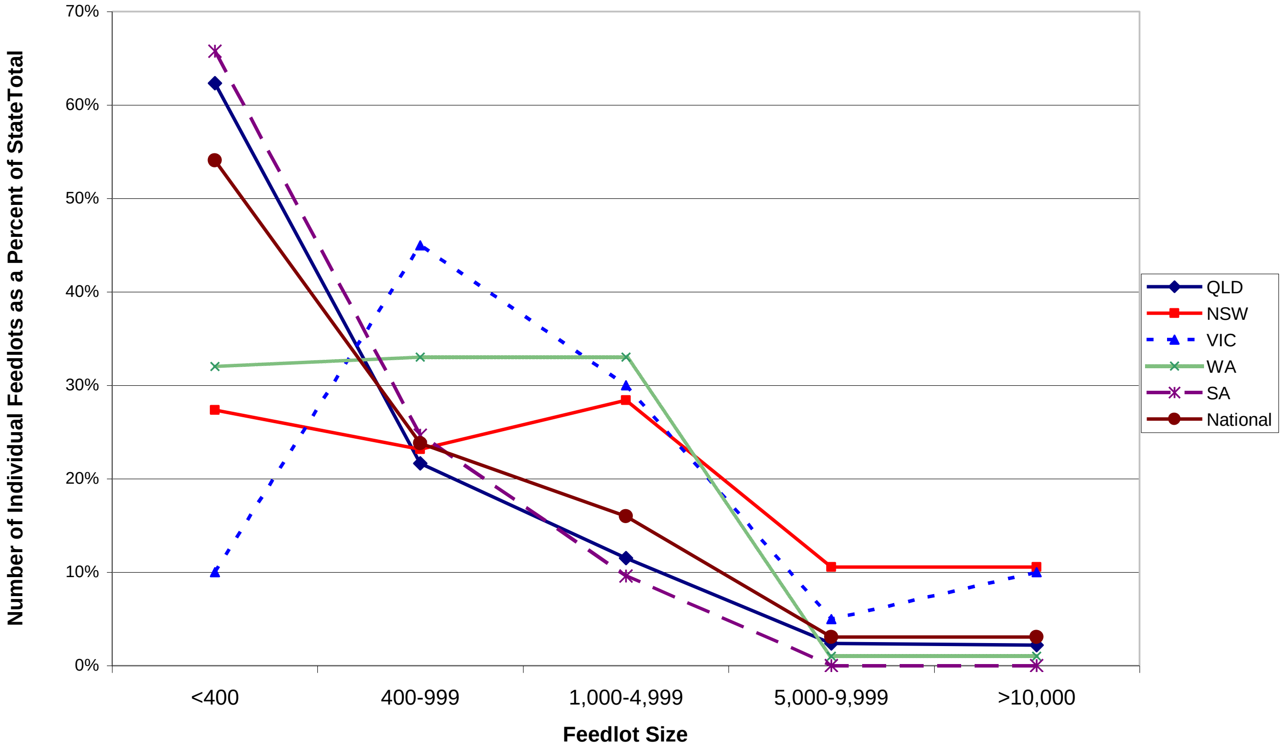


Figure 9 - A Breakdown of Individual State Feedlots on the Size of Individual Feedlots – displayed as a percentage of State Totals

It is significant to note in Figure 9 that in Queensland, South Australia and on a National Scale, the percentage of feedlots represented in each size falls successively. However, in Victoria, Western Australia and New South Wales it rises then falls because not having data of smaller feedlots within these states. Figure 9 excludes the Northern Territory and Tasmania due to only having a single feedlot each. Table 16 uses the proportions of Queensland's feedlot count to give the number of feedlots each state would have if their numbers corresponded to Queensland's proportion. In each, the number in the greater than 10,000 was assumed to be true and used to transform the rest of the size categories.

Table 16 - A Predictive Model of Feedlot Numbers in States using Queensland as the Reference

	QLD	NSW (Predicted)	NSW	VIC (Predicted)	VIC	WA (Predicted)	WA
<400	376	285	24	57	0	28	28
400-999	129	98	21	20	9	10	33
1,000-4,999	68	52	27	10	6	5	33
5,000-9,999	14	11	10	2	1	1	1
>10,000	13	10	10	2	2	1	1
Total	600	455	92	91	18	45	96

The results from Table 16 show a large difference between the predicted numbers in New South Wales and Victoria then the actual numbers from the FSAFLdB. Western Australia's predicted count of the smallest category actually was the same as that contained in the

FSAFLdB. This shows that Western Australia may not be able to use Queensland numbers as a predictive measure of the feedlots numbers in each category, due to having only 1 feedlot larger than 10,000 head. South Australia was not included in this table as it largest feedlot was not in the greater than 10,000 head category.

5.5 Geographic location

Figure 10 to Figure 15 shows a current analysis of the feedlot industry relative geographic regions. This includes an overview of the feedlot locations at a National level, in Queensland, South-East Australia (New South Wales, Victoria, South Australia and Tasmania), Western Australia and then an analysis of South East Queensland. These figures give a picture of 1990 feedlots area (represented by a 50km buffer around known 1990 feedlots) and the location of the 2006 feedlots. The 1990 relative locations are based on another FSA Consulting database. Figure 11 gives insight into the growth of individual feedlot numbers between 1990 and 2006 based on Statistical Local Areas (SLA) regions. A comparison between capacities cannot be performed due to any capacity data being retained from Tucker et al. (1991). However, these results are clear:

- More feedlots in are located in central Queensland
- Fewer feedlots are located in SEQ (e.g. Beaudesert Shire) and this is due to urban encroachment. The trend is of feedlots moving out of areas close to the coast where “sea changers” are moving to and expecting a “clean” rural environment, without the presence of feedlots. There seems to be a trend for Local Governments to have amended planning schemes to allow from this

Further areas of smaller growth are within Western Australia. The rest of Australia has relative the same number of feedlots, with no great difference between the 1990 numbers and 2006 numbers. Figure 11 is misrepresented due to the poor representation of smaller feedlots, so this figure does not correctly display the growth in numbers, throughout the entirety of Australia. Due to Queensland’s complete census of feedlots means the growth within Central Queensland can be validated.

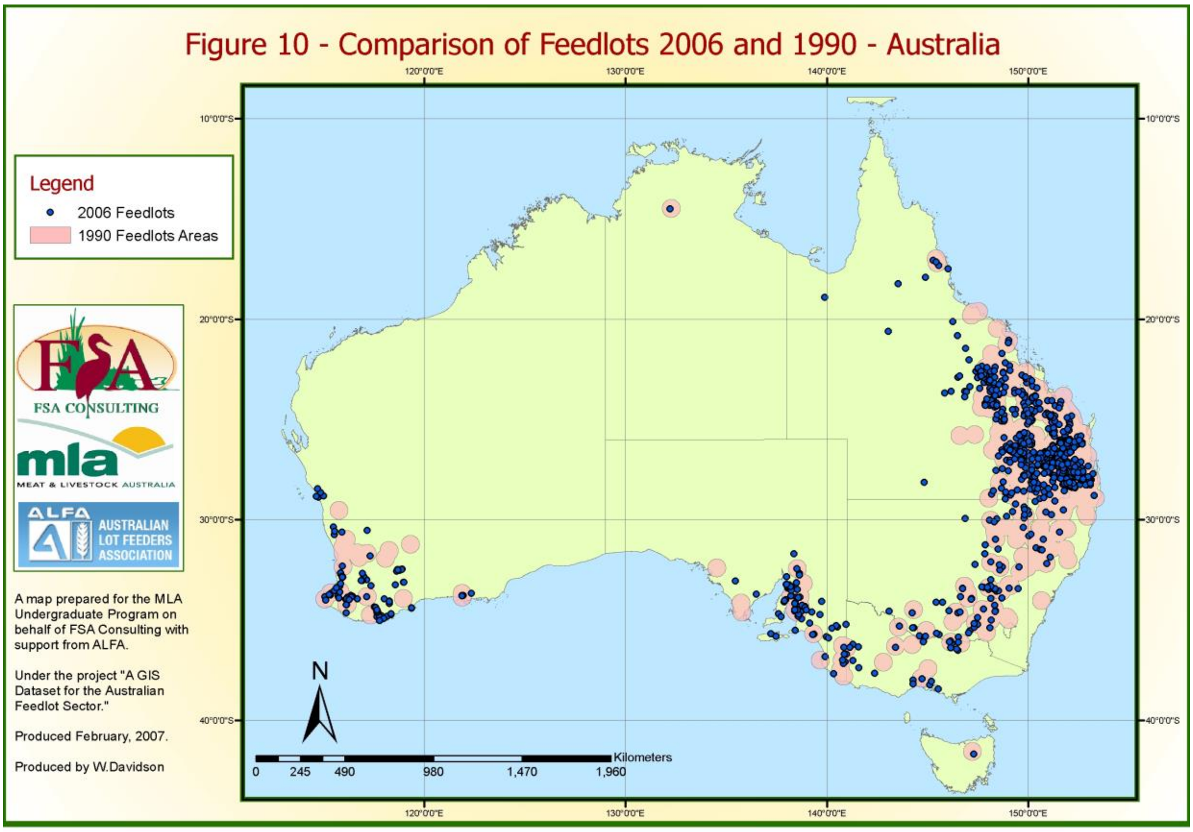


Figure 10 – Comparison of Feedlots 2006 and 1990 – Australia

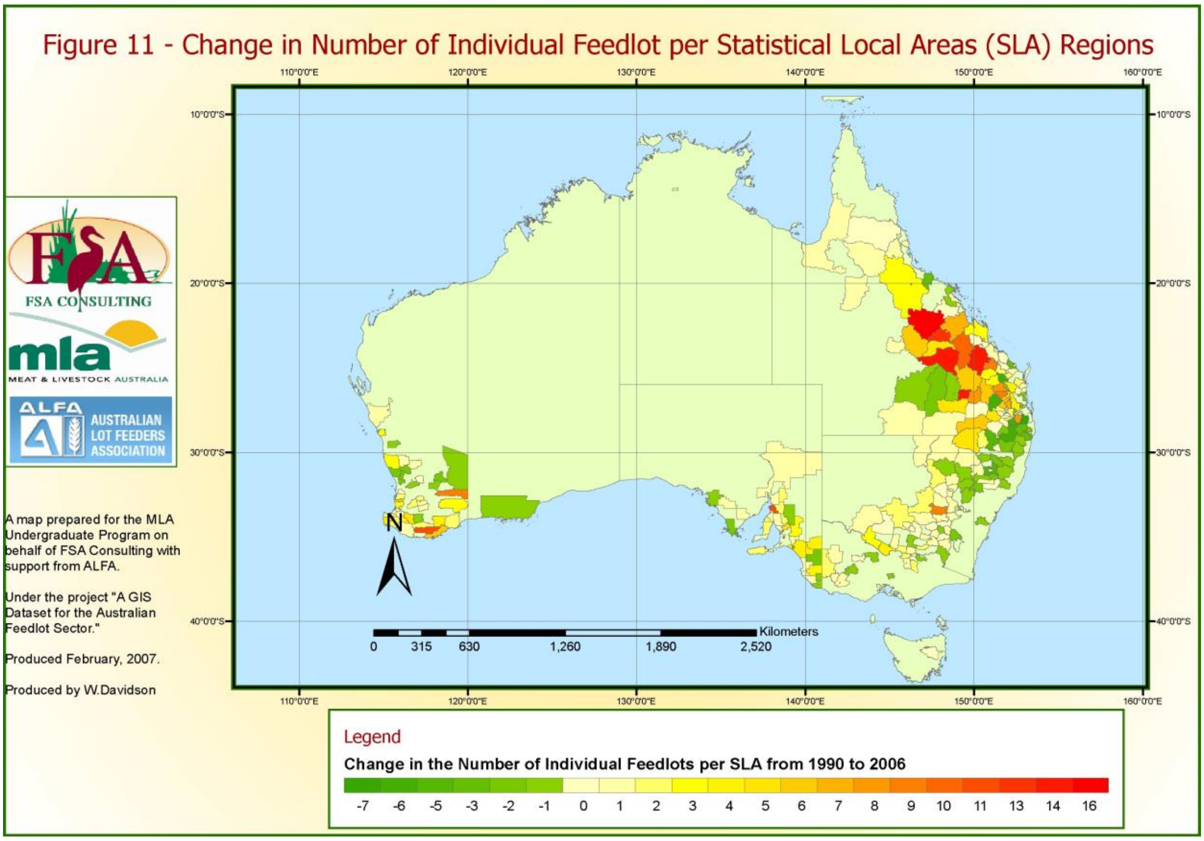


Figure 11 – Change in Number of Individual Feedlot per Statistical Local Areas (SLA) Regions

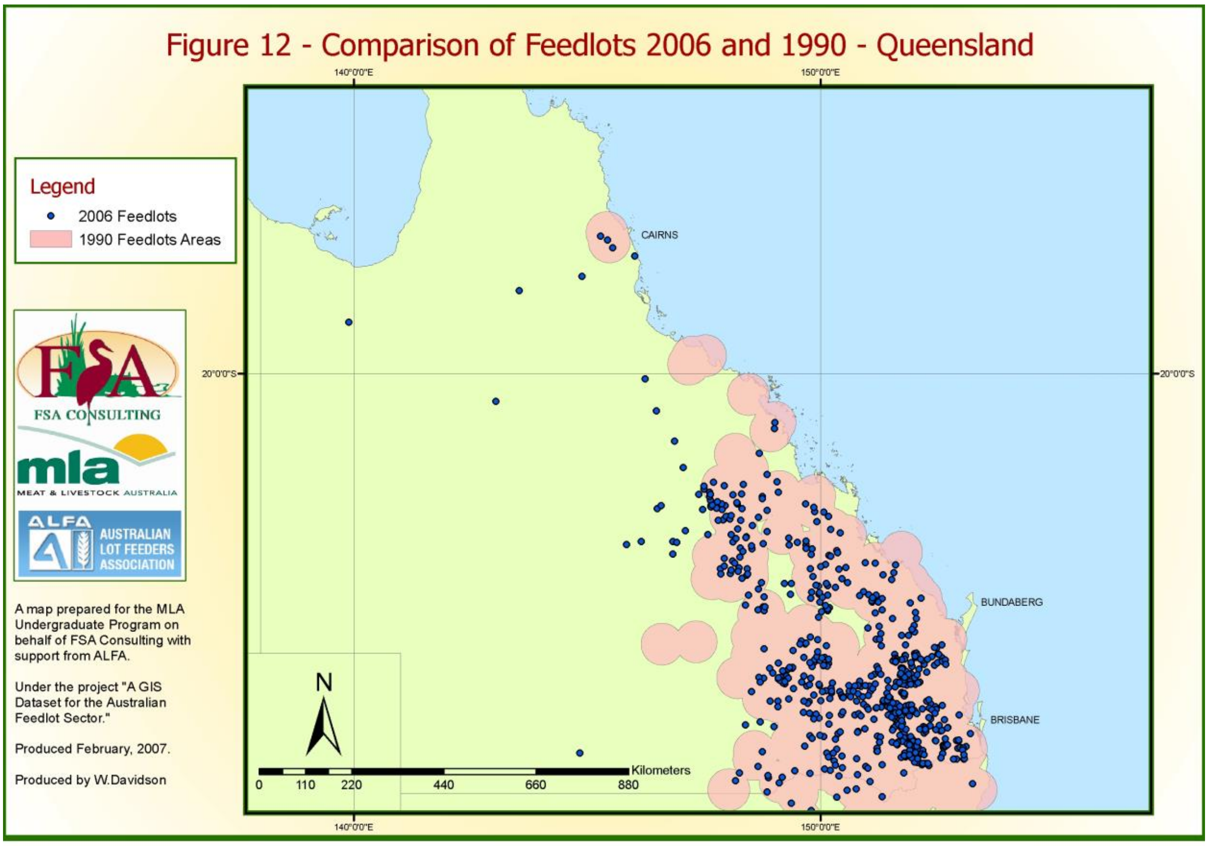


Figure 12 - Comparison of Feedlots 2006 and 1990 – Queensland

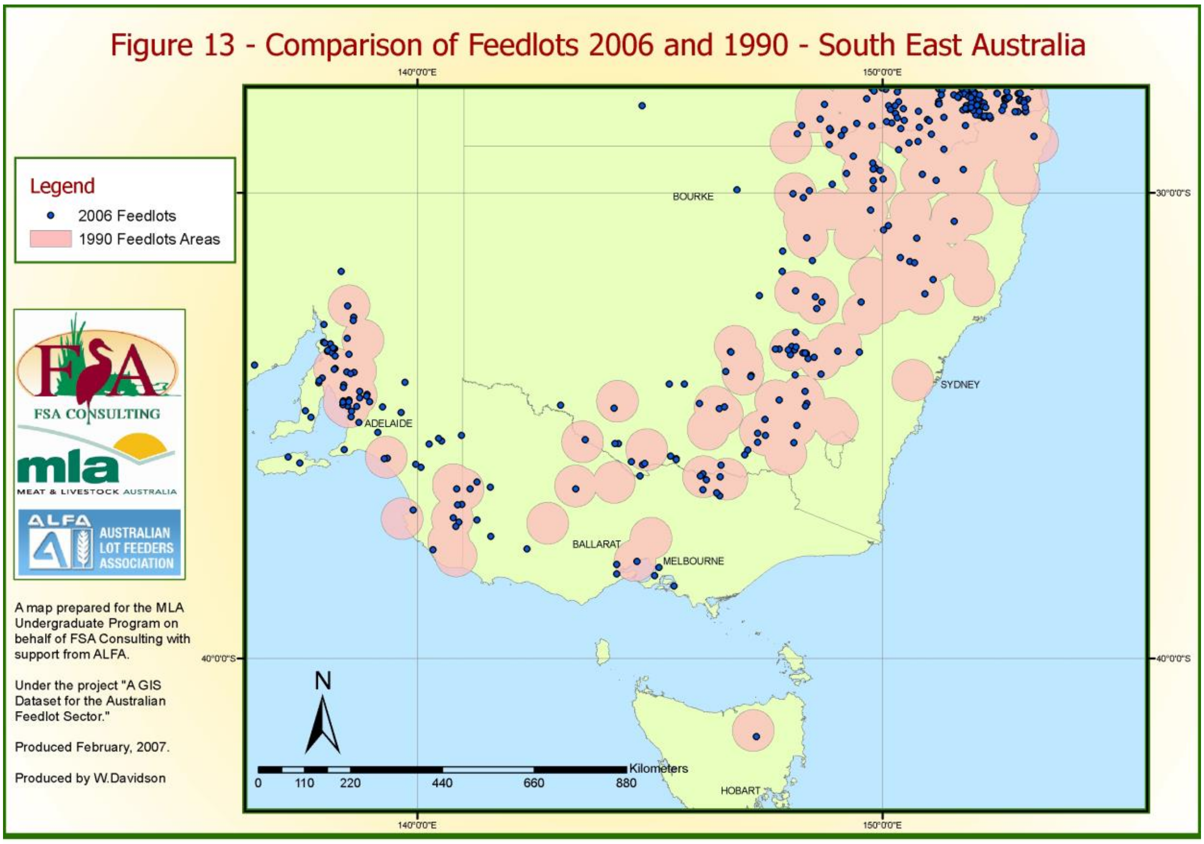


Figure 13 - Comparison of Feedlots 2006 and 1990 - South East Australia

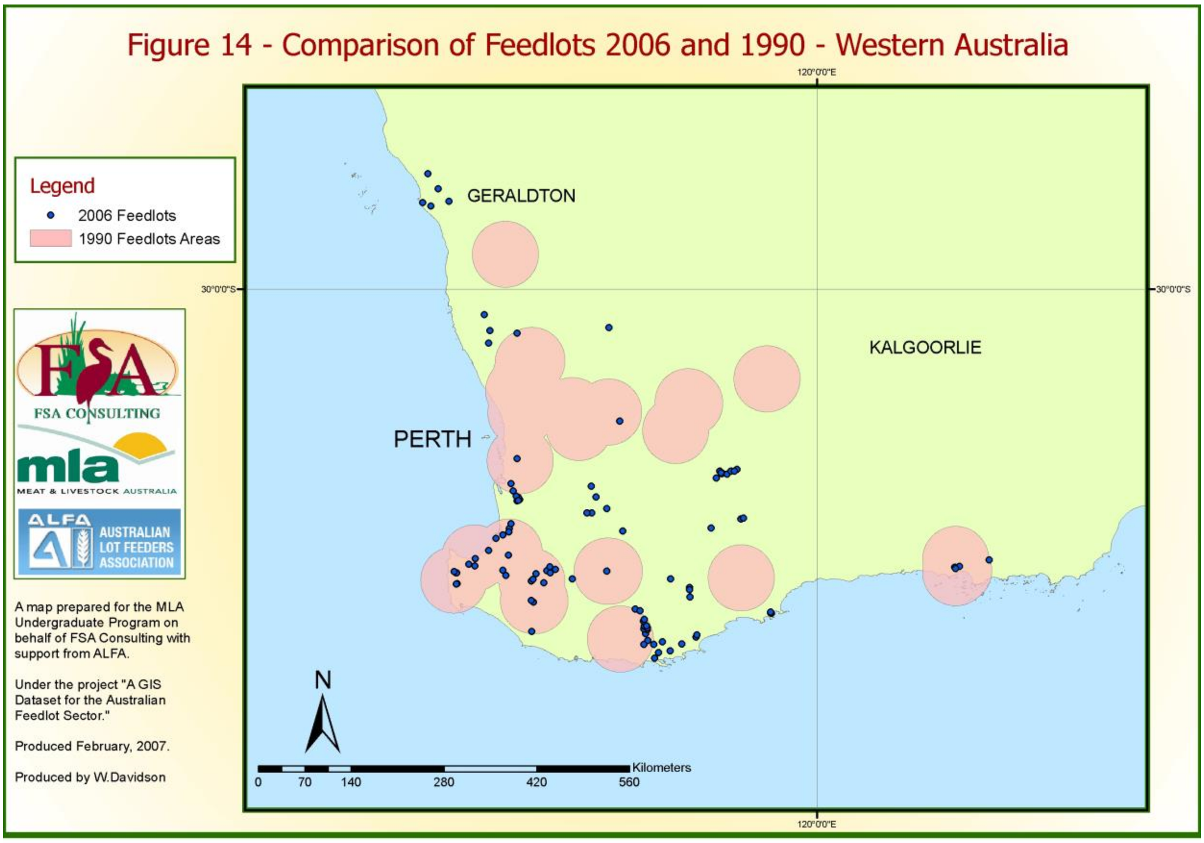


Figure 14 - Comparison of Feedlots 2006 and 1990 - Western Australia

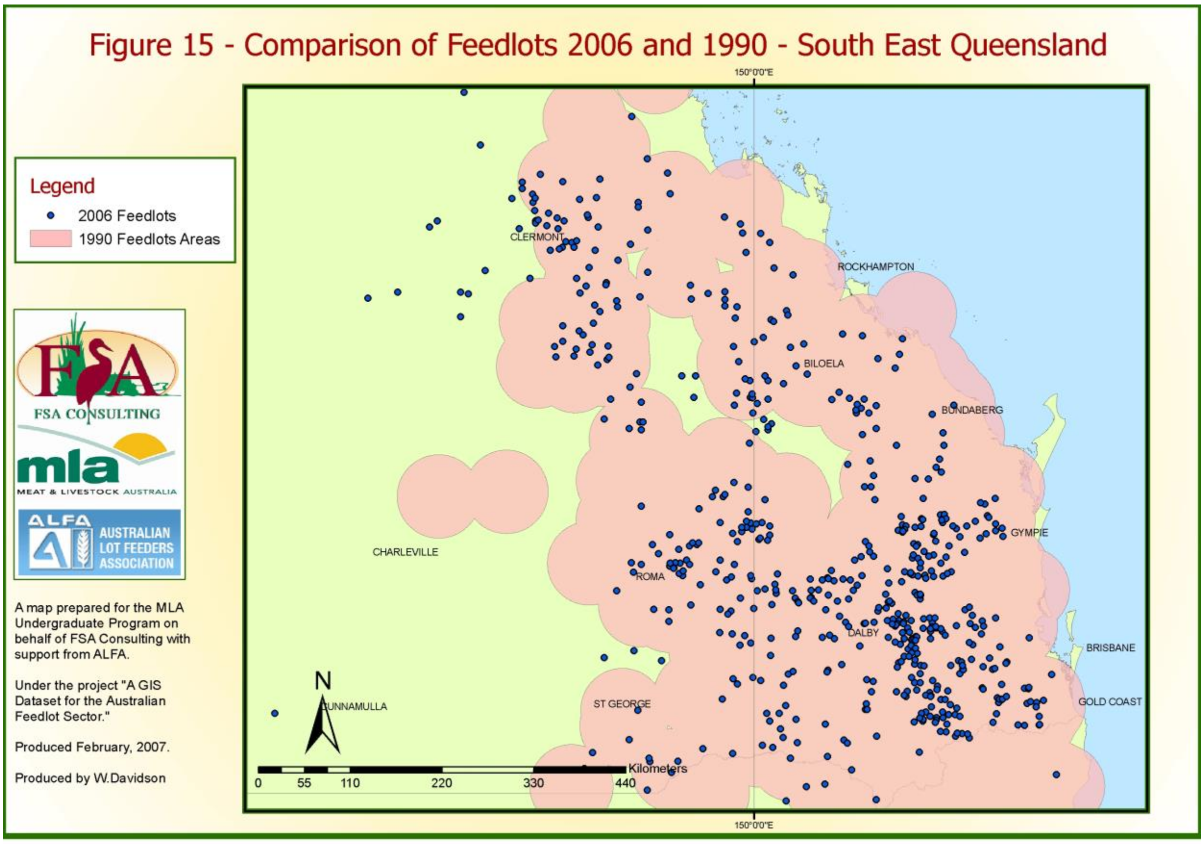


Figure 15 - Comparison of Feedlots 2006 and 1990 - South East Queensland

5.6 Catchments (River Systems)

5.6.1 Why is water an issue?

In the period from 1900 to date, 2006 was the driest August to November period averaged across SA, the second driest averaged over the Murray Darling Basin, the third driest across Australia and the fourth driest for Victoria (Bureau of Meteorology Drought Statement online, 2006). Considering that, this drought affects almost 70/% of feedlot capacity in the Murray-Darling Basin alone, feedlots having access a secure supply of good-quality water is a vitally important. Feedlots need a clean, regular water supply. Being an intensive industry, water pollution is possible. The runoff of water should be contained on site and disposed of on the property (Tucker et al., 1991) as organic wastes can heavily contaminate runoff and can pollute natural water resources such as surface and groundwater (Watts, and Tucker, 1994). Both the inputs and outputs of water to the feedlot industry play a vital role. An understanding of the role of water through feedlots to catchments is necessary.

This role of water extends in an environment where heat stress is a factor on cattle. Available water is used as a welfare mechanism on the beast to cool via spraying and via the cooling of available drinking water to below 25^{o}C. (E.A. Systems and MLA report, 2004).

5.6.2 2006 Analysis

The analysis of the current distribution of feedlots in catchments considers Australia's 12 Major Catchments (Figure 16). The current situation is that 85% of feedlot capacity and 79% of current feedlots are in the North-East Coast (NEC) and Murray-Darling Catchments (MDC). An interesting result is that while the MDC and the NEC both have relative feedlot counts (343 and 348 respectively) the accompanying capacities are significantly different with the MDC accounting for 67% of Australian capacity, while the NEC accounts for only 17.8% of Australia's capacity. Bulloo-Bancannia is the only catchment within Australia that does not contain feedlots.

Table 17 – Distribution of Current Feedlots by Catchments

	Number of Feedlots	%	Average Capacity	Current Pen Capacity	%
Murray-Darling	347	39.3%	2,277	790,241	67.0%
North East Coast	348	39.5%	603	209,833	17.8%
South West Coast	94	10.7%	1,013	95,251	8.1%
South East Coast	26	3.0%	897	23,313	2.0%
Gulf of Carpentaria	4	0.5%	5,250	20,999	1.8%
Tasmania	1	0.1%	12,500	12,500	1.1%
South Australian Gulf	50	5.7%	243	12,172	1.0%
Timor Sea	1	0.1%	8,000	8,000	0.7%
Indian Ocean	5	0.6%	592	2,960	0.3%
Western Plateau	2	0.2%	1,000	2,000	0.2%
Lake Eyre	4	0.5%	363	1,450	0.1%
Bulloo-Bancannia	0	0.0%	0	0	0.0%
TOTAL	882	100.0%	1,336	1,178,719	100.0%

A closer look at both the river systems that contain the feedlots in the North-East Coast and Murray-Darling Basin reveals a better picture of the feedlot locations.

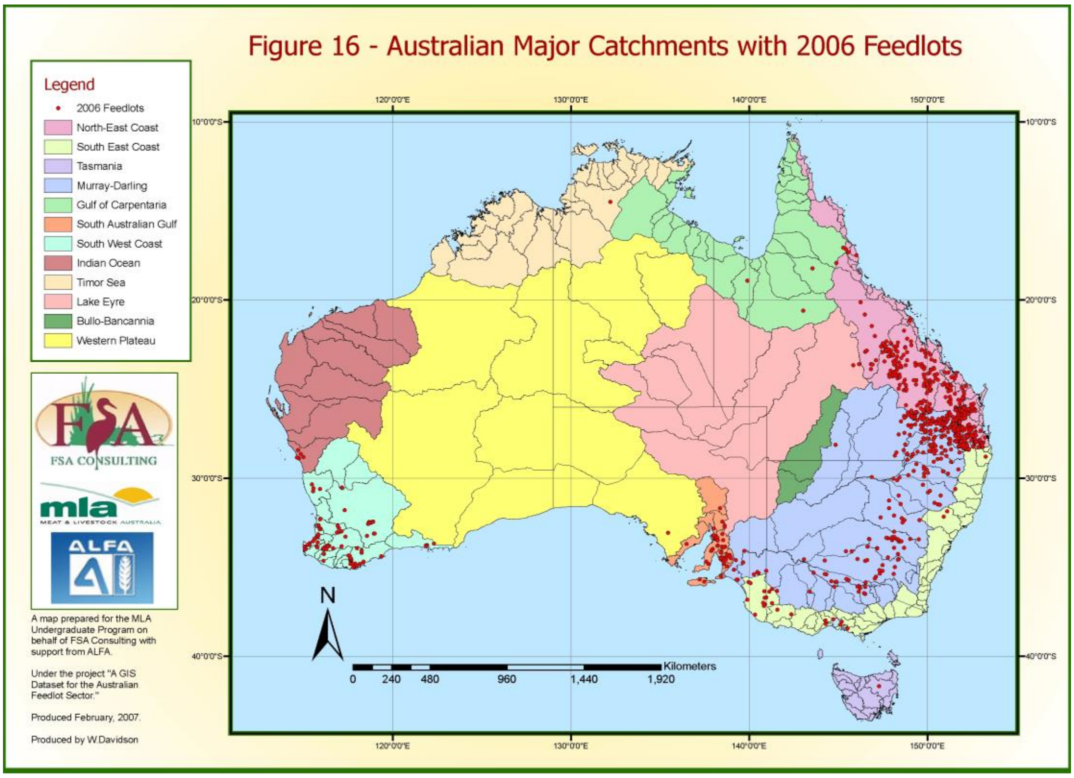


Figure 16 - Australian Major Catchments with 2006 Feedlots

5.6.2.1 Murray-Darling Catchment

The Murray-Darling Catchment begins with the Condamine-Culgoa Rivers in southeast Queensland and works its way through to the Murray River in Adelaide (Figure 17). This catchment affects four States, and is the main river system for most of the agricultural land of Australia and covers 1,057,000 square kilometres (MDBC online 8/12/06).

Table 18- Distribution of Feedlots in the Murray-Darling Catchment

	Number of Feedlots	%	Average Capacity	Current Pen Capacity	%
Condamine-Culgoa	195	56.2%	1,429	278,726	35.3%
Border Rivers	37	10.7%	3,723	137,764	17.4%
Murrumbidgee	16	4.6%	5,380	86,082	10.9%
Lachlan	23	6.6%	3,558	81,829	10.4%
Namoi	10	2.9%	5,870	58,699	7.4%
Gwydir	12	3.7%	2,754	33,049	4.2%
Murray-Riverina	10	2.9%	3,050	30,499	3.9%
Ovens	6	1.7%	4,353	26,120	3.3%
Avoca	1	0.3%	20,000	20,000	2.5%
Moonie	12	3.5%	862	10,338	1.3%
Macquaire-Bogan	10	2.9%	835	8,349	1.1%
Mallee	6	1.7%	965	5,787	0.7%
Lower Murray	4	1.2%	1,425	5,700	0.7%
Benamee	1	0.3%	2,500	2,500	0.3%
Wimmera-Avon	1	0.3%	2,000	2,000	0.3%
Castlereagh	2	0.6%	1,000	1,999	0.3%
Broken River	1	0.3%	800	800	0.1%
TOTAL	347	100.0%	2,277	790,241	100.0%

The Condamine-Culgoa River basin holds 56.2% of the feedlots in the Murray-Darling Catchment. However, this only accounts for 35.3% of the total capacity for this catchment. Border Rivers has 37 or 10.7% of individual feedlots, but has a capacity (137,764 head or 17.4%) of half of that of the Condamine-Culgoa sub-catchment. The rest of the sub-catchment holds less than 7% of individual feedlots, and less than 11% of capacity.

There are standouts within this analysis such as the Lachlan and Murrumbidgee sub-catchments producing 10.4% and 10.9% of capacity with 6.6% and 4.6% of the individual feedlots respectively.

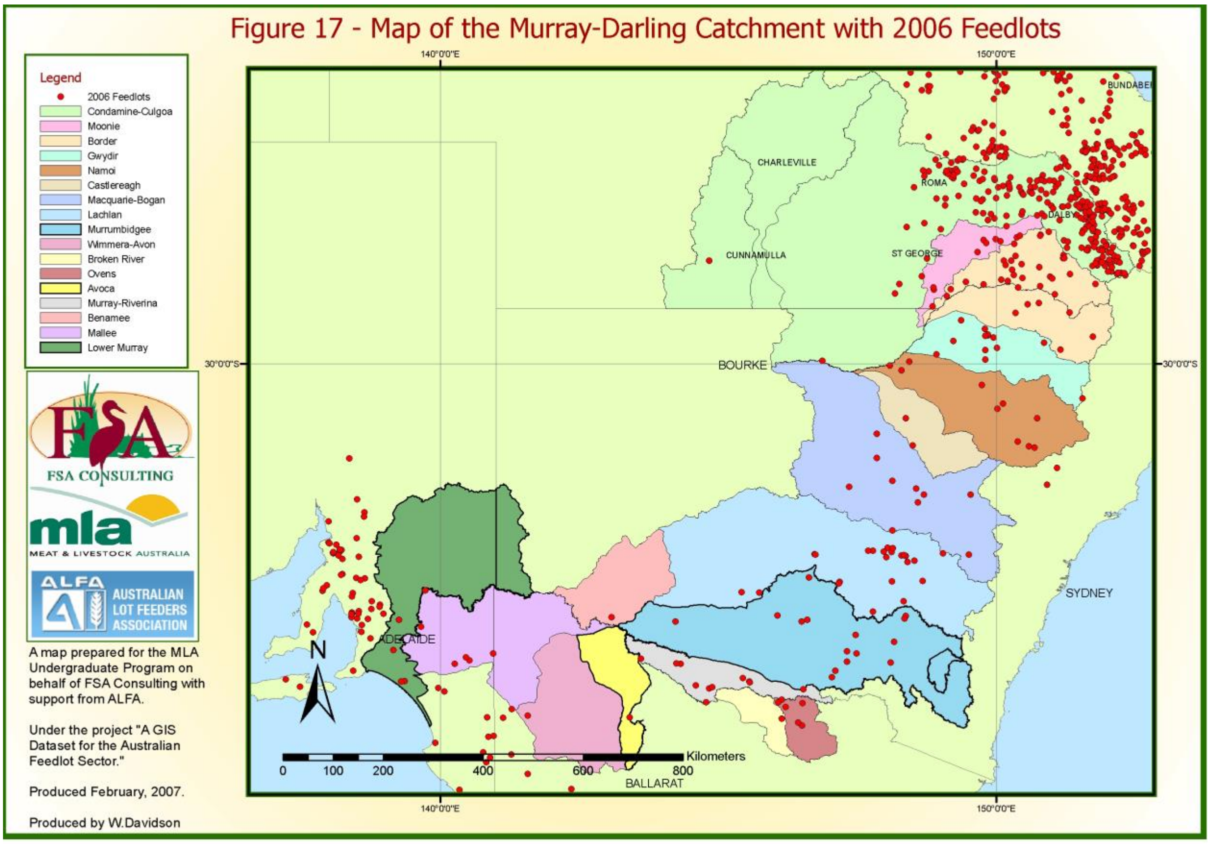


Figure 17 - Map of the Murray-Darling Catchment Sub-Catchments which contain 2006 Feedlots

5.6.2.2 North-East Coast Catchment

The North-East Coast Catchment covers 451,000 square kilometres (MDBC online 8/12/06) of Queensland's east coast, stretching from the beach to the Great Dividing Range.

Table 19 – Distribution of Feedlots in the North-East Coast Catchment

	Number of Feedlots	%	Average Capacity	Current Pen Capacity	%
Fitzroy	149	42.8%	762	113,534	54.1%
Burnett	86	24.7%	641	55,102	26.3%
Mary	16	4.6%	753	12,050	5.7%
Burdenkin	17	4.9%	655	11,127	5.3%
Brisbane	44	12.6%	202	8,897	4.2%
Logan Albert	20	5.6%	174	3,485	1.7%
Herbert	1	0.3%	2,000	2,000	1.0%
Barron	2	0.6%	275	550	0.3%
Boyne	1	0.3%	500	500	0.2%
Johnstone River	1	0.3%	499	499	0.2%
Styx	1	0.3%	499	499	0.2%
Kolan	2	0.6%	230	460	0.2%
Baffle Creek	3	0.9%	150	450	0.2%
Calliope	2	0.6%	150	300	0.1%
O-Connell	1	0.3%	150	150	0.1%
Pine River	1	0.3%	150	150	0.1%
Plane Creek	1	0.3%	80	80	~0.0%
TOTAL	348	100.0%	603	209,833	100.0%

The Fitzroy River basin holds 42.8% of the feedlots in the North-East Coast catchment and holds 54.1% of the capacity in the catchment. 67.5% of feedlots and 80.4% of capacity in this catchment are located in two basins, Fitzroy and Burnett. The stand out sub-catchments are the Brisbane and Logan-Albert with high percentages of individual feedlots (12.6% and 5.8 % respectively) and small percentages of capacities (4.2% and 1.7% respectively).

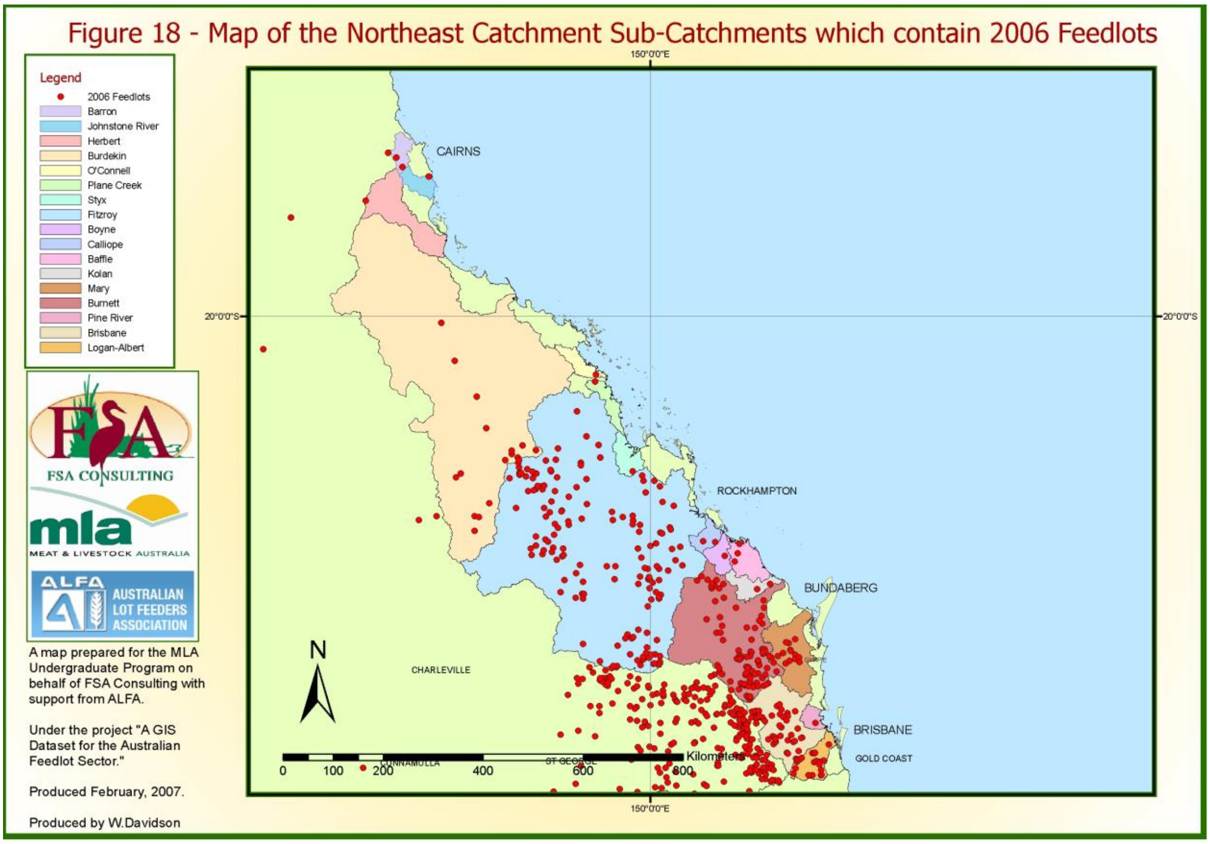


Figure 18 - Map of the Northeast Catchment Sub-Catchments which contain 2006 Feedlots

5.6.3 1990 Analysis

The analysis taken for the 1990 data in the text do not take the 12 catchments as standard for the calculation of the feedlot data. This data is still useful for comparison with the 2006 data as it breaks down the two major catchments for further examination.

Table 20 – 1990 Distribution of Feedlots over River Basin (Tucker et al, 1991)

River Basin Name	Number of Feedlots	%	1990 Current Pen Capacity	%
QUEENSLAND COASTAL BASINS				
QLD North Coast	3	1.4%	12,550	14.2%
Burdekin	0	0.0%	0	0.0%
QLD Central Coast	3	1.4%	600	0.7%
Fitzroy	65	30.1%	27,870	31.5%
QLD South Coast	145	67.1%	47,345	53.6%
Total QLD Coastal:	**216**	**38.6%**	**88,365**	**19.2%**
MURRAY-DARLING BASIN				
Upper Murray & Victoria	6	2.3%	41,240	13.4%
Murrumbidgee	10	3.8%	13,450	4.4%
Lachlan	4	1.5%	10,250	3.3%
Border Rivers	31	11.7%	55,895	18.2%
Moonie	17	6.4%	5,510	1.8%
Gwydir	7	2.7%	16,300	5.3%
Namoi	19	7.2%	37,400	12.2%
Castlereagh	3	1.1%	1,800	0.6%
Macquarie	5	1.9%	6,400	2.1%
Condamine-Culgoa	161	61.0%	119,075	38.7%
Other Murray-Darling	1	0.4%	450	0.2%
Total Murray-Darling:	**264**	**47.2%**	**307,770**	**66.8%**
OTHER BASINS				
New South Wales Coastal	16	20.3%	9,040	14.0%
Western Australia	29	36.7%	18,120	28.0%
South Australia (Central)	14	17.7%	15,400	23.8%
Others	20	25.3%	22,210	34.3%
Total Other Basins:	**79**	**14.1%**	**64,770**	**14.1%**
TOTAL	559	100.0%	460,905	100.0%

The major changes that have occurred in terms of growth in catchments are the total percent that have declined in the Murray Darling Catchment with a drop of the total percent from 47.2% in 1990 to 39.3% in 2006. The percent of total capacity has stayed relative at around 67%. The North East Coast Catchment or the Queensland Coastal Catchment in the 1990 figures stayed relative at 39%; however, this corresponded with a drop in levels of total capacity from 19.2% to 17.8%. The growth from 1990 to 2006 was the proportion of the total industry the other catchments made up. This grew from 14.1% to 21.2% in individual feedlot numbers and 14.1% to 15.2% in total capacity. Overall, the major changes in this time were the distribution of the individual feedlots while the total Catchment capacities stayed relative.

Closer examination of the two major Catchments including their sub-catchments - while this is limited by the sub-catchments reported on in the 1990 figures - it still demonstrates change. The Murray Darling Catchment was home to 264 individual feedlots in 1990 that fed 307,770 head of cattle. In 2006, this had grown to 347 feedlots feeding 790,241. In

1990, the North East Coast Catchment had 216 individual feedlots with a capacity of 88,365 head on feed to 348 individual feedlots with 209,833 head on feed in 2006.

Major growth within the Murray Darling Catchment sub-catchment occurred in the Lachlan moving from four individual feedlots and capacity of 10,250 head on feed in 1990 to 23 individual feedlots with a capacity of 81,829 head on feed in 2006. The Condamine-Culgoa Rivers sub-catchment grew in capacity without much growth in the individual feedlot numbers. In 1990, it was 161 individual feedlots with 119,075 on feed, while in 2006 this grew to 195 individual feedlots with 278,726 on feed. While the individual feedlot numbers grew by less than 25%, the feedlot capacity grew in excess of 230%. The Border River sub-catchment is another example of large growth in capacity with little growth in the individual feedlot numbers. In 1990, the Border Rivers sub-catchment had 31 feedlots and a capacity of 55,895 head on feed. In 2006, this grew to 37 individual feedlots and 137,764 head on feed.

The North East Coast Catchment sub-catchments also experienced growth specifically the Fitzroy and Burdekin sub-catchments. The Fitzroy sub-catchment grew from 65 individual feedlots and a capacity of 27,870 head on feed in 1990 to 149 individual feedlots with 113,534 head on feed. The Burdekin grew from no feedlots in 1990 to 17 feedlots with a capacity of 11,127 in 2006.

5.7 Annual rainfall

An important aspect of selecting potential sites for feedlots is the annual rainfall as this single element is able to affect a variety of issues in every feedlot. Climatic conditions have an impact both on the environmental performance of a feedlot and the welfare of the animals fed there (Watts and Tucker (eds.), 1994). Annual rainfall of less than 750mm is recommended, due to the impact of a wet climate on the water pollution and odour problems being kept to a minimum (Tucker et. al., 1991). Overflow causes pollution of the drainage system and inundates effluent ponds with large amounts of water with large quantities of dissolved nutrients.

5.7.1 2006 Feedlot distribution on rainfall

This rainfall data is sourced from the Bureau of Meteorology, 2006, using an annual rainfall map with isohyets with 50mm intervals from 600mm to 800mm. This is shown in Figure 19.

Table 21 - Distribution of Feedlots over Annual Rainfall Regions

	Number of Feedlots	**%**	**Average Capacity**	**Current Pen Capacity**	**%**
Summary					
Below 750mm	658	74.6%	1573	1,035,189	87.8%
Above 750mm	224	25.4%	641	143,530	12.2%
< 600mm	240	27.2%	1,648	395,620	33.6%
650mm	183	20.8%	1,761	322,319	27.3%
700mm	147	16.7%	1,544	226,925	19.3%
750m	88	10.0%	1,026	90,325	7.7%
> 750mm	224	25.4%	641	143,530	12.2%
TOTAL	882	100.0%	1,336	1,178,719	100.0%

Error! Reference source not found. shows a summary of Australia's feedlots above and below the annual rainfall of 750mm. This reveals that there are still 25.4% of individual feedlots are in areas that have greater than 750mm per annum. While this is a large number of individual feedlots, it only represents, however, 12.2% of Australia's industry capacity. Another distinction is found in the average feedlot size. Those feedlots fewer than 750 mm of rainfall per annum have an average current pen capacity that is 2.5 times greater than that of feedlots with annual rainfall greater than 750mm. This means that larger feedlots are located in the drier climatic zones.

5.7.2 1990 Feedlot distribution on rainfall

The rainfall data from 1990 was sourced from the Dept. of Science, 1977 (Tucker et al., 1991).

Table 22 - 1990 Distribution of Feedlots by Annual Rainfall (Tucker et al, 1991)

Annual Rainfall (mm)	Number of Feedlots	%	Average Capacity	Current Pen Capacity	%
Summary					
Below 750mm	351	60.2%	1,033	362,665	77.0%
Above 750mm	232	39.8%	466	108,160	23.0%
< 500	43	7.4%	1,132	48,660	10.3%
500-625	96	16.5%	1,526	146,465	31.1%
625-750	212	36.4%	790	167,540	35.6%
750-825	92	15.8%	481	44,260	9.4%
> 825	140	24.0%	456	63,900	13.6%
TOTAL	583	*100.0%*	808	470,825	*100.0%*

The significant change that has occurred between the 1990 and 2006 industry overview is that a smaller amount of individual feedlots are within an area that has greater than 750 mm of rain. The percent of individual feedlots above 750 mm per annum was 39.8%, which dropped to 25.4%. The capacity of those feedlots in 1990 in areas of 750 mm per annum was 23% that dropped to 12.2% in 2006. This means that site selection has improved since 1990 with a trend for larger feedlots to be in drier zones. However, an interesting fact is that both the 1990 figures and 2006 figures have around the same ratio in difference between the average capacity of those feedlots above 750mm annually and those in areas of below 750mm annually. The average capacity of feedlots below 750mm rainfall is 2.5 times greater than areas above 750mm rainfall in 2006, and 2.2 times greater in the 1990 figures.

It needs to be noted that there were two sets of rainfall data used in creating this comparison. Potentially the average rainfall zones have moved and changed between 1977 and 2006. Thus, some of the change could be represented by the change in average rainfall data used. However, the current data is taken from the 2006 data, and can be used as an effective base for the current industry standings.

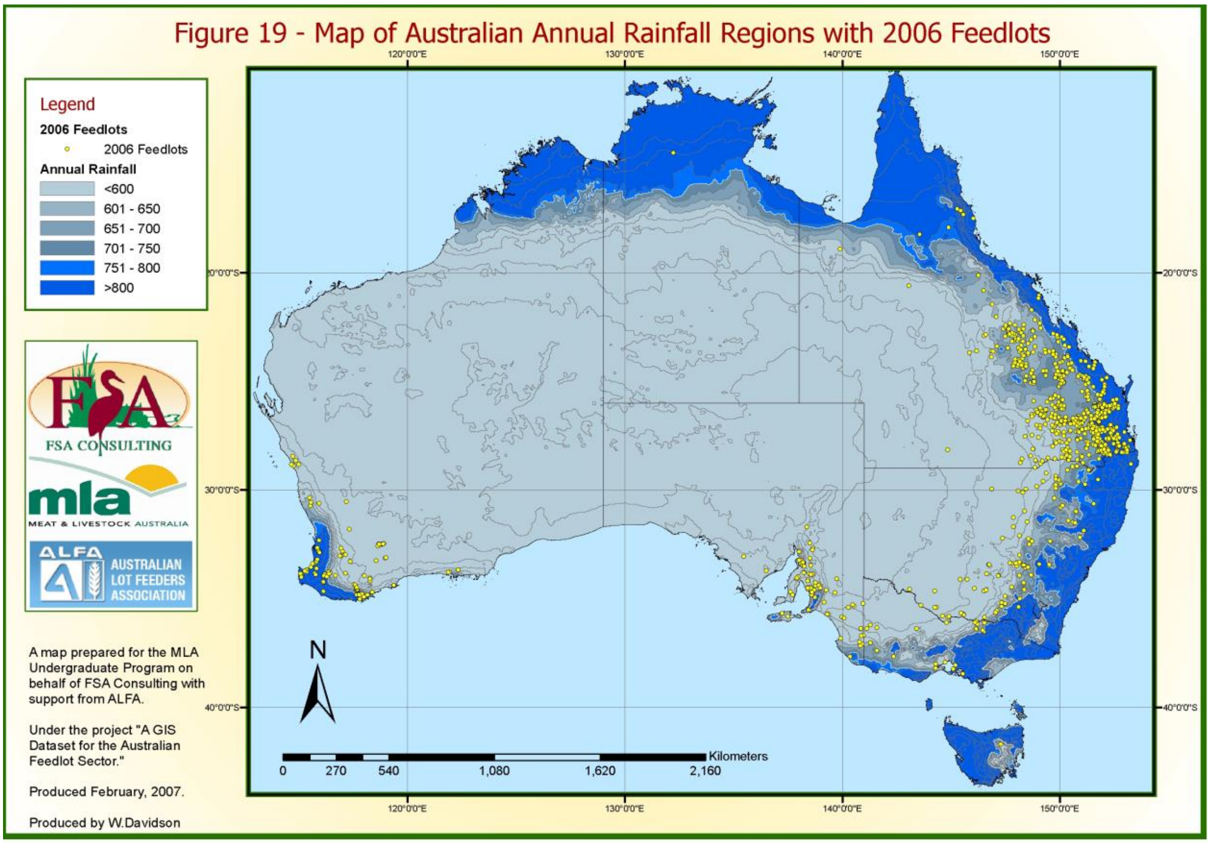


Figure 19 - Map of Australian Annual Rainfall Regions with 2006 Feedlots

5.8 Seasonal rainfall distribution

The distribution of rainfall throughout the year has a significant bearing on the management of a feedlot (Tucker et al., 1991). The problem occurs with the level of difficulty in management of the feedlot. Those with high winter rainfall and low evaporation rates have problems with pen and manure management, as a wet pad is the main cause of odour generation (Tucker, et al., 1991). Dry winters usually are easier to manage in a feedlot.

Classifying feedlot distribution is useful in understanding the management issues that face Australian feedlots. In a wet environment, excess runoff quickly fills the holding pond. Coupling this with a low evaporation rate, such as in winter months, the holding pond can become full before an opportunity presents to remove the accumulated effluent for irrigation. Pond overtopping can occur under those circumstances.

5.8.1 2006 Seasonal rainfall distribution

Table 23 - 2006 Distribution of Feedlots in Seasonal Rainfall Regions

	Number of Feedlots	%	Average Capacity	Current Pen Capacity	%
Winter Dominant	58	6.6%	866	50,255	4.3%
Winter	157	17.8%	1,574	247,106	20.9%
Total Winter	***215***	***24.4%***	***1,383***	***297,361***	***25.2%***
Summer Dominant	33	3.7%	1,828	60,326	5.1%
Summer	584	66.2%	1,103	644,282	54.7%
Total Summer	***617***	***69.9%***	***1,142***	***704,608***	***59.78%***
Arid	1	0.1%	400	400	~0.0%
Uniform	49	5.5%	3,599	176,350	15.0%
TOTAL	882	100.0%	1,336	1,178,719	100.0%

Currently, 24% of individual feedlots with 25% of Australian capacity are located in winter dominant rainfall areas.

5.8.2 1990 Seasonal rainfall distribution

The seasonal rainfall areas were sourced from a seasonal rainfall map from Colls & Whitaker (Tucker et al., 1991).

Table 24 - 1990 Distribution of Seasonal Rainfall Regions (Tucker et al., 1991)

Seasonal Rainfall	Number of Feedlots	%	Average Capacity	Current Pen Capacity	%
Winter Dominant Rainfall	77	12.2%	1,594	122,720	25.3%
Uniform Rainfall	18	2.9%	1,042	18,750	3.9%
Summer Dominant Rainfall	536	84.9%	641	343,415	70.8%
Total	631	100.0%	768	484,885	100.0%

Since 1990, the number of individual feedlots within winter dominant rainfall areas has increased from 12.2% to 24.4%. However, the number of these feedlots contributing to the total industry capacity has stayed the same, at around 25%, as has as the average capacity. The large increase comes from the uniform rainfall almost doubling in the number of individual feedlots and increasing from 3.9% of Australian capacity to 15% of the Australian capacity.

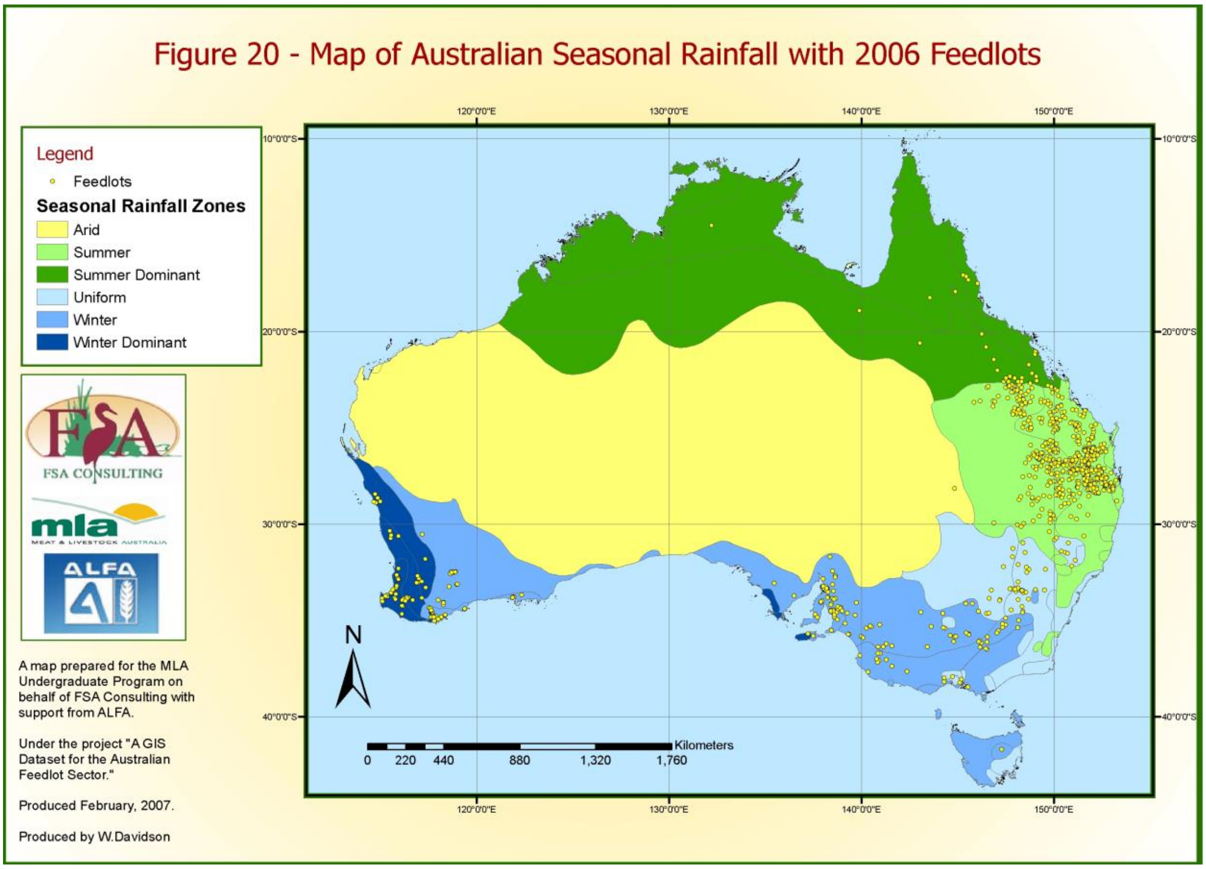


Figure 20 - Map of Australian Seasonal Rainfall with 2006 Feedlots

5.8.3 Potential heat stress areas

In selecting sites on an environmental basis, another important aspect to consider is the animal's wellbeing. In Australia, occasional periods of high heat load have and will impact on the performance and welfare of feedlot cattle (Gaughan et al., 2004) and these stresses are likely to increase with the prospect of global warming due to the accelerating emission of greenhouse gases (Howden and Turnpenny, 1998). Management of this potentially harmful issue begins with the informed placement of the feedlot, orientation of the pens to aid shade, and diligence in the observance of predictive measurements, such as the temperature heat index and watching the animal itself. An effective knowledge of current climatic conditions for the feedlot sector can help make informed choices about potential expansions of feedlots and the applications for new feedlots.
This is a new analysis undertaken for this project; and as such, there is no data to compare to from the 1990 survey.

Figure 21 is only an indicative model of how a heat stress model could be used; however, the current model of combining BOM data does give results that adhere to an avoidance of hot and humid areas.

This analysis involves taking two maps of Australian conditions, climatic zones and cooling degree-days, to form a map of the potential of Australian conditions to produce Heat Stress Areas. The climatic zones classify areas that are known as "humid." "Cooling degree days" gives a figure of the amount of degrees Celsius in an average year that the temperature is above a base temperature. The map used in this analysis had a base temperature of 18^{o}C, and areas that had an accumulation of 1000°C above this temperature over a year where used to select areas ranked being “warm”, 1500°C “hot”, and over 2000°C “very hot”.

Table 25 shows an analysis of the distribution of Feedlots while Figure 21 shows a map of the potential heat stress zones.

Table 25 - Distribution of Feedlots by Potential Heat Stress Zones

	Number of Feedlots	%	Average Capacity	Current Pen Capacity	%
Summary					
Humid	96	10.9%	861	82,616	7.0%
Not Humid	786	89.1%	1,395	1,096,103	93.0%
Mild, not humid	762	86.4%	1,420	1,081,785	91.8%
Mild, humid	16	1.8%	228	3,649	0.3%
Mild, very humid	70	7.9%	659	46,119	3.9%
Warm not humid	23	2.6%	514	11,818	1.0%
Warm, humid	2	0.2%	275	550	0.1%
Warm, very humid	6	0.7%	2,800	16,798	1.4%
Hot not necessarily humid	1	0.1%	2,500	2,500	0.2%
Hot, very humid	2	0.2%	7,750	15,500	1.3%
TOTAL	882	100.0%	1,336	1,178,719	100.0%

Currently within the Australian Feedlot Industry, there are 11% of individual feedlots located within an area classified humid by climatic zone, having 7% of overall capacity. However, those within the humid zones classifications based on temperature allow for further analysis. Currently, there are 1% of individual feedlots in regions that are have any of the variables of "humid" or "very humid" and "warm" or "hot". The corresponding capacity within these areas is 3% of the Australian capacity.

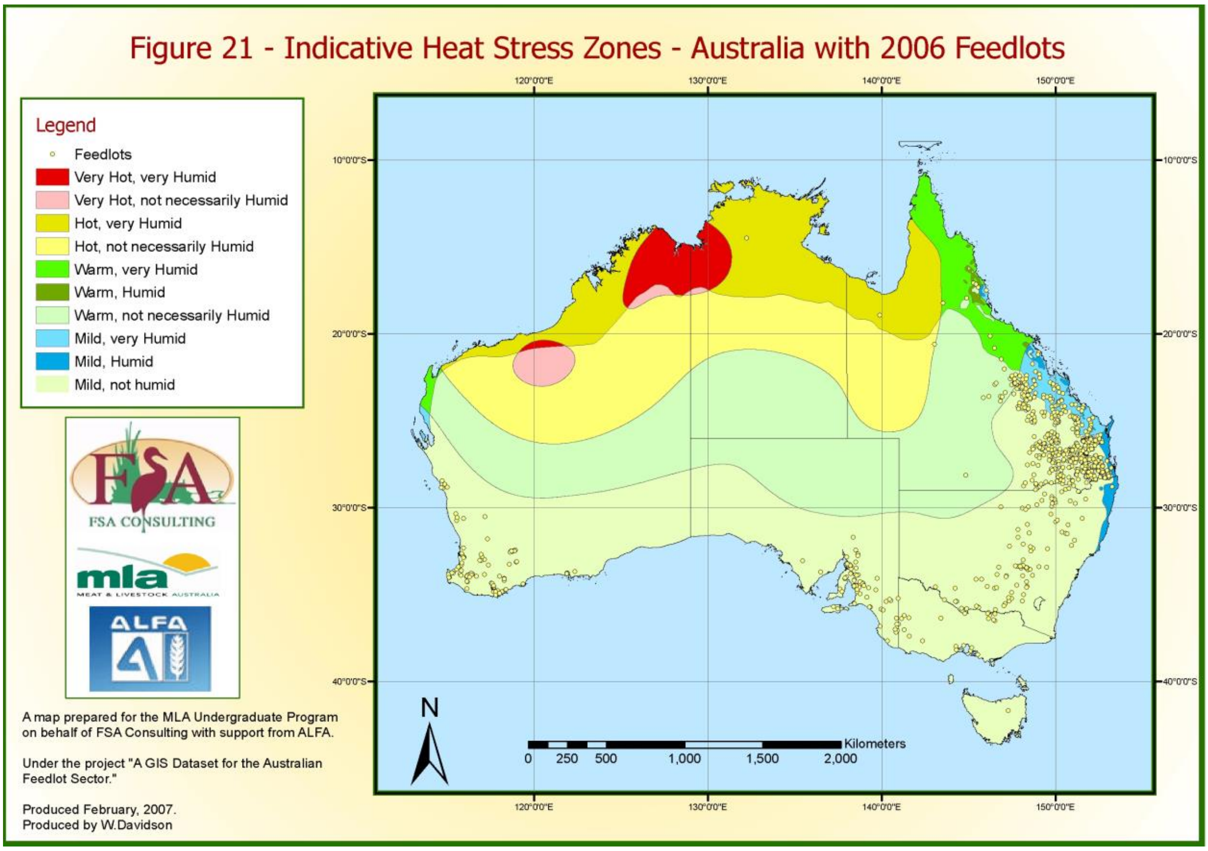


Figure 21 - Indicative Heat Stress Zones - Australia with 2006 Feedlots

6 Results for site selection

6.1 Method 1 - The reduction method of site selection

This method indicates that only 4.4% of Australia would be suitable for feedlots.

Table 26 - Validation of the Reduction Site Selection Method using 2006 Feedlots as the Basis

Suitability Ranking	Number of Feedlots	%	Average Capacity	Current Pen Capacity	%
Suitable	223	25.3%	1,373	306,194	26.0%
Not Suitable	659	74.7%	1,324	872,525	74.0%
Grand Total	882	100.0%	1,336	1,178,719	100.0%

This method has only 223 or 25.3% of all 2006 individual feedlots with a total of capacity of 306,194 head or 26% of total capacity in a suitable zone deemed by this method. Concurrently, there are a large proportion feedlots that are in areas that are classified as “Not Suitable.”

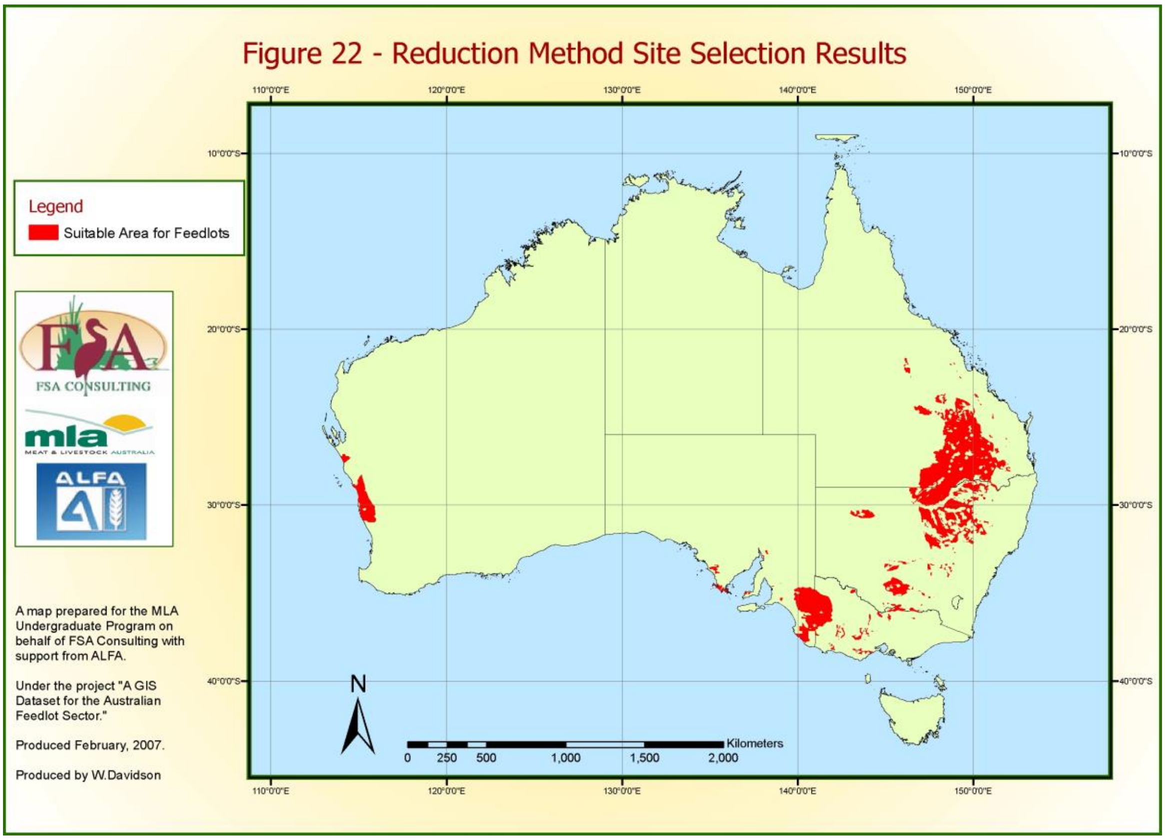


Figure 22 – Reduction Method Site Selection Results

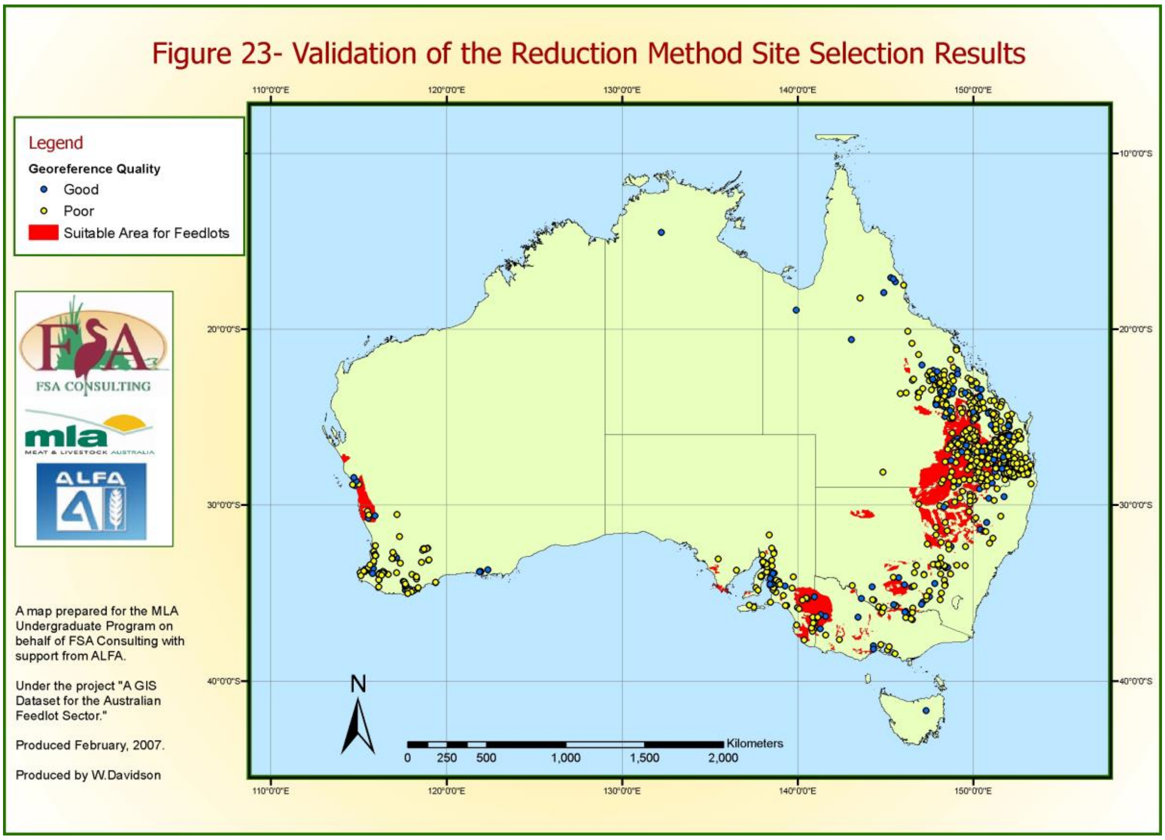


Figure 23- Validation of the Reduction Method Site Selection Results

6.2 Method 2 - The weighted method for site selection

An analysis of the number of cells in the categories of “High” and “Very High” suitability revealed that these areas contained 8895 cells out of 30915 cells. This translates into 29% of Australia being “High” and “Very High” in terms of suitability for feedlots. In terms of area, each cell is a rectangle of 16.6 km long and 14.6 km wide meaning each cell has an area of 242.36 square km. This translates into feedlots being suitable for an area of 2,160,000 square km.

Table 27 - Validation of the Weighted Site Selection Method using 2006 Feedlots as the Basis

Suitability Ranking	Number of Feedlots	%	Average Capacity	Current Pen Capacity	%
Not within Study Area*	2	0.2%	75	150	~0.0%
Low Suitability	4	0.5%	787	3,148	0.3%
Medium Suitability	77	8.7%	818	62,992	5.3%
High Suitability	321	36.4%	1,032	331,167	28.1%
Very High Suitability	478	54.2%	1,634	781,262	66.3%
Grand Total	882	100.0%	1,336	1,178,719	100.0%

** These feedlots were not located within a cell to validate this process*

The results for this model are that no current feedlots are in a “Not Suitable” area, and 9% of 2006 individual feedlots and 6% total capacity are in areas of “Low” or “Medium Suitability.” “High Suitability” held 321 individual feedlots (36.4%) and 331,167 head on feed (28.1%). “Very High Suitability” held 478 individual feedlots (54.2%) over 781,262 head on feed (66.3%). In total, 94% of capacity and 91% of individual feedlots were in the regions of “High” or “Very High” suitability.

The “Very High” suitability zone holds the most in the individual feedlot numbers and in capacity.

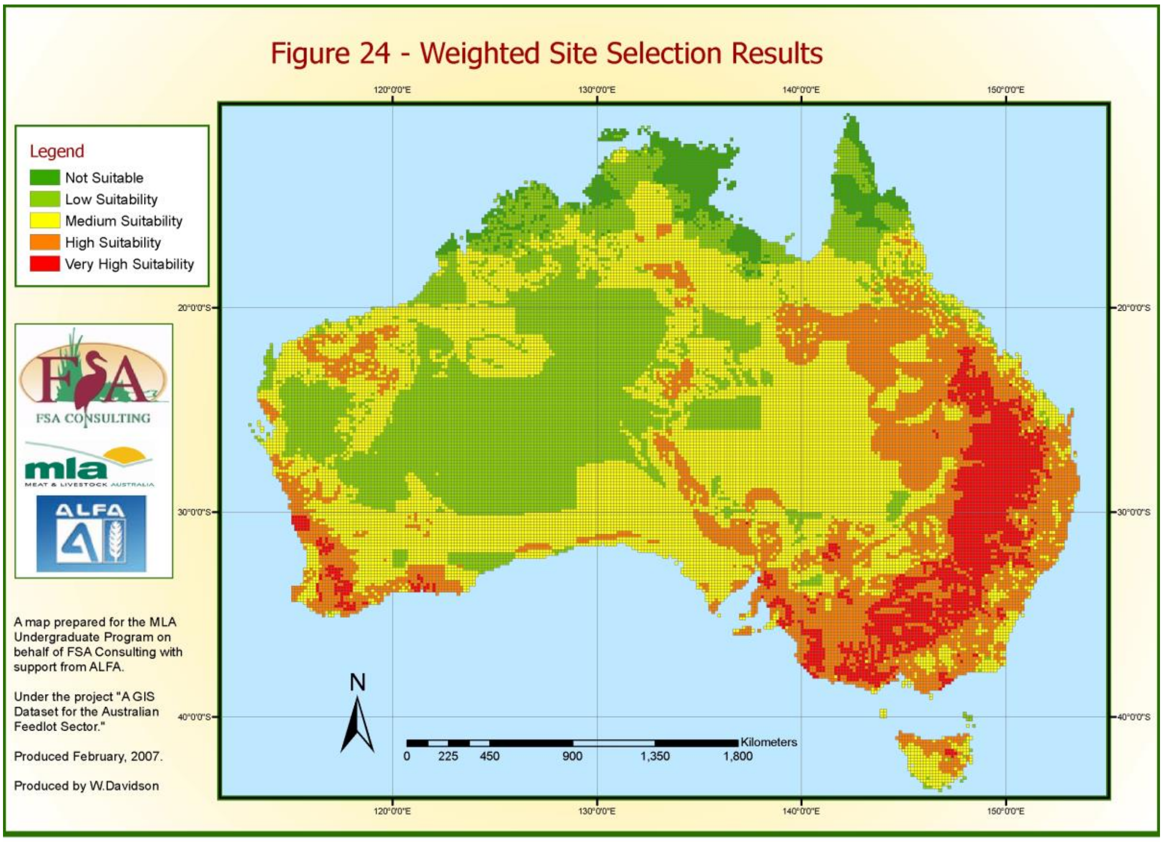


Figure 24 – Weighted Site Selection Results

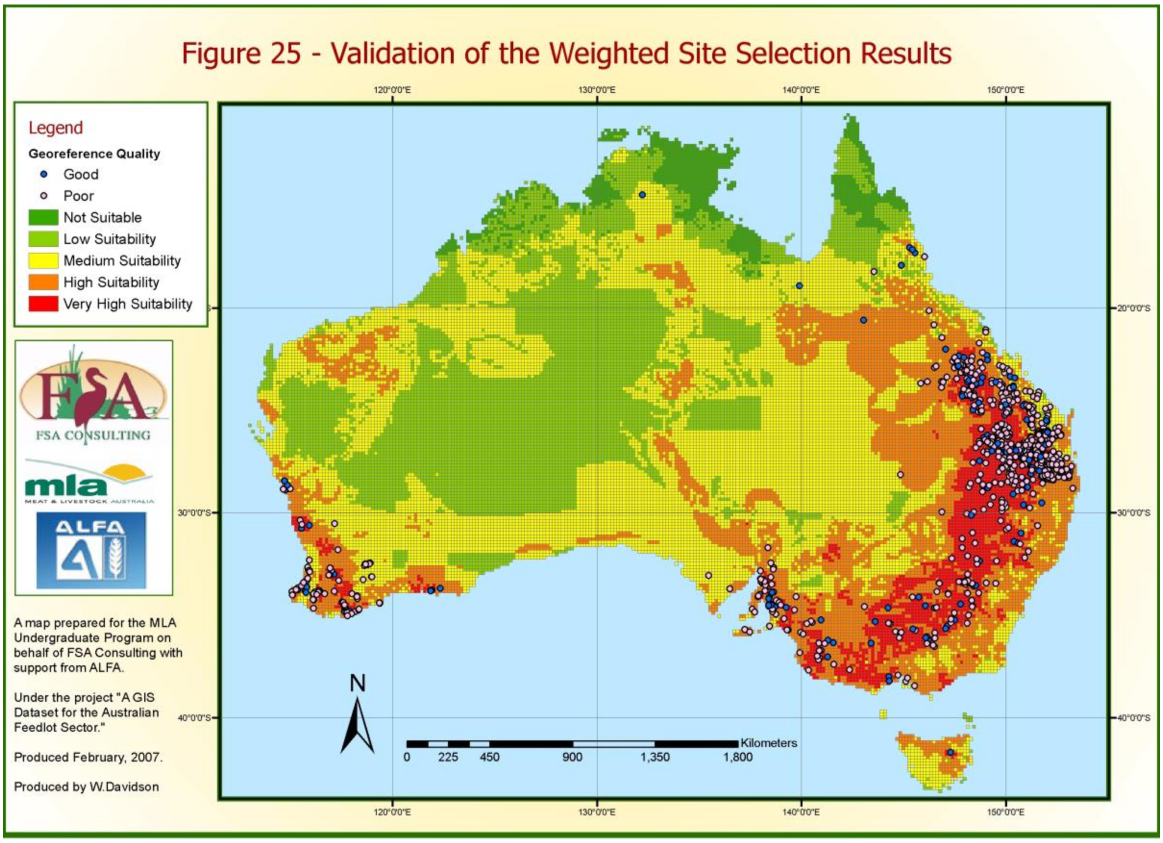


Figure 25 - Validation of the Weighted Site Selection Results

6.3 Method 3 - The non-weighted method for site selection

An analysis using the number of cells within either “High” or “Very High” suitability regions resulted with 6594 cells out of a total of 30,915 cells, or 21%. Each cell having an area of 242.36 square km means that that these suitable areas cover 1,600,000 square km.

Table 28 - Validation Results for the Non-Weighted Site Selection Method

Suitability Ranking	Number of Feedlots	%	Average Capacity	Current Pen Capacity	%
Not within Study Area*	2	0.2%	75	150	~0.0%
Low Suitability	2	0.2%	4,250	8,499	0.7%
Medium Suitability	63	7.1%	865	54,492	4.6%
High Suitability	492	55.8%	949	466,703	39.6%
Very High Suitability	323	36.6%	2,009	648,875	55.1%
Grand Total	882	100.0%	1,336	1,178,719	100.0%

** These feedlots were not located within a cell to validate this process*

The validation results for the Non-Weighted site selection model are as follows. There were no feedlots found in regions deemed at “Not Suitable.” “Low” and “Medium” suitability areas contained 7% of individual feedlots with a current pen capacity of 5%. “High” suitability areas contain 492 individual feedlots (55.8%), with a capacity of 466,703 (39.6%) with an average of 949 head per feedlot. “Very High” suitability areas contain 323 individual feedlots (36.6%) with a capacity of 648,875 (55.1%). “High” and “Very High” suitability zones contain a combined 92% of individual feedlots, and a current pen capacity of 95%.

Within this model, the “High” suitability zones hold the most individual feedlots, while the “Very High” suitability zone holds the most capacity.

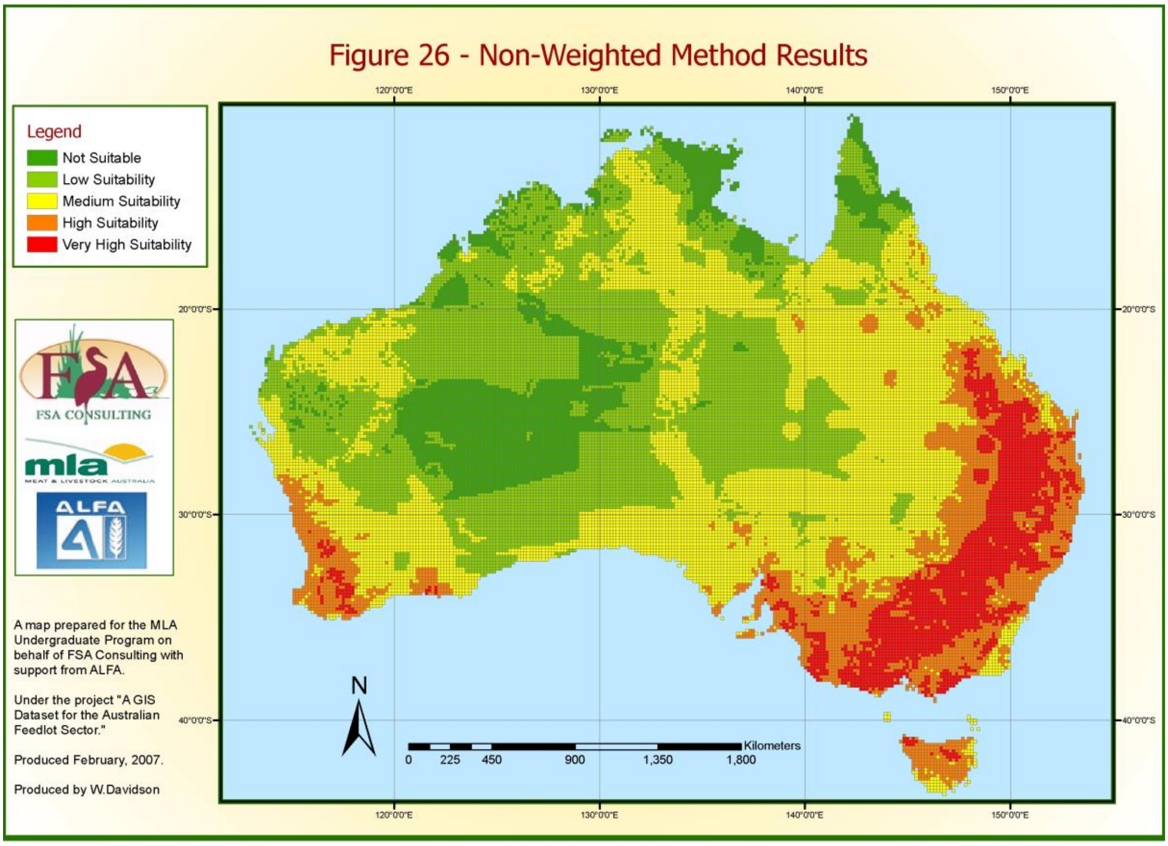


Figure 26 - Non-Weighted Method Results

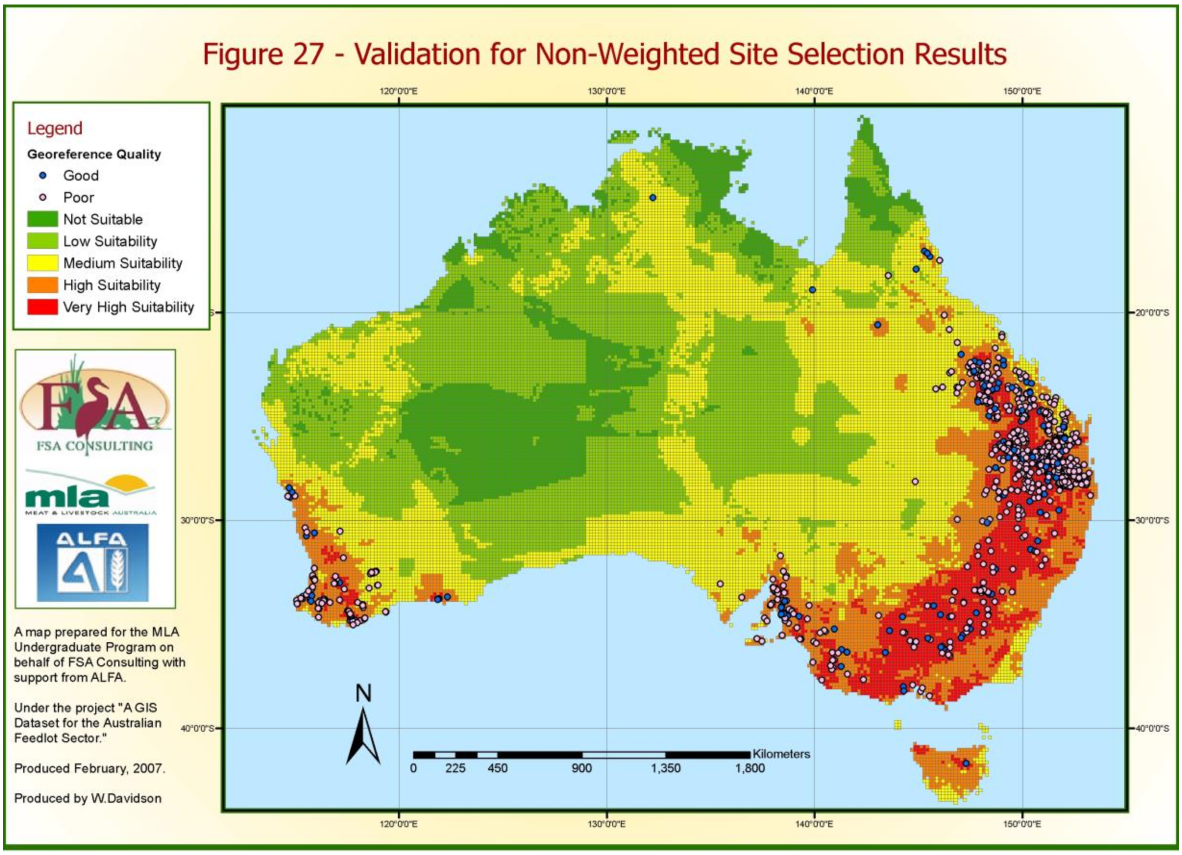


Figure 27 - Validation for Non-Weighted Site Selection Results

7 Discussion

7.1 The Australian feedlot industry survey discussion

7.1.1 Current pen capacity

The results for the current pen capacity illustrate that the Australian Feedlot Industry is currently growing and is larger then any current methods of regulation or survey have indicated it being. Figure 2- Growth of Feedlot Capacities from the December Quarter 1995 to September Quarter 2006 (MLA, 2006) gives the largest recorded feedlot capacity in June 2006, where 940,097 cattle were on feed (MLA, 2006). The figure that this survey obtained of 1,180,848 head on feed, is 240,000 head of cattle higher then that figure regarded as the current industry snapshot. Therefore, the industry is making decisions and policies considering only 80% of the industry. This report would recommend a census for the total head on feed within Australia to allow for future sustainability.

The limit of this survey is also reflected in Figure 9 with some States having a high percentage of their overall feedlot representation in the lower size capacities, and with others being underrepresented in the lower size capacities, indicating the potential for “missed” or “unknown” feedlots that have not been counted in this report. Table 16 predictive figures show a number of missing smaller feedlots. Section 7.1.4 discusses this further.

7.1.2 Major Australian feedlots

The comparison between the 1990 feedlots and the 2006 feedlots demonstrated how the top end of the industry has developed over the last 16 years. In these 16 years, the minimum size to be included in the top 21 has tripled from 4000 head on feed to 12,000 head on feed. Five feedlots from the 1990 list have closed in the last 16 years, while half of the feedlots in this list in 1990 are still on the list in 2006.

Geographically, NSW sees major growth, with five additional major feedlots opening in this State within the last 16 years and only two feedlots closing. In Queensland, two closed and three opened. In Victoria, one closed and one opened. Tasmania is the only additional State to join the Major Feedlots list in 2006. This illustrates the amount of growth in the large feedlots that NSW has had.

7.1.3 State distribution

Although there has been some movement in terms of relative states number of individual feedlots and capacities, the proportion of individual states share of the feedlot industry has stayed much the same over the last 16 years. Queensland’s industry despite its growth loses ground in both the individual feedlot numbers and the percent capacity of the Australian Industry, and gives an indication of what a total count of feedlots within in a State looks like. Table 16 reinforces the potential for missing numbers of smaller feedlots throughout other states. South Australian feedlots may have potential problems in understanding the true capacity, as a number have no current capacities, thus potential distort the figures taken from this state. This maybe because of these feedlots running only in certain periods, but it also may be due to lack of information on these feedlots.

7.1.4 Feedlot size and capacities

The growth that is seen in this industry comes largely from not a great increase in individual number of feedlot but expansions of existing feedlots to a larger capacity. This is seen from the numbers presented in the difference size capacities between 1990 and 2006. The feedlots under the size of 400 head experience a drop from around 67% of individual feedlots in 1990 to 54% of individual feedlots in 2006. The total Australian capacity dropped from 10% to 5% in this period. This is due to a potentially less complete less of smaller feedlots in 2006 then that of contained in the 1990 survey. At the other end, feedlots over 5000 head grew from 3% of individual feedlots in 1990 to 6% in 2006. This size bracket increased from 46% to 60% of Australian total capacity along in this time. This growth here is well represented within the FSAFLdB.

This dramatic drop, in the proportion of smaller individual feedlots can be seen as a number of expansions in smaller 1990 feedlots, or that there is a large number of feedlots under 400 head that have not been counted in this survey. Figure 9 shows a graph of the percentage of each size capacity from each State. While the National, Queensland and South Australian numbers all start with a high proportion of 400 head feedlots compared to the other size rankings, New South Wales and Western Australia start with a smaller proportion of feedlots in these size ranking. Victoria starts with none. This indicates that although there may be some merit to the theory of growth in this size class through expansion, the more likely scenario from Figure 9 is that this database is missing feedlot data from the under 400 head capacities and even under the 1000 head capacities in New South Wales, Victoria and Western Australia. Table 16 confirms this theory with predictive feedlot numbers.

7.1.5 Geographic locations

From Figure 11, we see the growth in numbers from 1990 to 2006. The distinctive areas of feedlots finishing up are below Brisbane in South East Queensland. This is potential due to the large growth that South East Queensland has experienced over the last decade, turning local shires areas into residential rather then agricultural uses. Large growth has occurred in Central Queensland. This figure is under represented in all states bar Queensland, due to a lack of smaller feedlot numbers in all states but Queensland.

7.1.6 Catchments

Water, and the uses of water, is an issue for the entirety of Australia. Drought has led the federal government to announce that it is planning a move to take control of the Murray-Darling as a part of a $10-billion, 10-year plan to upgrade ageing irrigation infrastructure and address the over-allocation of water in the drought-ravaged river system (News.com.au, 1/2/07). This vital catchment represents 75% of irrigated agriculture based on 2000/2001 figures (Murray-Darling Basin E-resources, 2005). Currently, the Murray-Darling is also where 347 individual feedlots reside, with a capacity of 790,241 head. This translates to 39.3% of Australia's individual feedlots, and 67% of Australia's feedlot current capacity. Within this catchment, there is not much diversity in terms of feedlot placement. Over half (56.2%) of the feedlots within the Murray-Darling reside in the Condamine-Culgoa river system. However, this is only 35.3% of the total capacity for the Murray-Darling. Major growth from 1990 to 2006 within the Condamine-Culgoa sub-catchments suggest massive expansions of operating feedlots as individual feedlots numbers have grown only slightly (25% of its 1990 count) while the capacity of this catchment has grown by over 200% of its 1990 capacity. The Border River sub-catchment is another example of large growth in capacity with little growth in the individual feedlot numbers. In 1990, Border River's sub-catchment had 31 feedlots and a capacity of 55,895 head on feed. In 2006, this grew to 37 individual feedlots and 137,764 head on feed. Throughout the Murray-Darling the growth occurring can be seen as expansionistic.

The other great Catchment in terms of feedlot location is the North-East Coast, containing one more individual feedlot then the Murray-Darling, giving it 39.5% of the Australian industry. In capacity, Murray-Darling beats it easily with 67% of the Australian industry capacity and the North-East Coast holding only 17.8% of Australia's capacity. This catchment has experienced the greatest growth through the sub-catchment of the Burdekin.

In 1990, the Burdekin sub-catchment had no feedlots within it, however, now it holds 4.9% of the Catchments individual feedlots and 5.3% of the Catchments capacity. To compare growth for this catchment relies on the 1990 data, and due to very few sub-catchments being examined. The major growth in terms of individual feedlots numbers is seen in the Burdekin. The major growth through expansion in seen in the Fitzroy sub-catchment, growing from 65 individual feedlots and a capacity of 27,870 head on feed in 1990 to 149 individual feedlots with 113,534 head on feed.

Looking through the current guidelines for the establishment of feedlots both nationally and within individual States, most of these guidelines stipulate prevention of water pollution, and protection of this resource. This leaves the question, is the future of the feedlot industry available water access? Right now, due to the distribution of feedlots within catchments, there is high potential for the feedlot industry to become the enemy with amount of feedlots in certain catchments and made scapegoat on water usage. Therefore, further studies into the water use and efficiencies of feedlot operations are needed.

7.1.7 Annual rainfall

The annual rainfall amount gives insight to the managerial practices of the feedlot industry. The recommended level of rainfall is less than 750mm per annum, as operations in areas that are higher then less level need better managerial practices for the operation of the feedlot, due to the accumulation of wastes and the potential odours the wet pads give off. In 2006, there was a ratio of a quarter (25.4%) of individual feedlots operating in areas with higher than 750mm rainfall. However, this was only 12.2% of the total Australian capacity. This comes from the industry statistics of 1990 where there were 39.8% of individual feedlots in areas of 750mm of annual rainfall or higher. In 1990, feedlots had a capacity of 23% of the industry at that time. Over the past 16 years, there is evidence of a move away from areas with greater than 750mm per annum. This is seen as the number of individual feedlots in areas of 750mm or more has dropped from 232 feedlots in 1990 to 224 feedlots in 2006. Growth is evident in this data in the size of the capacities, growing from 108,160 head capacity in 1990 to 143,530 head capacity in 2006. The amount of annual rainfall seems to be a limiting factor in the feedlot industry.

7.1.8 Seasonal rainfall distribution

The seasonal rainfall analysis of the Australian feedlot industry reveals change between the 1990 survey and the current situation. The number of individual feedlots in winter dominant rainfall zones has grown from 77 in 1990 to 215 in 2006. This growth as a percent of the total Australian industry changes from 12.2% to 24.4%. While the capacities for these zones have stayed a relative 25% of the Australian industry from 1990 to 2006, the capacity in 1990 (122,720 head on feed) has grown to 297,361 head on feed in 2006. The average size for feedlots in these areas is in 2006, 1384 head per feedlot, while in 1990 it was 1594 head per feedlot. This demonstrates that in this area, growth has occurred due to the opening of new feedlots, rather than expanding the existing ones. The main area of winter dominant rainfall in Australia is Western Australia and South Australia. The situation with the winter dominant rainfall areas coincide with a drop in individual feedlot numbers and capacities of summer dominant areas. This factor despite adding management pressures to the operation of a feedlot, does not seem to be a limiting factor to the placement of a feedlot, however, it may be limited in the size capacities that these areas can hold.

7.1.9 Potential heat stress areas

These numbers do not correspond to any figures from the 1990 survey, and are not representative of all areas within Australia in which heat stress can occur. These are included in this survey to give an example of how a map could be produced on the data produced relating to heat stress. Currently, this map shows that even a rudimentary attempt at a map can potentially give results on humid and hot areas.

7.2 Site selection discussion

The methods undertaken here allowed for a significant start in the process of analysing a base set of criteria and selection constraints for the feedlot industry. These models have several flaws. These are tied to the availability of data, and potentially the translation of site selection criteria into relevant GIS selection criteria. As a part of this research, it has become more and more apparent that the future growth potential for this industry is locked into the need for resources and the subsequent cost of obtaining these resources. Due to the "middleman" impact, the cost of resources and the price to be realized by the feedlot cattle sometimes determines the establishment of a new feedlot. This is more so with middle to large sized operations and less so with feedlots less than 1000 head. However, while these economic pressures may not affect smaller feedlots to the same extent, these smaller feedlots are often based on family farms and are unlikely to search for further suitable sites.

One large constraint within site selection is the availability of data on water access. This report defined as best it could a method to reflect water availability but this may not be the true reflection of the availability of water. Research is needed to discover how water access can be mapped on national scale, or that it is better if water access should be a local scale site selection criterion.

The data found on the indicative Heat Stress areas have a long way to go to be relevant for within this industry; however, they were useful in determining areas that were unsuitable for feedlots. Further work and research is recommended to be performed to allow for a better representation of these areas within Australia.

A large limiting factor for these models is the criteria chosen and used. Site selection needs to be relevant on the environmental legislation requirements, as well as the requirements for the areas represented to be commercial viable. Criteria were added to this project late to allow for the better representation of the commercial reality of feedlots. A criterion of the economic cost of grain was not included, due to access to suitable data within this project timeframe. Recommendations would be to research the economic reality of grain cost transport within the Australian Feedlot Industry.

7.2.1 Method 1 -The reduction method of site selection

While this method held promise when originally proposed, its downfall was the lack of mandatory criteria to allow this method to have a definitive basis for site selection. Because in the business of feedlot site selection, a professional will be able to work around some adverse conditions, this system did not. The result reflected a small area that was deemed acceptable for all criteria, yet was under represented by the current locations of feedlots. The validation using the current feedlots meant that the resulting area of this site selection process does not give a true reflection of the potential or even the current reality of feedlot placement. Thus, this method is not suitable for use in for site selection for the Australian feedlot industry. This is potential due to the site selection criteria being soft rather then hard, not giving definite criteria to be used in site selection.

7.2.2 Method 2 - The weighted method for site selection

This model demonstrates that an approximate attempt to recreate the current commercial and regulatory pressures to the current industry situation can produce satisfactory results using weighting to relate the theory of these objectives to a real-world situation. This attempt utilises weightings from professional consultants within the industry to effectively weight criteria so they would be able to overcome some site disadvantages. This would then be able to give a generalised ratio of the difficulty to set up a feedlot in this area.

This method was successfully validated with 91% of individual feedlots and 94% of Australian capacity were found within the areas of “High” and “Very High” suitability.

However, this method produced a large area of “High” areas over most of Queensland, through the middle of Australia and Port Hedland in Western Australia. This resulted in this model showing 29% of Australia as “High” or “Very High” suitability. This is potentially due to weighting *infrastructure* (major roads and railways) too high. It is because of these areas of excess that this method while it holds potential to correctly represent the feedlot industry, that make the model lose value. These excesses are not commercially viable. To create a site selection dataset that would better fit the commercial reality would allow greater potential to “test” how suitable a site could be through additional data being added to this model.

7.2.3 Method 3 - The non-weighted method for site selection

This model was created to represent the additional data gained late in the research for this project. Due to this information being accessed after the OOC surveys were completed, a need to test the additional site selection criteria was created. The simplest way was through a simple additional and subtraction equation. The criteria that were beneficial or needed for a site were added, while those areas that were potentially harmful were subtracted.

This model was also successfully validated with the locations of current feedlots. The areas of “High” and “Very High” suitability were represented by 92% of all individual feedlots and 95% of all capacity.

This model was successful in representing areas to the commercial reality of the current feedlots, with “High” and “Very High” areas extending only around the current feedlots. The “High” or “Very High” suitability covered 21% of Australia. This model fell down in the representation of the average rainfall, and areas that are known of rainfall having higher than 750mm per annum being classed as “High” or “Very High.” These locations are found on the East Coast of Australia. It is because of these being here, and close to large populated areas, that this criterion of rainfall needs to be observed as the additional rainfall causing additional odour issues.

However, even with this problem this model potentially best represents the commercial reality of the feedlot industry within Australia. This can be seen because the larger operations are better represented in the “Very High” suitability regions. This is identified in this model as this class has the higher amount of capacity, while in individual feedlot count “High” has the higher amount. Therefore, the smaller number of feedlots in the “Very High” class holds feedlots with larger capacities. It is assumed that these large feedlots are in locations that represent the best commercial reality of the industry. In the Weighted model, the “Very High” class was highest in both, meaning that this represented commercial reality, but was a more blunt or broad approach, while the Non-Weighted model, was “sharper” in its representation.

7.2.4 Site selection summary

Currently, Method 3 the Non-Weighted method best reflects the commercial reality of the Australia feedlot industry due to having the largest of individual feedlots and current feedlot capacity within its ”Selected” areas, as well as not having areas covered within Australia that are known as not suitable. With the advent of better criteria, a better model can be made.

Table 29 - Comparison of the Site Selection Methods

	Method 1	Method 2	Method 3
Percent of Australia in “Selected” Areas	4%	28%	21%
Number of Feedlots in "Suitable" Areas	25%	91%	92%
Current Pen Capacity in "Suitable" Areas	26%	94%	95%

Having confirmed the ability of GIS to predict current site selection using current criteria, then it could be used to see what happens if one criterion is changed (e.g. using the model to predict how much space would be available to feedlots if grain could be cheaply imported, would this make areas around ports suitable?). This ability would give the Australian Feedlot Sector the ability to see how adaptation of specific areas within the industry could allow for further overall development of the Australian Feedlot Sector.

8 Success in achieving objectives

This project has demonstrated the great potential for the utilisation of GIS software to perform an industry snapshot and assist with future growth. Upon the outset of this project two objectives were identified as”

1) Provide a dataset for the feedlot industry
2) To assess GIS as a basis for future site selection.

8.1 Objective 1 - Provide a dataset for the Australian feedlot industry

Starting with the text, *Lot Feeding in Australia: A survey of the Australian Lot Feeding industry* (Tucker et al., 1991) which provided a basis for analysis of the current situation of this industry. Using this as a starting point, analyses were performed on the current data. This allowed for an updated picture of the industry. Through a thorough comparison between the 1990 data and the 2006, changes were observed in the evolution of the Australian Feedlot industry. The current data was required to be built into a format that could be used in a GIS. The georeferencing of over 882 feedlot locations to two levels of accuracy, absolute and vocational, provided advancement in the industry's mapping and spatial analysis abilities. The objectives onus was to provide a dataset for the industry that gave insight into the current situation of the Australian Feedlot Industry. This report achieved this. The current observed problems come from the within the industry, unable to have an absolute census of feedlots Australia wide. Due to the two levels of accuracy, the updating of this dataset is vital for any future work for within this industry.

8.2 Objective 2 - To assess GIS as a basis for future site selection

GIS can be used to undertake a more rigorous site selection for new feedlots, taking into account economic and environmental factors. This project proved this. Site selection occurred within this project, however to a limited degree. The limiting factors that were encountered were based on two major groupings, the criteria used and the data that was available. The criteria was were problematic as taking criteria from guidelines for the development of feedlots, give environmental criteria, but miss a large amount of the economic reality of this industry. Data access limited the project as finding suitable data to represent certain variables. In the project, these were water access and the potential for Heat Stress. Furthermore, data limited the criteria that were available for use.

In using GIS, site selection needs to occur on two levels. This project only attempted to perform a broad scale site selection. Research needs to be done to see if GIS could be used for a fine-scale site selection. Further research could allow GIS to predict future potential of sites for feedlots, if some criteria were adapted.

9 Conclusions

9.1 Conclusions of the Australian industry survey

In conclusion, a large amount of growth has occurred over the last 16 years. New areas have opened to feedlots (Central Queensland) and feedlots have been removed from other areas. Growth has occurred in two main ways, through expansion of existing feedlots, or the additions of new feedlots to the industry. The greater of these two seems to be the expansion of existing feedlots, though it is hard to determine due to the lack of a complete picture. This is seen by the lack of numbers of the smaller feedlots in states other then Queensland. Due to the limited scope of this database in terms of feedlot numbers in the smaller size categories, it is only apparent that the Australian Feedlot Sector has grown through expansion in the 16 years between the surveys. However, even within Queensland numbers expansion can be seen for the bulk of the growth within the Queensland feedlot industry.

As a result, it seems while areas with greater than 750mm per annum of rainfall are a limiting factor in the placement of feedlots, seasonal rainfall, is not, and thus has been used in site selection of feedlots between 1990 and 2006. While it was suggested that winter dominant areas are not recommended due to issues from low evaporation rate keeping the manure wet longer, with potential odour issues, this is not the reality in the Australian industry. Areas of winter dominant rainfall have grown, showing that this is potentially not a limiting factor.

Additional work can be performed to map out the Heat Stress areas of Australia, as this would provide an important tool in the future of this industry.

The problem with this survey is the lack of complete information. Even with the amalgamation of several sources of feedlot information, it is apparent that there are some details still missing. However, the results gained from this survey give a better picture of the entire industry, than that of just one data source. Potentially with the continuation of this database, a dataset including all feedlots within Australia can be a reality one day.

9.2 Conclusion for site selection potential

For a start in the journey of site selection for the Australian feedlot industry, these models have created a groundwork on which further work can be developed. In further work, greater input from feedlot managers would be required to represent the “true” costs of operation. While consultants have an idea of operating costs, they do not deal with these costs day in, day out. In terms of usefulness due to have a complete list of feedlot development guidelines from national and State sources, effective criteria can be created to map these areas. The economic costs or the commercial realities are criteria that have proven more difficult to map. This is due to the selection of relevant criteria being based on the experience of consultants, rather then feedlot managers. A recommendation would be to use the OOC survey with a number of feedlot managers before further work is undertaken to balance the environmental limiting factors as well as the economic factors..
Out of the three models, the Non-weighted result gave the best indication of the current commercial reality. While this is the case, there is still great potential for the weighted model

to produce better results. The limiting factor is time and the right criteria that accurately represent the industry.

As a result of this project, the conclusion is that GIS is able to be used as a method for broad-scale feedlot site selection.

10 Recommendations

10.1.1 Recommendations from the Australian feedlot industry survey

A recommendation would be to echo the recommendation out of Tucker et al. (1991) that a census of all feedlots operating within Australia should be taken.

A recommendation would be for this dataset to be updatable to handle future applications for this industry.

A recommendation would be to look into the water use and efficiencies of feedlot operations.

A recommendation would be to further Heat Stress tools by creating a map of Heat Stress areas within Australia, based on the potential number of heat stress days per year.

10.1.2 Site Selection recommendations

A recommendation would be to research how water access can be mapped on national scale, or that water access should be a local scale site selection criteria.

A recommendation would to access the advice of feedlot managers to gain their perspective in the operating costs of feedlots to better represent the commercial reality of feedlots within Australia.

A recommendation would be for further site suitability models that access to better data regarding the economic costs of grain for feedlots.

A recommendation would be to research the ability of GIS to provide a fine-scale site selection.

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<u>SOFTWARE</u>

ArcGIS 9.1, ESRI, 380 New York Street, Redlands, CA, United States of America, 92373-8100.

Google Earth, Google, Google Inc., 1600 Amphitheatre Parkway, Mountain View, CA, United States of America, 94043.

12 Appendices

12.1 Appendix A

This is the initial project brief for this project::

THE RED MEAT INDUSTRY
UNDERGRADUATE PROGRAM 2006/2007

Company:	**FSA Consulting**		
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MLA mentor:	Heidi Philpott	0404 079 179	hphilpott@mla.com.au

Project title: **GIS dataset for the Feedlot Sector**

Background:

This project would complement the current MLA FLOT.132 (Vision 2020) project but should be useful for future MLA projects. The project would also improve FSA Consulting's GIS capacity.

Project Rationale:

The concept is to develop a GIS dataset of feedlot related information. The dataset could include:

- location / size of all feedlots in Australia (currently being developed in Vision 2020)
- location / size of all abattoirs in Australia (currently being developed in Vision 2020)
- catchment boundaries
- water resource data (surface / groundwater)
- climate data (rainfall, temperature) and perhaps a heat stress index parameter that could be calculated across Australia relevant to feedlot site selection.
- shire boundaries
- SLA (statistical divisions used by ABS / ABARE)
- infrastructure (roads, railways, etc)
- urban areas (people)
- ABS data on breeding / grazing cattle (distribution of breeding herds, etc across Australia)
- ABS data on grain production (production / area for each major grain type)

With this data set, industry could extract various statistics (feedlot numbers vs. shires, feedlot numbers in each catchment, etc). More complex analyses or research projects can then follow. It may be possible to do broad-scale feedlot site selection.

Objectives:

The student will be required to achieve the following:

1. Develop a clear understanding of the feedlot sector and its relationship with grain production and cattle breeding areas.
2. Collect GIS datasets from as many sources as possible (within and without of MLA and FSA Consulting)
3. Combine the datasets within ArcView or MapInfo.
4. Prepare various maps / analyses as suggested by FSA Consulting, MLA, etc
5. Prepare a final report outlining the project, findings and recommendations.

Deliverables:

1. A weekly 1 page brief covering achievements for the week and aims for the next week
2. A mid program presentation
3. Intermediate report write up, milestones as set by MLA
4. A final report – with recommendations for future updating / maintenance of the dataset.
5. A site presentation of findings

12.2 Appendix B

Example of a text files entry to GIS point position map. Major Australian feedlots 3.1.2.1.4

C:\SuveryofFLAusdata\1990data\1990majorfeedlots.txt

```
Feedlot_Name,Locality,State,Commenced,Closed,Current_Capacity,Lat,Lon
Beef_City,Purrawanda,QLD,1975,,25000,-27.523559,151.617418
Whylla,Texas,QLD,1989,,20000,-28.745240,151.051478
Charlton,Charlton,VIC,1970,,18000,-36.631929,143.402328
Peechalbah,Wangaratta,VIC,1973,,17000,-36.169751,146210097
Caroona,Quirindi,NSW,1972,,15500,-31.390236,150.378974
Rangers_Valley,Glen_Innes,NSW,1988,,12000,-29.505441,151.735039
Burdekin_Valley Beeflot,Home_Hill,QLD,1987,y,12000,-19.800000,147.170000
AMH_Beaudesert,Beaudesert,QLD,1970,Y,12000,-27.979768,152.935330
Aronui,Dalby,QLD,1964,,10000,-27.033684,151.332620
Caroona,Mungindi,QLD,na,,10000,-28.772781,149.108223
Jindalee,Cootamundra,NSW,na,,9000,-34.455556,147.777218
Gunee,Delungra,NSW,1982,,8000,-29.609340,150.857751
Killara,Quirindi,NSW,1975,,6500,-31.474409,150.585042
Crown_Beef,Stawell,VIC,1975,y,6000,-37.10000,142.800000
Lillyvale,Condamine,QLD,1972,,5300,-27.006512,149.995796
Sandalwood,Dalby,QLD,1986,,5000,-27.136806,151.434019
Wide_Bay,Kilkivan,QLD,1972,,5000,-26.150000,152.180000
Gurley,Moree,NSW,1969,y,5000,-29.815170,14.905750
Perenc,Yass,NSW,na,,5000,-34.850000,-148.930000
Balgowan,Acland,QLD,1985,Y,5000,-27.269474,151.660242
CRM,Wagga_Wagga,NSW,na,,4500,-35.209152,147.482224
Kurrawong,Quinalow,QLD,1987,,4000,-27.124016,151.558856
```

12.3 Appendix C

These are an explanation of operations used in the Methodology.

Add Field - An editing operation that adds a field to the selected database keeping new values

Buffer - An operation that creates a new layer that contains areas that are within a nominated distance from the map feature. I.e. a 50 km buffer of feedlot events would select all the area within a 50 km radius of individual feedlots.

Calculate Values - An editing operation that can calculate the values entered in a field on a large scale, instead of entering value individually. These values can be simple text, or integers, or even arithmetic functions depending on the field it is being entered into.

Clip or Clipped - An operation that removes part of a map based on selected criteria, while keeping the initial map intact. The removed parts then create their own layer or map e.g. a map of Australia clips to form a map of Queensland.

Join on Spatial Location – An operation that allows two individual dataset to be merging on the spatial criteria of one of those datasets. I.e. feedlot events within one region can be merged with the regional figure allowing additional analysis to be completed on this figure.

Select – An operation selects from a layer certain attributes based on the Structured Query Language (SQL), takes these only and makes a new layer.

Select by Attributes – An operation that searches the database component to select records based on a SQL statement e.g. Select from the records all that fulfil this query “Feedlot_Capacity” >= 10000 returns all feedlots with a capacity higher than or equal to 10000.

Select by Location – An operation that searches the database on the spatial location of criteria. Selection Criteria are not as broad as SQL, but only refer to the spatial capabilities i.e. completely within, contained, intersect, contained by, etc.

Union – A function that joins two databases on their features spatial location.

Generalised flow diagram of the ArcGIS Operations used in the Australian Industry Survey.

Thematic Map “Select by attributes” features and “Clip”

Merge with FSAFLdB

“Select by location” feedlot points and “Add field” and record what area or value is associated with the feedlot through “Calculate Values”

Generate Report

“Select by attributes” all feedlots with a lat/long. Group the report results by the thematic feature that is being studied. E.g. rainfall zones

Export to Excel

12.4 Appendix D

Five consultants at FSA Consulting participated in this survey. There results are within the following tables

Participant 1	Criteria A	Criteria B	Criteria C	Criteria D	Criteria E
Water Access	0.5	0.5	1	0	1
Proximity to Grain	0.5	1	1	0	1
High Annual Rainfall	1	1	1	1	0
Low Annual Rainfall	0	0	0.5	0.5	0.5
Proximity to Abattoirs	0	1	1	0	0.5
Access to Major Road*	1	0.5	0.5	0	0.5
Heat Stress Factors**	1	1	1	0	0.5
Under 1500k to Cattle	0	0.5	0.5	0	0.5
Over 1500k to Cattle	0	1	1	0	0.5

Participant 2	Criteria A	Criteria B	Criteria C	Criteria D	Criteria E
Water Access	1	0.5	0	0	1
Proximity to Grain	0.5	1	0.5	0	0.5
High Annual Rainfall	0.5	1	1	1	0
Low Annual Rainfall	0.5	0	0	0	0
Proximity to Abattoirs	0.5	1	0	0	0.5
Access to Major Road*	0	1	0	0	0.5
Heat Stress Factors**	0.5	0	0	0	0
Under 1500k to Cattle	0	0.5	0	0	0
Over 1500k to Cattle	0	1	0.5	0	0

Participant 3	Criteria A	Criteria B	Criteria C	Criteria D	Criteria E
Water Access	1	1	0	1	1
Proximity to Grain	0	1	0.5	0	0.5
High Annual Rainfall	0	0	0	0.5	0.5
Low Annual Rainfall	0	0	0	0	0.5
Proximity to Abattoirs	0	0.5	0	0	0
Access to Major Road*	0.5	0.5	0	0.5	0.5
Heat Stress Factors**	0.5	1	0.5	0	0
Under 1500k to Cattle	0.5	1	0	0	0.5
Over 1500k to Cattle	0.5	0.5	0	0	0.5

Participant 4	Criteria A	Criteria B	Criteria C	Criteria D	Criteria E
Water Access	0	0.5	1	0.5	1
Proximity to Grain	0	1	0.5	0	0.5
High Annual Rainfall	0	0.5	1	0.5	0.5
Low Annual Rainfall	0	0.5	1	0.5	0.5
Proximity to Abattoirs	0	0.5	0	0	0
Access to Major Road*	0.5	0	0	0	0.5
Heat Stress Factors**	0	0.5	1	0.5	1
Under 1500k to Cattle	0	0	0	0	0
Over 1500k to Cattle	0	0.5	0.5	0	0

Participant 5	Criteria A	Criteria B	Criteria C	Criteria D	Criteria E
Water Access	1	1	1	0.5	1
Proximity to Grain	0	0.5	0.5	0	0.5
High Annual Rainfall	0.5	0.5	0.5	1	0
Low Annual Rainfall	0	0.5	0.5	0	0
Proximity to Abattoirs	0	0.5	0	0	0
Access to Major Road*	0.5	0.5	0	0	0
Heat Stress Factors**	0	0	1	0	0
Under 1500k to Cattle	0	0.5	0.5	0	1
Over 1500k to Cattle	0	1	1	0	1