A NUTRIENT BALANCE MODEL FOR TYPICAL IRISH FARMING SYSTEMS

Presented for the Degree of Master in Science in Environmental Protection

by

Seamus P. Hynds, Dip.Eng.A.M.I.E.I.

Supervised by

Dr. O.T. Carton and Dr. R. Thorn

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Seamus P. Hynds

ABSTRACT

The twin objectives of the work described were to construct nutrient balance models (NBM) for a range of Irish animal production systems and to evaluate their potential as a means of estimating the nutrient composition of farm wastes.

The NBM has three components. The first is the intake of nutrients in the animal's diet. The second is retention or the nutrients the animal retains for the production of milk, meat or eggs. The third is the balance or the difference between the nutrient intake and retention. Data on the intake levels and their nutrient value for dairy cows, beef cattle, pigs and poultry systems were assembled. Literature searches and interviews with National experts were the primary sources of information. NBMs were then constructed for each production system. Summary tables of the nutrient values for the common diet constituents used in Irish animal production systems, the nutrient composition of the animal products and the NBMs (nutrient intake, retention and excretion) for a range of production systems were assembled. These represent the first comprehensive data set of this type for Irish animal production systems. There was generally good agreement between the derived NBMs values and those published in the literature.

The NBMs were validated on a number of farms. Data on animal numbers, fertiliser use, concentrates inputs and production output were recorded on seven farms. Using the data a nutrient input/output balance was constructed for each farm. This was compared with the NBM estimate of the farm nutrient balance. The results showed good agreement between the measured balance and the NBM estimate particularly for the pig and poultry farms. However, the validation emphasised the inherent risks associated with NBMs. The average values used for feed intake and production parameters in the NBMs may result in the under or over estimate of actual nutrient balances on individual farms where these variables are substantially different. On the grassland farms there was a poor correlation between the input/output estimate and the NBM. This possibly results from the omission of the soil's contribution to the nutrient balance. However, the results indicate that the NBMs developed are a potentially useful tool for estimating nutrient balances. They also will serve to highlight the significant fraction of the nutrient inputs into farming systems that are retained on the farm.

The potential of the NBM as a means of estimating the nutrient composition of farm wastes was evaluated on two farms. Feed intake and composition, animal production, slurry production was monitored during the indoor winter feeding period. Slurry samples were taken for analysis. The appropriates NBMs were used to estimate the nutrient balance for each farm. The nutrient content of the slurry produced was calculated. There was a good agreement between the NBM estimate and the measured values. This preliminary evaluation suggests that the NBM has a potential to provide the farmer with a simple means of estimating the nutrient value of his slurry.

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CHAPTER 1

INTRODUCTION

The primary objective of modern farming is the optimization of profit. This objective is generally achieved by maximising animal and crop output which usually involves modifying the agro-ecosystem. Changes in farming practice over the last number of years include larger animal herds, increased use of fertilisers, modified animal housing designs and the use of high density, confined animal production practices. These changes have not only results in increased farm output but also in larger concentrations of nutrients, organic materials and chemicals in modern farms compared to those operating a few decades ago. The net effect has been an increase in their pollution potential. This is reflected in the general decline in water, air and soil quality - the resources on which farming depends.

Against this background, the objective of the EU and national environmental policy for agriculture is for a more sustainable balance between farming activity and the natural resources. In Ireland, the recycling of the nutrients in animal wastes by land spreading is a very important element of sustainability on animal production farms. This is because almost 85% of the nutrients ingested by the animal are excreted. Effective recycling of these nutrients will reduce the potential for nutrient losses to the environment and the requirement for inorganic fertilisers. Consequently, the environmental and economic sustainability of the farm will improve.

However, animal waste management creates many problems for the farmer. These include cheap inorganic fertilisers, variable nutrient composition of wastes, few spreading opportunities, machinery designed for disposal rather than recycling and the filthy nature of the work.

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Therefore, the farmer often regards animal manures as wastes requiring disposal rather than a valuable resource. Strategies are required to assist farmers realise the value of animal waste nutrients.

The twin objectives of the work described in this thesis are

i) to construct nutrient balances for a range of Irish animal production systems

and

ii) to examine the potential of a simple input /output model for estimating the nutrient composition of farm wastes.

Currently, only a nutrient balance for pigs is published in Ireland (Lynch, 1992). None are available for dairy cows, beef cattle or poultry systems. The nutrient balances will serve three potential functions. Firstly, they will assist in highlighting the importance of animal manures in farm nutrient management. Secondly, it will provide Local Authorities with a fast reliable means of estimating the nutrient loads associated with a range of animal production systems to assist in the evaluation of Environmental Impact Statements. Finally, a simple nutrient input/output model may provide a reliable and rapid estimate of slurry nutrient composition on the farm. This would be a useful management tool for farmers to assist with improving crop recovery of the slurry nutrients.

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CHAPTER 2

LITERATURE REVIEW

2.1. INTRODUCTION

Animal manures can be classified as slurry (liquid), dungstead manure (semi-solid slurry) and farmyard manure (solid). Slurry contains faeces, urine and variable quantities of added water. Farm slurries are composed of the undigested remains of the animal's feed intake, often diluted with varying quantities of water and bedding material. They also contain intestinal and microbial cells from the animal's digestive tract. Dungstead manure is a mixture of faeces, urine and small amounts of bedding material and rejected silage. It is generally stored in dungsteads which allows the liquid fraction to drain away to a separate tank. Farmyard manures contain faeces and urine mixed with sufficient quantities of bedding material to absorb all the liquid.

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2.2. QUANTITIES OF MANURE AND NUTRIENT COMPOSITION

In Ireland, annual fresh manure production has been estimated at almost 87 million tonnes (Carton and Harnett, 1990). Eighty-five million tonnes from grazing animals (bovines and ovines) and two million from pigs and poultry. At grazing, the manure is recycled directly back to the pasture. However, a significant fraction of all grazing animals are housed during the winter. Carton and Harnett, (1990) estimated that 28 million tonnes of manure are produced annually by these animals. Two million tonnes of manure are produced annually on pig and poultry farms. Therefore, there is approximately 30 million tonnes of manure requiring management (storage and land spreading) each year on Irish farms.

It is difficult to estimate the proportion of the manures as slurries, dungstead manure or farmyard manure. However, it is generally regarded that 35% of all farmers are intensive and use slurry systems. These account for almost 80% of the total annual output from Irish agriculture. This suggests that the greatest nutrient concentration in animal manures is likely to be found in the form of slurries. Therefore, the largest impact in terms of improving national crop recovery of the nutrients in animal manures and reducing losses to the environment can be achieved by improving the management of slurries.

Animal manures contain nutrients which are required for crop growth. These include significant amounts of nitrogen (N), phosphorus (P) and potassium (K). Carton and Harnett (1990) estimated the quantities of nutrients in animal manures produced annually and these are compared with the quantities of inorganic fertiliser used (Table 2.1).

TABLE 2.1: The nutrient content of animal manures produced in Ireland compared with annual fertiliser use (Carton and Harnett, 1990).

	Quantity ('000 tonnes)	
Nutrient	Manure	Fertiliser
Nitrogen	139	370
Phosphorus	25	62
Potassium	138	156

This estimate not only illustrates the potential value of manures, to contribute to national nutrient requirements but also highlights their pollution potential if not properly utilised and managed.

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2.3. AGRICULTURAL POLLUTION CONTROL

There are a number of characteristics of modern land-based farming systems that make pollution control difficult. Agricultural production occurs under different circumstances than those in most non-farm industries. Soils provide the basis for nearly all farming systems. The soil has physical, chemical and biological characteristics that vary greatly. Agricultural production systems utilise large areas of land, unlike manufacturing industries that are based in confined areas under controlled conditions. Most agricultural production system are open to the effects of variable and unpredictable weather which contrasts with industry that has greater control over the production environment. Finally, the production of agricultural produce realise small profit and the increased costs associated with pollution control are generally difficult to transfer to consumers because of the EU price support system.

Pollution problems in farming are more difficult to manage than in a factory situation. In the factory the wastes can be collected and diverted to a treatment plant where trained personnel operate the plant so as to produce a standard effluent. The "collection and treatment" approach to pollution control is generally not feasible for land-based agricultural systems because the volume of wastes are large and their occurrence unpredictable due to variable soils and weather.

2.3.1. Control of agricultural pollution

Pollutants of primary concern from agriculture include nutrients (N and P), organic matter and pathogens. Pollution from farming derives both from 'point' sources such as slurry tanks and dungsteads and from 'non-point' sources, such as fields. The same principles used to control industrial sources (*e.g.* reduction of pollutants at source) are applicable to farming sources but must be applied in the context of an open, uncontrolled and variable environment.

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2.3.2. Point sources

Key point sources of pollution in agricultural system are the farmyard itself, silage pits, manure stores and facilities for collecting and storing silage effluent and soiled water. They create a pollution risk because they concentrate large amounts of potential pollutants in a confined area. The objectives of controlling agricultural point sources of pollution are (i) to contain pollutants and (ii) prevent their uncontrolled release into the environment. The requirements for such facilities are sufficient waste storage capacities, structural integrity and careful site location. Equally important, however, is the proper management of these facilities.

2.3.3. Non-point sources

Non-point sources of agricultural pollution are the fields or areas in the farm where farming takes place. The diffuse nature of this type of pollution gives rise to its definition as 'non-point source' (NPS) pollution. Following the land spreading of animal manures and fertilisers, heavy rainfall may cause surface run-off which carries the nutrients to surface waters and drainage water. Drainage water percolating down through the soil profile may transports pollutants to ground water. Controlling NPS pollution is concerned with preventing the pollutants leaving the soil following application.

2.4. OFFALY FARM SURVEY

In 1987 most counties in Ireland reported incidents of fish kills during the summer months. Investigations into the causes implicated agricultural activities in most cases. As a result, the Minister for the Environment requested all Local Authorities to organise a task force to survey farms in their functional areas. The task force comprised personnel from the Local Authority, the Fisheries Board and the Farm Development Service. The purpose of the survey was to identify

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farm enterprises that were causing or had potential to cause water pollution from point sources. A standard report form was prepared by the Department to allow for a ranking system of the farms based on pollution potential either high, medium or low.

The approach taken in Offaly was to select three catchment areas based on importance to the local authority water supplies. These accounted for about 30% of the entire county. A total of 210 farms were surveyed covering 7,700 ha (McCarthy, 1990). The results are summarized in Figure 2.1.

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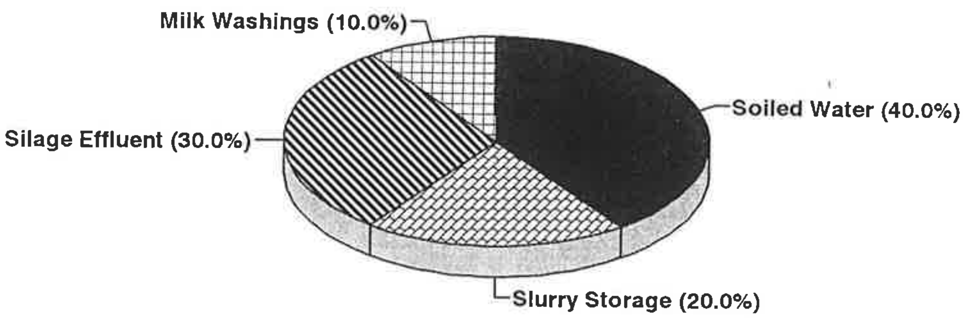

Figure 2.1. The primary point sources of pollution identified on farms in Co. Offaly from the task force survey.

The Local Authority served Section 12 Notices, under the Local Government Water Pollution Act of 1977, on all farms in the high risk category as a result of the survey. This notice empowers the

Local Authority to set out the remedial work necessary to eliminate pollution or reduce pollution potential. In addition, warning letters were served on the medium risk farms. All of the notices had been complied with in full by 1990. Since then a further 50 Section 12 Notices were served on farms in the county that had a high pollution potential. Some of the latter recipients have complied while the remainder are in the process of doing so.

The setting up of the task force in 1988 addressed the problems of point sources of pollution. However, recent water quality surveys have shown that while there has been a reduction in rivers classified as seriously polluted, there has been an increase in the slight to moderately polluted category (Clabby *et al.,* 1992). This increase has been attributed to NPS, particularly from agriculture. The land spreading of manure is one potential source. Where manure is land spread as a disposal exercise the pollution risk will be higher than if crop recovery of the nutrients was the objective.

2.5. MANURE - THE PROBLEMS FOR THE FARMER

The value of animal manures as a nutrient source for plant growth and crop production has been recognised through the ages. However, in recent years, farmers tend to regard animal manure as a waste product requiring disposal rather than a nutrient source. This is attributed to:

(a) The relative low cost of inorganic fertilisers.

(b) The nutrient composition of slurry is very variable between farms (O'Bric, 1991).

(c) The machinery for land spreading was designed for disposal rather than utilisation.

(d) The disamenity to the farmer when working with manure, particularly slurry, is unpleasant and often regarded as degrading.

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Any strategy to improve farmer attitudes to manures must address these problems. It is in this context the approach proposed in this study has relevance. There is a requirement for an easy to use system to provide a reliable estimate of slurry nutrient value. The nutrient balance model (NBM) may be such a system. The NBM can also be used to highlight the significant quantities of nutrients in farm wastes relative to those exported off the farm thereby indicating their potential to reduce the requirement for purchased inorganic fertilisers.

2.6. NUTRIENT CYCLES ON IRISH FARMS

Crop production supplies food for humans directly as plant material or indirectly as milk, meat or eggs. Crops take up water and inorganic minerals including N, P and K from the soil and combine these with carbon dioxide in the leaf, using the sun's energy to form plant tissue.

Farm animals eat the plants and a small fraction of the plant N, P and K are absorbed by the animal and used for their growth and development. The remaining plant nutrients are excreted in the faeces and urine. Following excretion, bacteria decompose the organic matter resulting in the release of carbon dioxide, water and the inorganic minerals back to the air and soil. This 'cycling' of minerals from the soil to the plant to the animal and back to the soil again forms the basis of sustainable agricultural systems (Carton *et al.*, 1993). Nutrients are removed from the farm system in the export of crop or animal products. However, this accounts for only a small fraction of the total with the remainder accounted for in the animal manures. The efficient recycling of these nutrients, thereby reducing losses, is the objective of manure management on farms.

A brief review of the N and P cycles is considered below as these are the two nutrients with a significant potential to cause pollution and are agronomically important.

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2.6.1. Nitrogen

Most of the N on earth exists as N gas in the atmosphere. This can be transformed into inorganic N by leguminous plants, such as clover, in a process called biological fixation. It can also be transformed into inorganic forms by lightening or by manufacturing processes used to make fertiliser N. The organic matter in the soil accounts for the largest fraction, 3 to 8 t ha^{-1}, of the total N in soils. Generally, less than 200 kg ha^{-1} will be in the inorganic or plant available form. In the soil there are a number of N transformations which can take place. Inorganic N, from applied fertilisers, can be taken up by growing crops. It may be temporarily immobilised by soil micro-organisms. The organic N in plant materials and in the soil flora and fauna can be transformed to inorganic N by soil bacteria in a process called mineralisation. Losses of N to the atmosphere from the soil/crop system can occur through volatilisation or denitrification. Leaching of nitrate from the soil will result in a loss of N from the system and may under certain circumstances cause groundwater pollution.

A national N balance for agriculture was constructed and is shown in Table 2.2. Inputs are from inorganic fertilisers, biological fixation and deposition. The results show a recovery in products (milk, meat crops) of about 16% of total N inputs to agricultural systems. Twelve percent of the total N input are immobilised into the soil organic matter. The remaining 72% is unaccounted for or is lost either to water (leaching and run-off) or the atmosphere (volatilisation and denitrification). The losses of N are not only a financial loss but also represent a pollution threat. Fertiliser N use has increased from about 7,000 t in 1950 to about 340,000 t per year at the present time. This reflects the intensification of agriculture during the period. Over 120,000 t of N is potentially available in animal manures based on the total quantity available (Carton and Harnett, 1990) and the average N content (O'Bric, 1991) which is equivalent to just over 30% of the fertiliser N inputs to agriculture. This highlights the relative importance of the N in stored animal manures to the

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total national N balance.

TABLE 2.2: Estimated N balance for Irish agriculture in 1988 (Sherwood and Tunney, 1991).

Inputs (t)	
Chemical fertiliser N	340,000
Biological N fixation	219,000
Atmospheric Deposition (10 kg ha^{-1} on 6.5 m ha)	65,000
Concentrates fed to Animals	60,000

Total N Inputs	684,000
Outputs (t)	
Milk 5170 x 10^6 litres (6.69 N l^{-1})	35,000
Meat 1381 t (12 kg N t^{-1})	17,000
Tillage Crops 451 x 10^3 ha (130 kg N ha^{-1})	60,000
Volatilisation of Ammonia	130,000
Losses to water @ 14% of Inputs	96,000
Immobilisation	85,000
Denitrification @ 10% of Inputs	68,000
Unaccounted for	193,000

Total N Outputs	684,000

2.6.2. Phosphorus

Phosphorus is essential in the intercellular energy transformations and is a constituent of many proteins, nucleic acids and enzymes. The primary sources of P in the soil are crop residues, animal manures and chemical fertilisers. It is present in the organic and inorganic form in roughly equal proportions. Both forms are involved in transformations that release water soluble phosphorus, which can be used by plants, from solid forms and *vice versa*.

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Since 1950 there has been a steady increase in the soil P status from 1 mg kg^{-1} to 9 mg kg^{-1} (Tunney and Power, 1988). The use of fertiliser phosphorus has also shown an increase from about 20,000 t in 1950 to about 90,000 t in 1975. Its usage since then has decreased and over the last few years has stabilised at about 60,000 t per year. Despite this usage reduction, the soil P status continues to increase. A study in the early 1970's (Hanley and Murphy, 1973) suggested more P was been applied than removed in produce and this explained the increasing soil P values. A similar study was carried out in the late 1980's (Tunney, 1990) to establish a reason for the continuing increase in soil P values despite the decrease in P fertiliser use (Table 2.3).

TABLE 2.3: Estimate of phosphorus balance for 1988 (t) (Tunney, 1990).

Inputs (t)		
	Chemical phosphorus fertiliser:	62,446
	Concentrates fed to cattle and sheep: 1.8 x 10^6 t (5 g P kg^{-1})	9,000
	Concentrates fed to pigs and poultry: 0.9 x 10^6 t (6.5 g P kg^{-1})	5,800
	Total Inputs	77,296
Outputs		
	Tillage crops: 451 x 10^3 ha (27 kg P ha^{-1})	12,177
	Cattle and sheep production: 1089.6 x 10^3 t (8g P kg^{-1})	8,717
	Milk: 5170 x 10^6 L (1 g P l^{-1})	5,170
	Soluble P loss to water: 6.89 x 10^6 ha (0.5 kg P ha^{-1})	3,475
	Pig and poultry production: 291.0 x 10^3 (6 g P kg^{-1})	1,746
	Total P Outputs	31,255
	Surplus	**46,041**

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It can be concluded from these studies that one of the most important reason for the excess of P inputs over P outputs is that farmers continue to apply fertiliser P in addition to animal manures despite the latter being of equal nutrient value. An awareness of the P content of animal manures in farming systems is very important in relation to proper recycling of the manure. The use of a farm nutrient balance to highlight the potential P value of slurry/manure on farms may contribute to reducing P losses to surface water.

2.7. NUTRIENT BALANCES ON CATTLE, PIG AND POULTRY FARMS

The number of animals which can be kept on any farm has traditionally been limited by the land requirements for production of their food and by the problem of housing and handling large numbers of animals. Both of these considerations have become less restrictive in recent years. The nutrients excreted by grazing animals are returned directly to the land and generally ensures the return of the nutrients to the soil. However, the nutrients produced by animals kept indoors and fed silage or concentrate or both is collected and stored. Land spreading of this manure on the land area that produced the silage or cereal crop is the best management option as it returns the nutrients to the soil that produced the crop. In general, on grassland farms the quantity of imported feed in the form of concentrates is low. Therefore, there will be an annual nutrient deficit equivalent to the nutrients in the milk and meat exported off the farm. The nutrient exports and losses must be balanced by importing nutrients in the form of inorganic fertilisers or other animal manures. This is important so as to avoid depletion of the soil nutrient status which would result in reduced crop output. Therefore, all the manure produced on grassland farms can be safely applied to the grassland which supports the animals (Carton and Harnett, 1990).

However, on intensive pig and poultry farms the feed is generally imported as concentrates derived

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from cereals grown on other farms. This creates a nutrient surplus on the pig and poultry farms. It is often not practical to transport the manure to the land that produced the cereals. In order to prevent the potentially polluting accumulation of nutrients, the surplus manure must be spread on farms which have a nutrient deficit (Pettigrew, 1992). Therefore, intensive livestock farms must find sufficient land area locally which can safely accept the nutrient load in the manure. This is a very important element in the preparation of Environmental Impact Statements for new pig and poultry developments. It is likely also to be a very important issue in the Environmental Protection Agency's licensing of existing and proposed pig and poultry enterprises.

Both the N and P balances for Irish agricultural suggest significant scope for improving the efficiency of recycling for manure nutrients. Obstacles preventing this, include a lack of awareness among those concerned about the significant fraction of nutrients excreted in the manure relative to those exported off the farm in crop or animal product. Nutrient balance models for a range of Irish farming systems might provide a mechanism for focusing attention on this issue.

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CHAPTER 3

NUTRIENT BALANCE MODELS FOR ANIMAL PRODUCTION SYSTEMS IN IRELAND

3.1. INTRODUCTION

The objective of this chapter is to construct nutrient balances models (NBM) for Irish animal production systems. Included are dairy cows, beef cattle, pigs and poultry (layers and broilers). The approach was to determine the inputs (grass, silage or concentrates) and the outputs (milk meat or eggs) with the difference giving the balance of nutrients in the manure.

Animal manure is a natural product, the composition of which is determined by several factors. These factors include the animal type its diet, its physiological state and environmental factors which will vary from farm to farm. The NBM approach is based on "averaged" nutrient values for outputs (milk, meat, eggs, etc.) and "average" values for feed intake. A brief description of the different livestock systems follows with a NBM constructed for each.

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3.2. NBM FOR IRISH LIVESTOCK PRODUCTION SYSTEMS

3.2.1. Dairy systems

At the present time there are approximately 1.3 m dairy cows and 0.25 m replacement stock in this country. More than 90% of these animals are housed during the winter period with about 60% in traditional straw bedded houses, 15% on fully slatted units and the remaining 15% in cubicle systems (Drennan, 1993). The average weight of the Irish cow is approximately 550 kg and the animal output includes milk, weight gain and a calf (assuming 1 calf per cow per year). Milk production ranges from 4200 to 7000 kg between low and high performance cows respectively (Table 3.1). The calf and the cow's own annual growth are equivalent to 40 and 20 kg, respectively. The cows intake consists of grass at grazing and silage and concentrates during the indoor winter feeding period. The higher the cow performance the higher the intake of grazed grass and silage ranging from 3000 to 3800 kg and 1000 to 1400 kg, respectively (Murphy, 1994).

Milk production systems in Ireland, pre-EU milk quota (1984), were based on a spring-calving herd with compact calving in mid-February. During the late 70's and early 80's many cooperatives introduced price incentives to increase milk production during the winter months. The initial approach in most cases was to offer a bonus payment for milk produced from November to February. However, the incentives had modest success in changing the pattern of milk supply. The introduction of quotas concentrated the efforts of researchers and farmers to reduce production costs. Research has shown that calving closer to turnout to pasture in spring, thereby providing more of the cows diet as grass rather than silage or concentrates, significantly reduces the costs of milk production (Murphy, 1994).

The different levels of the dairy cow production performance *i.e.* low, medium and high is mainly attributed to animal breeding. Other factors such as the quality, quantity and type of feed are also important regarding level of animal production. However, their impact on production are directly related to the breeding of the animal.

Animal output and intake parameters for low (4,200 l), medium (5,600 l) and high (7,000 l) performance Irish dairy cows are given in Table 3.1. Cow and calf growth are similar for all performance levels. Intake of grass and silage increases in line with higher milk production.

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TABLE 3.1: Annual production and intake parameters for low, medium and high performance dairy cows (Murphy, 1994).

	Performance Level		
	Low	Medium	High
Output (kg DM)			
Growth	20	20	20
Calf	40	40	40
Milk	4200	5600	7000
Intake (kg DM)			
Grass	3000	3400	3800
Silage	1000	1200	1400
Concentrates	450	450	450
(Total DM Intake)	4450	5050	5650

The average nutrient composition of the production and intake variables for Irish dairy cows taken from several sources are summarised in Table 3.2.

TABLE 3.2: The nutrient composition of the production and intake variables for Irish cows.

Variable	Nitrogen	Phosphorus	Potassium	Source
		($g\ kg^{-1}$)		
Cow growth	24	7.8	1.8	(ARC, 1980)
Calf growth	26	8.0	2.0	(ARC, 1980)
Milk	5	0.9	1.4	(McCance &Widdowson,1988)
Grass	23	3.5	26.0	(Drennan, 1994)
Silage	23	3.0	25.0	(Drennan, 1994)
Concentrates	28	7.0	10.0	(Murphy, 1994)

A NBM for Irish dairy cows was calculated using data from Tables 3.1 and 3.2. The nutrient input was calculated by multiplying the quantity of feed intake by its appropriate nutrient content.

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Similarly, nutrient retention in production was calculated by multiplying the quantity of production by its nutrient composition. The quantity of nutrients excreted was calculated as the difference between input and retention. The percentage of excreted nutrients was then calculated. This exercise was repeated for all of the three performance levels. The results are summarized in Table 3.3 and Figure 3.1

TABLE 3.3: Nutrient balance for Irish dairy cows (550 kg) at three performance levels.

	Performance Level	Nitrogen	Phosphorus	Potassium
			(kg cow^{-1})	
Intake	Low	104.60	16.65	107.50
Retention	(4,200 l)	22.52	4.26	6.00
Excretion (%)		**82.08 (78%)**	**12.39 (74%)**	**101.50 (94%)**
Intake	Medium	118.40	18.65	122.90
Retention	(5,600 l)	29.52	5.50	(79.5%)
Excretion		**88.88 (75%)**	**13.15 (71%)**	**114.95 (94%)**
Intake	High	132.20	20.65	138.30
Retention	(7,000 l)	36.52	6.78	9.91
Excretion		**95.68 (72%)**	**13.87 (67%)**	**128.39 (93%)**

The annual N intake for dairy cows ranged from 105 kg for low performance cows to 132 kg for high performance cows reflecting higher feed intakes for the high performance animals. Nitrogen retention ranged between 23 and 37 kg per cow. The annual N excretion ranged from 82 to 96 kg per cow. Between 72 and 78% of the N ingested by the dairy cow is excreted (Table 3.3). While N excretion was highest in the high performance cows the overall of N efficiency for these animals was greatest.

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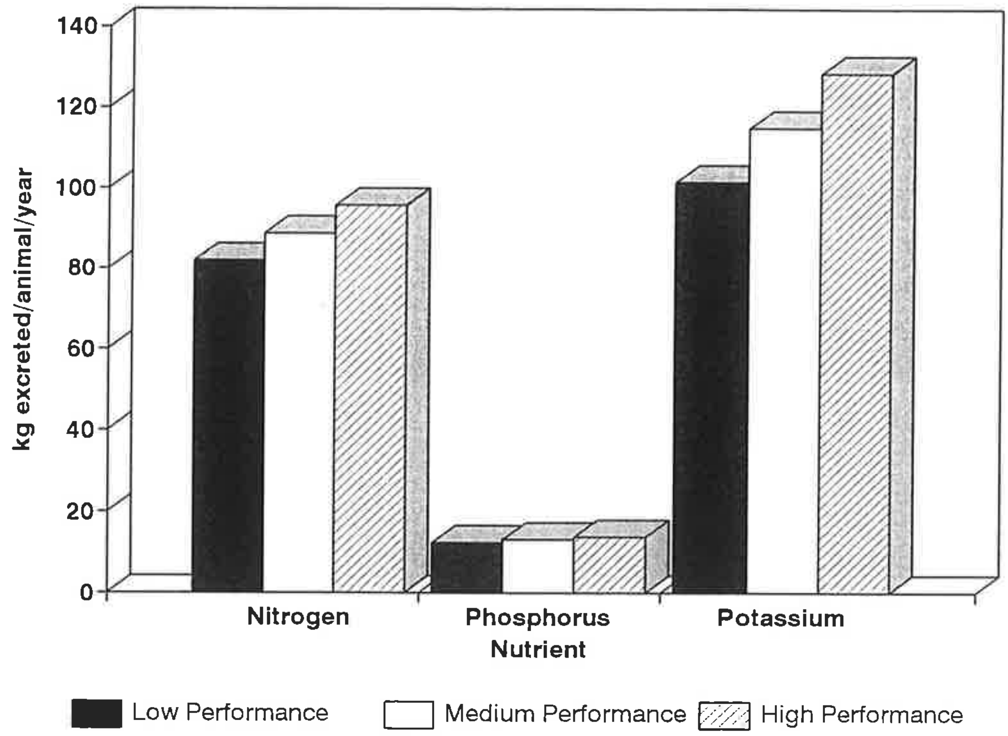

Figure 3.1. The quantity (kg) of N, P and K excreted by low (4,200 l), medium (5,600 l) and high (7,000 l) performance dairy cows.

The annual P intake for dairy cows ranged from 17 kg for low performance cows to 21 kg for high performance cows. Phosphorus retention ranged from just over 4 to almost 7 kg per cow. The annual P excretion ranged from 12 to 14 kg per cow. Between 67 and 78% of the P ingested by the dairy cow is excreted (Table 3.3).

The annual K intake for dairy cows ranged from 108 kg for low performance cows to 138 kg for high performance cows. Annual potassium retention ranged from 6 to almost 10 kg per cow. The annual K excretion ranged from 102 to 129 kg per cow. Approximately 94% of K ingested by dairy cows is excreted (Table 3.3).

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An "average" Irish dairy cow producing 5,600 l of milk and one calf annually has an intake of 118, 19 and 123 kg of N, P and K, respectively. Of this 75, 71 and 94% of the N, P and K, respectively is excreted. This clearly demonstrates the relatively low level of nutrient export off the dairy farm and the significance of the nutrients in animal manures in nutrient cycling on dairy farms.

3.2.2. Beef cattle systems

The beef cattle population in Ireland is currently about 5.5 m. Approximately, 40% are housed in slatted units during the winter period and 45% are housed in straw bedded sheds or cubicle systems. The remaining 15% are out wintered (Drennan, 1993). Calves for beef production come from the national herd of approximately 2 m cows. This includes dairy and suckler cows. In the early '80's the national herd consisted of 80% dairy cows and 20% suckler cows. The introduction of EU milk quotas in 1984 resulted in a gradual decline in dairy cow numbers from 1.6 m in 1984 to 1.3 m in 1992. This decrease in dairy cow numbers and the expansion into beef enterprises on dairy farms, to compensate for the limit on milk production, resulted in a decrease in the supply of calves for beef farmers and an increase in their price. The response to these changes was an increase in the suckler cow herd from 0.42 m in 1984 to 0.81 m in 1992 (Drennan, 1993).

The cow herd is predominately spring calving. After receiving milk or milk replacer for 6-8 weeks with some concentrates, the calves are then grazed on pasture from April to November and generally no concentrates are feed during this period. In winter the young cattle are fed silage or hay and may receive a concentrate supplement (1 kg per head per day). The following spring these "yearling" animals are again grazed on pasture from April to November. They spend their second winter indoors and receive approximately 4 to 5 kg of supplementary concentrates per head per day as "finishing steers" (Drennan, 1993). The finished steers are generally slaughtered from

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24 to 30 months of age with heifers finished about 6 months earlier. Therefore, for the NBM balance there are two cycles. The first year (0-1) with weight gains or performance levels of 195, 225 or 250 kg per head for low, medium and high performance animals. The second year (1-2) with weight gains or performance levels of 170, 255 or 305 kg per head for low, medium and high performance animals. The animal production or output and intake parameters for low, medium and high performance beef animals for 0-1 and 1-2 years are shown in Table 3.4.

Similar to the pattern for dairy cows, intake of grass and silage increase in line with performance, with the higher performance animals having higher intake levels particularly grass and silage. The nutrient composition of the production and intake variables for beef cattle are shown in Table 3.5.

A NBM for beef animals was calculated using data from Tables 3.4 and 3. 5 using the same method described for dairy cows. The results are presented in Table 3.6 and Figures 3.2 and 3.3.

The annual N intake for 0-1 year beef animals varied from 32 kg for low performance animals to 39 kg for high performance animals. Nitrogen retention ranged between 5 and 7 kg per head. The annual N excretion ranged from 27 to 32 kg per head. Approximately 83% of the N ingested is excreted (Table 3.6). The annual N intake for 1-2 year beef animals varied from 57 kg for low performance animals to 77 kg for high performance animals. Nitrogen retention ranged between 4 and 7 kg per head. The annual N excretion ranged from 53 to 69 kg per head. Approximately 90% of the N ingested is excreted (Table 3.6). It is interesting to note that while performance levels for the 1-2 year animals were slightly higher than the 0-1 year animals, N intake and excretion were almost double while N retention was similar for both (Table 3.6).

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TABLE 3.4: Annual production and intake parameters for low, medium and high performance beef cattle (Drennan, 1994).

Production	Performance Level		
	Low	Medium	High
Production (kg)			
0-1 Year			
Initial Weight	45	45	45
End Weight	240	270	295
Growth	195	225	250
Intake (kg DM)			
Milk Powder	25	25	25
Grass	507	570	700
Silage	555	645	750
Concentrates	275	250	190
(Total DM Intake)	1362	1490	1665
Production (kg)			
1-2 Year			
Initial Weight	240	270	295
End Weight	410	525	600
Growth	170	255	305
Intake (kg DM)			
Grass	1292	1454	1646
Silage	937	1146	1100
Concentrates	200	215	480
(Total DM Intake)	2429	2815	3226

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TABLE 3.5: The nutrient composition of the production and intake variables for the beef animal.

Variables	Nitrogen	Phosphorus	Potassium	Source
	g kg^{-1}			
Growth 0-1	26.0	8.0	2.0	ARC, 1980
Growth 1-2	24.0	8.0	2.0	ARC, 1980
Milk Powder	3.4	7.9	11.8	Warren, 1994
Silage	23.0	3.0	25.0	Drennan, 1994
Concentrate 0-1	28.0	6.0	10.0	Drennan, 1994
Concentrate 1-2	28.0	7.0	10.0	Drennan, 1994
Grass	23.0	3.5	26.0	Drennan, 1994

The annual P intake for 0-1 beef cattle ranged from 5.3 to 6 kg between low and high performance animals. Phosphorus retention ranged from 1.6 to 2 kg per head. The annual P excretion ranged from 3.7 to 3.9 kg per head. Between 66 and 70% of the P ingested by the 0-1 year beef animal is excreted (Table 3.6). For the 1-2 year beef cattle the annual P intake varied between 8.7 and 12.4 kg for low and high performance animals, respectively. Phosphorus retention ranged from just over 1.4 to 2.4 kg per head. The annual P excretion ranged from 7.4 to almost 10 kg per head for the three performance levels. Between 80 and 84% of the P ingested by 1-2 year beef cattle is excreted depending on performance (Table 3.6).

The annual K intake for 0-1 year beef cattle ranged from 30 kg for low performance animals to 39 kg for high performance animals. Annual K retention ranged from 0.39 to 0.5 kg per head. The K excretion ranged from 30 to 39 kg per animal depending on performance. Approximately 99% of K ingested by 0-1 year beef animals is excreted (Table 3.6). The annual K intake for 1-2 year beef cattle ranged from 59 kg for low performance animals to 75 kg for high performance animals. Annual K retention ranged from 0.34 to 0.6 kg per head. The K excretion ranged from

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58 to 74 kg per animal depending on performance. Approximately 99% of K ingested by 1-2 year beef animals is excreted (Table 3.6).

TABLE 3.6: Nutrient balance for 0-1 and 1-2 year old beef animals at three levels of performance levels.

	Performance Level	Nitrogen	Phosphorus	Potassium
			(kg animal^{-1})	
0-1 Year Old				
Intake Retention	Low (195 kg)	32.20 5.07	5.29 1.56	30.10 0.39
Excretion		**27.13 (84%)**	**3.73 (70%)**	**29.71 (99%)**
Intake Retention	Medium (225 kg)	35.03 5.85	5.63 1.80	33.75 0.45
Excretion		**29.18 (83%)**	**3.83 (68%)**	**33.30 (99%)**
Intake Retention	High (250 kg)	38.75 6.50	5.94 2.00	39.15 0.51
Excretion		**32.25 (83%)**	**3.94 (66%)**	**38.64 (99%)**
1-2 Years Old				
Intake Retention	Low (170 kg)	56.87 4.08	8.73 1.36	59.02 0.34
Excretion		**52.70 (93%)**	**7.37 (84%)**	**58.68 (99%)**
Intake Retention	Medium (255 kg)	65.82 6.38	10.03 2.04	68.60 0.51
Excretion		**59.44 (90%)**	**7.99 (80%)**	**68.09 (99%)**
Intake Retention	High (305 kg)	76.60 7.32	12.42 2.44	75.09 0.61
Excretion		**69.28 (90%)**	**9.98 (80%)**	**74.48 (99%)**

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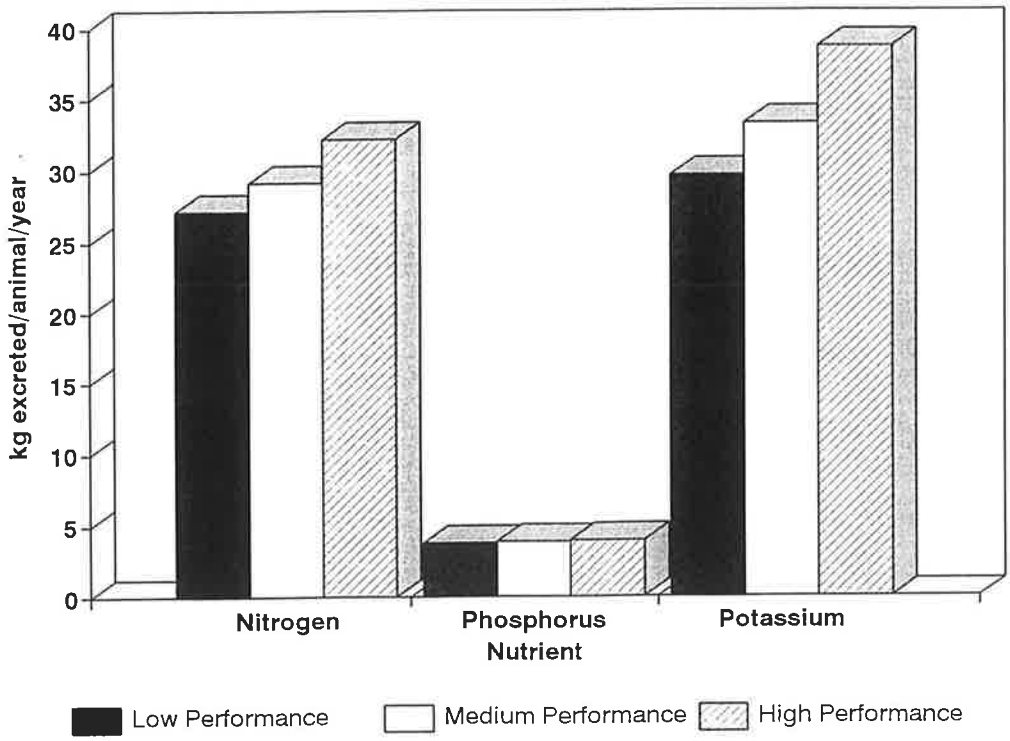

Figure 3.2. The quantity (kg) of N, P and K excreted by low (195 kg), medium (225 kg) and high (250 kg) performance 0-1 year beef cattle.

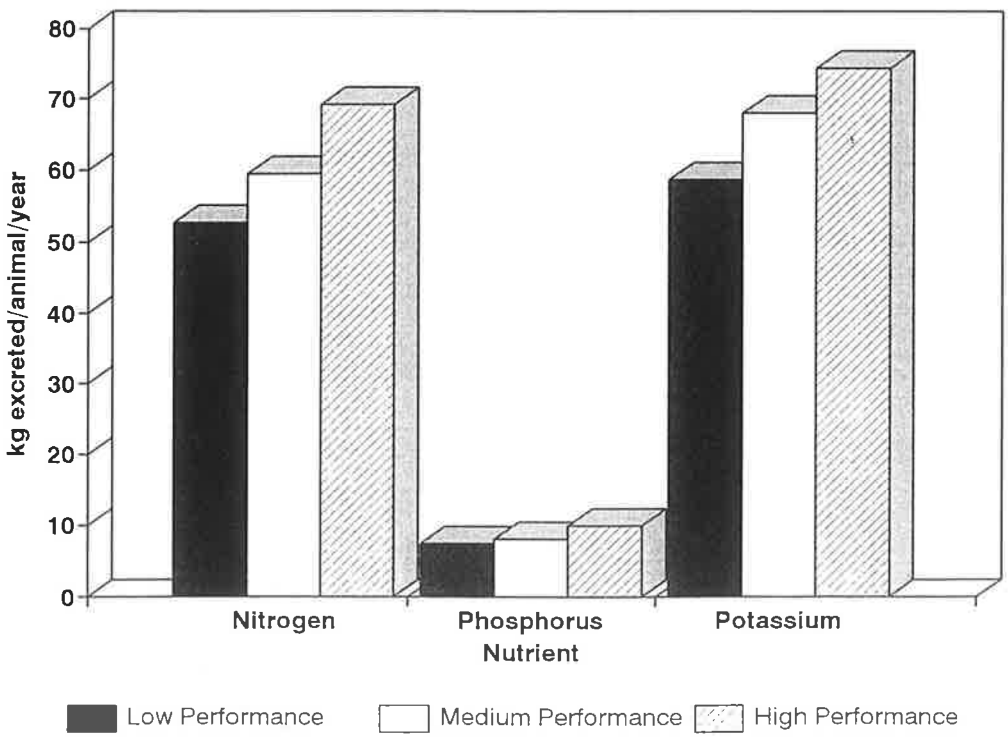

Figure 3.3. The quantity (kg) of N, P and K excreted by low (170), medium (255 kg) and high (305 kg) performance 1-2 year beef cattle.

An "average" 0-1 year beef animal gaining 225 kg annually has an intake of 35, 6 and 34 kg of N, P and K, respectively. Eighty three, 68 and 99% of the N, P and K ingested is excreted. An average 1-2 year beef animal graining 255 kg annually has an intake of 66, 10 and 69 kg of N, P and K, respectively. Sixty, 8 and 68 kg of the N, P and K, respectively are excreted.

3.2.3. Pig Systems

Pig production in Ireland has shown a steady increase over the last number of years having been cyclical over several decades as periods of market over supply and low prices were followed by falls in the breeding herd and periods of relative scarcity.

The present population of pigs is about 1.42 m which includes breeders, weaners and finishers in addition to 150,000 breeding sows (Drennan, 1993). Output is now close to about 3 m pigs per year with 40% for home consumption and 60% for export. The average production per sow in Ireland at present is 20 piglets per year with a productive life of about five litters (Lynch, 1993).

There are three basic types of pig production system, integrated, weaner and fattener. In the integrated system the pigs are fed from birth to slaughter weight (90 kg liveweight) at approximately 23 weeks old. For the weaning system the pigs are fed from birth to about 30 kg liveweight at approximately 12 weeks old and then sold to a fattener unit. In the fattener system, the weaners are fed for about 13 weeks at which stage they are ready for slaughter at about 90 kg.

Virtually all pig houses, regardless of the production system have slatted floors with the slurry stored in either under or over ground tanks. They all have mechanical ventilation systems. The pig industry is a major user of home grown cereals and provides the feed manufacturing industry with a year round market. However, home compounding of feed is increasing as producers use

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computerised wet feed system to blend a limited range of ingredients and sometimes by-product feeds such as whey and molasses.

TABLE 3.7: Annual production and intake parameters for weaner (based on 20 piglets per sow per year), fattener (based on 4.5 fatteners per place per year) and integrated systems (based on 20 piglets per sow per year) systems (Lynch, 1993).

WEANER	Production (kg)
Growth of Sow	35
Growth of Piglets (20)	600
Intake (kg DM)	
Sow	1100
Piglets	20
Weaners	910
FATTENER	
Growth	
Fatteners (30-90 kg) x 4.5	270
Intake (kg DM)	
Fatteners 160 x 4.5	720
INTEGRATED	
Growth	
Growth of Sow	35
Growth of Pig	1800
Intake (kg DM)	
Sow	1100
Piglets	20
Weaners	910
Fatteners	3200

The annual production or output and intake parameters for the three production systems are shown in Table 3.7. For the purpose of this study only single production parameters are used unlike the balances for dairy cows or beef cattle. The values used for sow production, feed intake and number of fattener pigs produced per place each year are "averages". In practice these will vary from pig unit to pig unit.

The average composition of the growth (meat) and intake variables for the three pig production systems are summarised in Table 3.8.

TABLE 3.8: The nutrient composition of the growth (meat) and intake variables for weaner, fattener and integrated pig production systems.

Variables	Nitrogen	Phosphorus	Potassium	Source
	(g kg^{-1})			
Growth				
Sow	23.0	5.0	2.0	A.R.C, 1981
Piglet	24.0	5.1	2.3	A.R.C, 1981
Weaner	24.0	5.1	2.3	A.R.C, 1981
Fattener	23.0	5.0	2.0	A.R.C, 1981
Feed				
Sow	27.0	6	8	Lynch, 1993
Piglet	33.0	7	9	Lynch, 1993
Weaner	32.0	7	9	Lynch, 1993
Fattener	28.0	6	8	Lynch, 1993

A NBM for the three production systems was calculated using data from Tables 3.7 and 3.8 using the same approach described for dairy cows. The results are presented in Table 3.9 and Figures 3.4.

The annual N intake for weaners, fatteners and integrated systems was 59, 20 and 149 kg per place, respectively. Corresponding N retention were 15, 6 and 42 kg per place, respectively. The annual

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N excretions were 44, 14 and 107 kg per place. Approximately 70% of the N ingested is excreted for all production systems (Table 3.9).

TABLE 3.9: Nutrient balance for weaner, fattener and integrated pig production systems.

	System	Nitrogen	Phosphorus	Potassium
		(kg unit of system^{-1})		
Intake	Weaner	59.48	13.11	17.17
Retention		15.21	3.24	1.45
Excretion		**44.27 (74%)**	**9.87 (75%)**	**15.72 (92%)**
Intake	Fattener	20.16	4.32	5.76
Retention		6.21	1.35	0.54
Excretion		**13.95 (69%)**	**2.97 (69%)**	**5.22 (91%)**
Intake	Integrated	149.08	32.31	42.77
Retention		42.21	9.18	3.67
Excretion		**106.87 (72%)**	**23.13 (72%)**	**39.10 (91%)**

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The annual P intake for weaners, fatteners and integrated systems was 13, 4 and 32 kg per place, respectively. Corresponding P retention were 3, 1 and 9 kg per place, respectively . The annual P excretions were 10, 3 and 23 kg per place for weaners, fatteners and integrated systems, respectively. Approximately 70% of the P ingested is excreted for all production systems (Table 3.9). It is interesting to note that the P excretion from the integrated unit is almost twice that of an average dairy cow, three times that of a 1-2 year beef animal and six times that of a 0-1 year beef animal (Tables 3.3 and 3.6). This relatively high P excretion combined with the relatively large size of the pig units is responsible for the very high surface water pollution potential associated with intensive pig enterprises

The annual K intake for weaners, fatteners and integrated systems was 17, 6 and 43 kg per place, respectively. Corresponding K retention were 1.5, 0.5 and 3.7 kg per place, respectively. The annual K excretions were 16, 5 and 39 kg per place for the weaner, fattener and integrated systems respectively. Approximately 91% of the K ingested is excreted for all production systems (Table 3.9).

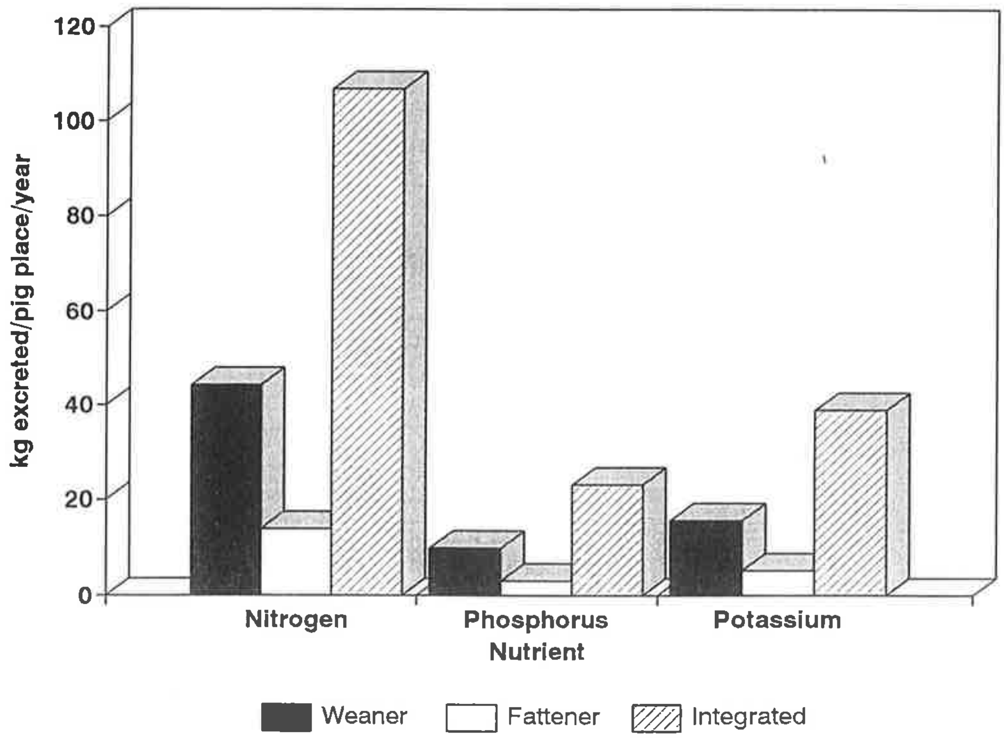

Figure 3.4. The quantity (kg) of N, P and K excreted by weaner, fattener and integrated pig units.

3.2.4. Poultry Systems

The Irish commercial poultry industry has developed from the 1950's to be one of the most modern systems of animal production in Ireland. The industry is divided into meat and egg production, and at the present time the annual production is approximately 50 m broilers, 4 m turkeys, and about 1 m layers (Drennan, 1993). Broilers have a rapid growth rate and are fed ad-lib to ensure rapid development. Depending on market demands, they are slaughtered at 45 days for small birds or at 56 days for large birds (Mannion, 1993).

The rearing of broilers is carried out in controlled environment houses incorporating computer controlled systems of ventilation, feed and weight recording. The end product *i.e.* well presented processed birds with good feed efficiency is dependent on, among other factors good litter management. Litter comprises of wood shavings or quality chopped straw. Poor litter conditions can result in disease and downgrading of the carcasses.

Layers start production at 18 weeks old and the average production period is 54 weeks. They are then either slaughtered or rested (moulted) for 6 weeks and then produce for a final period of 35 weeks (Mannion, 1993).

Commercial egg production is operated on a battery house system. The birds are housed in cages in controlled environment houses. Feed, water and egg collection are generally automatic. The cages are either erected over a manure storage pit where droppings are allowed to build up and removed at the end of the laying period *i.e.* average 54 weeks or a belt cleaning system removes the droppings each week to an outside storage pit.

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The production or output and intake parameters for layers and broilers are summarized in Table 3.10. As for the pig production systems only single production parameters are used. The values used for production, feed intake and number of broiler cycles produced per place each year are "averages". In practice these will vary from unit to unit as will the quantity of concentrate fed.

TABLE 3.10: The annual production and intake parameters for layers and broilers (based on 6 production cycles per annum for broiler) (Mannion, 1993).

		Production (kg)
Production		
Layers - Egg		18.00
Growth		0.55
Broiler		12.60
Intake (kg DM)		
Layers		45.00
Broilers	Starter	3.50
	Grower	6.00
	Finisher	15.06

The nutrient composition of the production and intake variables for layers and broilers are summarised in Table 3.11.

A NBM for the two production systems was calculated using data from Tables 3.10 and 3.11 using the same approach described for dairy systems above. The results are presented in Table 3.12 and Figure 3.5.

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TABLE 3.11: The nutrient composition for the production and intake variables for layers and broilers.

Variables	Nitrogen	Phosphorus	Potassium	Source
	(g kg^{-1})			
Layers				
Eggs	18.00	2.10	1.22	McDonald *et al.*, 1988
Growth	30.40	6.20	1.85	Van der Hook, 1992
Broilers:				
Growth	30.40	4.80	1.50	Van der Hook, 1992
Feed Intake				
Layers	27.20	5.50	6.50	Mannion, 1993
Broilers Starter	36.80	6.00	8.50	Mannion, 1993
Grower	33.60	6.00	8.50	
Finisher	30.40	6.00	8.50	

TABLE 3.12: Nutrient balance for layers and broilers.

	Poultry Type	Nitrogen	Phosphorus	Potassium
		(kg bird^{-1})		
Intake	Layer	1.22	0.25	0.29
Retention		0.34	0.04	0.02
Excretion		**0.88 (72%)**	**0.21 (84%)**	**0.27 (93%)**
Intake	Broiler	0.78	0.144	0.204
Retention		0.36	0.060	0.018
Excretion		**0.42 (54%)**	**0.084 (58%)**	**0.186 (91%)**

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The annual N intake for layers and broilers was 1.22 and 0.78 kg per bird, respectively. Corresponding retention were 0.34 and 0.36 kg per bird, respectively. The annual N excretions were 0.88 and 0.42 kg for a layer and a broiler, respectively. The fraction of ingested N excreted was 72% for layers and 54% for broilers (Table 3.13).

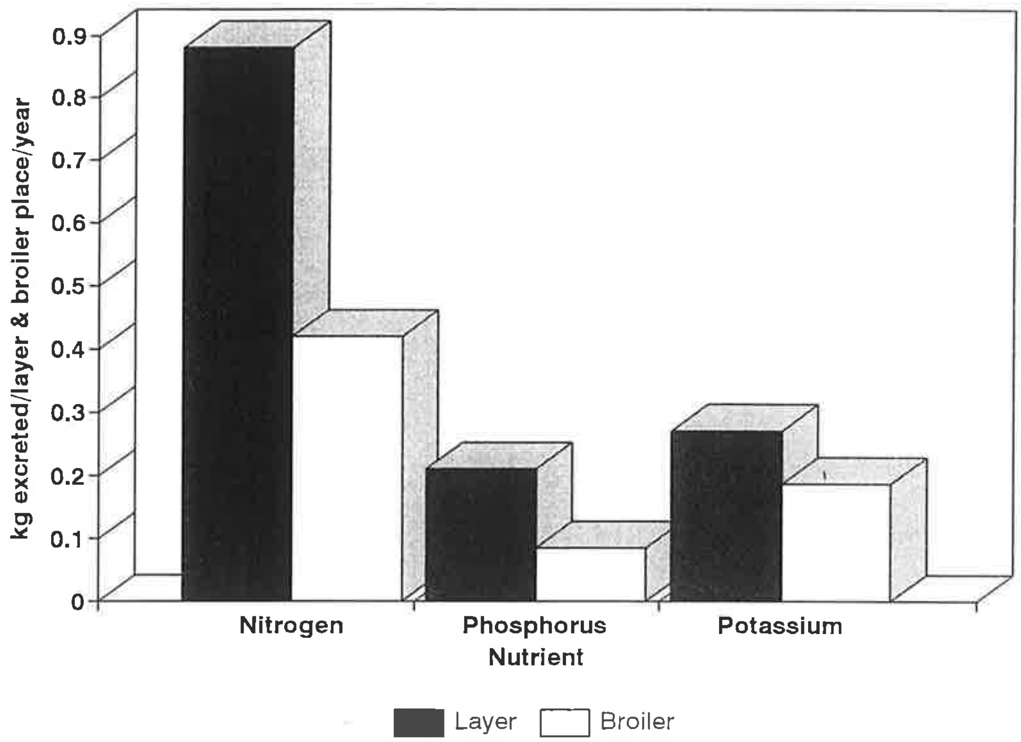

Figure 3.5. The quantity (kg) of N, P and K excreted annually per layer and broiler place.

The annual P intake for layers and broilers was 0.25 and 0.144 kg per bird, respectively. Corresponding retentions were 0.04 and 0.06 kg per bird, respectively. The annual P excretions were 0.21 and 0.084 kg for a layer and a broiler, respectively. The fraction of ingested P excreted was 84% for layers and 58% for broilers (Table 3.12).

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The annual K intake for layers and broilers was 0.29 and 0.204 kg per bird, respectively. Corresponding retention were 0.02 and 0.018 kg per bird, respectively. The annual K excretions were 0.27 and 0.186 kg for a layer and a broiler, respectively. The fraction of ingested K excreted was 93% for layers and 91% for broilers (Table 3.12).

3.3. SUMMARY

The calculated nutrient excretion for dairy cow, cattle pig and poultry production systems (Tables 3.3, 3.6, 3.9 and 3.12) indicate they are inefficient converters of feed nutrients into animal product - milk, meat or eggs. A large fraction of the nutrients in the feed is excreted in the manure. The data derived and presented show that from 54 to 93% of the N intake is excreted. The broiler chicken is the most efficient converter of N to animal product while the 1-2 year beef animal is the poorest converter. A similar situation exists for P. The excretion of K for all animal production systems is greater than 88% and as high as 99% for beef animals. These NBM's clearly indicate the potential of animal manures as sources of nutrients in all farming systems. The data could be used to highlight this fact to farmers. It should clearly indicate that the requirement for inorganic fertilisers on most farms is lower than farmers tend to believe.

Two summary tales have been compiled. The first presents the data on the nutrient composition of the major diet constituents for Irish farming systems (Table 3.13). The second assembles the data on the nutrient composition of the main animal products from the production system (Table 3.14). The final table presents a summary of the NBM components *i.e.* nutrient intakes, retention and excretions for dairy cows, 0-1 and 1-2 year beef cattle, weaner, fattener and integrated pig production systems and both layer and broiler systems (Table 3.15).

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The NBM for three systems of pig production derived in this study is very similar to the model proposed by Lynch (1992). The differences in P excretion between the two models can be accounted for by differences in feed intakes. Van der Hook (1992) developed NBMs for a range of Dutch farming systems. There is general agreement between the Dutch NBMs and the models presented in this thesis. However, the balance, or quantity of nutrients in the excreta, tends to be higher for the Dutch grassland systems. This reflects higher concentrate use on Dutch compared with Irish farms.

The potential use of the NBM models proposed are twofold. Firstly, they offer an opportunity to quickly assess the expected nutrient output from a range of Irish farming systems. These can be used by Local Authorities in assessing the nutrient loads associated with proposed agricultural developments. It offers greater accuracy in estimating the nutrient load than the volumetric approach currently being used. The volume of manures produced by the animals is multiplied by its average nutrient value. This can at best only provide a rough estimate. The NBM approach proposed here offers an improved and more realistic measure of nutrient load. The relationships between the NBM balances developed and a measured input/output balance on a number of different farm types is presented in Chapter 4.

The second use of NBM is as a means of providing an easy to use estimator of the nutrient value of farm slurries. This is evaluated in Chapter 5.

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TABLE 3.13: The nutrient composition of the main diet constituents for dairy cows, beef cattle, pigs and poultry production systems.

Production System	Feed	Nitrogen	Phosphorus	Potassium	Source
			($g\ kg^{-1}$)		
Dairy Cows	Grass	23.0	3.5	26.0	Drennan, 1994.
	Silage	23.0	3.0	25.0	Drennan, 1994.
	Concentrates	28.0	7.0	10.0	Murphy, 1994.
Beef Cattle	Grass	23.0	3.5	26.0	Drennan, 1994.
	Silage	23.0	3.0	25.0	
	Concentrates	28.0	6.0	10.0	
Poultry					
Broilers	Ration	27.2	5.5	6.5	Mannion, 1993
Layers	Starter	36.8	6.0	8.5	
	Grower	33.6	6.0	8.5	
	Finisher	30.4	6.0	8.5	
Pigs	Sows	27.0	6.0	8.0	Lynch, 1993
	Piglets	33.0	7.0	9.0	
	Weaners	32.0	7.0	9.0	
	Fatteners	28.0	6.0	8.0	

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TABLE 3.14: The nutrient composition of animal products for dairy cows, beef cattle, pigs and poultry systems.

Production System	Product	Nitrogen	Phosphorus	Potassium	Source
			(g kg^{-1})		
Dairy Cows	Milk	5.0	0.9	1.4	McCance & Widdowson
	Growth	24.0	1.8	1.8	ARC, 1980
	Calf	26.0	8.0	2.0	ARC, 1980
Beef Animals					
(0-1)	Growth	26.0	8.0	2.0	ARC, 1980
(1-2)	Growth	24.0	8.0	2.0	
Pigs (Sow)	Growth	23.0	5.0	2.0	ARC 1981
(Piglet)	Growth	24.0	5.1	2.3	
(Weaner)	Growth	24.0	5.1	2.3	
(Fattener)	Growth	23.0	5.0	2.0	
Poultry (Layer)	Eggs	18.0	2.1	1.22	McDonald, Edwards & Greenhalgh, 1988
(Layer)	Growth	30.4	6.2	1.85	van der Hook 1992
(Broiler)	Growth	30.4	4.8	1.50	van der Hook 1992

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TABLE 3.15: The nutrient intake, retention and excretion of dairy cows, beef cattle, pigs and poultry in typical production systems.

Production System	Animal Type	Intake			Retention kg Animal^{-1}			Excretion		
		N	P	K	N	P	K	N	P	K
Dairy	Low Performance	104.60	16.65	107.50	22.52	4.26	6.00	**82.08**	**12.39**	**101.50**
	Med Performance	118.40	18.65	122.90	29.52	5.50	7.95	**88.88**	**13.15**	**114.95**
	High Performance	132.20	20.65	138.30	36.52	6.78	9.91	**95.68**	**13.87**	**128.39**
Beef (0-1)	Low Performance	32.20	5.29	30.10	5.07	1.56	0.39	**27.13**	**3.73**	**29.71**
	Med Performance	35.03	5.63	33.75	5.85	1.80	0.45	**29.18**	**3.83**	**33.30**
	High Performance	38.75	5.94	39.15	6.50	2.00	0.51	**32.25**	**3.94**	**38.64**
(1-2)	Low Performance	56.87	8.73	59.02	4.08	1.36	0.34	**52.79**	**7.37**	**58.68**
	Med Performance	65.82	10.03	68.60	6.38	2.04	0.51	**59.44**	**7.99**	**68.09**
	High Performance	76.60	12.42	75.09	7.32	2.44	0.61	**69.28**	**9.98**	**74.48**
Pigs	Integrated	149.08	32.31	42.77	42.21	9.18	3.67	**106.87**	**23.13**	**39.10**
	Weaner	59.48	13.11	17.17	15.21	3.24	1.45	**44.27**	**9.87**	**15.72**
	Fattener	20.16	4.32	5.76	6.21	1.35	0.54	**13.95**	**2.97**	**5.22**
Poultry	Layer	1.22	0.25	0.29	0.34	0.04	0.02	**0.88**	**0.21**	**0.27**
	Broiler	0.78	0.144	0.204	0.36	0.060	0.018	**0.42**	**0.084**	**0.186**

CHAPTER 4

NUTRIENT BALANCES ON TYPICAL FARMS

4.1. INTRODUCTION

The objective of the work was to develop nutrient balances on a number of farms using input/output data supplied by the farmer. The resulting input/output nutrient balance was compared with the NBM's from the balance models in Chapter 3. This approach was taken to provide a test of the NBM's and highlight any problems that might arise when practically applying them. A total of seven farms were visited. These included two dairy, two beef, one integrated pig unit, a broiler farm and a layer farm. All of the farms except the layer farm were in County Offaly. The farms were surveyed in February 1994.

4.2. FARM SURVEY AND NUTRIENT BALANCES.

A standardized questionnaire was designed to assist with the data collection on the farm (Appendix 1). The objective was to ensure all relevant nutrient input/output data was collected. The form was supplied to the farmer a week before the visit to record the data. This was to allow the farmer to gather all relevant invoices, record sheets and sales documents.

4.2.1. Dairy farms

Two dairy farms were selected. These were Rosemount and Horseleap farms. Rosemount is a 63 ha liquid milk farm. Stock numbers and type are given in Table 4.1. Approximately 20% of the calves are kept for dairy herd replacements. The overwintering facilities include slatted units and

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a large concrete base for silage (Appendix 2). The milking cows are overwintered separate from the dry cows and replacements. Measured slurry storage capacity was 440 m^3 for the dairy cows. The tank had to emptied during the winter as slurry production from the cows was 900 m^3. Slurry storage for the dry stock was 300 m^3 which was adequate for the indoor winter period.

The nutrient imports, as fertilisers and concentrates, to the farm were calculated. A total of 17.5t of fertiliser was purchased in 1993. This consisted of 4.31, 0.43 and 1.20 t of N, P and K, respectively. Eighty tons of concentrates were purchased. This was equivalent to the import of 2.25, 0.55 and 0.79 t of N, P and K, respectively onto the farm.

The nutrient exports from the farm were calculated from milk and meat sales and the data is summarized in Table 3.14. Milk accounted for the export of 1.50, 0.27 and 0.42 t of N, P and K, respectively. Meat (sales of calves and dry cows) resulted in the export of 0.23, 0.07 and 0.02 t of N, P and K, respectively.

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TABLE 4.1: Stock numbers and type on Rosemount and Horseleap dairy farms in February 1994.

Stock Type	Rosemount	Horseleap
Cows	72	72
Dry cows	10	14
Replacements	16	20
Calves born	69	70
Calves sold	34	47
0-1 year	20	15
1-2 year	5	6

Horseleap farm is similar in size and stock number (Table 4.1) to Rosemount with 57 ha of grassland and 72 cows producing liquid milk. Stock numbers are given in Table 4.1. The overwintering facilities are similar to Rosemount but all stock are housed in the one facility (Appendix 3). Slurry storage capacity was 472 m^3 and the estimated overwintering production was 909 m^3.

The nutrient imports, as fertilisers and concentrates, to the Horseleap farm were calculated from the data provided by the farmer during the survey. A total of 32 t of fertiliser was purchased in 1993. This consisted of 7.12, 0.80 and 3.1 t of N, P and K, respectively. Eighty tons of concentrates were purchased. This was equivalent to the import of 2.31, 0.55 and 0.71 t of N, P and K, respectively onto the farm.

The nutrient exports from the farm were calculated from milk and meat sales and the data is presented in Table 3.14. Milk accounted for 1.73, 0.31 and 0.49 t of N, P and K, respectively. Meat (sales of calves and dry cows) resulted in the export of 0.39, 0.10 and 0.02 t of N, P and K, respectively.

An input/output balance was constructed using these data and the results are presented in Table 4.2. Nutrient inputs to Horseleap farm were higher than to Rosemount farm reflecting their higher use of fertilisers in 1993. Concentrate use was similar on both farms. Nutrient outputs or exports were higher on Horseleap reflecting the higher sales of calves and dry cows. The nutrient balance shows the percentage of nutrients remaining on the farm in the manure is equivalent to 76, 67 and 83% of the imported N, P and K, respectively. These percentages are similar to those for dairy cows in Table 3.3.

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An NBM estimate of the farm nutrient balance was also made using stock numbers and the nutrient input and balance data from Table 3.15. The results are included in Table 4.2.

TABLE 4.2: The nutrient input/output balance for two dairy farms in Offaly and the NBM estimate based on stock numbers and the data in Table 3.15.

	---------- Rosemount ----------			---------- Horseleap ----------		
	N	P	K	N	P	K
<u>Inputs (t)</u>						
Fertiliser	4.31	0.43	1.20	7.12	0.80	3.10
Concentrates	2.25	0.55	0.79	2.31	0.55	0.71
Total	6.56	0.98	1.99	9.43	1.35	3.81
NBM Estimate	*10.60*	*1.66*	*10.96*	*10.76*	*1.68*	*11.13*
<u>Outputs (t)</u>						
Milk	1.50	0.27	0.42	1.73	0.31	0.49
Meat	0.23	0.07	0.02	0.39	0.10	0.02
Total	1.73	0.34	0.44	2.12	0.41	0.43
BALANCE	**4.83**	**0.64**	**1.55**	**7.31**	**0.94**	**3.38**
Model Balance	***8.23***	***1.19***	***10.35***	***8.39***	***1.22***	***10.53***

There were large and variable discrepancies between the N, P and K input/output balance and the NBM balance. These were larger on Rosemount compared with Horseleap farm. The NBM uses input data based on "average" grass and silage intakes multiplied by "average" nutrient values. These are shown in Table 4.2. The differences between the NBM input and the fertiliser and concentrate inputs of the input/outputs balance explain the differences between the two nutrient balances (Table 4.2). The difference in the two estimates of nutrient inputs appears to indicate that the soil is making a contribution to nutrient inputs. It is acting as a nutrient buffer absorbing surpluses and releasing nutrients when nutrient inputs are less than crop requirements. There is

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some indication of this in the data. Both farms are of the same size with similar stocking rates. Yet the fertiliser inputs to Horseleap are almost twice those for Rosemount. The input/output nutrient balance estimate for Horseleap is much closer to the NBM balance than for Rosemount (Table 4.2). This is because the nutrient inputs as fertiliser are higher and there was a lower nutrient requirement from the soil reserves. Another consideration in attempting to reconcile the input/output and the NBM balances is the accuracy of the farm data. Every effort was made during the survey to ensure the data collected was correct. However, it is recognised that there could be some inaccuracies.

This data indicates that a nutrient input for grassland farms based on fertilisers and concentrates may underestimate the real nutrient inputs. Therefore, the use of an input/output model for estimating nutrient balances on grassland farms without some means of accounting for the contribution of the soil to the balance may not provide a good indication of actual nutrient balances. However, the NBM approach on these farms is still a useful approach to highlight nutrient retention on the farm in the manure. This can provide the stimulus to farmers to examine more closely nutrient efficiency. A more careful approach to nutrient management on the farm will have a positive environmental effect as well as reducing farm costs through lower fertiliser bills.

4.2.2. Beef farms

Two beef farms were selected. These were Shanvalley and Boyanna farms. Shanvalley farm, 16 ha, operates a beef producing system based on the purchase of cattle in the autumn at 450 kg liveweight and selling them to the meat factory within 12 months. The newly purchased animals, on average 25 head (1-2 year), are kept indoors over the winter. They are fed silage and some concentrates. The animals are turned out to grass in spring and are sold during the summer as they reach factory weight. For this evaluation 25 animals were housed for the period. The

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overwintering facility is new. It consists of a slatted floor shed with a concrete silage base (Appendix 4). There is a slurry storage capacity of 123 m^3 which is just short of the expected production of 138 m^3.

A total of 8.5 and 2 t of fertilisers and concentrates, respectively, were purchased. The N, P and K inputs from fertilisers were 1.32, 0.31 and 1.10 t, respectively. The nutrient inputs from concentrates was small at 0.05, 0.01 and 0.02 t of N, P and K, respectively.

The nutrient exports or outputs from the farm were calculated on the animal liveweight gained and the data in Table 3.5 for its nutrient composition. This was estimated at 0.16, 0.05 and 0.01 t of N, P and K, respectively.

The Boyanna beef farm, 27 ha, operates a similar production system as Shanvalley. Cattle are purchased in the autumn and sold off grass the following summer/autumn. Stock numbers were 16, 0-1 year and 26, 1-2 year animals. The overwintering facilities include a loose shed, exercise yard and a concrete silage base (Appendix 5). The manure is regularly removed from shed and exercise yard and stored in a dungstead.

A total of 8.5 and 7 t of fertilisers and concentrates, respectively, were purchased. The N, P and K inputs from fertilisers were 1.88, 0.55 and 1.10 t, respectively. The nutrient inputs from concentrates was 1.18, 0.05 and 0.06 t of N, P and K, respectively.

The nutrient exports or outputs from the farm were calculated on the sale of animal liveweight gained and the data in Table 3.5 for its nutrient composition. This was estimated at 0.21, 0.07 and 0.02 t of N, P and K, respectively.

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A nutrient input/output balance was constructed for both farms based on the above data (Table 4.3)

TABLE 4.3: The nutrient input/output balance and model balance for two beef farms in Offaly.

Inputs	Shanvalley			Boyanna		
	N	P	K	N	P	K
Fertiliser	1.32	0.31	1.10	1.88	0.55	1.10
Concentrates	0.05	0.01	0.02	1.18	0.05	0.06
Total	1.37	0.32	1.12	3.06	0.60	1.16
NBM Estimate	*1.64*	*0.25*	*1.72*	*2.27*	*0.35*	*2.32*
Outputs						
Meat	0.16	0.05	0.01	0.21	0.07	0.02
Total	0.16	0.05	0.01	0.21	0.07	0.02
BALANCE	1.21	0.27	1.11	2.85	0.53	1.14
NBM Balance	***1.49***	***0.19***	***1.70***	***2.00***	***0.27***	***2.30***

The N and P input/output balance for Shanvalley was half that for Boyanna reflecting the higher fertiliser nutrient input on the latter. As with the two dairy farms there was a poor correlation between the input/output balance and the NBM balance estimate. The difference in the inputs between the NBM estimate and the actual nutrient inputs in the fertiliser and concentrate largely account for the discrepancies. This exercise supports the arguments made above that the soil is acting as a nutrient buffer in the system. In high soil fertility situations the production of grass and silage to meet the feed requirements of the animals can be met by the soil reserves. Therefore, the effect of added nutrients on the input/output balance will be relatively small unless account is taken of changes in soil fertility. In low soil fertility situations, where the nutrient reserves are not sufficient to produce the forage required by the animals then the fertiliser and concentrate inputs

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will be of greater importance.

Therefore, the benefit of a nutrient input/output balance on grassland farms is questionable. The results presented here highlight the importance of the soil as a nutrient buffer in the system. It also raises questions about the reliability of input/output nutrient balances like that of Tunney (1990). Therefore, great care should be exercised in interpreting this type of data. It is a very useful tool to illustrate general trends of excessive deficient nutrient inputs. Their value as an indicator of the extent of the surplus must be suspect based on the results presented here.

The NBM estimate of nutrient balance appears to be useful. It should provide an indication of the fertiliser requirements where soil fertility levels are adequate to support current crop production levels. However, the above exercise clearly indicates the need to consider soil fertility levels before making final fertiliser recommendations for crop production.

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4.2.3. Pig farms

One pig farm, Derrygolan, was surveyed. This was a 300 sow integrated unit. Feeding is by a computerised wet feeding system. All slurry is stored in underground tanks (Appendix 6). The stock on the farm at the time of the visit consisted of 300 sows, 40 gilts, 12 boars, 600 piglets, 620 weaners and 1750 fatteners. Sales off the farm in the last year were 6,150 fat pigs (88 kg) and 120 cull sows (210 kg), and using data in Table 3.8 this represented a N, P and K output of 13.28, 3.16, 1.27 t respectively. Feed intake was 415 t for the breeding herd, 31.6 t for the piglets, 132 t for weaners and 1173 t for the fatteners. The nutrient inputs from concentrates was 55.61, 11.38, 17.50 t of N, P and K, respectively.

A nutrient input/output balance was constructed for the farm and the data is presented in Table 4.4.

TABLE 4.4: The nutrient input/output balance and model balance for an integrated pig farm in Offaly.

Inputs	N	P	K
Concentrates	55.61	11.38	17.50
Total	55.61	11.38	17.50
NBM Estimate	*44.72*	*9.69*	*12.83*
Outputs			
Meat	13.28	3.16	1.27
Total	13.28	3.16	1.27
BALANCE	**42.33**	**8.22**	**16.23**
NBM Balance	***32.06***	***6.94***	***11.73***

The nutrient input/output balance showed 42, 8 and 16 t of N, P and K, respectively, in the manure. This significant nutrient surplus is in sharp contrast to the surpluses on the dairy and beef farms (Tables 4.2 and 4.3). It reflects the reliance of the pig unit on imported concentrates compared with grassland farms. However, the NBM balance estimate are approximately 30% lower than the input/output balance. This resulted from the significantly lower nutrient inputs in the NBM compared with actual feed used on the farm (Table 4.4). The total feed used on the farm was 1751 t whereas the NBM used a feed input of 1347 t. This difference in nutrient intake accounted for the difference in the two balance estimates.

Constructing a nutrient balance model for a pig unit is relatively easy. The only nutrient input is the feed and the only nutrient output is the meat. A simple model can provide a reasonable estimate of the nutrient balance. However, the above "validation" stresses caution is required in interpreting the results. The NBM approach proposed in Chapter 3 for pig farms uses "average"

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feed intake values. Consequently actual feeding levels above or below it will have a significant impact on the overall result. A potential use of the NBM is calculating the nutrient loads generated by pig farms. The importance for the users of the data *i.e.* Local Authorities or pig farmers are therefore significant. Some effort is required to agree the "average" feed input for Irish pig units and to incorporate this data into the model. If this approach is pursued the model is potentially a very useful tool.

4.2.4. Poultry farms

Two poultry farms were selected and surveyed. The Doon Farm, was a broiler unit producing 28,000 birds per batch. The broiler house is well insulated and is air conditioned (Appendix 7). Bedding is a 100 mm layer of woodchippings which is replaced for each new batch. Feeding is a dry system and is managed by a computer. The feed input was 117.5 t of concentrate. This is equivalent to 3.76, 0.71 and 0.99 t of N, P and K, respectively. Sales of 28,000 birds was recorded and this is equivalent to 1.85, 0.29 and 0.09 t of N, P and K , respectively based on the data for the nutrient composition of poultry meat in Table 3.11. The input/output nutrient balance is presented in Table 4.5.

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TABLE 4.5: The nutrient input/output balance and model balance per cycle for a broiler farm in Offaly.

Inputs	N	P	K
Concentrates	3.76	0.71	0.99
Total	3.76	0.71	0.99
NBM Estimate	*3.77*	*0.69*	*0.98*
Outputs			
Meat	1.85	0.29	0.09
Total	1.85	0.29	0.09
BALANCE	**1.91**	**0.42**	**0.90**
NBM *Balance*	***2.03***	***0.41***	***0.89***

The nutrient input/output balance showed 1.91, 0.42 and 0.90 t of N, P and K, respectively, in the manure. This compares very favourably with the NBM estimate. This close agreement between the two estimates suggests that the feed input data selected for the model may be appropriate. However, it must be stressed that this is a once only evaluation. It does indicate that a balance model could be used to determine the nutrient load in the manure from all broiler houses. It is again suggested that agreement is sought among the interested parties as to the feed input for broiler production.

The second poultry farm, Roscommon Farm, which produces eggs was also surveyed. It has 17,000 layers and produces 12,050 cases (360 per case) of eggs annually. The birds, layers, are kept in cages which are arranged in a stepped sequence with four birds in each cage (Appendix 8). Manure falls from the cages onto a moving belt which conveys it to an underground tank. The

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average layer has a production period of 54 week. Feeding is by a computerised dry feeding system. Annual feed input is 520 t with a nutrient value of 14.56, 2.86 and 3.38 t of N, P and K respectively. Annual sales of 12,050 cases of eggs is equivalent to 4.64, 0.56 and 0.33 t of N, P and K, respectively, based on the data for the nutrient composition of eggs in Table 3.11. All birds are also sold for slaughter and this represents a nutrient export of 0.28, 0.06 and 0.02 t of N, P and K, respectively. The input/output nutrient balance is presented in Table 4.6.

TABLE 4.6: The nutrient input/output balance and model balance for a layer farm.

Inputs	N	P	K
Concentrates	14.56	2.86	3.38
Total	14.56	2.86	3.38
NBM Estimate	*20.74*	*4.25*	*4.93*
Outputs			
Meat	0.28	0.06	0.02
Eggs	4.64	0.56	0.33
Total	4.92	0.62	0.35
BALANCE	**9.64**	**2.24**	**3.03**
NBM Balance	***14.96***	***3.57***	***3.03***

The input/output balance provides a lower estimate of the nutrient output, particularly N and P, than the NBM. This again arises from the feed input data used in the model. The model uses 45 kg of feed per bird per year. However, from the feed input data above it can be determined that the actual feed intake was just over 30 kg per bird per year. If an adjustment is made to allow for this in the model an improved correlation can be achieved. This re-emphasises the need to check the input data before using a farm nutrient balance model.

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4.3. SUMMARY.

In this study an attempt was made to validate the NBM for a range of production systems developed for this study. A number of farms were visited and data including stock number and type, nutrient inputs (fertiliser and concentrates), nutrient outputs (milk, meat, eggs) and stock number were recorded. These data were used to determine an annual nutrient input/output balance. The balance is the quantity of nutrients excreted by the animal. The NBM was also used to derive balances for the farms. The animal number and type on each farm provided the input data for the model.

For the pig and poultry farms there were good correlations between the balances derived from the model and the input/output balance. The comparisons showed that care is required in interpreting the NBM output. The use of the NBM on pig and poultry farms with higher or lower feed intakes than the "average" intakes used in the model could result in an incorrect balance for that particular farm. Equally, for broilers, differences between the actual number of cycles on individual units and "average"number of cycles per year used in the NMB, will have a significant impact on the resulting balance. However, both the NBM and input/output balance offer a rapid means of estimating the nutrient concentrations in the animal wastes. The NBM has the advantage of requiring only a minimum of easy to acquire farm data whereas the input/output model requires more detailed information that is not always available.

There was a very poor correlation between the calculated input/output balance and the NBM estimate for the grassland farms surveyed. There were up to sixfold differences in the balances for individual nutrients with NBM generally having the highest balance. This may have occurred because the input/output balance took no account of the soil contribution to the balance. However,

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they can still provide an estimate of the nutrient exports off the farm. For sustainable farming this can be used to provide an indication of the fertiliser requirements of the farm if soil nutrient levels are to be maintained at present levels.

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CHAPTER 5

ESTIMATING SLURRY NUTRIENT VALUE USING BALANCE MODEL

5.1. INTRODUCTION

The objective of the work presented here was to evaluate the potential of an input/output balance and the NBM model to provide a rapid estimate of the nutrient value of cattle slurry. Pig slurry was not included in this evaluation because of the difficulties with obtaining representative samples of pig slurry from storage tanks. Agitating pig slurry in storage tanks under the pig house is severely curtailed because of hydrogen sulphide emissions which could result in pig fatalities. Also the rapid settling of the suspended solids in pig slurry compared to cattle slurry increase the sampling difficulties. Without a representative slurry sample the validation exercise would be compromised.

The input/output balance is the difference between the nutrient intake in the feed and the nutrient offtake in animal product. The NBM developed for dairy cows and beef cattle, described in Chapter 3, provides an estimate of the quantity of nutrients excreted based on "average" intake and "average" production. Therefore, both approaches should provide an estimate of the nutrients load in the slurry collected from animals during indoor feeding period. NBM has the advantage over the intake/output approach in that it does not require the farmer to have accurate records of feed intake and nutrient composition nor animal performance data. Therefore, the NBM is potentially a very simple approach to provide the farmer with an estimate of the nutrient composition of his slurry.

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5.2. METHODS

A suitable dairy and cattle farm were selected for the evaluation. On both farms the slurry tanks were completely emptied before the animals were brought in for the winter. All the slurry produced by the animals over the period was collected and retained in the slurry tank on the beef farm. However, on the dairy farm the tanks were emptied during the winter. The volume removed was noted and added to the volume in the tank at the end of the indoor feeding period. There were 72 cows on the dairy farm while on the beef farm there were 85, 0-1 year and 75, 1-2 year beef cattle.

Both farmers provided information on the quantity of silage and concentrate fed to the animals. The silage fed was verified by estimating the volume removed from the pit using measurements made at the start and end of the overwintering feeding period. The concentrate fed was verified by reference to invoices. The milk production from the cows was taken from the creamery statements. An estimate of the calf growth during pregnancy was made based on the number of cows calving in the February/March period. This estimate made allowances for calves born before and after this period. The nutrient composition of the concentrate was provided by the feed compounder. A silage and slurry sample were taken in February for analysis. The volume of slurry produced during the period was also measured. The data collection and validation strategy was similar on the beef farm. Animal output as liveweight gain, was based on weighing during the winter period.

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5.3. RESULTS AND DISCUSSION

Dairy cows: The overwintering period for the dairy cows was 154 days. Silage and concentrate intake by the cows was 102 and 41 t, respectively. This represented a nutrient intake of 3.49, 0.59 and 3.47 t of N, P and K, respectively. Milk sales to the creamery for the period was 112,500 kg. An allowance was made for the foetal development of 50 calves during the feeding period. Using the data in the Table 3.15 an estimate of the nutrient output was made (Table 5.1). The input/output balance summary is shown in Table 5.1. It estimated that 2.88, 0.47 and 3.31 t of N, P and K should be in the slurry.

The NBM model estimate was derived by multiplying the N, P and K excretions from Table 3.15 (medium performance) by the number of cows, 72. This gave the annual nutrient output which was adjusted down for the 154 day winter period. The results are presented in Table 5.1. It estimated the N, P and K content of the slurry at 2.7, 0.40 and 3.49 t, respectively.

The total volume of dairy cow slurry produced during the period was 900 m^3. Following the agitation of the slurry a sample was taken for analysis. The N, P and K content was 2.61, 0.53, 3.92 kg t^{-1}, respectively with a dry matter content of 75 g kg^{-1}. It should be noted that compared with the "average" value of cattle slurry reported by O'Bric (1991), the N content of the slurry appears low - 2.61 *versus* 3.6 kg t^{-1}. The measured nutrient load in the slurry was calculated using the analysis results and the volume of slurry produced. The measured quantity of N, P and K in the slurry was 2.35, 0.47 and 3.52 t, respectively (Table 5.1). The NBM and input/output balance compare favourably with this value (Figure 5.1).

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TABLE 5.1: The nutrient content of the dairy cow slurry by i) input/output balance, ii) NBM and iii) measurement.

	N	P	K
Inputs (t)			
Silage and concentrate	3.49	0.59	3.47
Outputs (t)			
Milk, calf and growth	0.61	0.12	0.16
Input/Output Balance	**2.88**	**0.47**	**3.31**
NBM Estimate	**2.70**	**0.40**	**3.49**
Slurry (measured)	**2.35**	**0.47**	**3.52**

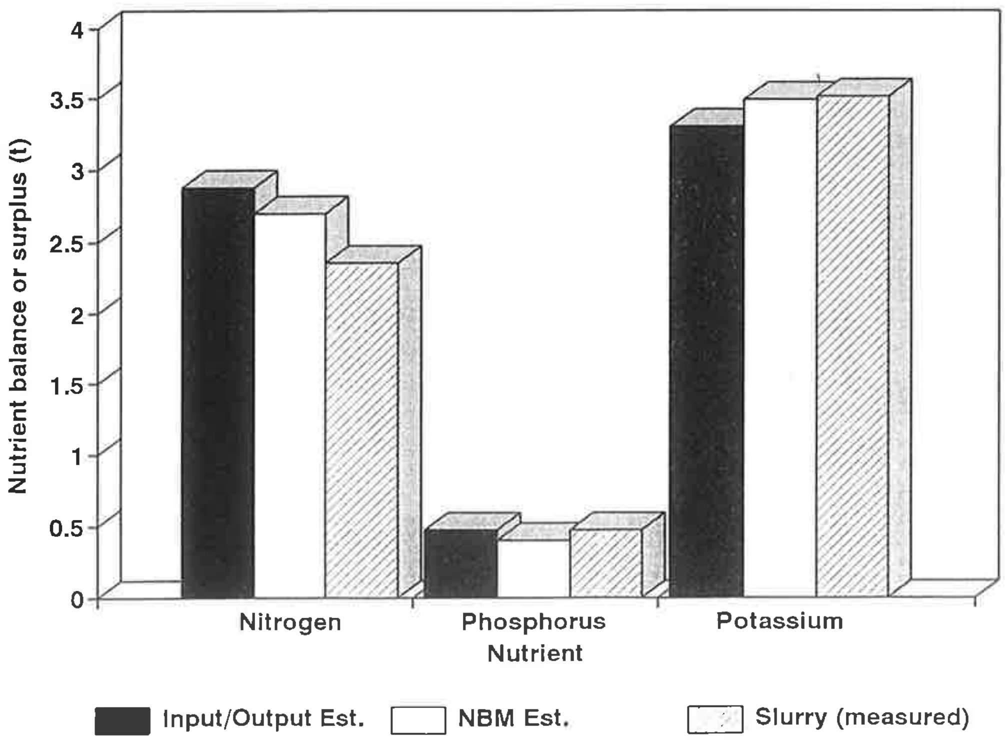

Figure 5.1. The nutrient content of a dairy cow slurry estimated by input/output balance, NBM and direct measurement.

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Beef Cattle: The overwintering period for the beef cattle was 144 days. Silage and concentrate intake was 126 and 23 t, respectively. The lower concentrate input for the beef cattle contrasts with that for the dairy cows. The nutrient intake by the cattle for the overwintering period was 3.47, 0.53 and 4.85 t, respectively. The average liveweight gains for the 0-1 year and 1-2 year animals was 0.50 and 0.75 kg head^{-1} day^{-1}, respectively. Total liveweight gain for the herd was 13.81 t which had a N, P and K content of 0.36, 0.11 and 0.03 t, respectively. The input/output balance summary is shown in Table 5.2. The estimated N, P and K balance was, 3.11, 0.42 and 4.82 t, respectively.

TABLE 5.2: The nutrient content of the cattle slurry by i) input/output balance, ii) NBM and iii) measurement.

	N	P	K
Inputs (t)			
Silage and concentrate	3.47	0.53	4.85
Outputs (t)			
Growth	0.36	0.11	0.03
Balance	**3.11**	**0.42**	**4.82**
NBM Estimate	**2.66**	**0.36**	**3.05**
Slurry (measured)	**2.73**	**0.30**	**4.90**

The NBM model estimate was derived by multiplying the N, P and K excretions from Table 3.15 by the number of 0-1 and 1-2 year animals (both medium performance). This provided an estimate of the annual nutrient output and this was adjusted to 144 days, the length of the winter period.

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The results are presented in Table 5.2. It estimated the N, P and K content of the slurry at 2.7, 0.36 and 3.05 t, respectively.

The total volume of slurry produced during the period was 909 m^3. Following the agitation of the slurry a sample was taken for analysis. The N, P and K content was 3.0, 0.33 and 5.4 kg t^{-1}, respectively, with a dry matter content of 55 g kg^{-1}. The P content of the slurry was low at 0.3 kg t^{-1} compared with 0.6 kg t^{-1} and the K content high 5.4 kg t^{-1} compared with 4.3 kg t^{-1} reported by O'Bric (1991). The measured nutrient load in the slurry was calculated using the analysis results and the volume of slurry produced. The total quantity of N, P and K was measured at 2.73, 0.3 and 4.9 t, respectively (Table 5.2). This compares favourably with the quantities estimated by both the input output estimation and the NBM (Figure 5.2).

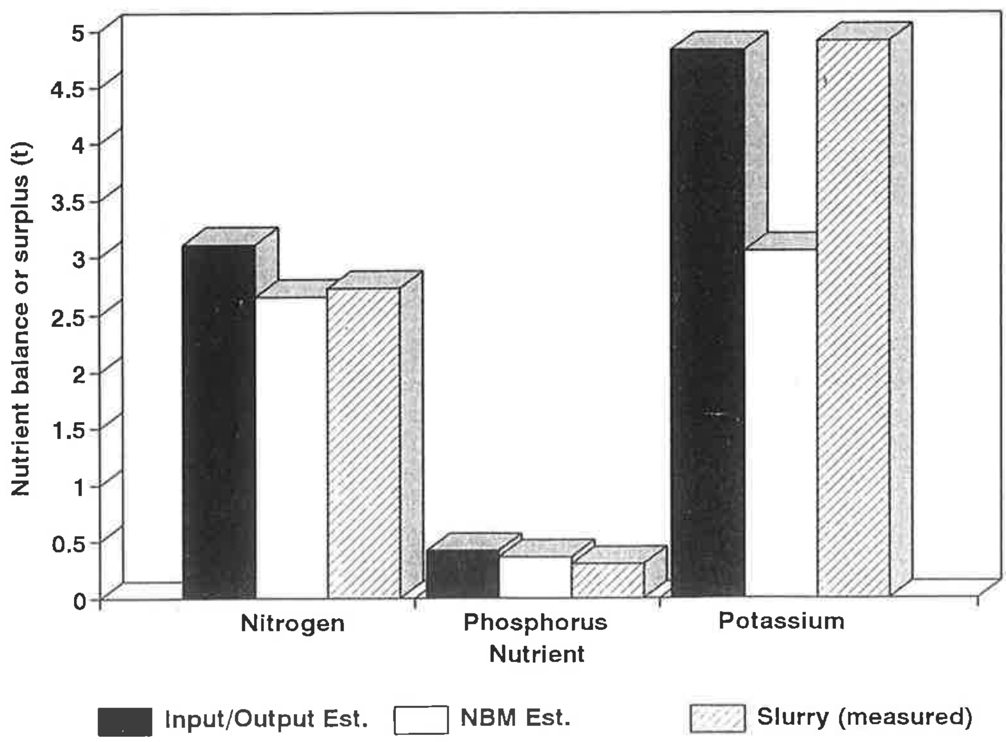

Figure 5.2. The nutrient content of a cattle slurry estimated by input/output balance, NBM and direct measurement.

The results presented here suggest a reasonable correlation between the input/output estimate of dairy cow and cattle slurry nutrient composition and measured nutrient value (Figures 5.1 and 5.2). The measured N content of the dairy cow slurry appears low when compared with the "average" value. Both estimates of the N content of the slurry are also higher, by at least 14%, than the measured value. This result could reveal a sampling error. It could also be explained by ammonia volatilisation losses during storage (OOsthoek *et al.*, 1990). The agreement between the estimated and measured N content of the cattle slurry was better. There was general agreement between measured and estimated P content of both slurries. However, both estimates of the P content were higher than the measured value. This reflects the low measured P concentration of the slurry. There was good agreement between the measured and estimates of the K content in the slurry with the exception of the NBM estimate for cattle slurry. The estimated K inputs for the NBM was 3.73 t compared with the measured input of 4.85 t. This accounts for the discrepancy between the two values. The high measured K input relative to the NBM estimate can be explained by the K content of the silage, 30 g kg^{-1}, which is high compared with "average" values of 20 to 25 g kg^{-1} for grass silage. This is indicated by the relatively high K content of the slurry noted above.

The results of this work suggest that both input/output balances and NBM may offer a potential for farmers to rapidly estimate the nutrient value of the slurry. The NBM has the advantage of being simple to use and requires a minimum of input data from the farmer. It is a concept that can be easily presented to farmers on a work sheet or as a simple computer program. Further validation trials are recommended and poultry slurry and litter should be included. If proven it could provide the farmer with a reliable estimate of the nutrient content of his slurry. In this form it would remove one of the obstacles that hinder the efficient recycling of slurry nutrients on Irish farms.

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REFERENCES

Agricultural Research Council (1980). The nutrient requirement of ruminant livestock . Published by the Commonwealth Agricultural Bureaux, pgs 27-47.

Agricultural Research Council (1981). The Nutrient Requirements of Pigs. Published by the Commonwealth Agricultural Bureaux. 78-119 and 215-263.

Carton, O.T. Lenehan, J.J., Magette, W.L. and Regan. S. (1993). Slurry Management on Farms. Journal of Irish Farm Buildings Association.

Carton, O.T. and Harnett, P. (1990). Developments in slurry handling equipment to reduce odour and ammonia emissions. Proceedings from Seminar on Environmental Impact of Landspreading of Wastes. Johnstown Castle Wexford.

Clabby K.J., Lucey, J., McGarrigle, M.L., Bownman, J.J., Flanagan, P.J. and Toner, P.F. (1992). Water Quality in Ireland 1987-1990. Part-One General Assessment. Environmental Research Unit, pp 8-13.

Drennan, M. (1994). Personal Communication. Teagasc, Grange Research Centre, Co. Meath.

Drennan, P. (1993). Personal Communication. Department of Agriculture, Dublin 2.

Hanley, P.K. and Murphy, M.D. (1973). Soil and phosphorus in the Irish ecosystem. Water Research. 7: 197-210.

Lynch, B. (1993). Personal Communication. Teagasc, Moorepark Research Centre, Fermoy, Co. Cork.

Lynch, B. (1992). Feeding to minimise wastes. Pig husbandry Dept. Teagasc, Moorepark, 21 pages.

Mannion, R. (1993). Personal Communication. Teagasc, Mellow's Agricultural College, Athenry, Co. Galway.

McCance, R.A. and Widdowson, E.M. (1988). The Composition of Foods. 4th Edition.

McCarthy, C. (1990). Report on Sanitary Services Dept., Offaly County Council. 8 pages.

McDonald, P., Edwards, R.A. and Greenhalgh, J.F.D. (1988). "Animal Nutrition", 4th Edition.

Murphy, J. (1994). Personal Communication. Teagasc, Moorepark Research Centre, Fermoy, Co. Cork.

O'Bric, C. (1991). A Survey of the Nutrient Composition of Cattle and Pig Slurries . Submissions for M.Sc. (Agriculture) in Environmental Resource Management to National University of Ireland. 61 pages.

Oosthoek, J., Kroodsma, W. and Hoeksma, P. (1990). Ammonia emission from dairy and pig housing systems. Odour and Ammonia Emission from Livestock Farming. (Ed. Nielsen, V.C., Voorburg, J.H., and L'Hermite, P).

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Pettigrew, J.E. (1992). Pigs and Poultry. "Waste Management and Pollution Control". *in* Biotechnology in the Feed Industry. Proceedings of Alltech's Eight Annual Symposium. pages 165-170.

Sherwood, M. and Tunney, H. (1991). The Nitrogen Cycle - A National Perspective (Abstract). Irish Journal of Agricultural Research, Vol. 30, No. 1, p 75.

Tunney, H. and Power, V. (1988). "Soil Fertility on Ireland - Phosphorus". Farm and Food Research, 19(5)L 13-14.

Tunney, H. (1990). A note on a balance sheet approach to estimating the phosphorus fertiliser needs of agriculture. Irish Journal of Agricultural Research, Vol. 29, No. 2, pgs 149-154.

Van der Hook, K. (1992). Report 773004003, National Institute of Public Health and Environmental Protection, Bicehoven, The Netherlands. pgs 1-6.

Warren, T. (1994). Personal Communication. Golden Vale Ltd., Charleville, Cork.

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APPENDICES 1 - 8

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APPENDIX 1

Farm Nutrient Management and Balance Form

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Surname: . . . .

First Names: . . . .

Phone No: . . . .

Address: . . . .

Date: . . . .

1. Waste Register

The volumes of waste estimated by farmer that he has to be spread.

Waste Type	*Volume (Cubic Metres)*
Dairy	. . . .
Beef	. . . .
Pigs	. . . .
Poultry	. . . .

2. Animal Register

The Animal Register is used to validate the volume of waste that the farmer estimates he has to spread.

2.1 Pigs

Suckling Sows	. . . .
Dry Sows	. . . .
Gilts	. . . .
Boars	. . . .
Weaners (6 - 32kg)	. . . .
Finishers (32 - 82kg)	
Dry Fed	. . . .
Liquid Fed 2.5:1	. . . .
Liquid Fed 3.0:1	. . . .
Liquid Fed 3.5:1	. . . .
Whey Fed	
Controlled	. . . .
Ad Lib	. . . .
Storage Period	. . . . weeks

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2.2 Beef

Cattle Group	*Average Size (kg)*	*Number of Animals*
1	140	. . . .
2	250	. . . .
3	450	. . . .
4	550	. . . .

Approximate Housing Date (dd/mm)	. . . .
Approximate Turnout Date (dd/mm)	. . . .
Storage Period	. . . . . .

2.3 Dairy

Cow Group *Average Size (kg)*	*Number of Animals*
550 (dairy	. . . .
450 (suckler)	. . . .
500 (replacement dairy)	. . . .
400 (replacement suckler	. . . .

Approximate Housing Date (dd/mm)	. . . .
Approximate Turnout Date (dd/mm)	. . . .
Storage Period	. . . .

2.4 Poultry

Poultry Group	*Number of Birds*	*Weeks per Flock*	*Flocks per Year*
Layers	. . . .	. . . .	. . . .
Broilers	. . . .	. . . .	. . . .
Turkeys	. . . .	. . . .	. . . .

Storage Period . . . .

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Slurry and Silage Sampling Register

3. Slurry

Storage capacity . . . .

Volume removed since housing of animals . . . .

Volume in storage at time of survey . . . .

When was slurry agitated . . . .

Slurry sample No: . . . .

Date of Sampling . . . .

3.1 Silage

Additives at ensiling . . . .

Type and amount . . . .

Silage sample No: . . . .

Date of Sampling . . . .

Slurry and Silage Test Register

4. Slurries

4.1 Pig Groups	*DM* *%*	*N*	*P* *kg per m³*	*K*
Group Average	. . . .	. . .	. . . .	. . . .
Suckling Sows	. . . .	. . .	. . . .	. . . .
Dry Sows	. . . .	. . .	. . . .	. . . .
Gilts	. . . .	. . .	. . . .	. . . .
Boars	. . . .	. . .	. . . .	. . . .
Weaners (6 - 32kg)	. . . .	. . .	. . . .	. . . .
Finishers (32 - 82kg)				
Dry Fed	. . . .	. . .	. . . .	. . . .
Liquid Fed 2.5:1	. . . .	. . .	. . . .	. . . .
Liquid Fed 3.0:1	. . . .	. . .	. . . .	. . . .
Liquid Fed 3.5:1	. . . .	. . .	. . . .	. . . .
Whey Fed				
Controlled	. . . .	. . .	. . . .	. . . .
Ad Lib	. . . .	. . .	. . . .	. . . .

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4.2 Dairy Groups

	DM %	*N*	*P kg per m³*	*K*
Group Average	....	...	....	....
550 kg (dairy	....	...	....	....
450 kg (suckler)	....	...	....	....
500 kg (replacement dairy)	....	...	....	....
400 kg (replacement suckler)	....	...	....	....

4.3 Beef Groups

	DM %	*N*	*P kg per m³*	*K*
Group Average	....	...	....	....
140kg	....	....	....	....
250kg	....	....	....	....
450kg	....	....	....	....
550kg	....	....	....	....

4.4 Poultry Groups

	DM %	*N*	*P kg per m³*	*K*
Group Average	....	...	....	....
Layers	....	....	....	....
Broilers	....	.. .	....	....
Turkeys	....	....	....	....

	DM %	N	P *g per kg*	K
5 **Silage**	....	....	....	....

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Data for Nutrient Balance

6.1 Type of Farm: . . . .

6.2 Total Acreage: . . . .

6.3 Silage Area: . . . .

6.4 Grazing Area: . . . .

. . . .

6.5 Crops Area: . . . .

. . . .

6.6 Manured Area: . . . .

. . . .

. . . .

Farm Inputs

7.1 Fertiliser (tonnes) . . . .

Composition . . . .

. . . .

. . . .

7.2 Concentrates (tonnes) . . . .

. . . .

. . . .

Composition *N* *P* *K*

. . . .

. . . .

. . . .

7.3 Silage / Hay (tonnes) . . . .

. . . .

7.4 Animals Purchased

Date	*Type*	*Weight (kg)*
. . . .	. . . .	. . . .
. . . .	. . . .	. . . .
. . . .	. . . .	. . . .

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Farm Outputs

8.1 Milk (gallons/year) ....

....

8.2 Animals (sold/year)

Type	*Jan*	*Feb*	*Mar*	*Apr*	*May*	*Jun*	*Jul*	*Aug*	*Sep*	*Oct*	*Nov*	*Dec*	*Av No.*
Calves													
0 - 6mths													
6 - 12 mths													
1 - 2 yrs													
>2 yrs													
Bulls													
Dry Cows													
Dairy Cows													

8.3 Number of calves born ....

8.4 Number of calves fed on farm ....

8.5 System of feeding ....

8.6 Liveweight gain (kg) of beef animals per year

0 - 1 yr	1 - 2 yrs	>2 yrs
....	....	....
....	....	....

9.1 Pigs sales

Type	*Number*	*Average Weight*
Weaners	...	....
Fatteners	...	....
Dry Sows	...	....

10 Poultry Sales

Type	*Number*
Layers (egg)	...
Broilers	...
Turkeys	...

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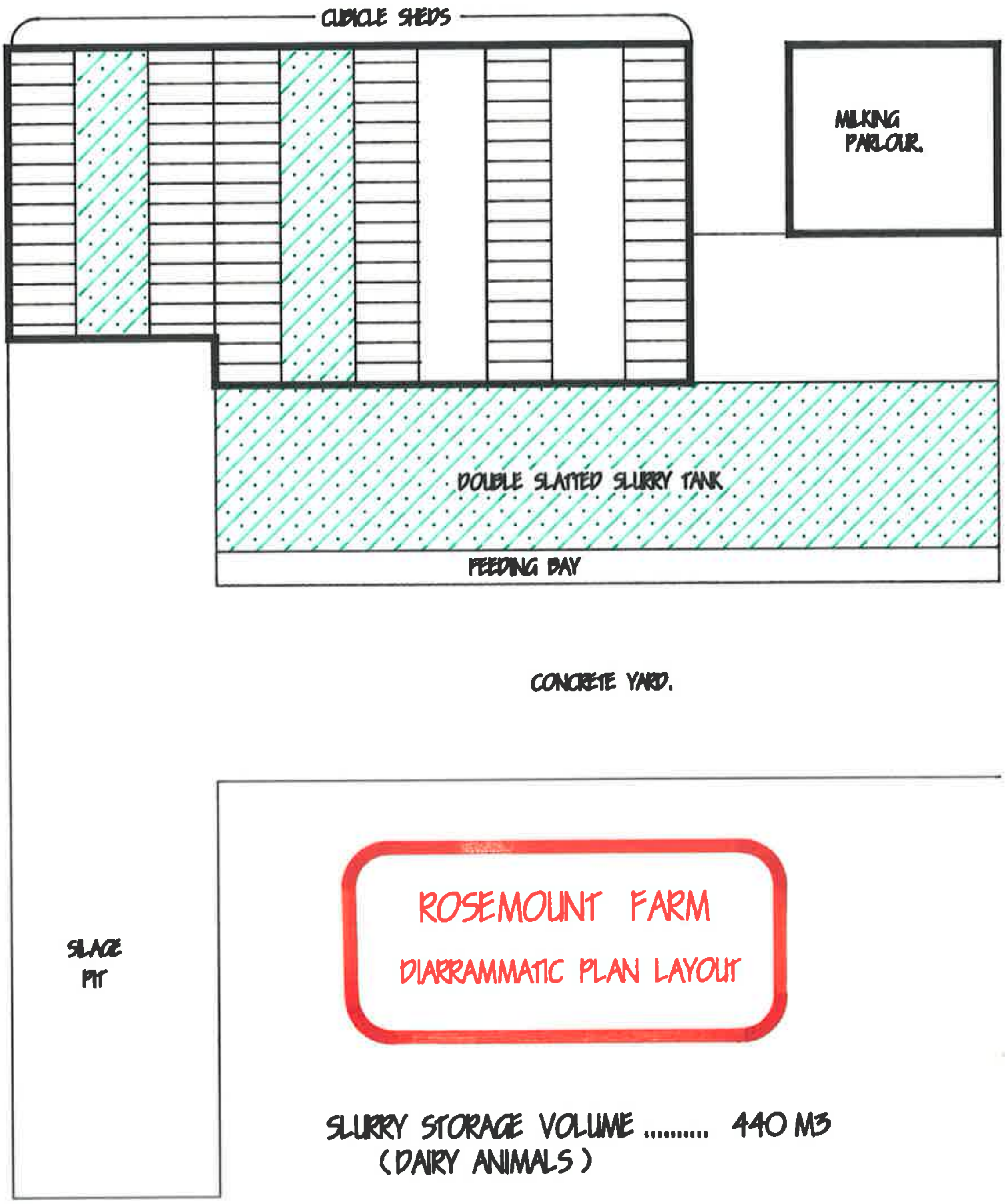
APPENDIX 2



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APPENDIX 2.1

Rosemount Farm

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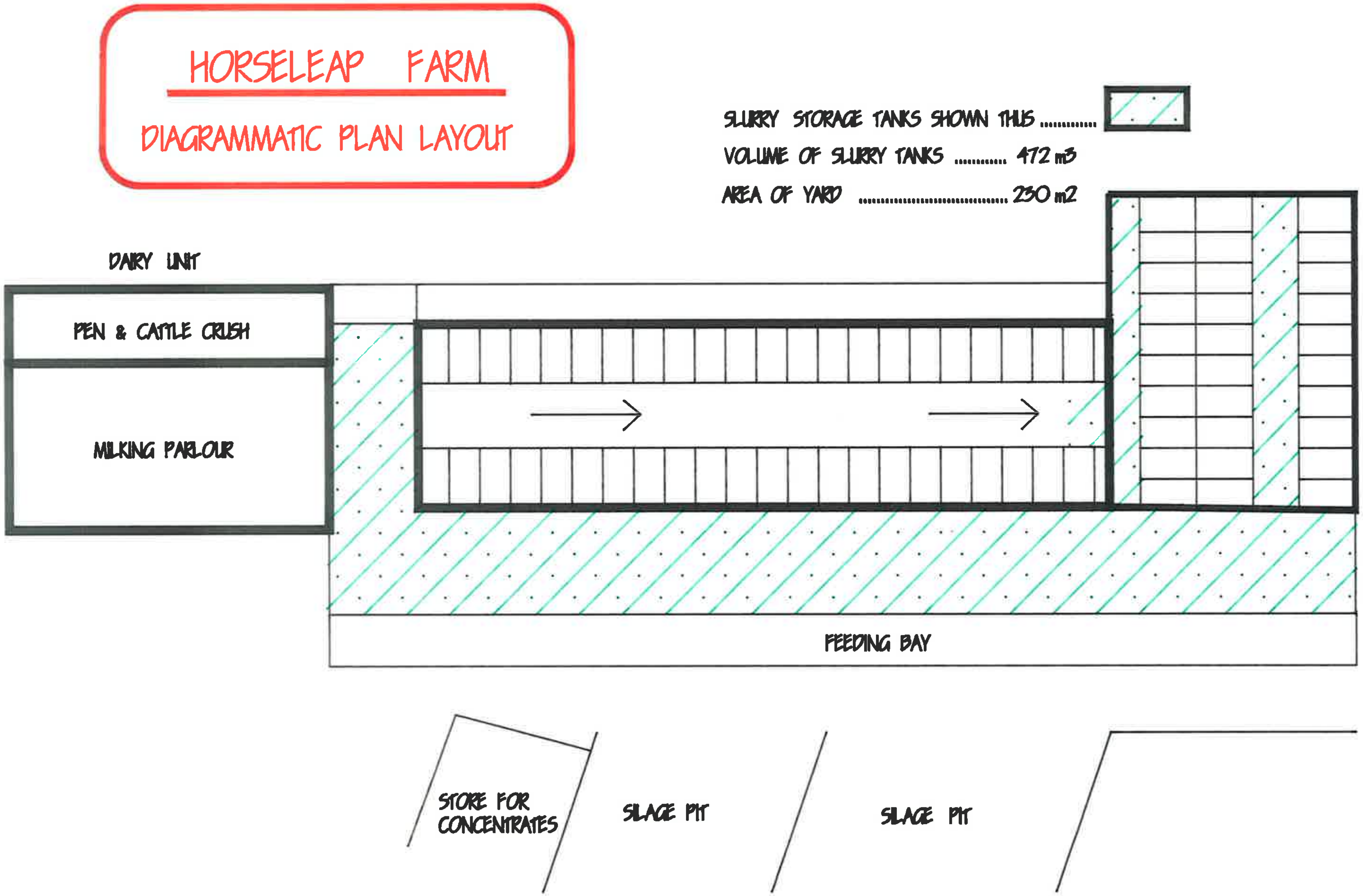
APPENDIX 3



APPENDIX 3.1

Horseleap Farm

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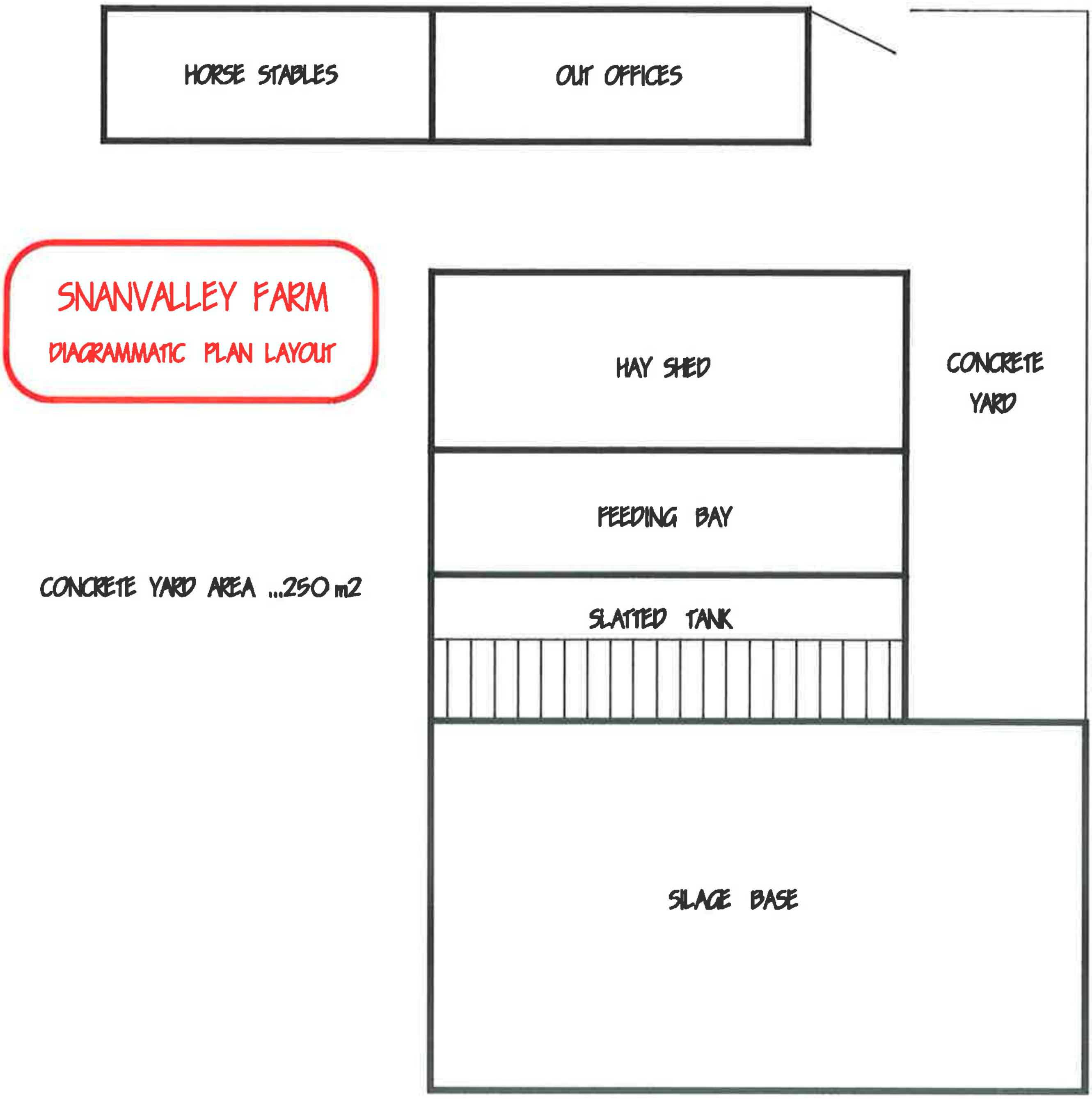
APPENDIX 4



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APPENDIX 4.1

Shanvalley Farm

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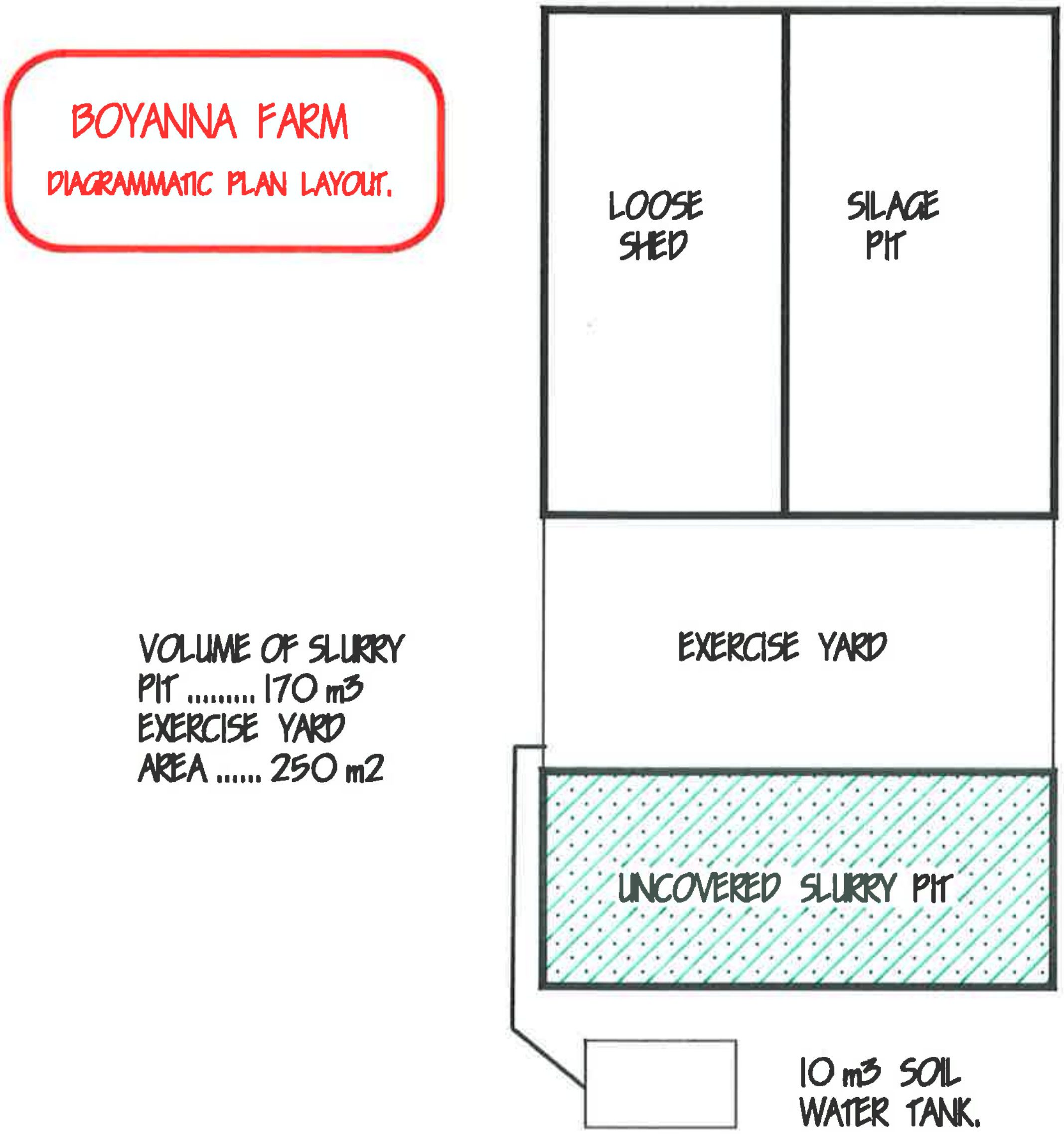
APPENDIX 5



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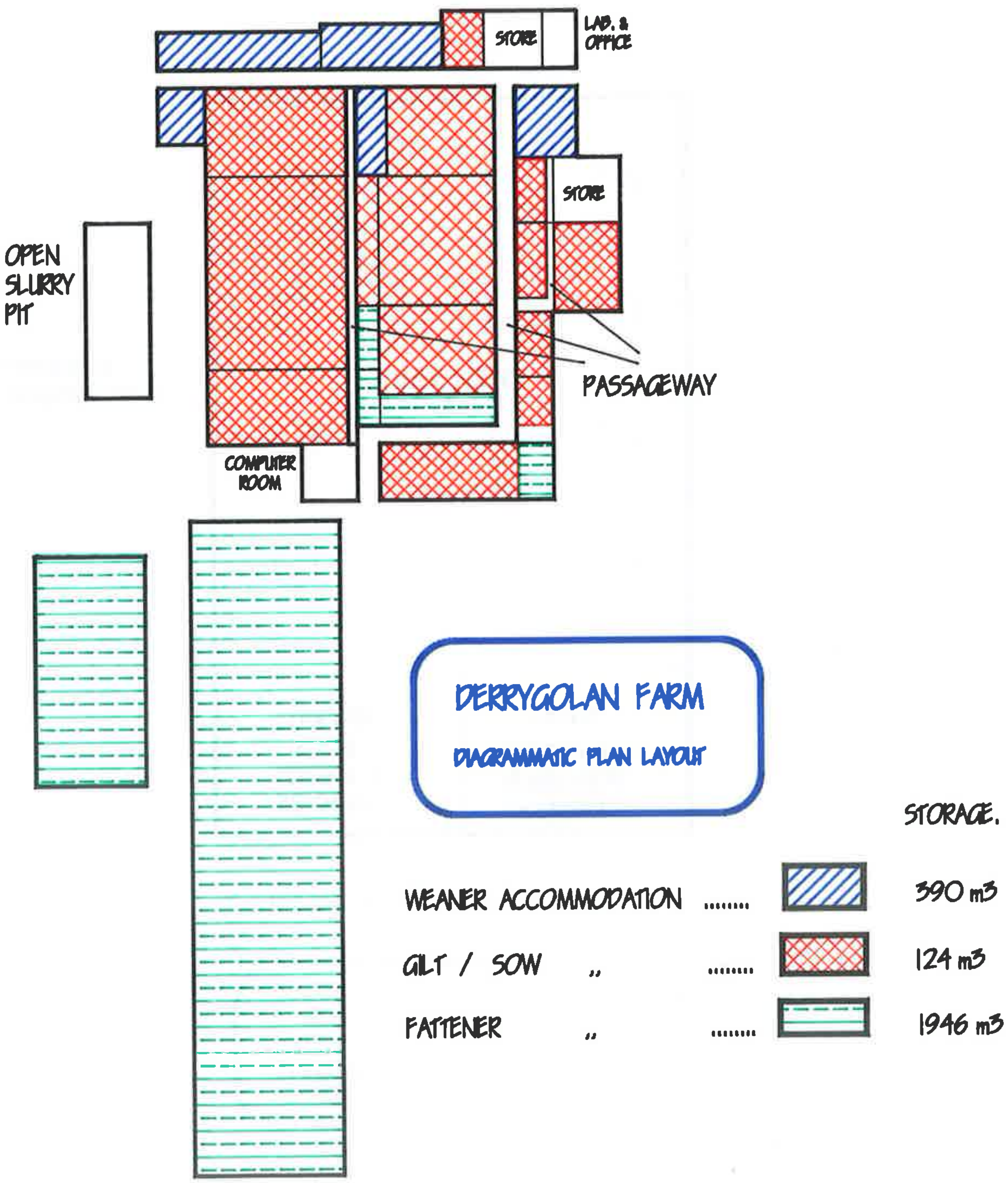
APPENDIX 5.1

Boyanna Farm

APPENDIX 6



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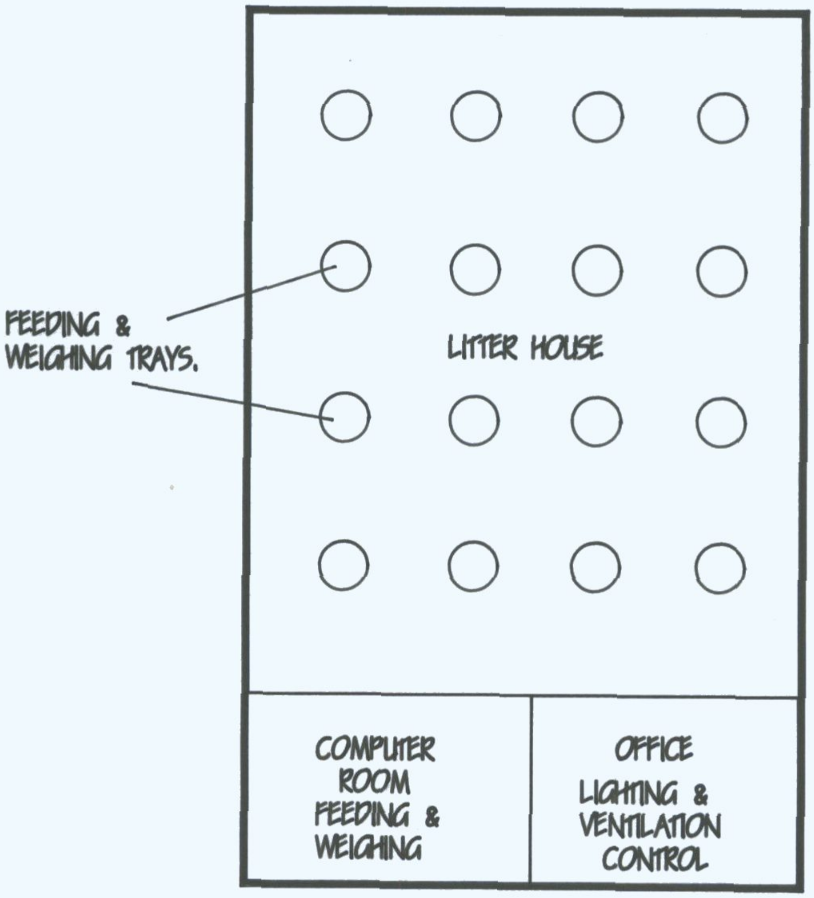
APPENDIX 7



VOLUME OF LITTER 62 m3

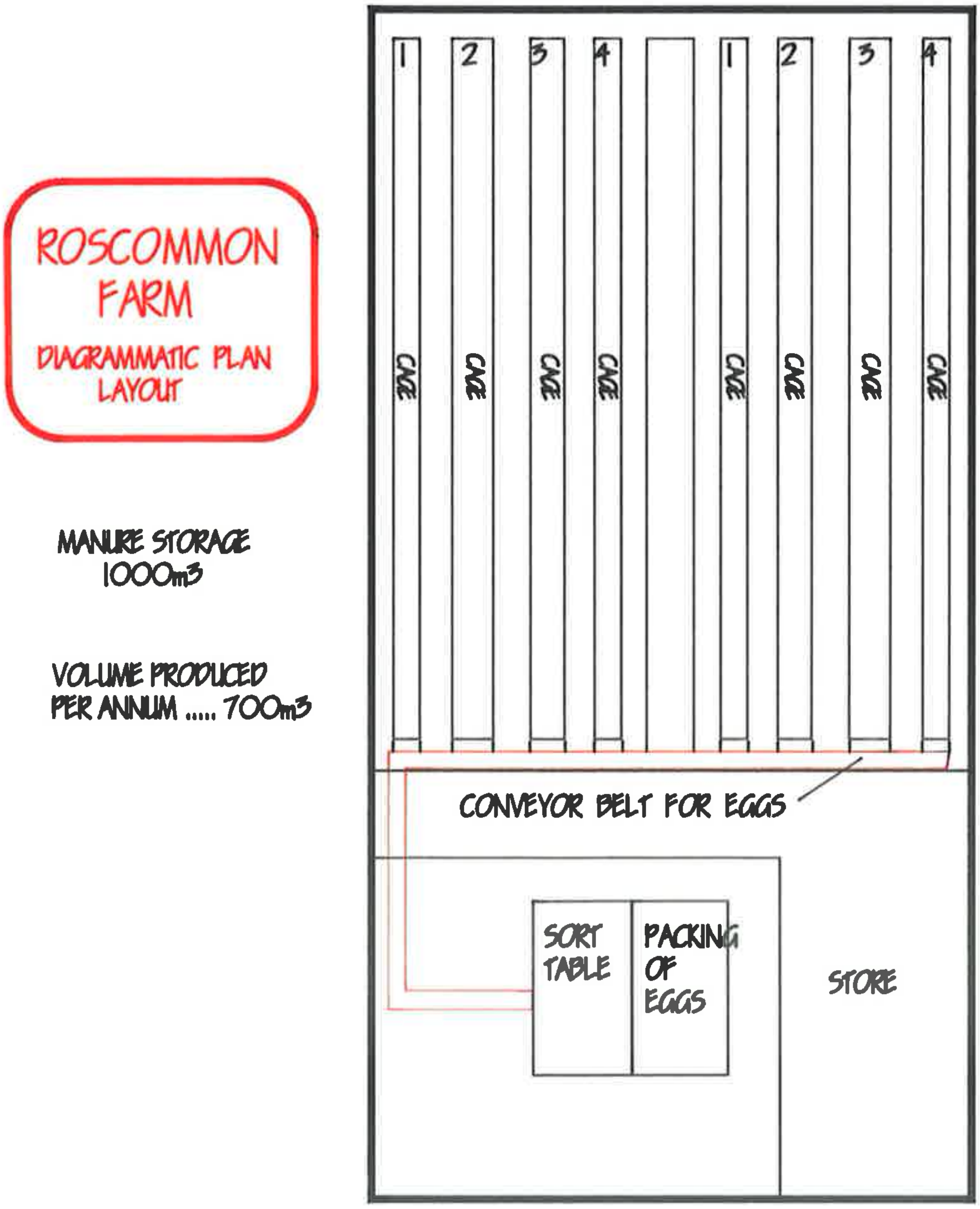
DOON FARM

DIAGRAMMATIC PLAN LAYOUT.

APPENDIX 7.1

Doon Farm

APPENDIX 8



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APPENDIX 8.1

Roscommon Farm

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