BEEF CATTLE FEEDLOTS:
WASTE MANAGEMENT AND UTILISATION

5. Utilisation of manure, compost and effluent

CONTENTS

Nutrients added to utilisation areas are most efficiently removed from soils by growing high-yielding crops.

Grazing removes nutrients at a slow rate and is not a preferred land use for utilisation areas.

Select areas with good quality agricultural land.

Introduction

Feedlot manure, compost and effluent can be valuable sources of nutrients and organic matter for improving soil fertility, structure, water-holding capacity and crop or pasture production. Careful management is needed to gain the most benefit from their utilisation while protecting the environment and preventing impacts to neighbours.

While manure and compost may be spread off-site, effluent is less readily transportable and its utilisation generally occurs on-site.

Environmental protection for utilisation areas

Application of effluent and manure to land may pose a risk to the environment through

- excessive nutrients or nutrient imbalances in soils
- loss of nutrients to surface waters through runoff
- nutrient leaching through soils into groundwater.

The risk of nutrient loss from utilisation areas can be prevented or mitigated by selecting areas that provide suitable land and buffers to sensitive sites, by using appropriate spreading or irrigation practices, and by regularly monitoring soil nutrient levels and responding appropriately.

Amenity can be protected from odour and dust by careful application practices and timing of utilisation, and by maintaining adequate separation distances to nearby sensitive land uses.

Selecting a utilisation area

When selecting a new utilisation area or assessing the viability of an existing utilisation area, the following should be considered

- Nutrients are most efficiently removed by growing a high-yielding crop that is harvested and transported from the site. Thus the area should either be able to produce dryland crops reliably or should be irrigated.
- Select areas with good agricultural soils (e.g. adequate nutrients, plant available water capacity) with no serious limitations to plant growth (e.g. no subsoil constraints, not prone to salinity, waterlogging or flooding). The land should have a suitable topography for cropping (not steeply sloping).
- The utilisation area needs to be large enough to spread the nutrients in the wastes at sustainable levels. While it may be possible to use land with some significant limitations, this will require increased land area and/or management.
- Grazing removes nutrients at a slow rate and is not a preferred land use for utilisation areas. In addition, the recommended withholding period between effluent irrigation or manure spreading and grazing by stock is 21 days.
- Provide buffers between utilisation areas and watercourses, and unprotected aquifers (e.g. shallow water table covered by permeable soil).
- Provide adequate separation distances to nearby sensitive uses. Distance between utilisation areas and sensitive land uses such as residences and public amenity areas allows odour to disperse and reduces the likelihood of odour nuisance.

Management practices that protect the environment

Good management of manure spreading or irrigation is necessary to protect the environment. The following principles should be adopted

- Apply the wastes at rates that are sustainable considering the nutrients, salts and organic matter of the waste stream, soil nutrient status, land use and expected yields and climatic conditions of the site. Supplementary irrigation helps ensure the crops grow and fully utilise the applied effluent.
- Do not spread or irrigate wastes if the soil is very wet or if heavy rainfall is imminent. This may promote increased drainage or runoff which can pose a pollution risk to groundwater and surface water.
- Control the effluent irrigation rate to prevent runoff.
- Spread manure and effluent evenly.
- Incorporate spread manure into the soil to a shallow depth.
- Monitor soil conditions on an ongoing basis.
- Record nutrient application rates and nutrient removal rates. This helps in understanding the ongoing suitability of utilisation areas and the likelihood of nutrient losses.
- Protect amenity by careful application and timing of utilisation.

Uneven or uncontrolled effluent irrigation may pose a threat to the environment.

Nutrient budgeting

In determining a sustainable utilisation rate for any waste, take into account

- the concentration of nitrogen, phosphorus and potassium in the waste
- the removal rate of the crop that will be grown on the area (yield multiplied by nutrient concentration)
- the properties of the soils of the utilisation area including their capacity to store the nutrients
- allowable losses from the system.

The composition and yield of in-field crops will determine nutrient removal.

The mass balance equation is a useful principle to adopt when determining appropriate application rates for wastes. The mass balance equation is:

Applied nutrient ≤ (Nutrient in harvested produce + Nutrient safely stored in soil + Acceptable nutrient losses to external environment)

Table 5.1 shows typical nutrient analyses for types of manure from Australian feedlots. More detailed analyses are shown in Section 2.

Table 5.1 Typical nutrient composition of types of manure

Parameter	Pen	Aged	Compost
Dry matter (%)	74	63	74
Total nitrogen (% db)	2.5	2.2	2.1
Total phosphorus (% db)	1.0	0.8	1.3
Potassium (% db)	1.9	1.9	2.5
Sodium (% db)	0.3	0.3	0.4
Sulfur (% db)	0.4	0.5	0.5
Zinc (mg/kg db)	280	220	254

Sample and analyse manure to accurately calculate application rates.

Spreading 3–4 years' worth of nutrients at a time helps to ensure plant nutrient requirements are available when needed.

As samples can vary widely, the nutrient and dry matter content of the wastes should be tested just before the main spreading time. Similarly, crop yields and nutrient removal rates vary considerably. Historical yields for the farm or other farms in the district will provide a guide to the likely yield.

For practical and agronomic reasons it is often beneficial to apply several years of manure or compost nutrients at each spreading. Spreading at higher rates less frequently can help to spread wastes more evenly, overcome some nutrient availability challenges, minimise the need for regular soil disturbance that may damage soil structure, reduce the risk of causing nuisance for neighbours and minimise dissolved nutrient losses.

This strategy relies on storing some nutrients in the soil. The amount of nutrient that can be safely stored depends on the form of the nutrient and the physical and nutrient properties of the soil. For example, some soils can store large amounts of phosphorus that can be removed over several years. Where a particular nutrient is deficient, it is reasonable to build soil levels through applying waste; conversely, if soils have elevated nutrient levels, rates of waste application should be lower.

Since manure nutrients are not all available in the year of spreading, applying nutrients to last several years helps to meet plant needs. For example, one third of manure nitrogen may be available in year one, with 20–30% being available in year two (Wylie 2005). Applying three to four years' worth of manure initially will help to ensure there are enough nutrients for the plants.

Soils with high clay content usually have a high phosphorus sorption capacity.

Regardless of whether manure is applied annually or as one large application every few years, inorganic nitrogen and in many cases potassium will generally also need to be applied at some stage.

The following formula can be used to calculate the nutrient limited application rate (NLAR) of manure (t/ha) and effluent (kL/ha) and the sustainable annual application rate for manure or effluent.

$$\text{NLAR} = \frac{\text{CR} + \text{SS} + \text{EL}}{\text{NW} \times 10^{-3}}$$

Where

NLAR = nutrient limited application rate of feedlot manure (t/ha) or effluent kL/ha
CR = crop requirement for the applied nutrient (kg/ha)
SS = soil storage (kg/ha)
EL = allowable nutrient losses to the environment (kg/ha)
NW = available nutrient concentration in the feedlot manure (mg/kg) or effluent (mg/L)

Except for phosphorus, soil storage of nutrients is generally small and can be disregarded. The amount of phosphorus (kg/ha) that can be stored by the soil can be determined using phosphorus sorption analysis. ANZECC & ARMCANZ (2000) provides a method for estimating the environmentally-safe phosphorus storage capacity of the soil using the result of this analysis and the following formula

$$P = \frac{d \times P_b \times x/m}{100}$$

Where

P = phosphorus storage capacity (kg/ha)
d = profile depth (m)
P_b = soil bulk density (kg/m^3)
x/m = phosphorus sorbed per mass of soil (mg/kg) at 0.05 mg/L

The annual value for the soil storage (SS) variable in the NLAR equation can be determined based on the expected effective operational life of a feedlot in number (n) of years where

$$SS = \frac{P}{n}$$

Apart from nitrogen losses through ammonia volatilisation, allowable nutrient losses (EL) to the environment are also small and can be disregarded.

The NLAR equation assumes that manure or effluent is applied regularly. Under this scenario, the mineralisation rate does not need to be considered and it can be assumed that all of the applied nutrient is available every year. (For example, 60% of the nutrient applied this year would be available, along with say 30% of that applied the previous year and 10% of that applied the year before. Hence, the nutrient potentially available this year is 60% + 30% + 10% = 100%). Where manure is spread every few years, the mineralisation rate needs to be taken into account. In the case of effluent, almost all of the nutrients are in a readily available form so the mineralisation rate is not an issue.

Since plant nutrients in feedlot manure and effluent are not present in ratios that meet all of the needs of a growing crop, additional inorganic fertilisers are often applied to meet crop nutrient requirements. If mixed fertilisers are used it is important to consider the amounts of nutrients being applied in addition to those that are deficient.

In the example given on page 7, if manure is applied to satisfy the target potassium requirement there will be insufficient nitrogen for the crop. Consequently inorganic nitrogen would need to be added to optimise the crop yield.

Smaller feedlots generally spread manure on their own or nearby land.

Manure and compost spreading

Australian manure and compost utilisation practices

Most of the larger Australian feedlots send at least part of their manure off-site. The spreading rates used on-farm by these feedlots are highly variable, ranging from less than 5 t/ha to more than 30 t/ha. Manure is mainly spread on land used to grow hay, silage or grain crops (O'Keefe et al. 2011).

Most of the smaller feedlots spread manure on their own or nearby land, typically at rates of up to 5 t/ha.

An automatic weather station can help determine when conditions are suitable for manure and effluent utilisation.

Timing of manure and compost spreading

The ideal timing of manure applications depends on factors including

- crop or pasture needs
- manure or compost maturity
- timing of other management events (cultivation to incorporate manure)
- field conditions (soil moisture)
- wind conditions.

Avoid spreading manure under windy conditions.

Manure is often spread before planting but minimum till equipment does not incorporate it into the soil very well.

Withhold cattle from utilisation areas for at least 21 days after spreading.

In broadacre cropping, manure is generally spread before planting the crop and incorporated with the cultivation associated with the seeder pass.

On soils with low background nutrient levels, spreading manure just before sowing may result in crops that are less vigorous and lower yielding than those grown using inorganic fertilisers. This can occur because the nutrients in the manure are less available for immediate uptake by the plant roots. Nitrogen and phosphorus are present in manure and compost in both inorganic and organic forms; the latter have to be mineralised into inorganic forms to be available to the plants. Most potassium in manure is in the inorganic form and ready for uptake.

Applying manure 4–6 months before the crop is established allows nutrients to mineralise from their organic matter and reduces the risk of nitrogen draw-down, which may occur after aged manure is spread. However, nitrogen losses can increase if manure is applied too far ahead of crop planting, particularly if there is minimal incorporation of the manure. Nutrient availability is likely to be less of a concern if the manure is well-aged or composted before spreading, particularly if the soil has reasonable background nutrient levels.

Accessibility of manure nutrients to plant roots can also be an issue. In modern broadacre cropping systems, manure is generally broadcast before the crop is sown using low disturbance, no till (e.g. knife points and press wheels) or zero till (e.g. disc seed systems) seeding equipment. This results in little incorporation of manure at planting and minimal manure in the seed row close to the tiny roots of germinating crop seedlings. Minimal manure incorporation can also result in increased nitrogen losses. Thus spreading manure as close as possible to planting is sometimes recommended to allow the crop to take up rapidly mineralised nitrogen as it becomes available. In many cases poor crop vigour is phosphorus-related.

The problems described above can be overcome by spreading manure annually or using a ‘starter’ application of inorganic phosphorus fertiliser with the manure just before planting. Depending on the background phosphorus levels in the soil, the fertiliser rates may be significantly lower than conventional application rates. The levels of available nutrients in paddocks planned for manure or compost spreading should be tested. Recent improvements in soil testing technologies such as DGT (Diffuse Gradients in Thin Films) tests have increased confidence in making decisions on whether inorganic fertiliser should be applied in conjunction with manure applications.

If the paddocks are to be ploughed for sowing, spreading manure beforehand will allow it to be incorporated into the soil. If possible manure should be spread when the soil is not too wet to limit compaction.

Manure spreading should be avoided under windy conditions especially if the wind is blowing towards nearby houses or public use areas.

To protect grazing livestock from risk of pathogens a withholding period of 21 days applies to paddocks that have been spread with manure or compost.

Manure and crop requirement

The crop requirement (CR) depends on the yield and nutrient content of the crop grown. If the utilisation area is used to grow an oat hay crop with a dry matter yield of 7 t/ha and a nutrient content of 2% nitrogen, 0.2% phosphorus and 1.4% potassium, the CR will be 140 kg N/ha, 14 kg P/ha and 98 kg K/ha.

If the soil of the utilisation area has a depth of 0.6 m, a bulk density of 1,400 kg/m^3 and can adsorb 200 g P/kg, the total soil storage (SS) capacity is1,680 kg of phosphorus. If the expected life of the feedlot is 30 years, the annualised SS is 56 kg P/ha.

The mass of nitrogen, phosphorus and potassium in each tonne of manure for spreading can be calculated from nutrient and dry matter analysis results.

The allowable loss (EL) of nitrogen might be 20 kg N/ha/yr.

In this example, the average nutrient concentrations for aged manure presented in Table 5.1 are used as the available nutrient concentration (NW). With a dry matter content of 63%, each tonne of aged manure contains 630 kg of dry matter with 2.2% nitrogen, 0.8% phosphorus and 1.9% potassium. Multiplying the dry matter mass (630 kg) by the nutrient concentration (%) provides kilograms of nutrients in each tonne of manure. In this case, each tonne of manure contains 13.8 kg of nitrogen, 5.0 kg of phosphorus and 12.0 kg of potassium.

Applying the NLAR formula for nitrogen:

$$\text{NLAR (t/ha)} = \frac{140\text{ kg} + 0 + 20}{13.8}$$

$$\text{NLAR (t/ha)} = 11.6\text{ t/ha}$$

Applying the NLAR formula for phosphorus:

$$\text{NLAR (t/ha)} = \frac{14\text{ kg} + 56 + 0}{5.0}$$

$$\text{NLAR (t/ha)} = 14.0\text{ t/ha}$$

Applying the NLAR formula for potassium:

$$\text{NLAR (t/ha)} = \frac{98\text{ kg} + 0 + 0}{12.0}$$

$$\text{NLAR (t/ha)} = 8.2\text{ t/ha}$$

On this basis, potassium is the limiting nutrient, and the sustainable annual spreading rate is 8.2 t/ha/yr for an oat hay crop yielding 7 t/ha.

Manure should be tested just before the main utilisation period.

Balance the nutrients added to the crop and soil requirement.

Manure and compost spreaders

There is a wide range of manure spreaders. The amount of manure for spreading, the quality of the manure and the proposed spreading rate all determine which spreader will be most suitable. The cost and efficiency of manure spreading influences the value of manure as a fertiliser.

A horizontal beater manure spreader

Spinning disc spreader

Features to consider when selecting a spreader include

- *Spreading pattern and width* – some spreaders have an effective spreading width of 2 m while some of the specialised European manure spreaders spread up to 10 m. A greater spreading width reduces soil compaction.
- *Horizontal versus vertical beaters* – horizontal beaters usually spread only about the width of the spreader whereas vertically mounted beaters generally spread over a larger area with each pass. Beaters are essential for spreading unscreened lumpy or high moisture manure as they break up the lumps.
- *Conveyor belt versus moving-floor chains* – manure can be moved to the back of the spreader using a conveyor belt or a chain and slats. These can be hydraulic or PTO driven. Conveyor belts wear more rapidly than the chains. Floor chains are better when spreading unscreened or high moisture manure and tend to have fewer problems with manure bridging.
- *Beater/spinner design* – the rotation speed of the beaters will affect the width of spread and application rate. Generally the greater the height of the spinner or beater above the ground the greater the width of spread, but a high centre of gravity can result in instability on uneven ground.
- *Spreader power requirements* – check the power requirements of the spreader in relation to the tractor or truck.
- *Application rate* – most spreaders need a minimum application rate of about 5 t/ha to get an even spread and this may be higher for some spreaders. Fresh lumpy manure does not spread well and is likely to be uneven at rates of less than 10 t/ha.
- *Load capacity* – larger capacity spreaders offer better efficiency by minimising time between loads. Spreader capacity ranges from under 3 m^3 to 15–30 m^3 models. Some spreaders can be fitted with extension sides ('hungry boards') to increase capacity.
- *Design of sides* – vertical sides are preferable to angled sides as these are less likely to result in manure 'bridging'.
- *Engineering* – under-engineered spreaders may require increased maintenance (e.g. due to bearing failures, bent shafts) compared to those with more robust engineering.

Purpose-built manure spreaders are typically categorised as rear or side discharge systems with capacities of 1–20 t. Rear discharge spreaders are usually equipped with a moving conveyor belt, moving floor chain or hydraulic push door that transfers manure to horizontal or vertical beaters, or spinning discs. Side discharge systems use a horizontal auger to transfer manure to the spinning discs or beaters. Both discharge systems can be self-propelled (i.e. mounted on a truck or tractor chassis) or towed behind a tractor as an independent unit.

Conventional fertiliser spreaders typically use a rear door to control the rate of fertiliser falling onto the spinning discs (to ensure accurate, uniform application rates). Chunks of manure can become trapped in the rear door and prevent manure from being uniformly spread over land. Hence, conventional fertiliser spreaders are not suited to applying unscreened manure.

The best coverage is often achieved by belt or moving floor-fed horizontal disc spinners with screened or composted manure. Belt-fed spreaders are less effective with inconsistent manure. While side-delivery spreaders use more power, they are suitable for all manure. Horizontal beater spreaders also suit all manure but spread at higher rates.

The uniformity and time efficiency of manure application is highly dependent on manure physical properties. Manure with a low moisture content (<35% moisture) that has been either composted and/or screened can be effectively applied using a spreader with either beaters or spinning discs but inconsistent, lumpy manure can be effectively applied only using a spreader with beaters.

Operator efficiency influences where manure is spread on the paddock and at what rate. This is especially relevant for spreaders where operation speed influences the rate applied. Consistent spacings between spreader passes are important for covering the whole paddock evenly. GPS guidance aids the accuracy and efficiency of the spreading operation, reducing overlap and missed areas, compared to estimation by the operator.

Most spreaders need a minimum rate of 5 t/ha for even spreading.

Off-site use of manure and compost

Many feedlots provide at least part of their manure or compost to off-site buyers. *Appendix 3: Duty of care: manure utilisation* can be provided to people buying manure to ensure they are aware of their duty of care.

Appendix 4: Manure valuation pro forma provides a valuation method using fertiliser price and manure nutrient content to place a value on manure.

Manure transport

To avoid manure spillage and associated odour or dust concerns, loads of manure being transported along public roads should always be covered.

Utilisation of carcase compost

The principles for utilising carcase compost are generally the same as those for manure or compost. Since carcase compost contains material of animal origin, it should not be spread on land that is being grazed.

Operator efficiency influences how evenly manure is spread and at what rate.

Travelling spray irrigator

High-pressure spray irrigation of effluent can generate odours and aerosols.

Well-designed flood irrigation reduces aerosols but must not create run-off of effluent.

Effluent irrigation

Australian effluent utilisation practices

Most larger feedlots irrigate some effluent, generally using spray irrigation systems; some use surface irrigation. Effluent is mostly used to grow hay or silage crops although it is also used to produce grain.

Timing of effluent irrigation

The timing of effluent irrigation will often be driven by the need to empty effluent ponds so that they are ready to receive future runoff. To reduce pathogen levels, effluent should be stored in the holding pond for at least a month before irrigating and then used to meet crop water demands like other irrigation. If a terminal pond is used to capture runoff from an effluent irrigation area this water should be irrigated back onto the land as soon as practical after any significant inflow.

Effluent applications should never raise the soil moisture content above field capacity and the application rate must be controlled to ensure runoff does not occur. Effluent should not be irrigated under heavy cloud, if rain is forecast or on windy days.

Effluent should not be irrigated in the four weeks before harvest on human food crops that will be eaten raw or with minimal processing. To protect grazing livestock from pathogen risks, a withholding period of 21 days after effluent irrigation is recommended.

Practical effluent irrigation

A range of different effluent irrigation methods is available. The most suitable methods will depend on the following factors

- effluent composition
- topography – slope and uniformity
- crop type – cultivation requirements, value, required accuracy and uniformity of application
- soils – permeability, sealing characteristics, water holding capacity, variability
- costs – capital, labour and energy
- physical shape of the utilisation area – fences, drainage lines, other infrastructure
- prevailing seasonal conditions.

The salt content of effluent may be a constraint and cause leaf burn, yield reduction and degradation of some soils and crop types. Sustainable effluent irrigation rates may need to be very low to manage the salt load. Management options could include using a low pressure spray or drip system, effluent dilution with clean water, or following effluent with irrigation with clean water.

Some form of sprinkler irrigation is generally preferred to flood irrigation because

- there is reduced potential for runoff and subsequent collection problems
- it can provide greater uniformity of application
- it can be used on soils with high infiltration rates (e.g. >10 mm/hr)
- it can accurately apply smaller quantities more regularly to more closely balance crop or pasture water requirements and utilise more effluent.

Travelling drip irrigation may also be an option.

Small travelling irrigators generally operate at higher pressures to pivot and lateral move irrigators which means a higher operating cost per unit of water applied.

For irrigation of resuspended sludge or other effluent with a high solids concentration system, the irrigation system requires high-pressure main lines to prevent settling in the pipeline, capacity for clean water flushing along the pipeline and large aperture spray nozzles.

Table 5.2 compares effluent irrigation methods.

Travelling drip irrigators can apply effluent evenly at low rates.

Table 5.2 Comparison of irrigation methods

Irrigation method	Typical area range (ha)	Typical operating pressures (kPa)	Site slope limitations	Typical application rates (mm/hr)	Comparative costs			Uniformity of application
					Capital	Labour	Energy	
Sprinkler								
Handshift	<10	200–400	<10%	3–10	low	very high	medium	high
Powered side toll	20–50	200–400	<3%	3–10	medium	medium	medium	high
Travelling irrigator	8–50	400–650	<7%	5–25	medium	high	high	medium/ high
Centre pivot	40–100	100–300	<2%	variable	high	low	low	very high
Lateral move	50–200	100–300	<2%	variable	high	low	low	very high
Surface Systems								
Border check	–	10–50	0.1–1.0%	5–10	low	medium	-	low
Contour ditch	–	10–50	1.0–7.0%	5–10	low	medium	-	low
Furrow	–	10–50	0.05–1.0%	5–10	medium	high	-	medium
Gated pipe /layflat fluming	–	10–100	0.05–1.0%	5–10	medium	high	-	medium

Source: Skerman 2000 adapted from Lott and Skerman 1995

In some cases, terminal ponds may be positioned below utilisation areas to capture the initial and possibly heavily polluted runoff from storm events and runoff from flood irrigation. Captured runoff should be re-irrigated onto the utilisation area when the soil has a suitable moisture content.

Further reading

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