2. Beetle Benefits

This section outlines the importance of sustainable farming practices and describes the agricultural and environmental benefits provided by dung beetles

"A nation that destroys its soils destroys itself." – Franklin Roosevelt

"...the soil is the essence of the earth's critical zone. It contributes to the origin and development of life on this planet, the rise and decline of human civilizations, and the sustainability or deterioration of global ecosystems. Water flux into and through the soil in the landscape resembles the way blood circulates in a human body. Soil and water combined thus create the foundation that sustains the earth's ecosystems and human society." Henry Lin 2005

Towards sustainable farming systems

Ever since humans began to sow crops and tend livestock, land has been used more and more intensively for agricultural production. This increasing intensity has in many parts of the world adversely affected the quality of the soil resource.

The major forms of degradation include:

- wind and water erosion
- reduced fertility because of nutrient loss
- physical breakdown of soil structure
- soil acidification
- salinisation

Agriculture is Australia's most extensive form of land use, occupying 60 per cent of the total land area (461 million hectares). Livestock grazing constitutes the largest use of agricultural land in Australia (ABS, Australia's Environment: Issues and Trends, 2007).

Estimated Livestock numbers in Australia as at 30th June 2006

- Dairy: 2.8 million head (Victoria dominates with 1.7 million)
- Beef: 25.7 million head (Queensland; 11.5 million, NSW; 5.8 million)
- Sheep: 91.9 million head (NSW; 31.3 million, WA; 23.0 million, Victoria;18.2 million)

Source: ABS, Principal Agricultural Commodities, Australia, Preliminary 2005-06.

The estimated cost of land degradation in Australia

In 1993 the annual cost of lost agricultural production due to land degradation was put at over $1.4 billion per annum, approximately 6 per cent of the gross value of Australian agricultural production.

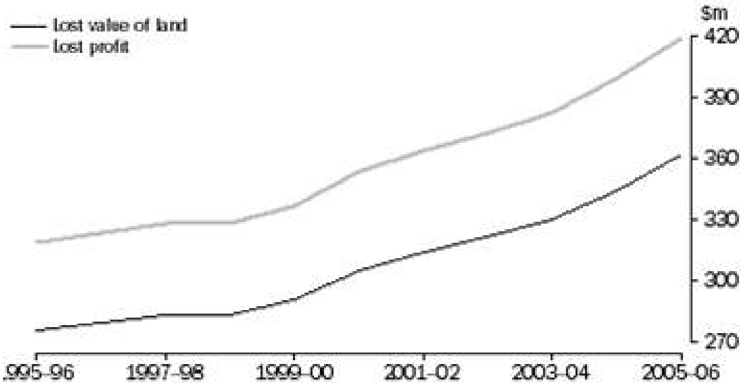
Cause	Value, in $ million
Waterlogging	180
Erosion	80
Soil structure decline	200
Soil acidity	300
Deterioration of water resources	450
Salinity	200
Total	1,410

Lost production resulting from land degradation is calculated to be over one billion dollars annually

Source: LMTF (1995): Managing for the Future: Report of the Land Management Task Force.

The Australian Bureau of Statistics has combined data from several studies to produce estimates on the cost of land degradation using two criteria:

1. the lost value of land
2. the lost profits from agricultural production each year (using the concept of "yield gap")



The graph on the left provides a summary of the rising cost of land degradation between 1995 and 2006. The lower line represents the lost value of land and the upper line represents the estimated lost agricultural profit (yield gap).

Source: ABS Australian Year Book, 2008

The challenge to agriculture is to employ systems that are both sustainable and profitable.

The benefits of healthy soils

Healthy soils are the engine room of sustainable, productive farms in Australia. They serve as an economic and natural asset and will:

- assist with environmental health
- improve the quality of Australia's water resources
- offer life support for soil-borne organisms
- incorporate and assimilate waste
- store carbon

Land management and soil carbon (excerpt from Christine Jones, 2006)

With appropriate changes to land management, agricultural soils have the capacity to sequester and store large volumes of carbon, thus improving microbial content, biological activity, fertility, structure, stability, resistance to erosion and ultimately biodiversity, productivity and profitability. Increasing soil carbon can significantly reduce the impact of dryland salinity, reduce sedimentation rates in rivers and streams, improve water quality, improve air quality and decrease the impact of the greenhouse effect, global warming and climate change

Any farming practice that improves soil structure is building soil carbon. When soils become light, soft and springy, easier to dig or till and less prone to erosion, waterlogging or dryland salinity – then organic carbon levels are increasing. If soils are becoming more compact, eroded or saline – organic carbon levels are falling.

Water, energy, life, nutrients and profit will increase on-farm as soil organic carbon levels rise. The alternative is evaporation of water, energy, life, nutrients and profit if carbon is mismanaged and goes into the air. It's all about turning carbon loss into carbon gain.

The true bottom line for any agricultural practice, is whether soil is being formed or lost. If it is being lost, farming will eventually become both ecologically and economically impossible.

The building of new topsoil depends on us, and our future depends on building new topsoil.

This is the greatest challenge facing modern agriculture.

Source: Christine Jones, Carbon and Catchments 'Managing the Carbon Cycle' NATIONAL Forum 22-23 November 2006

The many and varied benefits provided by dung beetles.

THE TOP TEN BENEFITS OF DUNG BEETLES

Dung beetles will:

1. improve soil fertility
2. improve soil structure
3. improve soil biology
4. increase available grazing area
5. increase pasture productivity
6. improve water quality
7. improve water infiltration
8. reduce pest species
9. reduce disease associated with pest species
10. sequester carbon

These benefits will reduce the costs of agricultural inputs, boost productivity and increase profitability. Once established, the system is self-sustaining and will operate without running or maintenance costs.

1. IMPROVING SOIL FERTILITY

Making the most of an abundant resource

It is estimated that one cow excretes 18 kilograms of dung each day. For a herd of 100 cattle this represents 1800 kgs per day, 12,600 kgs per week and a massive 655,200 kgs per year.

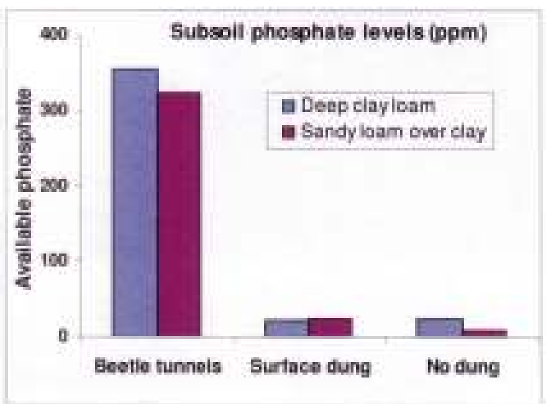
Cattle dung contains important essential plant nutrients such as nitrogen and phosphorus. These nutrients are commonly in short supply in Australian soils.

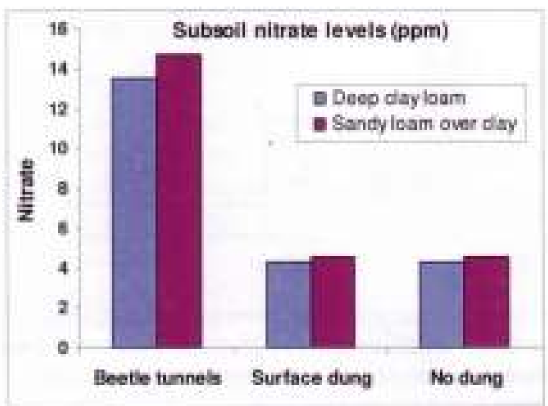
The level of nutrients found in the dung will vary, and is related to the animal's diet. One analysis found that for every 100 kgs of dry cattle dung there was 0.82 kgs of phosphorus and 2.7 kgs of nitrogen (William & Haynes, 1995).

When dung remains on the soil surface, a considerable percentage of these beneficial nutrients are lost to the atmosphere or are washed into waterways. The dung then becomes a pollutant of both air and water.

Research conducted by Dung Beetle Solutions Australia has shown that deep tunnelling beetles increase levels of plant nutrients in the subsoil. The graphs below show the effects on subsoil 16 months after dung was buried by *Bubas bison*. Similar results were obtained for subsoil levels of ammonia, sulphur and organic carbon. The effects have persisted for at least 2.5 years. Dung burial also increases levels of soil carbon.

Deep tunnelling dung beetles increase plant nutrients in the subsoil





Source: Doube, B. 2008, Introducing and managing deep-tunnelling beetles in southern Australia, DBSA

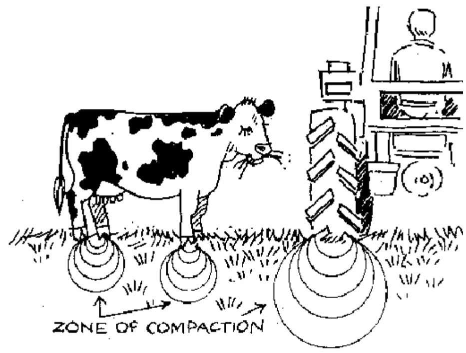
2. BUILDING HEALTHY SOIL STRUCTURES

Soil structure describes the arrangement of the solid parts of the soil and the pore space located between them. The structure has a major influence on water and air movement and impacts on both biological activity and root growth.

Soil compaction

Soil compaction occurs when soil particles are packed close together, reducing the pore space between particles and results in increased soil bulk density. It is caused by pressure exerted by agricultural machinery or grazing animals and is more likely to occur when soils are wet.

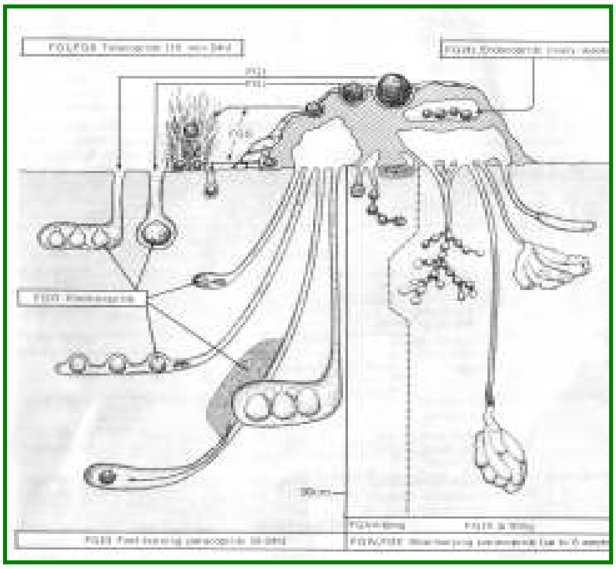
Compaction impedes root growth, which in turn reduces plant water and nutrient uptake resulting in lower yields. Compaction also decreases soil pore space which affects the water holding capacity of the soil and the activity of soil microorganisms. This further results in decreased water infiltration rates and increases the likelihood of run-off, erosion and surface ponding (DPI, Victoria).



Causes of soil compaction Image: DPI NSW

How dung beetles improve soil structure

The tunnelling dung beetle species construct tunnels under the dung pad which can vary in depth from less than 10 cm to up to 1 metre, depending on the species and soil type. The tunnels are often lined with dung and the beetles construct “brood balls” from dung in which they lay their eggs. Soil casts around dung pads are an indication of dung beetle activity.



The tunnel systems improve the physical structure of the soil by:

- increasing aeration
- reducing compaction
- bringing subsoils to the soil surface (bio-turbation)
- incorporating organic matter into the soil profile.

Right: A schematic representation of the modes of dung burial by a range of dung beetle species

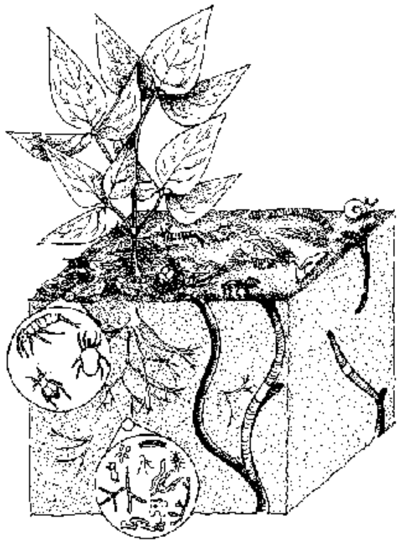
Source: *Doube, B., 1990, A functional classification for analysis of the structure of dung beetle assemblages, Ecological Entomology, 15, 371-383.*

Improvements to the physical structure have a “flow-on” effect which can include:

- increased water infiltration and reduced soil erosion
- increased biological activity (micro-organisms and earthworms)
- stronger root growth leading to higher yields
- improved water holding capacity
- improved soil fertility through soil mixing of clay subsoils (bio-turbation)
- reduced surface ponding

A soil cast (excavated soil) next to a dung pad

3. ENHANCING SOIL BIOLOGY



The soil is teeming with organisms

Soil biology relates to the living components in the soil. Soil organisms (or soil biota) are made up of two main groups:

1. soil invertebrate animals and
2. soil micro-organisms (or microbes: bacteria and fungi)

They all play an essential role in decomposing organic matter, cycling nutrients and fertilising the soil. Soil-dwelling organisms release bound-up minerals by converting them into plant-available forms.

Almost all soil organisms need the same things we need to live – food, water and oxygen. They require a moist habitat, with access to oxygen in the air spaces in soil. There are other factors that determine whether species can survive and grow, including pH, temperature and salt content (DPI NSW).

By burying dung, dung beetles

- increase the amount of organic matter in the soil
- provide a food source for soil organisms such as earthworms
- stimulate microbial activity and nutrient cycling

Trials have shown that dung beetle activity is associated with increased numbers of earthworms, and the depth at which they are found (Doube, 2008).

4. INCREASING AVAILABLE GRAZING AREA

Pasture fouling by dung and the surrounding rank growth significantly reduces the area available for grazing. Research in north Queensland found dung pads persisted for at least three months and sometimes for a year or more depending on dung properties and seasonal conditions (Ferrar, 1975).

The average area of pasture smothered by a single pad is estimated at 1000 cm² and the surrounding growth is not grazed by cattle for at least one year (Bornemissza, 1960).

Dung littering pastures reduces available grazing area

Five cows can decrease the effective area of pasture by one acre over one year.

The loss associated with cattle pasture fouling and resulting rank growth is substantial. It is estimated that five cows will decrease the effective area of pasture by one acre over one year (Bornemissza, 1960). For a herd of 100 cattle this equates to a loss of 20 acres per year.

An American economic analysis estimated that pasture fouling causes an annual loss of 7.63 kg of beef per head of cattle and places the cost of reduced pasture fouling at $122 million per annum (Losey & Vaughan, 2006).

The cost of pasture fouling is significant. Dung beetles can make a substantial contribution to ensuring that these losses are kept to a minimum. The need to harrow is also eliminated, further reducing fuel and labour costs.

5. INCREASING PASTURE PRODUCTIVITY

There have been numerous studies that demonstrate that dung beetle activity increases plant yield (Bornemissza & Williams, 1969). In an extensive review of published research, Nichols *et al.* (2008) found that "dung + beetles" resulted in significant increases in plant height, above ground biomass, grain production, protein levels and nitrogen content. The review indicated that most experimental studies have been conducted using single plant species in laboratory settings, and highlighted the need for field studies.

Australian Field Research: Initial findings

With the support of bodies such as Meat and Livestock Australia, Dairy SA, WA Water Corporation and the National Landcare Program, Australian research has been undertaken to measure the effect of dung beetles on pasture productivity. Initial research has found increases of up to 25%, with the most pronounced effects associated with unimproved pastures. These positive effects have persisted into the following season. An unexpected result has been the suppression of a weed species (Doube, 2006).

Capeweed can compete with desirable clover and grass species and dominate pastures. Field trials in SA found significant decreases in the amount of capeweed in the "dung + beetles" plots compared to "dung only" and "control" plots. Further research is required to investigate this beneficial effect. It is also believed that dung beetles will increase the drought resilience capacity of pastures by fostering deeper pasture root growth.

Pasture production field trials in the Margaret River region of WA ***Photo: Dung Beetle Solutions Australia***

Resource CD: Pasture production field trials in Australia

Goulburn Broken Dung Beetle - Soil Health Project (see also section 5.22)

Lobert, B. 2008, Effect of dung burial on soil health and pasture productivity, April 2008 Project Update (interim findings)

Dairy South Australia (see also section 5.34)

Doube, B. 2006, Evaluation of pasture growth due to the late summer/autumn-active dung beetle *Geotrupes spiniger* at Flaxley SA.

Western Australia Water Corporation (see also section 5.44)

Doube, B. 2007, Pasture growth benefits of the dung beetle *Bubas bison* in the Margaret River region of Western Australia*: Interim report for June 2007.*

Meat and Livestock Australia (see also section 5.32)

Doube, B. 2008, The Pasture growth and environmental benefits of dung beetles to the southern Australian cattle industry.

6. IMPROVING WATER QUALITY

The quality of surface water influences not only the health of aquatic ecosystems, but also whether the water can safely be used for drinking, agriculture, or recreation. There are a number of indicators used to measure water quality. These include (but are not limited to):

Algae and Blue-green algae (cyanobacteria)

Algal counts can increase dramatically in warm nutrient-rich waters. High counts can result in the production of chemicals that can be toxic to both humans and livestock. These conditions can occur when stream flows are low and when there are high levels of sediments and nutrients entering the waterways.

Faecal coliforms

Faecal coliforms are bacteria mainly associated with the colon of animals (including humans) and are excreted in faeces. Coliforms can have serious implications for human health. Their presence in water is used as an indicator of faecal contamination.

Nitrogen & Phosphorus

Sources of nitrogen include sewage, animal wastes, fertilisers and organic matter. Nitrogen contributes to algal bloom outbreaks. Phosphorus in streams can also cause excessive growth of algae and weeds. Sources of phosphorus include eroded soil material, animal faeces, treated and untreated sewage waste water and fertilisers.

Cattle dung, water quality and dung beetles

Water quality research has found that dung burial results in substantially cleaner run-off from pastures (Doube, 2008). Numerous beetle release projects have been established in Australia to specifically address water quality issues (Section 5, Projects 1965-2008).

Dung beetles may play a role in reducing the presence of harmful human pathogens such as *Giardia* and *Cryptosporidium*. These pathogens are found in the faeces of warm-blooded animals and can infect drinking water causing diarrhoea, abdominal cramps and nausea. These pathogens are problematic as they're resistant to conventional water treatment, remain infective for long periods, are difficult to detect and cross-infect different animal species.

Experimental plots at Flaxley South Australia ***Photo: Dung Beetle Solutions Australia***

Resource CD: Dung beetles and Water Quality

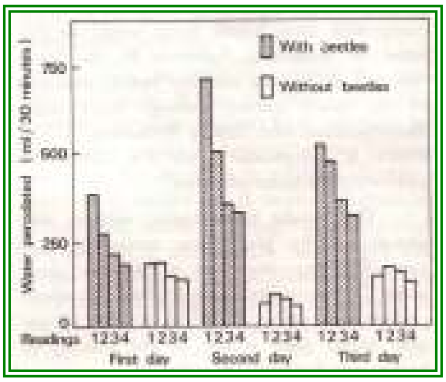
Dairy South Australia (see also section 5.34)

Doube, B. 2006, Evaluation of pasture growth due to the late summer/autumn-active dung beetle *Geotrupes spiniger* at Flaxley SA.

Watershed Protection Office of the Environment Protection Agency (see also section 5.35)
Doube B. 2004, Dung Beetle–Cryptosporidium research: Review and a pilot study on the recovery of C.parvum oocysts from dung buried by the dung beetle *Bubas bison.*

7. IMPROVING WATER INFILTRATION

Infiltration relates to the movement of water into the soil layer. If rainfall intensity is greater than the infiltration rate, water will accumulate on the surface and runoff will occur. Soil texture, soil structure, and slope have the largest impact on infiltration rates. Water moves by gravity into the open pore spaces in the soil, and the size of the soil particles and their spacing determines how much water can flow in.



The extensive tunnel systems created by dung beetles would be expected to increase the rates of water infiltration, assist agricultural inputs such as lime and fertilisers to enter the soil profile and reduce the level of contaminants entering the waterways. Bornemissza (1976) placed beetles and dung on the surface of the soil packed into 30cm long drainage pipes. The values on the graph are means of ten pipes "with beetles" and five pipes "without beetles" and demonstrates how water penetration is increased in the "with beetles" pipes over the first three days.

Graph demonstrating increased water percolation as the result of dung beetle activity
Source: Bornemissza, G.F., 1976, The Australian Dung Beetle Project 1965-75, AMRC Review, No. 30

Australian Field Research

Barwon Region Water is Victoria's largest regional urban water corporation. In 2004 they supported research into the impact of dung beetle activity on soil properties. Plots were established comprising three treatments "dung only" "dung+beetles" and a control "no dung – no beetles". After four months of activity, the median time for 600 ml of water to soak into plots with beetles was 1-2 minutes and 8-16 minutes in plots without beetles (Doube, 2005).

Resource CD: (see also section 5.4 and 5.30)

Bornemissza, G.F., 1976, The Australian Dung Beetle Project 1965-75, AMRC Review, No. 30

Doube, B. 2005, Dung burial by the winter-active beetle *Bubas bison* and its impact on soil properties in the Barham River Catchment, Victoria. Final report for phase 1.

8. REDUCING PEST SPECIES

Bush fly and Buffalo fly control

The buffalo fly is a serious pest of cattle in northern parts of Australia. Each fly feeds up to 20 times a day by puncturing the skin and taking blood causing considerable discomfort and distress to cattle. Trials in the wet tropics have shown that buffalo fly can reduce beef cattle production by up to 16% (DPI & F, 2005).

A major objective of the original CSIRO dung beetle project was to control buffalo fly populations in northern Australia. This was in response to increasing concerns about chemical residues in meat and the rising levels of resistance to chemical control methods.

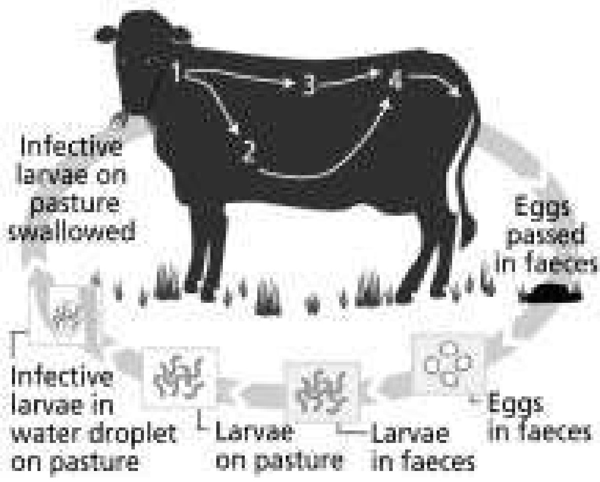
In temperate parts of Australia the bush fly is a pest of both livestock and humans. Both bush flies and buffalo flies breed in dung. By rapidly burying dung, dung beetles disrupt the breeding medium of flies resulting in substantially reduced survival rates. Speed of dung burial is a critical factor in fly control and it was found that if half a cow pad was buried within the first 24 hours, few or no adult flies emerged (Bornemissza, 1970). The CSIRO Division of Entomology in Western Australia demonstrated an 88% reduction in bush fly activity caused by the activity of introduced dung beetle species (Ridsdill-Smith & Matthiessen, 1988).

Funding to the CSIRO dung beetle project was terminated before all of the desired dung beetle species were introduced. As a result, many parts of temperate Australia do not have a species that will rapidly bury dung during the spring months. This coincides with the peak breeding season of the bush fly.

Internal parasites

Sackett and Holmes (2006) found that gastrointestinal parasites have a high economic impact on beef productivity in southern temperate Australia, and estimates productivity losses at $25 million per annum.

The small brown stomach worm (*Ostertagia ostertagi*) can dramatically reduce growth rates in weaners and yearlings. Cattle grazing contaminated pastures during autumn and winter can ingest large numbers of larvae and heavy worm burdens can occur in late winter and early spring after weaning.



Adult *Ostertagia* reside in the abomasum (fourth stomach). After mating, adult females lay eggs that are passed in the faeces. These eggs are tiny and can only be seen under a microscope. The eggs hatch within the dung pad to produce early-stage larvae if the temperature is between 10°C and 35°C and there is sufficient moisture. These young larvae feed on bacteria in the dung and grow to become infective-stage larvae within a fortnight. During rainfall, infective larvae migrate from the dung onto adjacent pasture where they are ingested by cattle (MLA Cattle Parasite Atlas)

Resource CD: Meat and Livestock Australia
"The Cattle Parasite Atlas"

Further information on cattle parasites, life cycles and regional distribution is available in the Meat and Livestock Association publication "The Cattle Parasite Atlas" which is included (with permission) on the resource CD.

Dung Beetles and internal parasites

Dung beetles can significantly reduce the survival rate of larvae in cattle dung. In one study, control pads with no dung beetles contained 50 times more worm larvae than those with dung beetles (Bryan, 1976). An American field trial found that calves grazed on pastures without dung beetles acquired four times more parasites (*Ostertagia* and *Cooperia*) than those in pastures with dung beetles (Fincher, 1975).

The breaking of the parasitic life cycles and reduced worm loads in cattle will assist increased productivity and reduce reliance on costly drenches. Drench resistance is an emerging issue, and there is increasing recognition of the importance of integrated pest management strategies. Information on how to manage parasites in horses is outlined in the research paper "Integrated pest management for the horse farm" located on the resource CD.

Resource CD: Resources relating to pest species

Drench resistance is an emerging issue

Rural Industries Research and Development Corporation

Edward, C and Hoffman, A. 2007, Integrated pest management for the horse farm

Jim Heath – Viacorp (see also section 5.43)

Heath, J. 1989, The fly in your eye

Northern Tablelands Dung Beetle Express (see also section 5.15)

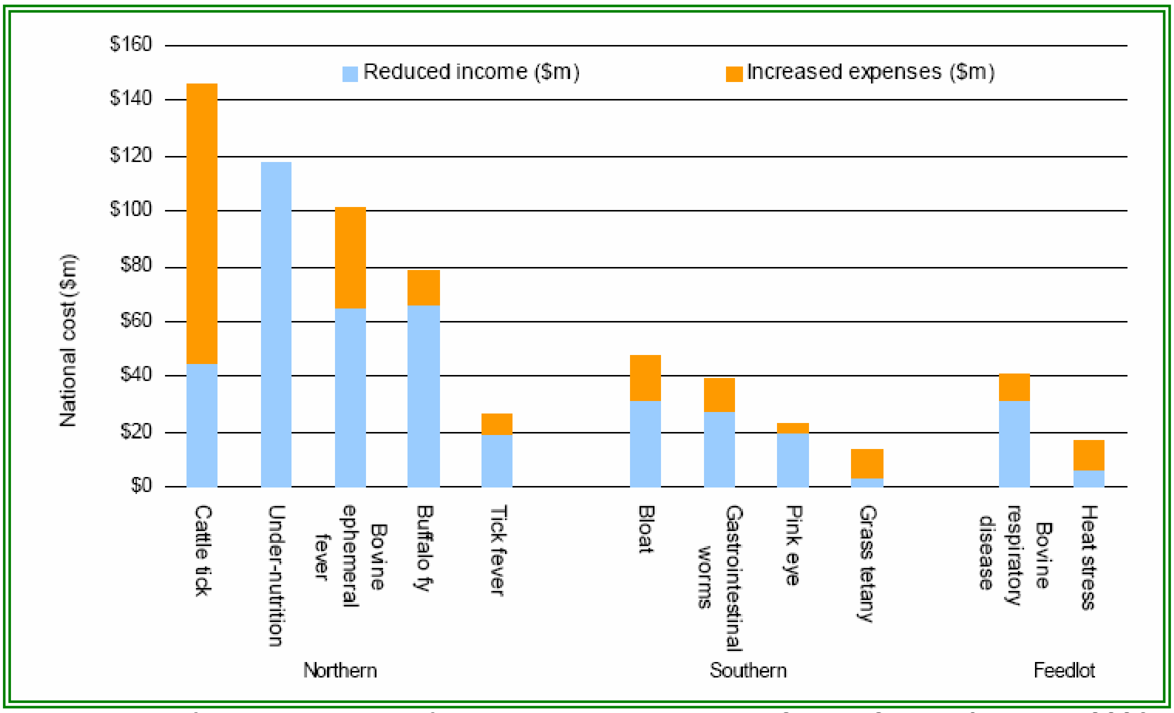
Dung Beetles and Buffalo Fly fact sheet

9. REDUCING DISEASE

In addition to reducing internal parasite loads in cattle and faecal coliforms in drinking water, dung beetles can assist in reducing fly-borne diseases such as pink eye.

Pink Eye (infectious bovine kerato-conjunctivitis or IBK) in cattle

Pink eye is a painful and debilitating condition that can severely affect animal productivity. It is a bacterial infection of the eye that causes inflammation, and in severe cases, temporary or permanent blindness. Pink eye persists in the eyes of carrier cattle (carriers do not show any signs of the disease). Eye irritation from dust, bright sunlight and long grass can cause tear production which then attract flies. The flies feed on infected secretions and move from animal to animal spreading the bacteria (DPI NSW Prime Fact, 2007). The National cost of pink eye due to reduced income is estimated at $20 million per annum (Sackett & Holmes, 2006).



National costs of diseases to the Beef Industry ***(Source: Sackett & Holmes, 2006)***

Trachoma in humans

Trachoma is a contagious infection of the eye caused by strains of the bacteria, *Chlamydia trachomatis.* Repeated infections can cause eyelid scarring, in-turned eyelashes and blindness. It is prevalent amongst children in Aboriginal communities. Depending on the area, infection rates range from two to over 50 per cent. The Western Australia Health Foundation (Healthway) supported research to investigate the role of bush flies in the transmission of trachoma.

The study demonstrated that bush flies carry the trachoma bacteria. Bush fly samples were collected from areas with a high incidence of trachoma and tested for the presence of the bacteria. 0.5 % of flies collected tested positive for the bacteria (Dadour & Cook, 1998). The study recommended that dung beetles be introduced to remove the dung in which flies breed. The project stated that decreased bush fly populations could assist in reducing gastrointestinal diseases.

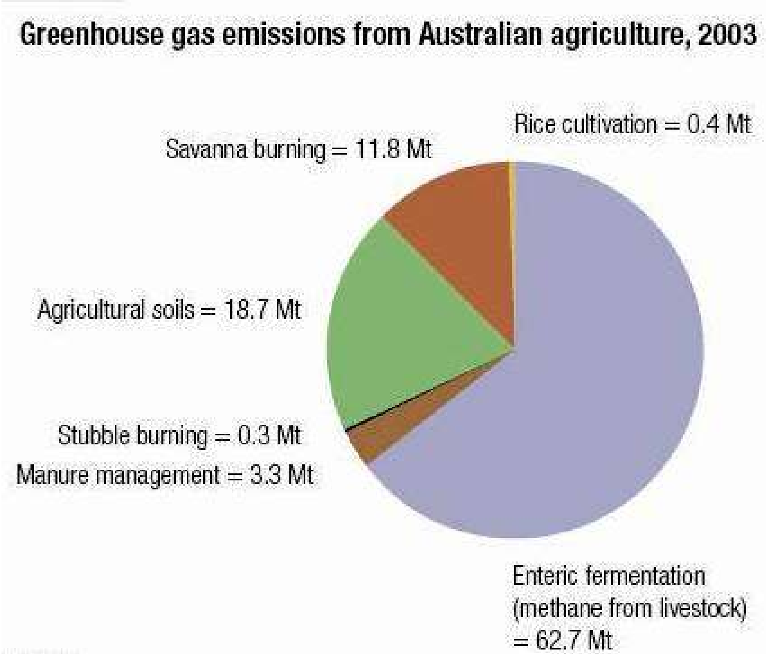
Published research: da Cruz, L., Dadour, I.R., McAllister, I.L., Jackson, A. and Isaacs, T. 2002, Seasonal variation in trachoma and bush flies in north-western Australian Aboriginal Communities, *Clinical and Experimental Opthamology*, 30:2, pp 80-83.

Resource CD: Bush flies as vectors of trachoma (see also section 5.43)

Dadour, I.R. and Cook, D.F. 1998, Final Report: Biological control of bush flies: vectors of trachoma and enteric disease. Healthway: WA Health Foundation

10. SEQUESTERING CARBON

Agriculture, and livestock production have been identified as leading sources of greenhouse gas emissions. In 2006, greenhouse gas emissions from livestock (methane from livestock and manure management) were calculated at 69.7% of the agriculture sector's emissions and 10.9% of net national emissions (Dept. of Climate Change, 2008).



Source: Agriculture Industry Partnership: Australian Greenhouse Office, 2006

Agriculture produced an estimated 15.6% of net national emissions in 2006.

What is carbon sequestration?

Carbon sequestration refers to the capture and storage of a carbon in a manner that prevents it from being released into the atmosphere. Biological sequestration (bio-sequestration) includes direct removal of carbon dioxide from the atmosphere through land-use change, reforestation, carbon storage in landfills and practices that enhance soil carbon in agriculture.

How can dung beetles contribute to bio-sequestration?

- removal of decomposing organic matter (dung) from the soil surface
- increase in soil carbon content through the burial of organic matter (dung)
- increased plant root production through improvements to soil physical, biological and chemical properties

The Garnaut Climate Change Review (Commonwealth of Australia, 2008) states that "significant opportunities may be in the area of improved carbon sequestration through better management of soil carbon" (p. 355). In an interview with Rural Press, Professor Ross Garnaut stated: "It's very important that the arrangements put in place give true credit for carbon that is in the soil". He also acknowledged that the amount of carbon which that could be stored in the soil "could be very big" (Skuthorp, 2008).

One estimate suggests that it would only require a 0.5% increase in soil carbon on 2% of Australian agricultural land to sequester all of Australia's greenhouse gas emissions (Jones quoted in Stock in Land 3/7/08, *Quiet carbon revolution on Australian Farms*)

Given the enormous quantities of dung produced by cattle on a daily basis, the potential to sequester carbon is large. The challenge is to quantify the contribution of dung beetles and to incorporate these benefits into the National greenhouse gas emissions accounting inventory. This will become increasingly important as carbon trading schemes are devised and implemented.

Reducing the net greenhouse impact of the cattle industry by introducing deep-tunnelling dung beetles to sequester carbon in soil organic matter in southern Australia:

Excerpts from an article written by Bernard Doube

The 2008 Federal Government Carbon Green Paper indicates that beef and dairy cattle produce 11.2% and 2.4% respectively of Australia's greenhouse gas emissions. Dung beetles provide the opportunity to offset this by a substantial amount by burying the dung produced by cattle, thereby promoting soil fertility and pasture root growth, with a corresponding and permanent increase in levels of carbon stored in soil organic matter (SOM).

Soils store substantial amounts of carbon, with the total global soil carbon store being three-fold greater than that present in the atmosphere and four-fold greater than that present in terrestrial vegetation. Clearing lands for agriculture has led to a 50+% reduction in the amount of carbon stored in soil organic matter and is in part due to the loss of the roots of deep-rooted trees and shrubs from the subsoil. Currently impenetrable subsoil has provided a major constraint to pasture production by denying pasture roots access to the moisture and nutrients in the subsoil. Deep-tunnelling dung beetles provide a unique opportunity to break this nexus.

MLA-funded studies with *Bubas bison* (Doube, 2008) have shown that dung burial caused a matrix of permanent tunnels in the subsoil (20–45 cm) that increased capacity to store carbon in soil organic matter (SOM) (Table 1) by 0.5% at each of two test sites (from 1.0% to 1.5% at site 2 and from 2.0% to 2.5% at site 1) in response to dung burial. The elevated carbon levels have persisted for over two years so far, suggesting a permanent increase in the subsoil organic carbon pool. An absolute increase of 0.5% in the soil carbon content in the subsoil is equivalent to an increase of about 19 tonnes of carbon per hectare. Summed over the grazing lands of southern Australia, this represents a permanent increase of many millions of tonnes of carbon in the dynamic SOM pool.

Table 1 *A comparison of the effect of dung burial activity by* Bubas bison *on the organic carbon (%) concentration in the subsoil (20–45 cm) in cores sampled between August 2006 and September 2007. Beetles and dung were added to the cores in mid-September 2005.*

	August 2006		November 2006		May 2007		September 2007	
Treatment	**Site 1**	**Site 2**	**Site 1**	**Site 2**	**Site 1**	**Site 2**	**Site 1**	**Site 2**
Controls subsoil	2.01	0.68	2.02	0.85	2.14	0.70	2.11	0.61
Dung-only subsoil			2.23	0.88	1.94	0.74	1.97	0.67
Total dung+beetles subsoil	2.56	1.10	2.66	1.54	2.54	1.21	2.55	0.97
Dung+beetles: tunnels+environs		4.12	7.20	4.25	4.80	2.70	3.35	1.38
Dung+beetles: remainder		0.79	2.27	1.20	2.49	1.15	2.32	0.89

Medium term studies on the impact of deep tunnelling dung beetles on the soil carbon pool on the Fleurieu Peninsula SA are being undertaken by Dung Beetle Solutions Australia using income derived from dung beetle sales.

DVD: ABC Stateline (South Australia) report on dung beetles and carbon sequestration

Resource CD: Meat and Livestock Australia (see also section 5.32)

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