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Feeding High Merit Cows on Pasture

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The Moorepark research programme on the feeding and management of dairy cows is now focused heavily on the achievement of very high performance from cows on grazed pastures. At farm level this entails high intakes of high quality leafy pastures. At research level, the focus is on the intake requirement of high genetic merit cows and on how to achieve adequate intakes and performance (defined in its broadest sense) on a pasture system of feeding.

The present technology with regard to production and grazing systems for 'Moorepark type' dairy cows has been described in detail elsewhere (Dillon, Crosse and Stakelum, 1995). The objective of this paper is to explore the issues which will arise with respect to feeding higher genetic merit cows. The production performance of the Moorepark farm over 20 years is given and the implications for daily dry matter intake of continued breeding for high daily output of milk solids is discussed. Various strategies for the provision of extra feed to dairy cows are considered and the economic implications of the various options are also discussed.

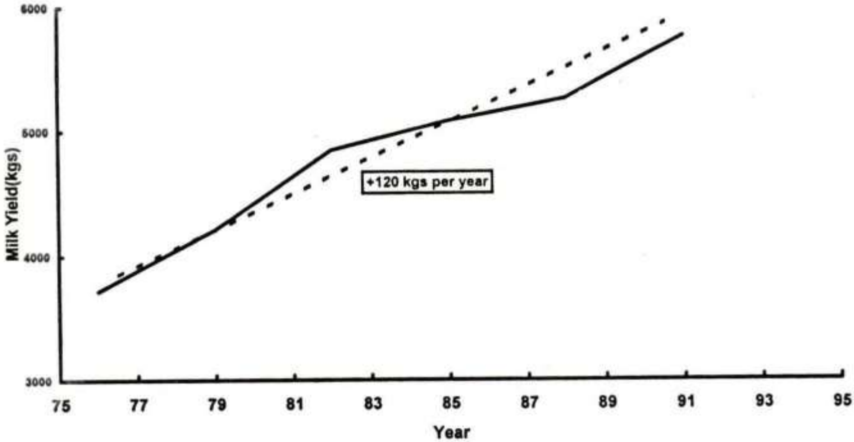
Rate of genetic gain in Ireland

The rate of gain in genetic merit of the national dairy herd in Ireland is now quite rapid. Breed substitution, as a concept, can be used to appreciate the rapid increase which is now happening. With a 20% heifer replacement rate, the entire dairy herd will turnover in 5-6 years. The average RBI 90 of the bulls going into Dairygold AI this year (1955) is 147. If we take the present RBI 90 of the national dairy herd at 100, then in 5 years, if progeny from those bulls are used as replacements, the herd RBI 90 would be in the region of 127-128. After a further 5 years the herd RBI would be 140-142. The top dairy farmers will achieve a more rapid genetic gain in their herds and they are also starting from a higher base. A fifty-unit increase in RBI is equivalent to about a 37.5-unit increase in breeding value. Therefore, with an average yield of 5500 L/cow, over 10 years this rate of genetic improvement will result in a milk production potential per cow of 7,562 L (1600 gallons). Can this potential be achieved on grass-based feeding systems? What is the most economical way of achieving this? What are the implications of underfeeding these higher merit cows. These are very important questions for dairy farmers.

Milk yield per cow

Crosse and Dillon (1995) have described the importance of achieving high performance from the dairy herd and the importance of herd productivity in reducing unit costs of milk production. Quite simply, if a farmer achieves 5850 L (1250 gallons) per cow for the same inputs as another who achieved 5150 L (1100 gallons), the higher yield will have much lower unit costs and higher

Figure 1: Increase in Milk Yield per Cow



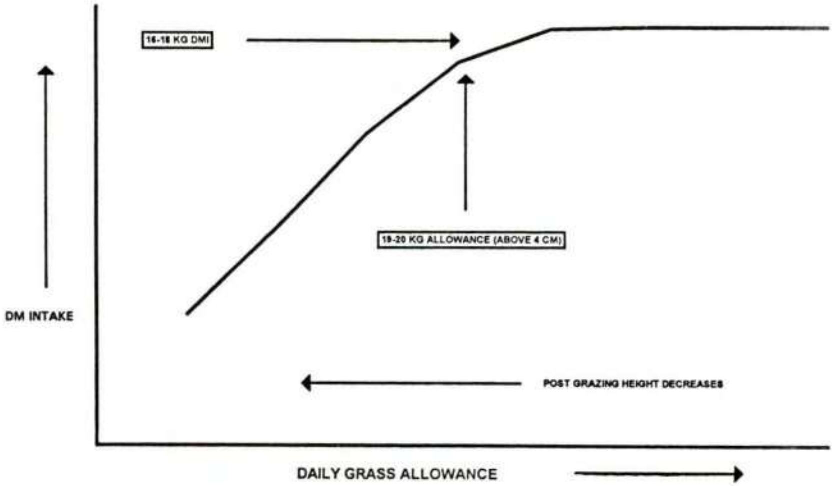
margin per cow. Figure 1 outlines the increase in yield per cow at Moorepark from 1976 to 1992. In all years, 500 kg of concentrate per cow were fed, the overall stocking rate was 2.91 cows per hectare and 377 kg N per hectare was applied to the grassland. Milk yields have increased from 3745 L (800 gallons) to 5851 L 1250 gallons) per cow over a 16 year period. This is equivalent to an increase in cow yields of 131 L per annum (28 gallons) or 4.8 kg of butterfat per annum. Over that period it is estimated that cow RBI 90 increased from 90 in 1975 to 95 in 1985 and up to 105 in 1995 (Teehan, 1995). Therefore, it is reasonable to assume that 80% of the yield increase came from the application of technology and the other 20% from increases in breeding value.

The technology aspects include a wide range of factors from grassland management, milking technology, forage conservation, supplementary feeding, reproductive efficiency and disease control. The important point, however, is that by the application of knowledge and an increase in skill level, that major improvements in cow performance were achieved. How far more can we progress this rate of improvement without the provision of more expensive feed?

Herbage allowance and intake

The amount of grass offered each day to grazing cows has a very large influence on the amount consumed each day. The amount offered is defined as daily herbage allowance and is calculated from the amount of utilizable grass per ha multiplied by the area grazed each day and divided by the herd size. It plays a very fundamental role in determining the performance of grazing livestock. Figure 2 outlines the generalised relationship between daily herbage allowance and daily herbage intake. It is impractical to operate at extremely high levels of daily herbage allowance because the levels of grass residue in the paddocks will be too high and the subsequent quality of the herbage for next grazing cycles will deteriorate badly. The grazing/intake work at Moorepark

Figure 2:Relationship between intake and grass allowance



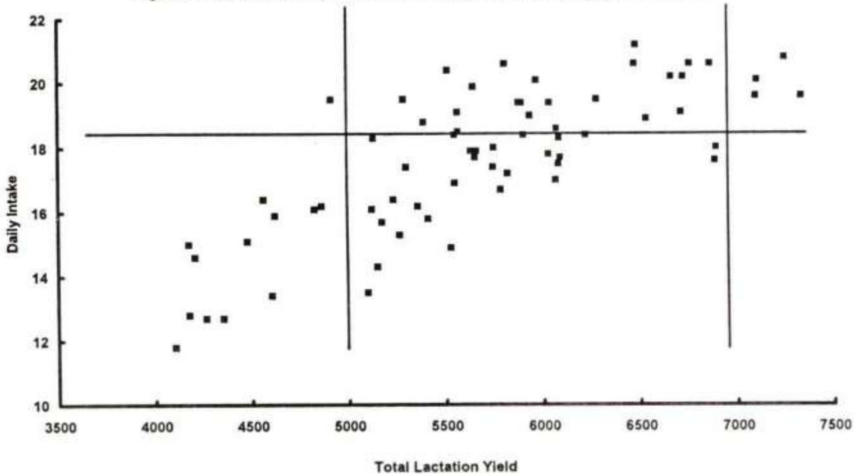
(Stakelum, 1995a) over the last number of years has shown that with an allowance of 19-20 kg grass DM above 4 cm daily, cows will achieve an intake of around 17-18 kg DM daily under good grazing conditions. This set of circumstances will normally lead to a post-grazing sward surface height of 6 cm in the paddocks.

To achieve success or more correctly to manage the pastures in such a way so as to realise this level of allowance each day is not easy. The overall system as described is finely tuned. It demands flexibility in grazing management and some knowledge of grass supply and grass growth. Sustained periods of below-normal growth rates will necessitate a certain level of supplementary feeding. It is beyond the scope of this paper to describe the various options which are available for management of pastures through the various cycles of high and low growth rates in order to sustain daily intakes close to 17-18 kg. Some detail has been given elsewhere (Stakelum, 1993 and 1995a and b). However, the important point that at the present level of genetic merit and a defined system of 2.9 cows per hectare, 380 kg N per ha and 500 kg concentrate per cow, that any further increase in milk yield potential will necessitate higher intakes. If we change nothing, the cows will have to graze below 6 cm in order to consume more feed.

Feed demand of lactating grazing cows

Let us consider daily intake of cows in a grazing herd yielding 25-27 L of milk at peak and giving a total lactation yield of 5500 L. Figure 3 shows 75 individual cow intakes of herbage averaged over the grazing season from a system trial carried out over the period of 1990-1992 (Dillon *et al.*, 1995). There are a number of points which need to be made in relation to the data.

Figure 3: Relationship between milk yield and daily grass intake



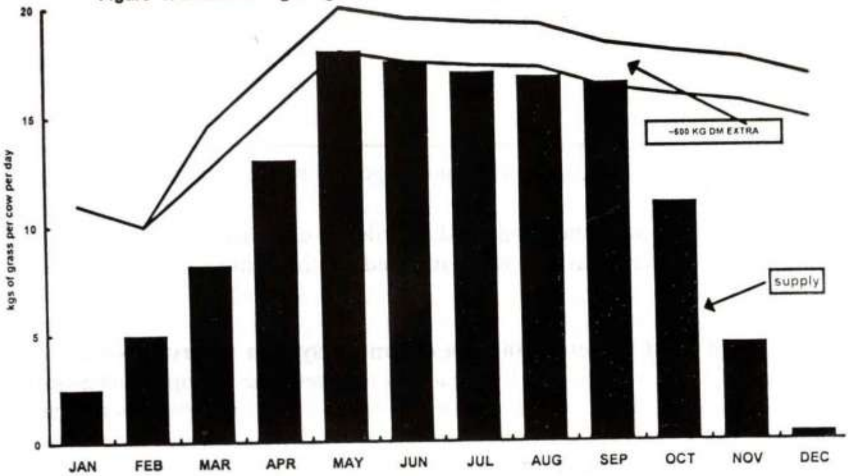
The majority of the lactation yield values lie between 5000-7000 L and the average intake is close to 18 kg DM per day. Statistically, the data are described as having spread and scatter but there is an obvious relationship between daily intake and total lactation yield. There are other factors other than milk yield which influence daily intake. Size of the cow, body weight gain or loss, calving date, and condition at calving are among the more important factors. Given an optimization of sward conditions and taking these animal factors into account, we can conclude from statistical analyses of the data, that a large proportion of the spread and scatter in the data is due to milk yield and size of cow. From these data and from the data from zero-grazing studies at Moorepark we know that for each extra 1 kg of FCM that a cow can potentially produce daily, she will need to consume between 0.4-0.5 kg of extra grass DM daily.

An interesting aspect of the data in Figure 3 is the number of cows in the group which are capable of achieving daily intakes above 18 kg of DM. The important issue here is that the large and/or high yield cows are able to harvest enough grass out of the daily allocation of 20 kg DM to sustain their higher yield potential. This of course adds enormously to the efficacy of the system. The extent of the variation in yields and intakes are similar to the normal distribution found in commercial herds with cows of varying yields around the average herd value.

Supply and demand pattern for grass in our present system

Figure 4 outlines the supply of grass feed demand pattern of a spring-calving herd that is typical of the generalised Moorepark system as defined by Dillon *et al,* 1995. The supply of grazed grass is the result of the combined effects of the overall stocking rate, the silage conservation policy, nitrogen application strategy and the rate and pattern of grass growth. The demand for feed is set

Figure 4: Effect of higher genetic merit on supply and demand of grass



by the genetic merit and the size and liveweight changes of the cows. The pattern of feed demand is determined by calving date and calving spread. It is evident that in the months of May to September, the system is basically in balance with respect to feed and demand and grass supply for the Moorepark type cow. In the March to April and October to December period a large deficit of grazed grass exists in this system.

An increase in milk yield per cow of 20% is equivalent to an increase in RBI from 115 to 140. This increase in total lactation yield of 1200 L, if evenly distributed over the lactation, will result in an increase in daily milk yield of 4 L per cow. This will result in an increased daily intake demand of around 2 kg DM. This is shown in Figure 4. Over the lactation, it means that an extra 500 kg DM needs to be fed to each cow in the herd. There is now a substantial shortfall in the supply of grazed grass under the present system.

Comparison of contrasting systems

Three options of providing this extra feed were examined for the various scenarios considered in this paper. An extra 500 kg of concentrate can be fed to the animals or the overall farm stocking rate can be reduced to such an extent so as to provide enough extra grass to allow the cows to perform to their potential. The third option considered involved reducing the area cut for both 1st and 2nd cut silage so as to make up the deficit of grazed grass during the main conservation period. In this scenario, purchased concentrates are used to make up the shortfall in the availability of conserved silage. Due to the unchanged overall farm stocking rate, extra concentrates may need to be fed during the early and later parts of the grazing season because there is still an increased deficit of grazed grass, compared to the lower dairy merit system, in the March to April period. It must be emphasised that detailed component and systems-

Table 1
Assumptions used in Model Farm

Quota size*	40,000 gallons
Farm size	60 acres
Enterprises	Dairying and Beef

*The application of the quota constraint depended on the scenarios compared.

based research needs to be conducted in order to establish the actual relevant biological coefficients associated with feeding these high merit animals at pasture.

Model farm used to determine the optimum system of production

A model farm was used in this analysis to determine the optimum system of production under various scenarios. This model farm represents a typical intensive dairy farming system in Ireland now where milk quota is usually limiting before land and where there has to be a combination of enterprises to use the land available. This allows the opportunity cost capital to be evaluated versus profitability of other farm production areas. The main assumptions used for the model farm are given in Table 1.

The amount of capital used varied depending on whether the quota or no-quota scenarios were considered. Capital was not a constraint as was Quota and farm size. Capital did however influence the final solution because different levels of capital were used for the various systems. A comparison of scenarios when quota constraints apply as against scenarios when no-quota constraints apply is not possible because of the assumptions applied above. This analysis is mainly focused on the potential for profit. It is recognised that detailed financial analysis of the various scenarios is necessary before adoption at farm level.

Financial evaluation of the scenarios compared

The financial evaluation, therefore, considered three options for feeding higher merit cows, (i) feeding more concentrates, (ii) feeding more grass (by reducing stocking rate), or (iii) cutting less silage (thereby feeding more grass and concentrates). The options were compared with the Moorepark system using medium merit cows. Three levels of each option were considered. Concentrate was increased by 0, 50 and 100%, stocking rate was reduced by 5, 10 and 15% and the area cut for silage was reduced by 5, 10 and 15%. The opportunity cost of land and capital was considered in the economic evaluation of the scenarios compared. The results are presented as opportunity costs per cow for the various options and the scenarios are compared to the optimum solution which is the use of high merit cows which achieve their higher yield potential without the provision of extra feed. This implies that they succeed in harvesting out extra grass from the system. This of course is an unlikely outcome but it is a necessary assumption for clarification of the comparisons.

Table 2 outlines the opportunity costs/unit at high milk price (103 p/gallon) with a farm quota applied. It is important to define the opportunity cost per unit. It is defined as the revenue per unit forgone or lost by replacing 1 unit of the optimum system by 1 unit of a less than optimum system. In Table 2 we can see that the present genetic merit cows carry an opportunity cost of £90 compared to the optimum system. If the higher genetic merit cows necessitate much increased concentrate input levels then their advantage is almost totally eroded. The medium level of concentrate input (0.75 tonnes) gives some advantage. However, there is a substantial benefit to higher merit cows if we can feed them by providing extra grass (by dropping the stocking rate). There is of course a great advantage if the change in stocking rate is relatively small. There was little advantage to reducing the amount of land cut for silage. These three systems were intermediate between the high level of concentrate and the stocking rate options. This is due mainly to the necessity to put concentrates back into the system to make up for the reduced availability of silage and this eroded to a large extent the benefit of the extra grazed grass made available by the conservation management.

In summary, there is a very large benefit to high merit cows under the quota restriction if they can be fed by adjustments in stocking rates or by providing some small extra levels of concentrate.

The systems were also compared with quota restrictions removed. The results are also shown in Table 2. The opportunity cost of medium merit cows compared to the optimum in this case is very large (£240/cow). All the options

Table 2

Opportunity cost of various production systems

System / Option	Opportunity cost / dairy unit (£)		
	High milk price		Low milk price
	Quota	No Quota	No Quota
Optimum solution	0[1]	0[1]	0[3]
Standard System & Medium Merit Cows	90	240	185
Concentrate feeding			
0 kg extra	0	0	0
250 kg extra	40	40	40
500 kg extra	80	80	80
Stocking rate reduction			
by 5%	9	40	28
by 10%	27	93	69
by 15%	30	131	96
Cut less area for silage			
by 5%	61	61	61
by 10%	65	65	65
by 15%	67	67	67

[1,2,3]A comparison across these scenarios cannot be made

for feeding are now strongly attractive. With quota restriction removed, farm production of milk can be increased by keeping more cows. High genetic merit cows have much more to offer in a non-quota situation than in a quota situation. Additionally, dropping stocking rate, especially if it has to be dropped excessively, has much less to offer than the other options. This is because land is the constraint in this situation.

Finally, the above options were analysed in a similar way with quota restrictions removed and milk price decreased by 20% to 87p/gallon. The opportunity cost of medium merit cows now changed from £240 to £185. The attractiveness of reduced stocking rate increased somewhat while all other options remained the same relative to the optimum solution. The one obvious point which presents itself strongly where quota restriction is removed is the attractiveness of feeding high merit cows concentrates and making less silage and making up this deficit with concentrates. The more obvious conclusion also is the really important role high genetic merit cows play in contributing to income in a no-quota situation.

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High Genetic Merit Dairy Cows and Profitable Milk Production – A Hillsborough Perspective

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There have been major increases in the rate of genetic improvement in the dairy herd in the United Kingdom and Ireland since the mid 1980's. This trend looks set to continue for the foreseeable future. For example, the average genetic merit of all Holstein/Friesian sires currently being marketed by one major semen supplier in Ireland is + 60 kg fat + protein (Predicted Transmitting Ability (PTA_{90})), equivalent to a relative breeding index (RBI) of 148. Furthermore, even the lowest ranking Holstein/Friesian sire being marketed by this company has a genetic merit of + 37 kg fat and protein (PTA_{90}) or RBI of 130, which is considerably above the current genetic merit of the national dairy herd.

These rapid increases in genetic merit will have major implications for the production of milk from grass and grass silage-based diets. The important question which remains unanswered at present is "How do we best modify our existing management systems to accommodate the high genetic merit dairy cow, whilst retaining low cost milk production systems with a major reliance on grazed grass?" Unless research is undertaken to answer this question, there is a very real danger that there will be a trend towards adoption of higher input systems, based on increased usage of cereals and/or concentrates, with a reduced reliance on grass. However, if we adopt this approach, milk production in Ireland will be at a considerable disadvantage relative to that elsewhere in Europe, given the more favourable cereal and forage maize growing conditions prevailing in mainland Europe. The aim of this paper is to examine the relative efficiency of high genetic merit dairy cows on grass and grass silage-based systems and to examine what modifications we need to consider in our current management systems.

Are high genetic merit cows more efficient?

Studies at Langhill and more recently at Hillsborough, presented in Table 1, clearly indicate that increasing genetic merit results in major increases in feed efficiency, reflecting increases in milk yield, or fat plus protein yield, but relatively small increases in food intake. For example in the Hillsborough studies, high merit cows have produced almost 22% more fat + protein yield per unit of food consumed, than cows of medium genetic merit. These studies have shown that selection for increased genetic merit alters the control of nutrient partitioning, with high merit cows having a greater drive towards milk production, even at the expense of severe liveweight loss in early lactation. High merit cows in the Hillsborough studies have lost up to 1 kg liveweight/day over the first 60 days of lactation, even though they were on a high level of concentrate input (14 kg concentrates/cow/day).

Table 1

Effects of increased genetic merit on feed efficiency (silage based systems)
(Data from Veerkamp *et al* 1994 and Patterson *et al* 1995)

	Langhill studies (182 days)		Hillsborough studies (160 days)
Genetic Merit (PTA 90 kg F + P)	4.3 vs 18.8		5 vs 45
Relative Breeding Index (RBI)	104 vs 115		104 vs 136
Comparative treatment	High conc	Low conc	
Animal performance (% change)			
Food intake	+ 5.0	+ 4.3	+ 6.3
Fat + protein yield	+11.5	+12.2	+29.6
Food conversion efficiency (% change)			
(Fat + protein yield/unit food intake)	+6.2	+7.6	+21.8

The small increases in food intake with increasing genetic merit may well reflect the fact that traditional cattle breeding programmes, based on progeny testing, did not include traits such as food intake capacity within their breeding objectives. Furthermore food intake capacity may be less important in North America and other European countries, given the opportunity to increase nutrient density of the ration by including cereals and other by-product feeds at relatively low cost. However, the relatively small increases in food intake with increasing genetic merit has major implications for milk production in the UK and Ireland, given the high reliance on forage. Food intake can now be assessed in nucleus breeding programmes, such as the Genus MOET programme, and selection for increased food intake could be highly important in future breeding programmes. However, in the meantime, there is a strong case for including some measure of intake capacity in sire assessment indexes used in the UK and Ireland.

Challenges in feeding high genetic merit dairy cows

The major challenge in feeding the high genetic merit dairy cows on grass or silage-based diets is to increase forage intake, particularly in early lactation. Failure to increase forage intake will result in greater liveweight loss which could have a major effect on the incidence of metabolic and/or reproductive disorders.

Dry cow management. Dry cow management will become much more important as genetic merit of the dairy herd increases. For example, cows calving in poor condition (less than condition score 2) will have limited reserves to draw on after calving, whereas calving in excessive body condition (condition score greater than 3) will result in reduced food intake in early lactation. Further research is needed to investigate the role of low digestibility forages, such as straw, as a "rumen conditioner" during the dry period, and also the role of high quality protein, fed during the last few weeks of the dry period, on food intake, milk production and fertility in the subsequent lactation.

Winter feeding systems

With autumn-calving cows on grass silage-based diets, low food intake is a major problem and there is considerable interest at present in opportunities to increase dry matter intake, either through wilting or by modifying silage fermentation. However, as yet, there is no evidence that high merit animals respond differently to low merit animals to pre-wilting, improvements in silage digestibility or alterations in silage fermentation.

Results of a major programme of research at Hillsborough on silage intake has now identified factors influencing intake, and this enables accurate prediction of intake potential of silages. Further research is currently in progress to examine if we can consistently produce high intake potential silages, by manipulating the grass crop during both the growth and ensiling phases. This research is particularly relevant to the high genetic merit cow.

Recent research at Hillsborough (Table 2) has examined the use of complete diet feeding versus out of parlour feeding of concentrates with medium and high genetic merit cows. High merit cows produced 6.6 kg more milk/day than low merit cows, although with a lower fat and protein content. With the high concentrate feed levels used in this experiment, cows performed better in complete diet feeding than with concentrates fed out of parlour. However, the response to complete diet feeding was similar with both medium and high merit cows, with no evidence of a better response with the high merit group.

Research at Langhill has shown that the small increases in food intake with high genetic merit cows has major implications for the concentrate component of the ration. For example Oldham *et al* (1992) estimated that to achieve similar liveweight change to cows with a PTA of + 20 kg fat plus protein (RBI 116), high merit cows with a PTA of + 60 kg fat plus protein (RBI 148) would require an increase in energy density in the total diet of 0.4 MJ/kg DM. Similarly, to meet their increased protein requirements, Oldham *et al* (1992) estimated that high merit cows would require an increase in protein content of the concentrate of 8.1%, with an associated decrease in protein degradability of 0.16.

Table 2

Effect of concentrate feeding system on performance of medium and high genetic merit cows

Feed system	Complete diet		Out of Parlour	
Genetic merit	Medium	High	Medium	High
PTA 90 (kg F + P)	+15	+45	+15	+45
RBI	111	136	111	136
Performance for first 160 days of lactation				
Food intake (kg DM/day)				
Concentrates	12.8	12.9	12.7	12.9
Silage	6.4	6.9	7.0	7.8
Total	19.2	19.8	19.7	20.7
Performance				
Milk yield (kg/day)	32.6	38.5	28.7	36.0
Butterfat (%)	3.89	3.64	3.94	3.89
Protein (%)	3.19	3.06	3.24	3.08

Increases in energy density and protein concentration, coupled with decreases in protein degradability of the total diet, are likely to incur considerable increases in feed costs and this could negate some, or all, of the improvements in the biological efficiency of high genetic merit cows. Consequently, it is essential that we give increased emphasis to food intake characteristics in dairy cattle breeding programmes and in sire selection in the UK and Ireland. Furthermore research on improving food intake with grass silage-based diets could have major implications for improved economic efficiency with high genetic merit cows.

Grazing systems

The majority of top sires currently being used in the UK and Ireland have been evaluated under intensive, and in many cases, fully housed production systems. The major question is do daughters of these sires perform equally well under grass-based production systems? Results from Canadian - New Zealand (CANZ) sire evaluation studies showed that, on average, there was little difference in performance between daughters of Canadian or New Zealand bulls in both countries. However, daughters of some Canadian sires performed significantly better on grass in New Zealand than was predicted from daughter performance in Canada. This highlights the need to have sires tested locally in order to confirm the accuracy of conversion of proofs of foreign sires.

More recently, detailed analysis of results from Langhill indicate that high genetic merit cows may be unable to express their full genetic potential for milk production when offered a high forage diet. Taken together, results from these two studies suggest caution is required in breeding very high genetic merit cows (e.g. greater than PTA + 50 kg fat + protein (RBI 140)) for use in grassland based production systems. Secondly, we need to examine opportunities for modifying existing management systems to better accommodate the high genetic merit dairy cow, without compromising the basic concept of low cost, grass based milk production.

Increasing grass intake. From a theoretical viewpoint a medium genetic merit cow (PTA 90 + 5 kg fat plus protein, RBI 104) producing 25 litres milk/day requires a grass intake of 15.0 kg DM/day. However, with a high genetic merit cow (PTA 90 + 60 kg fat plus protein, RBI 148) producing 32.5 litres milk/day, a grass intake of 18.7 DM/day is required to meet energy requirements. Previous studies have shown that under 'ideal' grazing conditions, grass intakes between 15-17 DM/day can be achieved in practice. However, intakes of this order can only be achieved with a reduced grazing severity and this will have major implications on sward quality, particularly if swards are undergrazed in early season. Furthermore, unless we can develop grazing management strategies to further increase grass intake above the level of 17 kg DM/day, it may be necessary to provide supplementary feeding at high genetic merit cows at grass in early lactation. However, the use of concentrate feeding at pasture with high genetic merit dairy cows could reduce the overall profitability of milk production, relative to grass only systems with cows of moderate genetic merit. The break-even point in terms of increasing genetic merit and level of concentrate feeding required vs moderate genetic merit and grass only systems will largely depend on future changes in milk price and cost of cereal grain.

With this in mind, research is currently under way at Hillsborough to investigate the following:-

(a) How can we maximise grass intake with high producing cows?
(b) Can we maintain high quality swards through the grazing season? e.g. increased need for topping, alternating and cutting, leader/follower grazing.
(c) Can we identify characteristics in the grass plant which can be used in future grass breeding programmes to produce new high intake grass varieties?
(d) Is there a place for concentrate feeding at grass with high genetic merit cows and if so, what type of concentrate should be used?

This research is being undertaken with high genetic merit cows (PTA 90 + 50 kg fat plus protein, RBI 140) and results of this work should provide guidelines for management of animals of this type.

Conclusions

Since the mid 1980's there have been major increases in the rate of genetic improvement in the dairy herd in the UK and Ireland, largely through use of imported semen. High genetic merit cows produce increased milk yields largely because they partition more nutrients into milk and less to body reserves. Increases in food intake with high merit cows on grass and grass silage-based diets are relatively small (between 5-8%). Consequently there is some evidence to suggest that high merit cows may be unable to express their full genetic potential for milk production when offered a high forage (or low energy density) diet. In order to prevent excessive liveweight loss in early lactation, with consequent detrimental effects on the incidence of reproductive failure and milk protein content, the major challenge for research and dairy herd management is to increase food intake with grass and/or grass silage-based diets. The alternative is to adopt "imported feeding systems" including use of total mixed rations and/or high levels of concentrate feeding. However, this approach could reduce the overall profitability of milk production relative to lower input systems based on animals of lower genetic merit.

The 'optimum' genetic merit of dairy cows in grass-based production systems will ultimately depend upon a number of factors including standard of grassland management and possible changes in milk price and the cost of cereal grains/ by-product feeds.

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How Competitive is Irish Dairy Farming?

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New Zealand Dairy Board.

Irish dairy farmers have the potential to be amongst the most competitive, low cost producers of milk in the world. Yet this potential is not being realised nor sought after.

The potential to increase profits on farms by reducing the cost of production is enormous. We know Irish dairying can be very competitive because there are farmers including Curtins at Moorepark, operating at very low cost and high profit.

However, the majority of Irish dairy farmers:

a) have very high cost structures and

b) retain little of the money they receive for milk and cattle.

Fingleton carried out a cost comparison between the major European Union (EU) milk producing countries for the years 1991/92 to see how the competitiveness of Ireland had fared since Boyle's study in 1988/89.

Firstly, costs were measured as a % of output (Table 1). This measure reflects how well farmers could cope with a price squeeze; the lower the percentage, the better.

Table 1

Total costs as % of total value of output

Country	1988/89 %	1991/92 %
Ireland	60	73
Germany	76	85
France	72	77
Italy	60	65
Belgium	55	66
Netherlands	67	82
Denmark	82	86
UK	74	81
Irish advantage relative to average	13%	5%

In 1988/89 Ireland's dairy farmers had a relatively healthy ratio of costs to output compared with the majority of EU countries. However by 1991/92, Ireland's advantage had fallen from 13% to being only 5% better than average.

Secondly, costs per kg of milksolids (i.e. butterfat plus protein) were compared as a measure of cost competitiveness (Table 2).

Table 2

Total costs per kg of milksolids (IR£)

Country	1988/89 IR£	1989/90 IR£	1990/91 IR£	1991/92 IR£
Ireland	1.76	2.15	2.09	2.05
Germany	2.65	2.69	2.59	2.70
France	2.17	2.36	2.38	2.36
Italy	3.13	3.41	3.21	3.17
Belgium	1.72	1.81	1.83	1.94
Netherlands	2.24	2.22	2.18	2.21
Denmark	2.81	2.91	2.91	2.90
UK	2.06	2.25	2.23	2.26
Irish advantage relative to average	24%	13%	14%	16%

In 1988/89 dairy farmers in Ireland and Belgium had the lowest average costs per kg of milksolids. However, in the following 3 years, Ireland's cost advantage was reduced by 8-10%. Although Ireland still held second place behind Belgium in 1991/2, the Netherlands and UK had closed the gap and had only marginally higher costs than Ireland. Fingleton also stated that in the period since 1991/92, milk production costs in Ireland have not improved. In fact average total costs per gallon have risen significantly in 1993.

"Competitiveness" is the ability of the industry to sell dairy products on future world markets. Given the predicted scenario of GATT, reducing the cost of production on farms will be critical if the Irish industry wants to sell dairy products at a competitive price.

Yet there is no clear overall objective or commitment by the Irish dairy industry to increase the competitiveness of its farmers. The farmer receives confusing and often conflicting signals. For example:

- signals from the EU are focused on the environment, not on farm efficiency;
- high tax rates encourage high farm spending;
- schemes and grants get so much attention, there is little room for helping farmers become more efficient;
- there is a strong agribusiness sector very successfully targeting the farmer's pocket.

Farmers cannot be blamed for not exploiting Ireland's competitive advantage; there is no strong leadership or united focus to encourage dairy farmers to be more competitive.

A cost competitive dairy industry must focus on:

(a) developing and promoting the production system that is best for Ireland and

(b) developing a "pro-active" attitude towards cost control within the farm-gate.

It is the combination of an attitude to cost control and a low cost production system that is missing on the majority of farms.

The technology to produce milk at low cost is here – calve cows to grass, manage the pastures to provide high quality grass for as much of the year as possible, and produce this milk through efficient cows. There are farmers using this technology very well but who do not have high profits. Why? Because the technology is not being combined with good financial control of the business. Physical management of the farm can be excellent, but the results are too often lost in wasteful expenditure and capital investment.

The failure to either use or combine technology with financial management is reflected in the following survey of farm accounts. Eddie McQuinn & Associates of Tralee carried out an analysis of dairy farm accounts for 1993. The survey size was substantial, made up of 2400 cows and 2.3 million gallons of milk. The results and trends are consistent with those found in the National Farm Management Survey.

The two main areas looked at were: total farm profit
net worth

These are two of the most important figures in accounts that every farmer should know.

A FARM PROFIT

Total Farm Profit is: Total Farm Income (from milk, calves, culls, cattle, sheep)
LESS
Total Farm Expenses (not including drawings or tax)

In the accounts analysis, average farm profit for 1993 was £11,400.

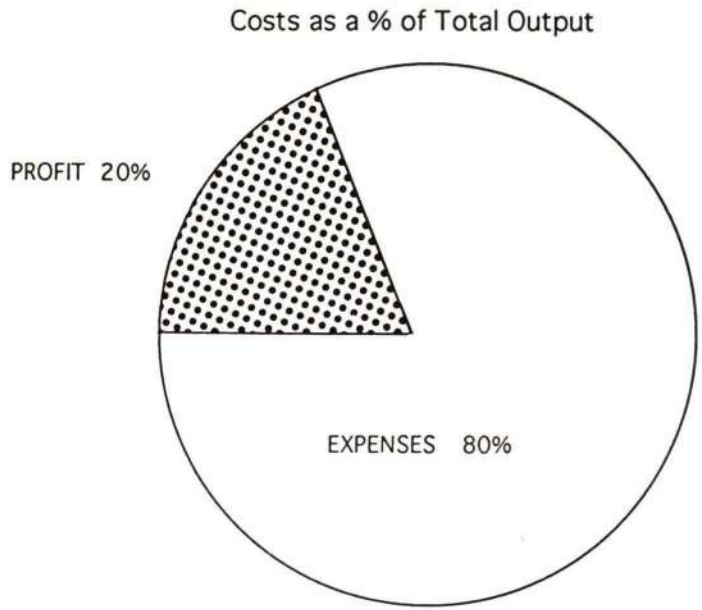

Fig. 1

Dividing farm profit by the number of gallons sold, gives the net profit per gallon. Profit per gallon is a measure of how efficiently milk is being produced.

The average number of gallons sold was 41,500 gal.

Profit/gal = £11,400/41,500 gal

= 28p/gal

The average farmer was making 28p/gal of milk sold in 1993.

Yet, the range in farm profitability was staggering and re-emphasises the enormous potential for Irish farmers to become more competitive and cut costs. The top 10% of farms had an average profit margin of 64p/gal vs 2p/gal for the bottom 10%. Total income, before expenses, was £58,000 (£1.40/gal) including milk calves, culls and some cattle sales.

For each £1 output, only 20p was retained by the farmer. 80% of total output was gobbled up in farm expenses. The biggest items of expenditure were feed and fertiliser followed by depreciation on machinery and buildings.

Some farmers will be making less than 10 pence for every gallon of milk sold, while a few will be making 70 pence or more.

Why is there such a range? Based on the accounts analysis, what factors were responsible?

1. Size of farm

You would expect that as farm size increases, there are more gallons over which to spread fixed costs, hence, larger farms should have lower costs of production. However, there appeared to be no correlation at all between farm size and efficiency (Figure 2).

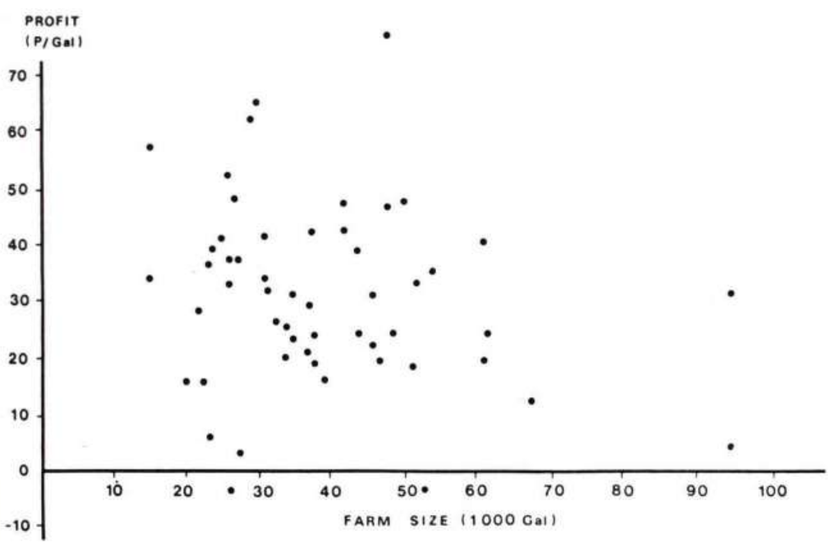

Fig. 2

2. Yield per cow

Gallons of milk produced per cow receives lots of attention. Yield is easily measured and recorded and tends to be a source of competition and pride.

Unfortunately, if your farm objective is profit, yield per cow will tell you nothing. The following graph shows there is no relationship between yield per cow and profit per cow.

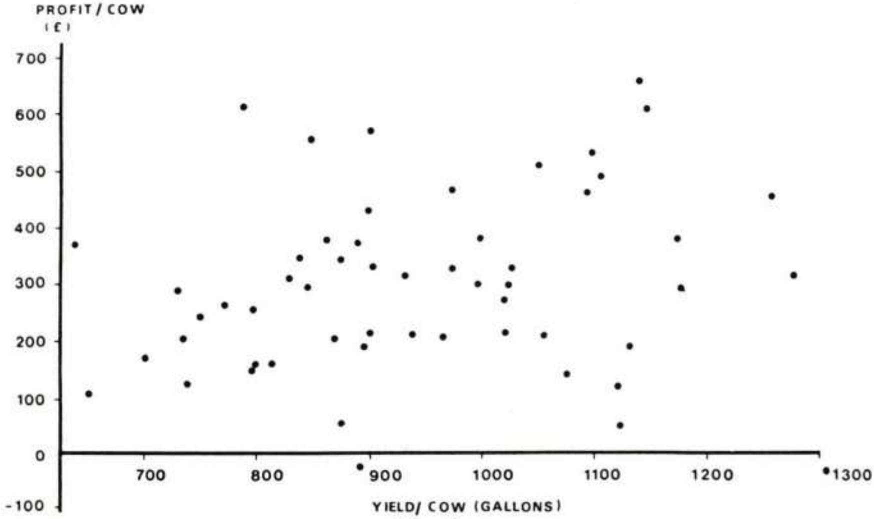

Fig. 3

Even looking at change in yield per cow on individual farms over two years showed no correlation to change in profit (Figure 4).

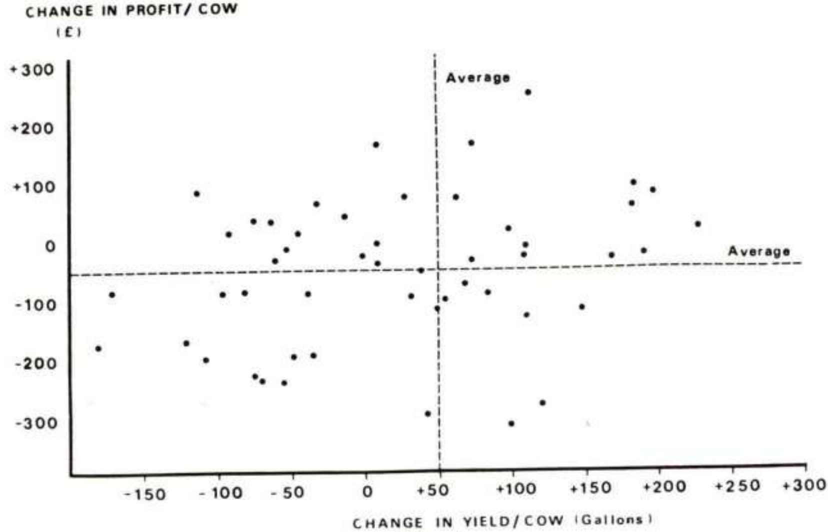

Fig. 4

Focusing simply on yield itself will achieve nothing in terms of increased profitability and may, in future years, only encourage higher cost systems of production.

On some farms there is a good relationship between yield per cow and profitability but only when increased yield is achieved at very little or no cost. Most likely it is the result of better breeding, grassland management or animal management.

3. Cost control

Clearly the range in farm profitability is not due to farm size or yield per cow. When the top 10% of farms are compared to the average, the top 10% had lower costs as a % of total farm output (Figure 5).

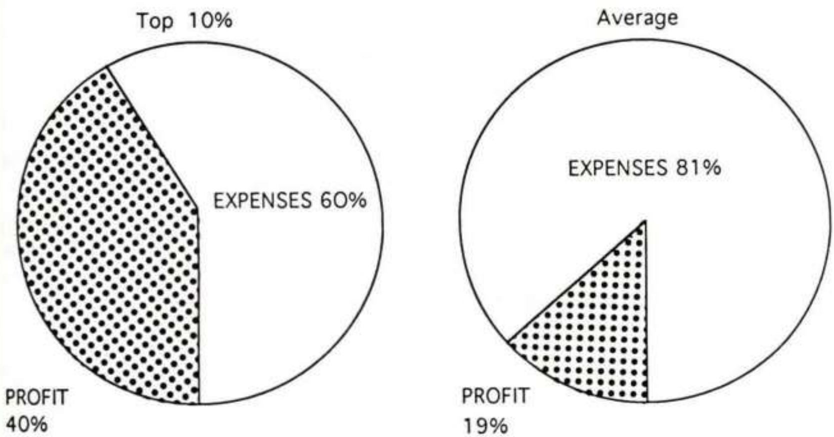

Fig. 5

The most efficient farmers were retaining nearly 40% of output while the average was retaining less than 20%. The top 10% were spending less on **all** items of expenditure, including all variable and fixed costs. This supports the view that it is the "attitude" to how the farm business is run that has the biggest effect on farm profit.

B NET WORTH

The second and most important area looked at in the accounts analysis was "net worth". Net worth is what the assets (farm, stock, machinery, cash, shares, etc.) are worth, LESS any borrowings. As a result of your management and hard work you obviously want to be worth MORE and not less over time.

In Eddie McQuinn's accounts analysis, the net worth of the average farmer had remained static in 1993, despite the milk price averaging £1.03/gal and excellent prices for calves and cattle. When incomes are booming, there should be an aim of increasing net worth. To grow net worth, farm profit must be high enough to cover living expenses, pay tax and still generate a surplus.

Farmers in the top 10% for increasing net worth averaged 7% growth. At the other end of the scale, the bottom 10% decreased net worth by 5%.

Farm size of the top 10% ranged from 29,000 to 95,000 gallons. Again, smaller farms that ran the business efficiently competed very well with large farms. Farm size was not an issue.

Summary

In summary, the lack of cost control relative to output is the main reason why the average Irish dairy farmer is not as competitive as he should be. The majority of farmers and the wider dairy industry are production and income-driven and not profit-driven. What is the point of focusing on income when so little of it is being retained as profit?

Ireland should have a competitive advantage but it is not being exploited. For Irish farmers to become more competitive, the entire industry must recognise the potential that is there and focus on achieving a more efficient, cohesive, profit-driven dairy industry.

Farming will become more competitive by:

1. Focusing on production systems which maximise the use of grazed grass;
2. Focusing on production systems which minimise the investment in depreciating assets of machinery and buildings;
3. Developing clear policies of spending only what is needed to produce milk efficiently;
4. Setting clear targets of increasing net worth.

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Manure Management

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Summary

Landspreading of manure on the silage ground is the most practical management strategy on grassland farms. Slurry can reliably substitute for fertiliser P and K while 0.25 of the N is available in spring though it is much less at all other times. Therefore, landspreading of manure can reduce grass production costs through lower fertiliser inputs. The need to protect the environment and existing legislative requirements demand slurry be managed without causing pollution. Landspreading at the right time and at the correct rate will help eliminate this risk. However, manure creates management problems for the farmer which militate against effective recycling of the manure nutrients and increase the pollution potential. These problems are being addressed by the Teagasc research programme and cost effective solutions will emerge to assist the grassland farmer in his attempt to achieve sustainable production systems.

Introduction

Grass provides an energy and nutrient source for animal maintenance and production. Between 0.05 and 0.20 of the minerals ingested by grazing animals are absorbed and the remainder excreted in the manure. The value of animal manures as a nutrient source for crop production has been known for millennia. Xenophon in 400 B.C. described its importance for crop production.

In the last 50 years there have been many changes in agricultural production. In Western Europe these reflect many social changes including an increased demand for livestock products. The availability of relatively cheap inorganic fertilisers as the major source of improving and maintaining soil fertility was an important response to this demand. A consequence has been that agricultural manures became agricultural wastes. In the last 10 years the environmental implications of this change in attitude may have contributed to the deterioration of the quality of our surface water. The degree of public concern is emphasised by the continuing introduction of legislative controls at National and European level.

Sustainable farming systems are required in response to both the current and future environmental legislation, CAP reform and GATT. The role of manure on grassland farms is being reconsidered as fertiliser accounts for about 0.33 of agriculture's energy requirements combined with the requirement to protect our environment. In this paper the potential of manure to substitute for chemical fertilisers and the practical problems facing the grassland farmer in achieving this objective are reviewed.

Background

Quantity of manure. Significant differences in the quantity of manure and the nutrient load they impose have been shown between individual EC countries.

For example, the Netherlands has an estimated animal manure load in excess of 42 t ha^{-1} of utilisable agricultural land whereas in Greece and Spain the corresponding values are only 3 t ha^{-1}. This contrast in the extent of the problem, between countries, is reflected in the different national approaches to providing solutions in one country may not be appropriate to another.

In Ireland, total annual manure production has been estimated at almost 87 million tonnes – 85 million tonnes from grazing animals and 2 million tonnes from pigs and poultry. At grazing the manure is returned or recycled, naturally, to the pasture. During the winter many of the grazing animals are housed for varying periods of time. It has been estimated that these animals produce 29 million tonnes of manure or 0.33 of the total during the indoor winter period. This is the quantity of manure which has to be managed each year.

Manure management systems on farm. Animal manures are generally stored in semi-solid or liquid form. The semi-solid waste is stored in dungsteads and is the excreta mixed with relatively small quantities of bedding material. Recent trends on intensive livestock production farms have resulted in liquid or slurry systems where animals are housed on slatted floors, without bedding material, over the storage tanks. The advantages of slurry systems are that it facilitates the management of large livestock units with savings in labour and material costs. There are no accurate data available on the labour and material costs. There are no accurate data available on the types of manure management systems for the different animal enterprises. A significant proportion of farmers are still operating solid storage (dungstead) manure systems for dairy and beef cattle. However, it is very likely that the smaller proportion of farmers using slurry storage systems are responsible for the biggest proportion of national manure output.

Nutrient composition. The nutrient composition of slurry is influenced by the type of animal, its diet, the storage conditions and the extent of the dilution with either water or litter. The effect of animal type and diet on the nutrient composition of their respective slurries is illustrated (Table 1). The phosphorus (P) and potassium (K) concentrations of cattle slurry are 0.5 and 2.0, respectively, of those in pig slurry. This reflects the grass based diet of the bovine compared with the cereal based diet of the pig. The nutrient values quoted reflect those reported in the literature in spite of the geographical diversity of the origin of the slurries. The nutrient values of slurries shown in Table 1 are at best a guide to composition.

Table 1

The average nutrient content of cattle and pig slurry

Slurry	Dry matter (%)	Nitrogen	Phosphorus (kg of nutrients 10 t^{-1})	Potassium
Cattle	8	38	6	42
Mean from literature	8	40	7	37
Pig	4	30	9	15
Mean from literature	8	58	14	23

In practice there is considerable variation in nutrient values of slurries between farms (Table 2). Dilution with extraneous water was responsible for the large between-farm variation in dry matter contents of the slurries. Transporting dilute slurry is expensive and the spreading operation will take longer as there will be more slurry to be spread. There is a clear need for some form of "quality control" on farms by reducing to a minimum the quantity of water entering into storage tanks.

The annual value of Irish manures was estimated to be IR£120m which is equivalent to about half the total amount Irish farmers spend on fertilisers. Complete substitution of manure for fertiliser is not possible. However, the value of the nutrients illustrates the potential of farm manures to replace part of the inorganic fertilisers as nutrient sources for grass production.

Table 2

Nutrient values of cattle and pig slurry

Slurry type	Dry matter (%) ($g\ kg^{-1}$)	Nitrogen	Phosphorus	Potassium
		kg 10 $tonnes^{-1}$ (fresh slurry)		
Cattle (50 samples)				
Mean	6.9	36	6	43
Range	2-12.3	11-71	1-12	10-82
Pig (52 samples)				
Mean	3.2	46	9	26
Range	1-10.2	15-95	1-32	7-52

The total quantity of organic matter and nutrients contained in slurry represent a serious threat to both ground and surface water. Therefore slurry must be managed in such a way as to maximize the slurry nutrient uptake by the crop while minimizing the risk of nutrient leaks to the environment. Landspreading is the most economical and environmentally friendly strategy for slurries on Irish farms. As 0.93 of the Irish land area is grassland, the manure is almost exclusively applied to grassland.

Summary

The variability in slurry composition highlights a problem for the farmer when trying to determine the correct slurry application rates. An objective of Teagasc's slurry research programme is to develop a reliable, automated and rapid method for estimating the nutrient composition of slurry on the farm.

The nutrient concentration of slurry is used to estimate the slurry application rates. The objective is to match as closely as possible the slurry nutrient application with the requirements of the crop. As a general rule the crop's K requirement is used as the basis for the assessment of the volume of cattle slurry while the crop's P requirement is used as the basis for the assessment of the volume of pig slurry.

Availability of slurry nutrients

The N and P in slurry is divided equally between mineral and organic forms while the K is nearly all in the mineral form. The mineral forms are immediately available to the plant while the organic forms must be mineralised before they become available to the plant. The rate of mineralisation is variable and may take a number of years.

Phosphorus and Potassium. The availability of slurry P and K was determined by field and pot trials and estimates of slurry nutrient availability were made (Table 3). In making these estimates cognizance was taken of soil fertility levels. Where soil fertility is low the rate of mineralisation is too slow to meet current crop requirements and account should be taken only of the mineral form of the nutrient in the slurry (Table 3).

Table 3

The proportion of slurry nutrients available in the season of application

Slurry type	Nitrogen	Phosphorus	Potassium
Cattle	0.25	0.50	0.88
Pig	0.50	0.57	0.60

Slurry P and K utilisation on grassland have efficiencies ranging from 0.1 to 1.0. However, on a fertile soil, the P and K in slurry have the same efficiency as inorganic fertiliser P and K provided that they are correctly applied.

Nitrogen. The efficiency of slurry N for crop production is considerably less than either the P or K (Table 3). The relatively low efficiency reflects the ease with which N, compared with P and K, can be lost from the system. Estimates from the Netherlands suggest that up to 0.80 of N is not accounted for on intensive grassland farms. Following storage, cattle slurry N is composed of organic-N and ammonium-N in approximately equal proportions. In soil there is a tendency for N in all forms to be converted to nitrate N by soil microorganisms. The rate at which this conversion proceeds can vary depending on the level of microbial activity.

Organic-N from slurry. The organic-N in slurry is not immediately available to plants but it is estimated that ca 0.50 of the organic-N will be converted to ammonium-N during the first 12 months after spreading. Fifty percent of the remainder will become available in the second year, and so on in succeeding years according to a typical decay series. For the grassland farmer the organic-N is not important in terms of a grass yield response because of its slow unpredictable release. Therefore only the ammonium N is potentially available when considering a nitrogen contribution from slurry for grass production.

Ammonium-N from slurry. Following landspreading there are a number of options for the ammonium-N including volatilisation of ammonia to the atmosphere, plant uptake as ammonium and conversion to nitrate. The ammonium compounds in slurry are unstable and decompose easily with ammonia gas volatilising to the atmosphere. Volatilising of ammonia is a mixed blessing. Where slurry is treated as a waste for disposal, volatilisation of ammonia saves the soils, and ultimately waters, from being overloaded with nitrogen. On the other hand, volatilised ammonia will be carried in the atmosphere and deposited in rain in some other area – possibly an environmentally sensitive area where nitrogen may be undesirable. The total loss on any one occasion depends on a number of variables including the composition of the slurry, weather and soil conditions and the spreading technique used.

The ammonium-N not volatilised or absorbed directly by the plant is mineralised to nitrate. In this form it is available to the plant. However, if the plant is not growing, the nitrate from the slurry application remains in the soil solution and is available for leaching. Leaching of nitrate to groundwater occurs on the lighter free draining soils. The concern about the health implications of nitrate in drinking water has resulted in an EC Directive (80/778) controlling admissible concentrations. The implications are that autumn or late winter slurry applications should be avoided on the lighter free draining soils.

Crop recovery of ammonium-N. From a grassland farmer's perspective volatilisation of ammonia is the loss of nitrogen potentially available to the crop. The new spreading techniques of shallow injection and bandspreading reduce volatilisation compared with the conventional splashplate method. Improved crop recovery of the ammonium-N in cattle slurry when applied to grass for silage using a bandspreader or shallow injector. This improvement in recovery reflected the reduced volatilisation losses. More recent data from field trials at Johnstown Castle have found similar results but with considerable variation.

Slurry treatments including dilution, separation and pH alteration to reduce volatilisation can improve the recovery of the ammonium-N in cattle slurry by a silage crop. While treatments improve N recovery compared with untreated slurry, the pH reduction treatment appeared to be the best practical option. Recently, the International Fund for Ireland has provided significant funding for a collaborative study between Queen's University Belfast and Teagasc (Johnstown Castle, Oak Park) to combine spreading and treatment approaches in the one operation. The primary objective is to improve the recovery of the ammonium-N in slurry by the plant.

Summary

The slurry P and K can contribute to the nutrient cycle on grassland farms by substituting directly for inorganic fertiliser P and K. The quantity of mineral fertiliser used should relate to the deficit remaining when the slurry nutrients have been recycled. To achieve this the farmer must ensure the slurry is applied as evenly as possible, at the correct rate and at the right time. The value of slurry N for silage is about 0.25 of the total N present in the slurry for spring applications and zero at all other times. Therefore slurry has a clear potential to replace fertiliser nutrients thus reducing farm costs. Nutrients utilised by the crop do not cause pollution.

Problems for the farmer

Slurry management creates a number of practical problems for the grassland farmer. These include relatively few spreading opportunities, unsuitable spreading equipment, agitation and variable nutrient composition. When these are considered it is easier to understand why grassland farmers tend to regard slurry as a waste rather than an integral part of the farm's nutrient cycle.

Spreading opportunities. It is recommended that cattle slurry be applied to the silage rather than the grazing ground to minimize the risk of disease transmission from the landspreading of cattle slurry. This implies that there are, at best, four spreading opportunities during the year. In early spring for first cut silage, immediately after the first cut for second cut silage, immediately after the second cut for third cut silage or in the autumn just before the animals are brought indoors for the winter. On wet-land farms wet soil conditions may eliminate the spring or autumn options reducing the spreading opportunities to two. In practice most of the slurry is spread in autumn. This increases the risk of nitrate leaching on the free draining soils and the risk of runoff on the wetter heavier soils. The time interval for spreading in spring is weather dependent in that suitable conditions must exist to ensure runoff losses are minimized. Therefore a major objective of Teagasc's research and advisory programme is to bring the spreading date forward into the spring and summer. However, solutions are required for a number of practical problems before this can be realistically achieved.

Agitation. The natural settling and flotation that occurs in slurry tanks necessitates agitation before spreading. To remove the slurry from the storage tank it must be agitated, otherwise the liquids would be drawn off leaving only the solids which cannot be evacuated by conventional methods. Also, if there is no agitation the initial slurry removed from the storage tank will contain the liquid fraction with most of ammonium-N and K while the slurry removed later will contain most of the P and the organic N. Therefore, for effective nutrient recycling, it is very important to ensure the slurry is agitated before spreading. This creates a problem for the spring spreading opportunity because the animals are still indoors. They must be removed from the building before the slurry can be agitated to reduce the risk of poisoning from hydrogen sulphide gas.

Effect of slurry contamination on ensilability. There is concern among farmers about the potentially negative impact of slurry spreading on the subsequent ensilability of silage crops. Teagasc research has established that there is no negative effects of slurry application on the grass composition or fermentation for all silage cuts provided it is applied at the correct time and rate.

Slurry spreading machinery. The most common machine available for slurry spreading (i.e. the vacuum tanker) has changed relatively little in 30 years with the exception of its increased capacity. Originally designed for disposal, i.e. spreading large quantities of slurry quickly, with a minimum of maintenance, little attention was given to evenness of application, rate of application or emissions (ammonia and odour). With the objective of utilising slurry as a nutrient source for crop production, agricultural engineering attention is now focusing on providing solutions. Much attention is being devoted to the spreading options of bandspreading and shallow injection which apply the slurry evenly and reduce odour and ammonia emissions and may also reduce the incidence of poor fermentation which can be associated with splashplate applied slurry. The new spreading techniques compared with the conventional splashplate reduce the opportunity for the dispersal of disease causing bacteria that may be present in the slurry

Methods to monitor slurry application rate from a vacuum tanker have been developed. The need for such a device is highlighted by a particular farm situation where the measured application rate was 2.5 times that of the operator's estimate.

Agriculture and Water Pollution – The Main Issues

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Up to the first half of the twentieth century, Ireland on the whole escaped the worst ravages of water pollution that were apparent in some of the more developed countries. This was mainly due to a combination of factors, the more important of which were that:

(i) the bulk of the population resided in rural areas,
(ii) the bulk of the urban population resided in coastal areas,
(iii) there was a very low level of industrial development, and
(iv) there was an abundance of water resources.

In the period 1961 to 1981 the population of the Republic of Ireland increased from 2.82M to 3.44M. This population growth was accompanied by a rapid decline in the rural, and a rapid expansion in the urban populations and was also accompanied by a very substantial increase in industrial activity and by an intensification of agriculture. A measure of this can be gauged from the country's export performance, the value of which increased from £103M in 1959 to £9,743M in 1985.

All of these developments over the last 30 years have led to the discharge of greater quantities of waste to rivers, lakes, estuaries and coastal areas. The introduction of the Local Government (Water Pollution) Act, 1977 was a recognition by the Government that new initiations were required to control and abate water pollution.

The main causes of water pollution in Ireland

The principal causes of water pollution in Ireland are:

1. *Untreated or inadequately treated municipal sewage.*
2. *Industrial effluents* - mainly from the longer established meat and sugar factories and from creameries and tanneries.
3. *Agricultural effluents* - particularly animal slurry and effluents from silage pits.
4. *Eutrophication* - There has been an increase in eutrophication (enrichment leading to increased weed/algal and caused mainly by increased phosphorous in fresh waters) in many Irish rivers and lakes over the past few years.
5. *Toxic and Hazardous Waste* - Including chemicals from industry, heavy metals from industry and mining, biocides (run-off of pesticides, insecticides, herbicides and fungicides from agricultural land), industrial and transport spillages, bacteriological contamination or ammonia from sewage or animal slurries, etc.

Dissolved oxygen in natural waters

Oxygen is only slightly soluble in water and concentrations will depend on temperature, salt content and on biochemical activity in the water body. Dissolved oxygen is essential for the survival of most aquatic animals and its determination is therefore a key test in pollution control.

Table 1

Some values for the solubility of oxygen in fresh water and in salt water at various temperatures

Temperature	Dissolved oxygen concentrations at equilibrium (100%) saturation	
	Fresh water	Salt water
5	12.8 mg/l O_2	10.0 mg/l O_2
10	11.3	9.0
15	10.2	8.1
20	9.2	7.4
25	8.4	6.7
30	7.6	6.1

Dissolved oxygen concentrations are expressed either in absolute values of mg/l O_2 or in relative units of percentage saturation (e.g. fresh water at 10°C and at 100% saturation contains 11.3 mg/l O_2, while at 10°C and 60% saturation the concentration is 60% of 11.3 = 6.8 mg/l O_2).

Waste assimilation and biochemical oxygen demand (B.O.D.)

When a biodegradable organic waste (e.g. domestic sewage, food factory effluent, animal slurry, silage effluent, etc.) is discharged to a water course, it serves as a food source for bacteria and other microorganisms (which are naturally present in the water). These aerobic bacteria will commence the breakdown of the organic material and in so doing will multiply in numbers and consume the oxygen dissolved in the water. If the quantity of waste present is sufficiently large then the rate of bacterial uptake of oxygen will outstrip the re-aeration capacity of the water (i.e. the rate at which dissolved oxygen is replenished from the atmosphere) and the dissolved oxygen concentration will diminish. This can have serious effects on fish and other aquatic life. Ultimately the dissolved oxygen level could drop to zero, then conditions would favour anaerobic bacteria which produce foul smelling odours (eg. the river Liffey smell of the 1960's).

The Biochemical Oxygen Demand (B.O.D.) of a water or effluent is the amount of oxygen which is used up by bacteria in breaking down that organic matter which is amenable to biological oxidation. The B.O.D. test is an important test in the determination of water quality, it is also used to determine the polluting strength of domestic, agricultural or industrial effluents. Some examples of B.O.D. levels are given in Table 2.

Table 2

Examples of B.O.D. levels for water and effluent samples

Sample	B.O.D. range (mg/l O2)
Clean water	< 3
Doubtful quality water	3 to 5
Poor quality water	> 5
Treated sewage	10 to 40
Untreated domestic sewage	300
Cattle slurry	12,000
Pig slurry	30,000
Silage effluent	60,000

It will take a period of time for the bacteria to degrade the waste and therefore, in a river, it will be some distance downstream from the discharge that the low dissolved oxygen levels will occur. The greater the amount of waste in the river, the greater will be the oxygen uptake. However, the re-aeration capacity may be such that no serious depletion in dissolved oxygen occurs, shallow or turbulent rivers will have a high re-aeration capacity. As the waste is assimilated by the bacteria, their food supply is reduced causing their numbers to diminish and the river gradually recovers.

A diagrammatic presentation of the effects of an organic effluent on a river and the changes as one passes downstream from the outfall is given in Figure 1. When sampling a river stretch to determine the effects of an effluent discharge on water quality, it is necessary to take samples of the effluent, an upstream sample from the river and several downstream samples (at various distances from the outfall).

Game fish will be affected if dissolved oxygen levels drop to 50% saturation for any significant period. Coarse fish will also be affected if levels are around 30% saturation.

Eutrophication

Another factor influencing dissolved oxygen levels in natural waters is the abundance of plant life, including algae. Eutrophication is the enrichment of water bodies with nutrients (mainly phosphorous and nitrogen) which leads to excessive growths of plants and algae.

Phosphorous is perceived to be the limiting nutrient for weed and algal growth in freshwater whereas nitrogen is more significant in saline waters.

Eutrophication can occur either naturally or artificially. Natural eutrophication occurs mainly in lakes and is due to the very gradual increase in phosphorous levels brought about by processes such as shallowing (filling up with organic and inorganic sediments) or by traditional agricultural practices. Artificial eutrophication arises from the marked increases in nutrient supply from wash off of artificial agricultural fertilisers or from domestic sewage, industrial effluents or waste from intensive farming operations.

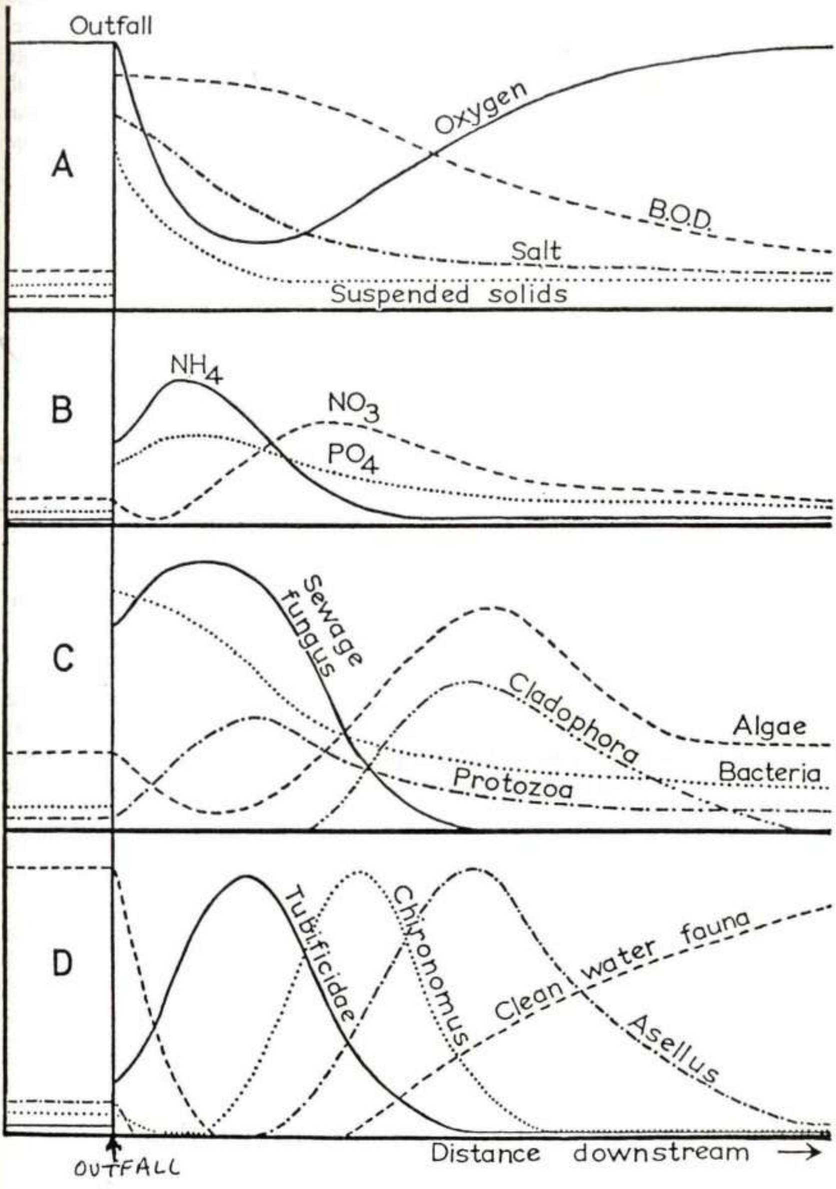


Fig. 1 – Diagrammatic presentation of the effects of an organic effluent on a river and the changes as one passes downstream from the outfall. A & B physical and chemical changes, C changes in micro-organisms, D changes in larger animals.

Plants undergo respiration at all times, during daylight hours they also undergo photosynthesis. This results in a net output of oxygen during the day and a net intake of oxygen by the plants at night. In eutrophic rivers or lakes the exchange of oxygen between the plants (including algae) and the water can lead to high (frequently super-saturated) levels of dissolved oxygen during the day but dissolved oxygen levels can decline seriously during the hours of darkness (see Figure 2).

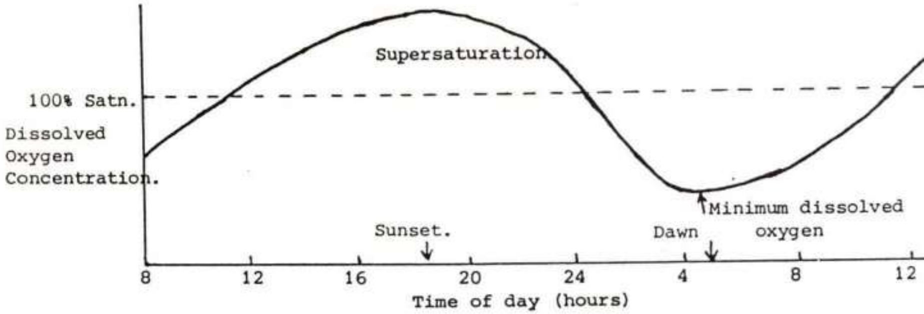


Figure 2 – A typical 24 hour study of dissolved oxygen at a point in a eutrophic river or lake.

The critical period for dissolved oxygen in eutrophic waters occurs just before dawn (i.e. after maximum hours of darkness). During summer, when the river flows are low and plant growth is at a maximum, eutrophic conditions have caused fish kills. However the short hours of darkness during summer nights in Ireland help to lessen this effect.

Eutrophication can be much more serious in lakes than in rivers. In lakes the phosphorous levels can build up and recycle between water, plants and sediments whereas in rivers the nutrients are eventually carried to the sea.

Phosphate is freely removed from water by plants and algae during the growing season. Therefore increases in eutrophication are not always evident from the analyses of phosphate in water samples. In many instances the eutrophication problem is more evident from the weed/algal growth and from the effects on dissolved oxygen.

Slime growths (sewage fungus)

Slime growths of bacteria/fungi/protozoans, commonly called Sewage Fungus, are often found in rivers with an excess of organic waste.

These visible slime growths which resemble "sheep's tails" cause adverse changes in the nature of the bottom fauna and flora. They can also exert an oxygen demand. Slime growths are often associated with silage effluent pollution and with sugar factory effluents, until recently they were also often found downstream from meat factory discharges.

Nitrates

The use of nitrogenous fertilisers in Ireland increased from 90,000 tonnes in 1970/71 to 323,000 tonnes in 1985/86. A high dietary intake of nitrate is known to lead to the condition methaemoglobinaemia (blue baby syndrome) in bottle-fed infants and is suspected to cause the formation of carcinogenic nitrosamines and nitrosamides. Normal treatment of water for domestic supply does not remove nitrate, therefore waters used for drinking must be protected from nitrate contamination at source.

Nitrates are of concern in some ground-waters, especially in areas where there is porous bed-rock covered with a shallow layer of soil.

Nitrate levels in river waters in Ireland are generally well below the E.C. maximum admissible concentration (11.3 mg/l N) for drinking water. However levels have increased especially in areas associated with intensive tillage farming (e.g. parts of counties Carlow and Wexford) where the recommended limit (5.65 mg/l N) is exceeded in some rivers at times, mainly during winter. High nitrate levels are of major concern in many of the developed countries and levels in Irish rivers therefore need to be carefully monitored.

Short-term pollution incidents

Public concern regarding "once-off" types of pollution of surface waters has increased significantly in recent years. Incidents of this type mostly involve the direct ingress of high-strength wastes to waters over a short period which result in fish kills in otherwise unpolluted rivers. In some cases water abstractions have also been affected.

In many cases the factor involved in these acute pollution incidents has been the waste liquor from silage-making operations or animal slurry. Water pollution problems arise when proper containment of the waste liquor is not allowed for and it flows directly to nearby streams or is rapidly leached there by rainfall.

The very high B.O.D. content of these agricultural wastes suggest that the fish mortality in pollution incidents arises from deoxygenation of the water. However, the presence of potentially toxic substances such as ammonia from slurry may also have a direct effect on fish or else act indirectly by lowering their tolerance of deoxygenation. The effects of silage liquor pollution are further aggravated in summer months, when river flows are likely to be reduced and water temperature are relatively high.

In many cases the pollution incident may not be discovered for a period of time and the polluting matter will have been washed downstream and will not be detected in chemical samples. However a biological examination of the macroinvertebrate fauna of the river may indicate the location of the spillage and also indicate the extent of the effects of the pollution (see Figure 1).

WATER QUALITY MANAGEMENT PLANS

Section 15 of the Local Government (Water Pollution) Act, 1977, provides for the preparation of Water Quality Management Plans. Such plans may cover the water located in one local authority area but the Act also provides for a number of local authorities to consult together to take Co-ordinate action on a river catchment basis by the preparation of river catchment Water Quality Management Plans.

The concept of river water quality management

Water is used for many beneficial purposes, some which involve changes in quality and some which do not. These uses include abstractions to meet the needs of public water supplies, industry and agriculture and the in situ uses associated with commercial and sport fishing and recreation. The controlled disposal of wastes, arising from domestic and industrial sources, is another important use, even though it is a potential constraint on the foregoing uses. These various water uses and associated factors are inter-related, often complex, sometimes conflicting and they cannot be managed properly as a whole without adopting a comprehensive approach and without the availability of a wide variety of data and basic information.

Objectives of water quality management planning

The main objective to be achieved by a Plan is to ensure that the quality of the waters are maintained in a satisfactory condition and where necessary improved, thereby:

- (i) safeguarding public health
- (ii) catering for the abstraction of increasing quantities of water for domestic, industrial and agricultural purposes,
- (iii) catering for the needs of commercial and game fisheries,
- (iv) catering for the relevant water-based amenities and recreational requirements (including bathing).

Other vital objectives of the Plan are to identify the control measures deemed necessary in relation to the satisfactory treatment and disposal of existing and future sewage and industrial effluent discharges and also to identify the priorities for investment in public and private (industrial) waste water treatment facilities.

Methodology adopted in preparing the Plan

(i) All the available basic data relating to water quality and water quantity are collated.

(ii) The existing waste loads discharged to surface waters in the catchment are determined and projections of the future generated waste loads over the next 20 years are also estimated.

(iii) Existing water abstractions for public, industrial and agricultural purposes are assessed and the projected future demand is estimated.

There are often many gaps in the data available and it is vital that these gaps are eliminated.

(iv) The beneficial water uses (existing and future) to be protected within the catchment are identified.

(v) The Water Quality Standards deemed necessary to support the various beneficial uses are defined. In doing this, reference is made to data and information from various sources including:

E.E.C. Directives and National Legislation concerning –

(a) Surface Water intended for the abstraction of drinking water.
(b) Freshwater fish (Salmonid waters).
(c) Bathing waters.
(d) Shellfish waters.

US Environmental Protection Agency Criteria for water quality. Memorandum No. 1 as issued by the Dept. of the Environment. The general water quality conditions pertaining in the catchment.

Where a variety of beneficial uses must be catered for, then those requiring the highest quality of water determine the standards which must be set.

(vi) Estimates of the assimilative capacity (i.e. the capacity of the water to deal with effluent discharges without exceeding the standards) are computed and the maximum permissible waste loads that can be discharged to the river at a number of key locations are determined. The assimilative capacities have normally been calculated at 95%ile river flows (i.e.. the flow which is exceeded for 95% of the time).

A computerised mathematical model to predict the effects on water quality of waste discharges at various locations may be developed. This is of particular importance in estuaries.

(vii) Any areas at present overloaded by waste discharges are identified as are the remedial actions deemed necessary to rectify these problems.

(viii) A number of options in relation to the treatment of existing and future waste waters may be identified. In earlier Water Quality Management Plans these options related mainly to B.O.D. removal and included primary sewage treatment as an option. However, the recent EC Directive concerning urban waste water treatment (91/271/EEC) has removed primary sewage treatment as an option at larger towns as the Directive requires a least secondary (biological) treatment at the main centres of population. This Directive will play an important part in the preparation of future Plans.

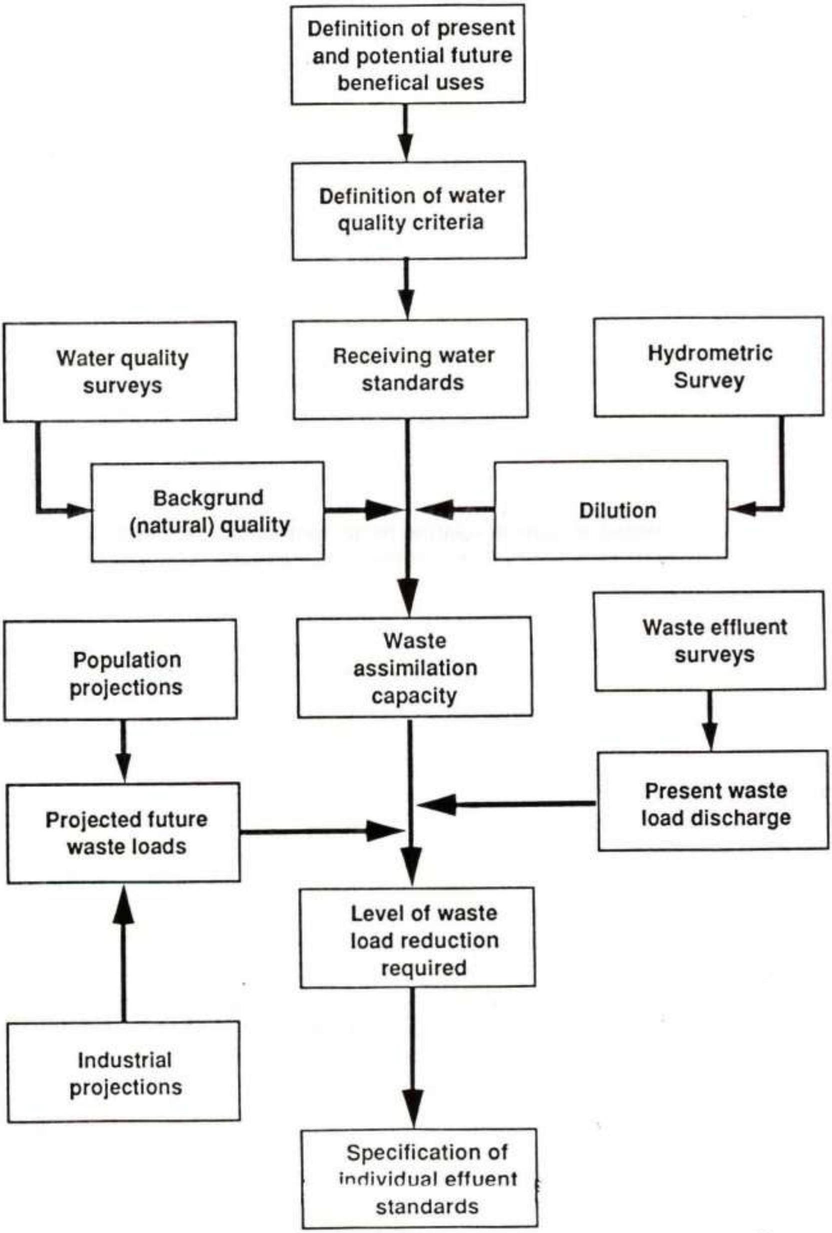
An increase in eutrophication in rivers and lakes in Ireland has been observed over the past few years and therefore the option of phosphorous, removal from treated sewage will probably be included in future Water Quality Management Plans and in existing plans as they are reviewed.

(ix) The main priorities for capital investment in both public and private waste water treatment facilities are identified.

(x) The Plan should also include recommendations on an active programme, including a programme of monitoring water quality for compliance with the standards, which will ensure that all the necessary basic data required are collected on an on-going basis to facilitate updating, revision, refinement and implementation of the present plan.

(xi) Provision is included for periodic reviews of the plan. This is necessary in order to judge the performance of the Plan. Also, unforeseen developments may arise. The monitoring may show up new or unknown problems and new EC Directives may be implemented or existing standards modified.

(xii) Provision for a study of the ground-water in the catchment area may be included in a plan. In this regard, a ground-water survey by the Regional Water Laboratory in the south-east region using a computerised map based system (GIS) is contracted under the EC STRIDE Programme and this will start in January 1993.



Simplified representation of the main elements of a water quality management plan

CONCLUSIONS

New sewage treatment plants have been constructed in many of the larger towns in the south-east region over the past decade or so ; these include Thurles, Nenagh, Cahir, Cashel, Tipperary, Kilkenny, Carlow, Gorey, Enniscorthy, Lismore, Callan and several other smaller towns and villages and there are plans for further effluent treatment plants (e.g. Wexford, Waterford, Carrick-on-Suir & Clonmel). Many industries in the region have also constructed or improved their effluent treatment plants. These treatment plants reduce the organic waste load discharged to the rivers resulting in better water quality, however most of them are not designed to remove phosphorus. The effluents from such plants are therefore likely to retain the eutrophication (or fertilising) properties of the untreated effluent. Also, the eutrophication properties of effluents are often enhanced on treatment because the levels of ortho-phosphate (the most readily 'bioavailable' form of phosphorus) may be higher in the treated effluent. Therefore the removal of phosphorus from some effluents by additional (tertiary) treatment is necessary.

As the various sewage treatment plants were commissioned and also as industrial effluent licences have become more fully complied with, monitoring has shown a definite improvement in water quality in many of the rivers previously polluted by industrial and municipal effluents. However some problem areas still exist. Most of these effluents are point discharges and their impact on receiving waters can be monitored accurately and relatively easily.

Agricultural pollution and eutrophication problems, on the other hand, are more difficult to monitor because of their intermittent and diffuse nature. Problems caused by agricultural pollution have been solved or conditions improved in some locations, however some of these have recurred and new problems have developed. Although many of these agricultural pollution incidents are of short duration, they can have serious effects on the river biota sometimes resulting in fish kills in otherwise unpolluted rivers.

A survey by the local authorities of all farms in the country with a view to identifying those with existing or potential pollution problems commenced in 1987. This survey was having a major influence in combating water pollution, however the survey work appears to have discontinued to a large extent in more recent years. The farm pollution advisory service which was also initiated by Teagasc (then A.C.O.T.) in 1987 is also of significant importance in reducing pollution from farm yards.

As further sewage treatment plants are commissioned and as industrial effluent licences become more fully complied with, it is expected that pollution problems from these sources will abate. However phosphate removal equipment needs to be installed in some of these plants.

Pollution from farm yards should also improve - especially if the local authority farm yard survey was intensified to the 1988 level. However run-off of fertilisers (especially phosphate and nitrogen) and slurry from land will be more difficult to control and this problem will require more attention in the future.

Soil Water and Pollution

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Water is the principal carrier of pollutants from the farm as run-off to streams and lakes and by infiltration down to ground-water. We now have a good understanding of the hydrology of most Irish soils largely because of investigative work for better land drainage. We can also with good site investigations quantify water movement in the soil as well as designing drainage systems that efficiently control watertable to a depth suitable for intensive farming.

Polluting materials from farms

There are three principal polluting materials of concern from farms.

1. Phosphate enrichment of surface waters: This is mainly of concern because of the role phosphorous plays in increased algal and other aquatic plant growth which can lead to eutrophication and the deterioration of surface waters for fish.

2. Nitrate leaching to roundwater: This is a problem associated with very specific geological and soil conditions. It is of concern because of its alleged effect on human health.

3. Organic materials with high BOD: These are mainly silage effluent and water contaminated with animal manure or slurry. They are of concern because they cause rivers and streams to be critically short of oxygen particularly in periods of warm weather and low flows resulting in fish kills. They can also cause taint and raised bacterial counts which can be a concern where surface waters are used for public supply. The latter problem can also affect borehole wells but it is mainly confined to domestic wells close to a farmyard (most often the farmer's own) where there are no well-head protection measures in place.

Pesticides and other manufactured chemicals used on farms are not a serious problem in Irish waters largely because of the low intensity of agriculture and the small acreage of horticulture. In the UK pesticide contamination of surface and ground water is due largely to spraying on roads, paths, railways and other urban and industrial areas without soil cover or a crop canopy that aid their breakdown in nature.

Recent research results

A number of small pilot measurements have recently being carried out with a view to quantifying water borne pollutants from agriculture.

Monitoring sources of farm pollution:

The quality of approximately 2,000km of the largest rivers are being monitored for a number of years. The smallest monitoring station will represent several km^2 of catchment making it difficult to properly partition the origin of any pollution present into point (farmyard) and diffuse (land) sources. We have recently begun monitoring land-drains and open field-boundary drains (called sheughs/gripes/dykes locally), some with continuous small flows originating in springs, others with intermittent flow. It is estimated that there are about 2 million km of land drains not counting mole drains and 200,000km of open field-boundary drains. Some of these are being monitored further down along small natural streams to an existing "official" river monitoring station. There are an estimated further 20,000km of such small streams.

Pilot survey of water quality in open field-boundary drains:

In recent years there has been concern that overland flow from nutrient rich soil surfaces is contributing to the increased nutrient status of some rivers and lakes. Long term monitoring on a national scale is only done on rivers, larger streams and lakes. Even where small catchments with different land uses are monitored, the precise effect of land-use and point versus diffuse sources remain confounded. Preliminary results from this trial suggest that analyses made along small open field boundary drains can be used to pinpoint significant sources of nutrient enrichment both point and diffuse and that these analyses can be used to quantify the contribution of each source to the overall nutrient load. While there was a small but measurable difference between forestry, fertilised only at planting, and intensive grassland, results suggest that farmyards and not intensive pasture are the major sources of enrichment. Several farmyards accounted for a 10 to 100 fold increase in open drain levels of BOD and nutrients. Only land areas with excessive slurry applications or with excessive irrigation of dirty water, or tillage with soil erosion, are likely to be significant sources of nutrients. Results also suggest that nutrient levels are attenuated along man-made watercourses with aquatic weed growth. A feature of all the near source levels is that the values for phosphate were much higher than that required by fisheries interests for the highest quality waters, suggesting that the uptake by aquatic plants in open drains is an essential part of the creation of good fishing rivers. It also follows that this system could break down when overloaded and that this is likely to happen when the combined sum of all sources exceeds the level capable of being absorbed by plant growth. There is also evidence that organic effluents from farmyards may by reducing oxygen levels, be responsible for releasing phosphates fixed in deposited stream silts. Open field boundary drains collect runoff not only from the land surface but also from shallow land-drains (moles), conventional piped drains (circa 1 m deep), newer deep land drains ($1^1/_2$ - $2^1/_2$ m deep) and directly from shallow or deep aquifers below the water-table from land with no land-drains. Inflow from the surface of enriched sites would have the highest P levels, while P levels in piped land drainage water is attenuated with depth of land-drain. The deeper the drain the longer the flow path, the greater the time of travel, the deeper the sward rooting and the lower the P levels.

Measurement of attenuation of nutrients and BOD in overland flow from applied slurry:

To make these measurements a long uniform slope on very wet undrained land in wet spring weather with very low nutrient status was deliberately chosen. Slurry was applied at 10,000 gall/ac (112m^3/ha). The nutrients in the overland run-off were measured at short intervals of time (days initially) and later in months. Nutrients and organic fractions were moved slowly downhill with dramatic attenuation. The situation after 4 weeks is given as an example.

Analyses of overland run-off water samples from un-fertilised and un-drained land which received 10 000 gall of 8% DM slatted floor slurry on 24th March in very wet weather

Analyses (mg/l) 4 weeks after spreading			
Distance down slope from treated area	P	NH_4-N	BOD
0.0m	20.30	51.40	810.00
0.5m	13.80	39.00	490.00
1.5m	0.20	0.70	81.50
5.0m	0.25	1.55	57.00
10.0m	0.78	2.50	20.80
40.0m	0.30	0.50	19.00
80.0m	0.06	0.37	9.25
	Base-line data for site day previous to spreading		
	0.017	0.22	5.4

There was a dramatic attenuation in NH_4-N, P and BOD even over short distances e.g. 2m. The results suggest that estimates of nutrient losses in overland run-off, based on small plots, can be greatly exaggerated. Because overland run-off occurs only as short pulses, the nutrient movement from freshly applied slurry could be described as a down-hill shift rather than an overall loss. This would particularly be the case in paddocks with long down-slope distances between across-slope open drainage channels. The results verify the tremendous cleaning effect of soil particularly soil with a grass canopy and its ability to absorb nutrients and suspended organic solids from water flowing over the surface.

Modelling overland run-off

Run-off to a hydrologist is the surplus of rainfall over evaporation that runs off the landscape into streams and rivers. On naturally dry land all this water surplus percolates down through the soil and by means of permeable rocks or gravel layers travels to the bottom of natural streams or rivers without ever flowing over the surface. Only on wet soils does run-off water travel over the surface or by means of man made drains to man made open drainage channels.

A simple single reservoir conceptual model has been assumed for surface layers of soil with the following characteristics:

1. All but the most extreme rainfall will percolate into the soil through the top sod unless a watertable has built up to the surface in which case run-off will take place.
2. Rainfall will percolate down to ground water-table level unless there exists a layer with an infiltration potential less than the rainfall rate where it will start to build a perched watertable at a rate proportional to the excess of rainfall rate over deep percolation rate.
3. Any soil moisture deficit on the surface will first be satisfied before watertable buildup starts. Estimates of actual evaporation are used with rainfall to calculate running soil moisture surpluses or deficits.

Experimentally it has been verified that grass sward top sods have higher infiltration capacities than the highest rainfall rates normally encountered in our climate. Only top sods in pasture damaged by excess treading (e.g. around feed troughs and gateways) or by excess application of slurry or sludge will have lower infiltration capacities.

A good fit between calculated and observed overland run-off has been obtained for the model on heavy wet soils at Ballinamore and Kilmaley. The results to date give a detailed picture of the occurrence of overland run-off over winter and the grass growing season and its relationship to rainfall and evaporation. Significant overland run-off, even in winter on undrained plots, occurs only after prolonged heavy rain over a number of days. Compared to drain-flow, overland run-off even on undrained plots, occurs far less frequently but in clearly defined events and only for short durations. Mole drains are next in order having more frequent flows. These flows start before overland flow and last longer. Conventional drains are next, followed by deep drains that flow at a moderate rate for long periods.

A major implication of these findings is that with good land drainage and the avoidance of soil structure damage on the grass sward overland run-off can be completely avoided. It also follows that land with natural drainage through deeper aquifer layers or that is drained through deep land-drains will not contribute to enrichment of surface waters. On land that is vulnerable, e.g. areas where excess nutrient loading occurs on wet soils from pig, poultry and mushroom farming, because of the random nature of rainfall and thus overland run off, rigid calendar based prohibitions on land spreading cannot be very effective. The single most effective treatment on vulnerable land would be to effectively drain the soil and thus prevent overland run-off in the first place.

With this simple model in mind and with glacial, hydro-geological and soil series information a crude ranking of the overland run-off potential of the principal Soils in Ireland was undertaken. A map of these has been published by the Information Technology Unit, Johnstown Castle.

Farm yard run-off

Farmyards including those with good slurry and silage effluent storage are showing up as very significant contributors not only to elevated BOD values but also to nutrient levels in our open channel measurements. The sources are often trivial e.g. small amounts of bedding stored in the open from calf houses, overflow from dairy washing, run-off from small open feeding yards, leakage from an otherwise adequately sized effluent tank and poorly managed irrigation of dirty waters and effluent, from land adjacent to the farmyard.

Remedial measures:

Clearly all farmyard effluent should ideally be stored and land spread. Good farmyard design and management will reduce volume to a minimum. The simplest of earth bunds (banks) can contain or divert minor effluent seepages from any source. Properly designed earth-bank slurry storage tanks can be built for about 5% the cost of a concrete equivalent. We have recently resumed monitoring the performance of these tanks and they can be recommended for a wide range of soil and geological conditions at least for emergency or extra storage where slatted floor storage is not adequate for prolonged wet winters. Slurry and effluent storage facilities are classified as exempted development for planning permission for any size of existing development provided such facilities do not themselves cause pollution. It makes sense to protect open drains in the vicinity of farmyards where occasional wash-off or accidental spillage of manures or effluents is possible. This can be done by piping the drain and diverting occasional surface flows onto land with simple earth bunds.

Pollution of ground-water

Where soils are very shallow (less than 500mm usually) over fissured limestone particularly in karstic areas farmyard effluents can easily leak through summer drying cracks in the soil and gain access to deep mobile ground-water bodies. However, contamination from surface streams going underground and excessively irrigated farm effluents and dirty waters are also equally likely causes.

Future research

Future research is directed towards quantifying accurately the contribution of overland runoff versus farmyard run-off to surface water enrichment. It is also an objective to better understand the conditions under which overland run-off occurs with a view to accurately forecasting same.

The case for land drainage

In recent years there has arisen a belief that land drainage is harmful to the natural environment. This erroneous belief arises from the need to conserve quality natural wetlands which in farmers language are generally flat marshy areas of high watertable that are scarcely farmland at all. The need to drain wet land for grass and crop production is an entirely different matter. Some soils have adequate natural drainage but a very high proportion of the farmland in Ireland benefits from some degree of artificial drainage. This can be verified by the large amount of land divided up by hedgerows with open drains at the base. Contrary to popular belief almost all new drainage systems are being installed on existing farmland that has previously been drained. In recent years there has been a deterioration in the drainage status of the farmland resource. Absence of grants, more intensive farming, heavier axle loads from slurry and silage wagons causing breakdown of old systems are to blame. The pity of this is that never have the basic principles underlying drainage being more understood and never has it being more possible to drain wet soils more thoroughly . The following are some of the advantages of draining farmland.

ADVANTAGES OF DRAINAGE

Environmental:

1. Eliminates the overland component of surface run-off and thus reduces loss of enriched soil and nutrients to surface waters.
2. Reduces denitrification and saves on fossil fuel input to fertiliser manufacture.
3. Reduces production of "greenhouse" gases from wet ground eg NOx, methane etc.
4. Reduces soil erosion in its own right.
5. Increases the crop efficiency, pasture and animal production and thus reduces all energy consuming inputs to agriculture with their associated pollutants.

Production:

1. Increases aeration and reduces denitrification losses.
2. Improves rooting depth which in turn improves nutrient uptake efficiency and nitrogen fixation.
3. Improves yield and quality of crops.
4. Increases longevity of sown swards and improves botanical composition.
5. Increases bearing strength and trafficability of soil.
6. Reduces poaching damage and thus reduces pasture yield loss, sward destruction, weed invasion, spoiling of grass with soil which in turn reduces grass intake, soil loss, structural degradation and thus infiltrability to water.
7. Reduces need for multiple tillage operations and thus costs of seedbed preparation.

SELECTING A DRAINAGE SYSTEM

The single most important physical characteristic of soil for drainage purposes is its permeability to water or its **hydraulic conductivity** which is a measure of how easily water can flow through it. A soil with coarse particles will have large pores between the particles and thus have high hydraulic conductivity. Similarly, a soil with very fine particles such as clay will have a very low hydraulic conductivity. The difference in hydraulic conductivity between soils or soil layers can be enormous. Gravels have values hundreds of millions of times those of heavy clays. The first step in proper drainage design is the identification of the particular drainage problem. The extent and depth of layers of different hydraulic conductivity can be estimated from deep test pits which should be dug up to 3m deep if necessary.

Drainage of permeable soils (soils with high hydraulic conductivity):

Field drainage for permeable soils consists of lowering the water-table from the root zone for all but the most extreme rainfalls by means of deep piped drains at optimum depth and spacing. Drains placed in or near the most permeable layer are much more effective. Optimum depth and spacing can be calculated from test pit estimates of the hydraulic conductivity of the different layers.

Drainage of heavy clay soils (soils with very low hydraulic conductivity):

These soils cannot be economically drained by conventional piped systems because of the close spacing required. Drainage methods that include disruption techniques to improve hydraulic conductivity are necessary. Mole drains are a very efficient and effective method of draining heavy soils, if the soils are stable. However, a large percentage of heavy soils in Ireland are unstable and the water-transporting channels may collapse at an early stage. The gravel-mole system does not suffer from channel collapse and is therefore an effective system for draining soils that are unstable for ordinary mole drains.

Influence of geology glaciation and soil on drainage characteristics

It is possible to generalise the occurrence of drainage problems when the solid geology, glacial history, land formation and soil type are known. Rainfall pattern will also have an influence. The primary influence on the landscape is usually the solid geology where the soil cover is less than 3m. The following are brief descriptions of the drainage characteristics of soils with shallow cover on different solid geological formations.

Shallow soils on upper carboniferous (Namurian and Westphalian) shales:

These rocks have very low permeability and usually give rise to soils with heavy texture and low permeability. They are usually as wet on the hillock crest as down slope. These soils usually require loosening and closely spaced drains (i.e. moles or gravel moles). Occasionally glacial action has fissured superficial layers of these rocks giving rise to good permeability. If this happens with a thin soil cover, soils will be dry on hillocks and wetter due to seepage down slope. Carboniferous shales suffer the added disadvantage in Ireland of being on the upper end of lowland elevation, being on raised plateaux and having higher rainfalls. At high altitudes these soils are usually covered with blanket peat. Typical areas are the Castlecomer and Ballingarry plateaux, west Clare, north Kerry, north Cork and west Limerick, as well as much of Leitrim and parts of Cavan and Fermanagh.

Shallow soils on limestone:

Limestone is a brittle and easily soluble rock. It tends to be highly fissured and cavernous and therefore pervious. Limestone soils are generally well drained except where the topography dips below the fairly flat groundwater. When this happens, basin peat forms. Some limestones are not so pure and are not fissured to any extent except near the surface. These "calp" limestones tend to give heavier soils on less well drained landscapes. They are often in areas contiguous to the upper carboniferous shales e.g. north County Dublin and County Meath. Most limestone in Ireland occurs on flat lowland landscape covered by deep glacial deposits which often dominate the drainage pattern. Generally, wet soils are peat covered and require deep drains.

Shallow soils on old red sandstones:

These are generally massive rocks with poor drainage characteristics except where they are strongly folded and fissured as in south Munster. They are always associated with hills or mountains in Ireland. They are of particular influence on the lower slopes of much central and southern hill land. They give rise to soils which vary from clay loams of low hydraulic conductivity to fine sandy soils. The soils are often considerably more permeable in deeper unweathered layers. Where these layers are present they respond very well to deep drains - particularly since seepage is often severe in these cases. Where the soil is tight (lowish hydraulic conductivity) for several metres, deep gravel mole drains usually give excellent results. The soils tend to loosen well and give good permeability after the ripping effect of the mole plough. Peat will develop on all permanent seepage surfaces. At high altitudes peat will also develop over iron-pan podzols where there once was sufficient free draining soil with a low water-table for podzolisation.

Shallow soils on granites:

These are massive impervious rocks. In their pure form (e.g. Connemara) they have little agricultural value - consisting of pools of water and peat. However when they are broken down by weathering and glacial action they often give rise to very coarse sandy material particularly deep down in the profile. They are significant on mountain slopes, e.g. Wicklow. In this situation if they are wet they will invariably have strong seepage. Deep drains give very good results.

Shallow soils on Avonian, Ordivician Silurian and Cambrian shales:

These can give rise to heavy soils like the upper carboniferous, but being older are generally partly metamorphosed so the soils tend to be somewhat coarse textured and more permeable. Furthermore, the rocks are usually highly folded. They tend to be much more fissured than the younger carboniferous shales and often give rise to quite dry soils e.g. the Clonroche series. Down slope seepage is often a problem. Deep drains give good results in these situations.

Shallow soils on Metamorphic rocks:

These are old rocks of various types fused by heat. The solid rocks tend to be massive and have poor drainage characteristics. Quartzites generally give fine sandy soils with low permeability. Schists and gneisses appear to weather more easily and give rise to coarser textured soils. Metamorphic rocks form the greater part of the Dalradians in the north west. The area was intensely glaciated and glacial deposits tend to dominate the drainage pattern of most of the lowland in these areas.

Deep glacial soil deposits:

These affect drainage in two ways. Firstly, large scale deposits destroy old river systems and block up natural drainage systems in the landscape. Secondly, the nature of the glacial deposit itself particularly its permeability can be of major importance. Where the deposits are deep they can even blot out the influence of an "impervious" bedrock. Since the nature of the deposit depends upon the rocks from which it was derived as well as its mode of deposition they can vary from clays of very low permeability to coarse gravels. Except for the deep clay deposits of low permeability most other glacial deposits are generally layered for permeability. Deep drains generally give good results on these. Where there are deep clay subsoil deposits, e.g. on the Drumlins, mole drains and gravel mole drains are required.

Soil formation and climatic effects:

From a drainage point of view podzolisation is the single most important soil forming process. It occurs on non-calcareous soils. It occurs on soils originally free draining with deep watertable. It is accelerated by high rainfall. Almost all free draining soils at high altitudes in Ireland are non-calcareous and have developed into podzols. There are also many soils at low altitudes where rainfall is high enough particularly in the west where podzols have developed. When podzols develop an "iron pan" downward percolation of water is virtually stopped and they will have a perched watertable in wet weather. Most iron pan podzols are peat covered. On many hill situations, particularly in high rainfall areas in the west, there is continuous peat cover over an iron pan podzol on hilltops and hillocks, down to seepage peat on mid slope and deep swamp peat in hollows. Where peat cover is relatively shallow (less than 500mm) iron pans are easily drained by bursting the pan by ripping. Deep ploughing can also be used but generally ripping will work equally well anywhere ploughing works without burying the surface fertility.

Conclusion

The successful control of drainage, water-table, overland flow of soils requires the application of the physical science of water flow through porous media and an accurate knowledge of the physical characteristics of the underlying soil and bedrock.

The Structure of Irish Farming in 2005

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I INTRODUCTION

In considering future needs and priorities in agricultural research, it is appropriate to turn attention to the broad context of change and adjustment in the agricultural sector. This wider canvas is the concern of the present paper. Our aim is to analyse from a socio-economic perspective the prevailing pattern of re-structuring in Irish agriculture and to pose a likely scenario for the next decade. Obviously, there is a degree of speculation in this exercise especially as we have not been in a position to draw on specialised research on scenario-building for the future structure of Irish farming.

There is now a substantial amount of statistical data on agricultural structures and this paper draws mainly from three sources: the EU Structures Surveys, the Census of Agriculture and the Teagasc National Farm Survey. There are, however, some difficulties in analysing trends over time. The different sources use somewhat different concepts and measurements (e.g. in recording labour inputs) and there is not a consistent methodology over time (in the agricultural censuses). Nevertheless, the main trajectory of structural change can be clearly traced; in fact changes in statistical definition and categorisation are very much a response to structural change itself.

Any attempt to project the future structure of agricultural production must be grounded in a knowledge of existing trends, identifying in particular those trends that are relatively stable - and set to continue - and bearing in mind that agricultural restructuring has different consequences for different areas.

Accordingly, the first main section of this paper examines changes in resource use at sectoral and regional level. The second section reviews changes at farm level, with particular reference to incomes and economic viability. The third part identifies the factors determining structural change and their likely impact over the next ten years. The main conclusions are presented in the final section.

II SECTORAL AND REGIONAL CHANGE

The dominant trends in the longer-term adjustments occurring in Irish agriculture are well known: the trend towards fewer farms and larger business units driven by economic forces which reward economies of size, concentration of production on a declining number of farms, dynamic specialisation in the more profitable sectors of production mirrored by residual specialisation, shifts from dairying and tillage to drystock production, and decline in farm labour – especially among family members.

The 1980 EU Farm Structures Survey showed there were 223,500 farms of one hectare or more in the country, whereas the 1991 Census of Agriculture recorded 179,000 farms. These two figures are not comparable because of differences in the method of enumeration. Significantly, it seems that the more rigorous screening procedures used in 1991 removed over 30,000 of the smaller or more marginal units which were included in the coverage of the earlier structures surveys. Even then there were 4,500 farms in the 1991 Census which had less than two ha, so that for all practical purposes there are now 166,000 farms in the country. Of these 77,000 (or just over one-half) are still under 20 ha.

In assessing farm structures it is necessary to supplement data on the surface area of farms with information on economic size. The economic size of a farm in an EU context is defined as the sum of the Standard Gross Margins (SGMs) of all its activities or enterprises expressed as European Size Units (ESUs). For the 1991 Census of Agriculture one ESU was taken as 1200 ECUs, or approximately £890[1]. The national averages in 1991 were 11.6 ESUs, and 26.0 ha per farm.

Table 1 shows that in 1991 there were 38 per cent of farms which were both comparatively small in area (under 20 ha) and of small-scale in terms of economic size (less than 4 ESUs). A further 4.8 per cent of farms were less than 4 ESUs although greater than 20 ha in area; another 17.6 per cent were between 4 and 8 ESUs - about half of this last group being less than 20 ha in size. Thus, up to 60 per cent of Irish farms are small or moderately small in terms of economic size. These account for about one-third of Agricultural Area Used [AAU].

Since SGMs are calculated in a way which reflects the economic realities of farming margins the type of farming system has a predominant influence

Table 1

Percentage distribution of farms by area (ha) and economic size units (ESUs)[1] 1991

	Economic size units (ESUs)					
Hectares	<4	4-8	8-16	16-40	40+	Total
<5	10.4	0.5	0.2	0.1	0.05	11.2
5-20	27.5	8.9	4.7	1.2	0.05	42.4
20-30	3.6	5.2	5.2	4.1	0.1	18.2
30-50	1.0	2.5	5.0	6.9	1.2	16.7
50+	0.2	0.5	1.7	4.9	4.2	11.4
Total	42.6	17.6	16.8	17.3	5.6	100.0
Average farm size (AAU)	**11.0**	**21.5**	**30.2**	**44.8**	**84.4**	**26.0**

[1]European size unit = 1,200 ECU using 1986 Standard Gross Margin.

Source: Derived from Census of Agriculture 1991, Table 6, p. 27.

1. The purpose of the SGM application is to allow comparisons to be made in relative terms between farms in regard to their overall economic activities. It should not be interpreted as an indicator of nominal income for individual farms (see Census of Agriculture 1991, p. 10).

Table 2
Structural characteristics of Irish farms by type of farm, 1991

	Type of Farm						
Economic size (ESUs)	Tillage	Dairying	Beef	Sheep	Mixed livestock	Crops and livestock	Other
<4	21.3	5.1	69.6	35.0	43.0	13.4	30.4
4-8	14.1	9.8	19.5	26.6	20.6	14.6	12.5
8-16	19.3	25.2	8.3	24.2	20.3	25.1	15.8
16-40	28.1	44.0	2.4	12.9	13.8	34.2	21.5
40+	17.2	16.0	0.2	1.3	2.3	12.7	19.8
Total	**100**	**100**	**100**	**100**	**100**	**100**	**100**
Average ESU	24.0	24.6	3.9	8.7	8.7	21.2	29.7
Average AAU (ha)	50.1	32.9	18.7	29.1	25.9	50.7	15.3
ESUs per ha	0.48	0.75	0.21	0.30	0.34	0.42	1.94
% of all farms	3.0	24.4	42.1	8.8	17.9	2.5	1.4
% of all AAU	5.7	30.8	30.2	9.8	17.8	4.9	0.8
% of all ESUs	6.1	51.6	14.1	6.6	13.4	4.6	3.5

Source: Derived from Census of Agriculture 1991, various Tables.

on the calculated economic size of a farm. The 1991 Census of Agriculture distinguished between 'specialist' and 'mixed' farm types. Specialist farms are those where a particular activity such as dairying or tillage accounted for at least two-thirds of the farm's total SGMs, whereas in mixed farms no individual activity was large enough to breach the two-thirds threshold. Specialist cattle farms, representing 42 per cent of all farms, were almost all less than 8 ECUs in scale. Sheep farms and mixed grazing livestock farms, constituting 8.8 per cent and 17.9 per cent of all farms respectively, had each approximately three out of every five units under the 8 ESU level. By contrast, on dairy farms (24.4 per cent of the total) three out of five units had more than 16 ESUs.

Cattle farms are smaller than average in area (18.7 ha AAU as against 26.0 ha AAU) and are operated at less than half the national average level of economic intensity (0.21 ESUs per ha compared to 0.45 ESUs per ha). Sheep and mixed livestock farms, though closer in area size to the national average, are also operated at low levels of intensity (Table 2).

Taken together, cattle, sheep and mixed livestock farms account for 69 per cent of all farms, 58 per cent of AAU but only 34 per cent of total ESUs. Dairy farms represent 24 per cent of all farms, 31 per cent of AAU and 52 per cent of all ESUs. The essence of the structural problem in agriculture, therefore, is that 60 per cent of farms are relatively small or moderately small businesses

Table 3

Changes in the numbers and percentages of farms with selected enterprises and in the size of enterprise per farm[1]

Year	Cereals	Potatoes	Sugar beet	Dairy cows	Cattle (all)	Sheep	Pigs
			Number of farms (000s)				
1975	99.2	122.0	11.3	127.5	140.7	53.6	26.4
1983	53.8	72.5	7.2	91.5	115.4	44.2	10.2
1991	23.2	12.4	3.9	49.1	151.4	54.8	2.9
			Per cent of farms				
1975	43.5	53.5	5.0	55.9	91.9	23.5	11.6
1983	23.6	32.8	3.2	41.4	86.0	20.0	4.6
1991	13.6	7.3	2.3	28.7	88.8	32.2	1.7
			Average per farm: hectares/animals				
1975	3.3	0.3	2.9	12	34	70	33
1983	6.7	0.4	4.9	18	36	92	103
1991	13.0	1.7	8.4	27	46	162	454

[1] 1991 figures are not strictly comparable with those of earlier years because of changes in methods of enumeration.

Source: O'Hanlon (1987); Census of Agriculture 1991.

because they comprise mainly non-dairy livestock enterprises which are not intensively farmed.

The current structure of agricultural production is, of course, an outcome of a process of adjustment and rationalisation that has been under way over recent decades. While the 1991 statistics are not strictly comparable with the data for earlier years, they serve to illustrate the scale and direction of restructuring. Structural change has been more pronounced in tillage, dairying and pig farms than on the holdings with other enterprises (Table 3). Cereal growing and potato production are now quite concentrated and very much the concern of a relatively small minority of farms compared to 20 years ago. The percentage of farms keeping dairy cows has halved during this period while average herd size has more than doubled. The numbers and percentages of farms keeping cattle and sheep have increased since 1983, both in absolute and in relative terms.

Clearly there has been a dramatic shift towards drystock systems, with sheep in particular becoming more prominent.

The figures indicating the increases in the average number of hectares or animals per farm (Table 6) do not reveal the full extent of the concentration of production on fewer farms. For example, 7.3 per cent of farms grew potatoes in 1991 but 80 per cent of production came from farms with over 16 ESUs and these represented 2.1 per cent of all farms in the State. As Table 4 shows,

Table 4

Number and percentage of farms with specific enterprises/activities, 1991

Enterprises or Activity	No. of farms	Per cent of farms in State	Per cent of area/animals on farms of 16+ ESUs	Farms of 16+ ESUs as per cent of all farms in State[1]
Cereals	23,183	13.6	81.1	6.8
Potatoes	12,393	7.3	79.8	2.1
Sugar beet	3,945	2.3	72.1	1.7
Arable crops[2]	41,282	24.2	81.1	8.9
Silage	81,354	47.6	65.6	19.5
Dairy cows	49,068	28.8	84.1	16.4
Other cows	92,557	54.3	27.6	10.1
All cattle	151,422	88.7	55.7	21.6
Sheep	54,842	32.1	51.2	8.5
Pigs	3,873	1.7	96.9	0.9
Poultry	26,627	15.6	71.1	4.4

[1]Farms of 16+ ESUs referred to in previous column.

[2]All crops, fruit and horticulture.

Source: Derived from Census of Agriculture 1991, Tables 14A to 31A.

by far the greater share of production in tillage crops was provided by less than 10 per cent of the country's farms.

While 84 per cent of dairy cows were on 16 per cent of farms the distribution of 'other cows' (the suckler herd) was much more widespread. About half the animals came from farms below 8 ha and these farms accounted for one-third of the country's total number of farms.

Regional aspects

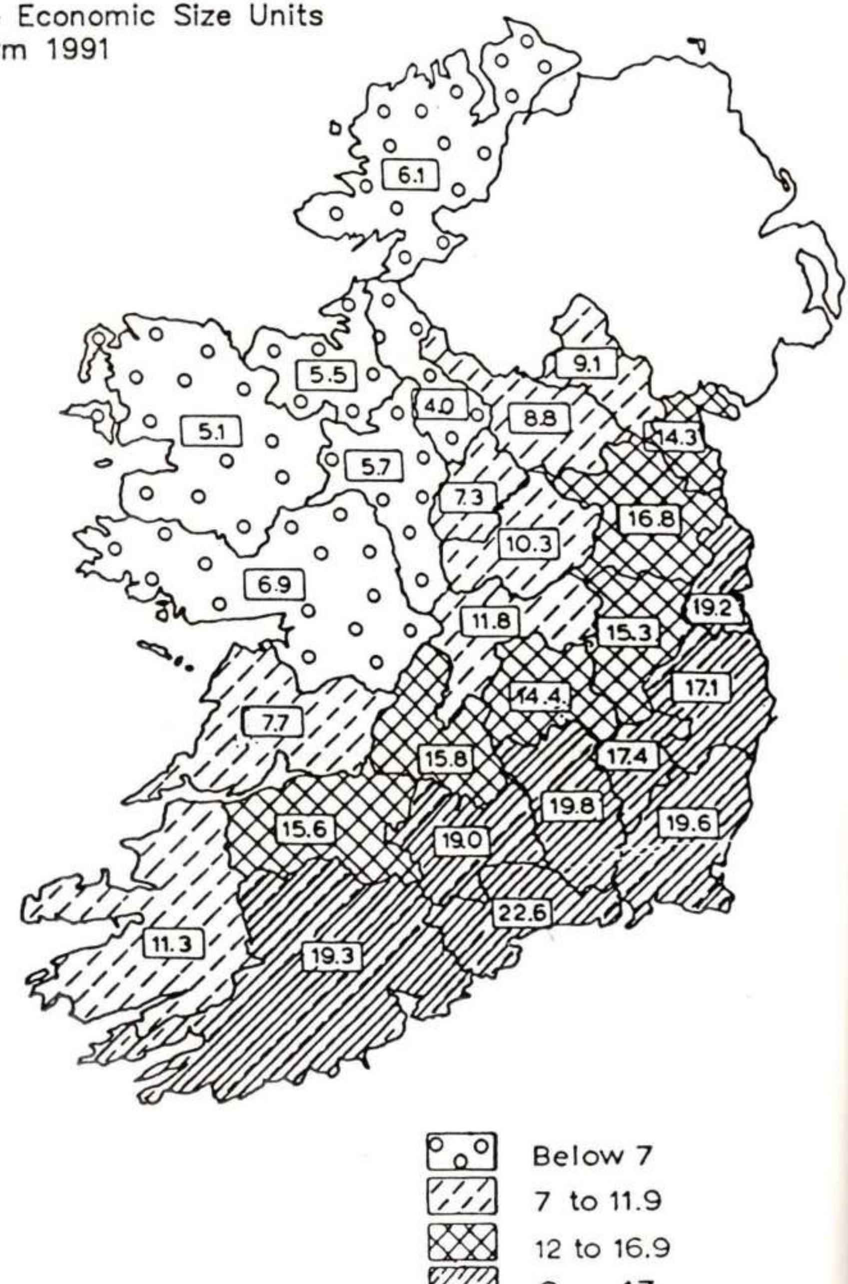
Because changes in the agricultural structure have differential impacts by farm size and system, restructuring clearly has regional dimensions. While there is an obvious distinction to be made between the Disadvantaged Areas and the rest of the country the approach taken here is to categorise counties into four groups according to their average ESU per farm as of 1991. This categorisation gives a useful gradation of the national territory from the small-farm counties of the north-west to the large-farm counties of the south-east (see Map 1). The four groups are as follows:

Group 1. Large-farm counties (over 17.0 ESUs per farm on average)
Carlow, Dublin, Kilkenny, Wexford, Wicklow, Cork, Tipperary South and Waterford.

Group 2. Medium-to-large farm counties (12.0 to 16.9 ESUs on average)
Kildare, Laois, Louth, Meath, Limerick and Tipperary North.

Group 3. Medium-to-small farm counties: (7.0 to 11.9 ESUs on average)
Longford, Offaly, Westmeath, Clare, Kerry, Cavan and Monaghan.

Map 1
Average Economic Size Units per Farm 1991



Group 4. Small-farm counties (under 7.0 ESUs on average) Connacht counties and Donegal

Farms in the 'large-farm' counties are, on average, 3.5 times bigger in scale than those in the 'small-farm' counties, when measured in ESU terms. Expectedly, the percentages of farms with crops and dairy cows (including heifers-in-calf) decline consistently across the spectrum from Group 1 to Group 4 (See Table A1, Appendix). Moreover, those farms with crops and dairy cows in Groups 3 and 4 have much smaller areas sown and fewer cows. Group 4 dairy farms, for example, had 14.3 cows, on average, compared to 35.9 cows for the dairy farms in Group 1. The proportion of farms with 'other cows' (including heifers-in-calf) increased consistently across Group 1 to Group 4 but the average number of animals per farm declined. Similarly, the average numbers of 'all cattle' and of sheep per farm (of the farms having these enterprises) declined consistently from Group 1 to Group 4.

Thus, while cattle and sheep production have become the mainstay of farming in the west and north-west, with dairying and tillage concentrated in the south and south-east, farms in these latter regions still manage to have larger drystock and sheep enterprises than in the northern and western counties (See Table A1, Appendix). There remains, apparently, greater diversity now in the farming economy of the better-off counties, perhaps accompanied by greater diversity within individual farms.

This leads us to consider one of the significant features of structural change in agriculture, viz., the comparative failure of county Groups 2, 3 and 4 to

Table 5

Percentage change in crops and livestock (hectares and animals), by categories of County

Years	Crops	Dairy cows[1]	Other cows[1]	All cattle	Sheep	Pigs
			Large Farm Counties			
1960-80	-4.3	+105.2	+2.4[2]	+55.4	-17.8	+0.4
1980-91	-25.8	-13.3	+83.4	+6.8	+188.2	+7.5
			Medium-to-Large Farm Counties			
1960-80	+2.1	+75.9	+10.6[2]	+35.6	-42.3	-7.7
1980-91	-16.7	-16.2	+84.7	+1.5	+277.9	+58.1
			Medium-to-Small Farm Counties			
1960-80	-56.7	+59.0	+56.2[2]	+43.2	-22.2	+38.5
1980-91	-53.4	-23.8	+95.2	-0.7	+204.6	+54.7
			Small Farm Counties			
1960-80	-54.8	-9.9	+229.7[2]	+45.2	-22.3	+1.7
1980-91	-60.2	-36.7	+47.7	-10.4	+122.2	-14.4

[1]Including heifers-in-calf [2]Estimates

Source: Census of Agriculture, various years offset their loss of tillage enterprises by sufficiently high rates of increase in livestock production.

Table 5 shows changes in the longer-term of trends in crop and livestock production for the groups of counties selected. For the later period in particular (1980-1991) it will be noted that crop area and dairy cow numbers declined steeply from the south-east to the north-west. The numbers of other stock did not increase consistently in a countervailing trend. In fact 'all cattle' numbers declined in the small farm counties; by contrast there was a progressive rate of increase in the numbers of young cattle in the north-south direction. Sheep numbers increased in all regions but the lowest rates of expansion were recorded in the smallest farm counties.

This regional dimension of structural change can be seen more clearly by converting livestock numbers to livestock units (Table 6). From 1960 to 1980 there was no clear-cut pattern, except that the south-eastern counties showed a higher rate of increase than the other groups. From 1980 to 1991, however, the fastest rates of expansion occurred in Groups 1 and 2.

The effect of these changes is that the small farm counties have failed to retain their percentage share of production, not alone in crops and dairying but in the other livestock enterprises also (see Table A2, Appendix). These changes also mean that since 1980 the gap in the intensity of land use has widened between the south-east and north-west, with livestock units per hectare now one-third higher in the south-east – although this differential would be halved if 'rough grazing in use' were eliminated from the calculation.

III FARM AND FARM HOUSEHOLDS

In turning attention to change at farm level, we are concerned essentially with three issues: (i) trends in family farm income; (ii) the role of direct payments in supporting incomes; and (iii) the economic viability of different categories of farm.

Family farm incomes

Despite relatively high levels of price supports and direct income subsidisation

Table 6

Percentage change in livestock units by category of county, and livestock units per hectare[1], 1991

	1960-80	1980-91	L.U. per ha 1991
Large Farm Counties	+39.1	+15.1	1.827
Medium-to-Large Farm Counties	+22.9	+9.1	1.743
Medium-to-Small Farm Counties	+30.5	+6.3	1.407
Small Farm Counties	+22.9	+6.3	1.345
TOTAL	+30.0	+9.8	1.576

[1]Pasture, hay, silage and grazing in use.

Source: Derived from Census of Agriculture, various years

Table 7

Trends in family farm income and comparisons with agricultural wage rate

	Average FFI £	% year-to-year change in FFI	Agricultural wage rate £
1984	5370	–	4910
1985	4482	-9.1	5291
1986	4327	-11.4	5576
1987	5779	33.6	5585
1988	7197	24.6	5950
1989	7282	1.2	6167
1990	6682	-8.3	6167
1991	6053	-9.5	6366
1992	7172	18.5	6627
1993	8075	12.6	6847
1994	–	–	7147

Source: Teagasc National Farm Survey, various years

(e.g. through headage payments) farm incomes have remained comparatively low, and they show a considerable degree of volatility on a year-to-year basis (Graph 1). In the decade of 1984-93, average Family Farm Income (FFI), as defined in the Teagasc National Farm Survey, increased by an average of 5 per cent per annum and, variability aside, remained little greater than the wage rate for an agricultural worker (Table 7). The wage rate refers to the earnings of an individual while the FFI is a return to the family labour, management and capital investment in the farm business. As will be made clear presently, there

Table 8

Trends in average family farm income for selected farm systems

	Dairying FFI (£)	Cattle FFI (£)	Sheep FFI (£)	All Systems FFI (£)
1984	8964	2301	3782	5370
1985	9926	1839	4196	4882
1986	8492	1588	3506	4327
1987	10838	2167	5041	5779
1988	14545	2590	5895	7197
1989	15706	1881	4442	7282
1990	12706	2416	5207	6682
1991	12172	2281	4455	6053
1992	15336	2943	4844	7172
1993[1]	17118	3277	5822	8075

[1]Systems not strictly comparable because of change of definition

Source: Teagasc National Farm Survey, various years are other points that may be made about this comparison but for the moment it serves to illustrate the weakness of the farm economy in a context of rising living standards and income expectations.

Over the past decade there has been a considerable degree of consistency in the FFI relativities between the major farming systems. On dairy farms, FFIs were generally five times greater than on cattle farms. Sheep farms yielded incomes in the order of twice the earnings on cattle farms, except for the last two years of the decade reviewed when the gap closed to some extent (Table 8).

Not only are FFIs on cattle and sheep systems substantially lower than for dairy systems but they are also subject to greater year-to-year variability (Table 9). Thus, an average for all systems masks the full effects of farm income volatility. Cattle systems, for example, experienced an average decrease of 27 per cent in 1989 but recovered the following year with an increase of 28 per cent. During the decade up to 1993, dairy farms accounted for approximately 40 per cent of total farm income, despite their declining numbers. Cattle farms represented approximately one-half of the farms in the country over the decade but in most years earned less than one-fifth of total farm income. This means that dairy farms have an influence disproportionate to their numbers in reducing their overall degree of volatility in farm income levels (Table 9).

Evidently, volatility in cattle farm incomes is not confined to any farm size category. In fact there appears to be even greater variability in the larger size groups (Table 10). Moreover, the very large farms in general show high variability in FFI (see Graph 1).

In summary then, we may say that variability is a highly pervasive feature of Irish farm income trends, within and between farm systems and between different scales of operation. Apart from the many problems attaching to low

Table 9

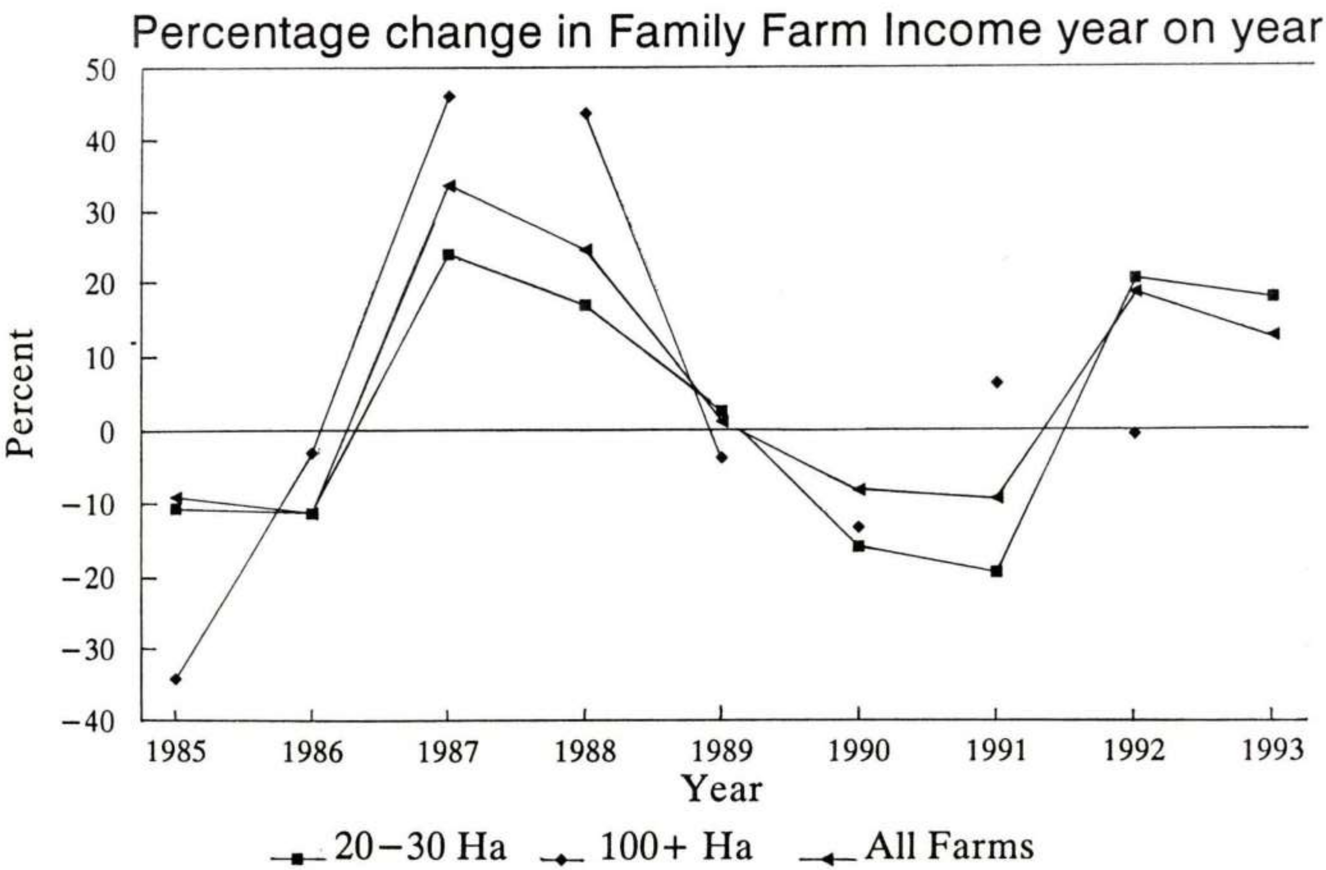
Percent change in family farm income over the previous year for selected farm systems

	Dairying	Cattle	Sheep	All Systems
1984	–	–	–	–
1985	11	-20	11	-9
1986	-14	-14	-17	-11
1987	28	37	44	34
1988	34	20	17	25
1989	8	-27	-25	1
1990	-19	28	17	-8
1991	-4	-6	-14	-10
1992	26	29	9	19
1993[1]	12	11	20	13

[1]Systems not strictly comparable because of change of definition

Source: Derived from Teagasc National Farm Survey

Graph 1



Source: Teagasc National Farm Survey

Table 10

Percent change in family farm income for cattle system farms by farm size, 1989-1992

Size (ha)	% Change 1989/90	% Change 1990/91	% Change 1991/92
2<10	28	-17	34
10<20	42	-17	27
20<30	8	19	15
30<50	2	-21	24
50<100	13	-2	14
100+	54	-41	47
Hill	9	-37	96
All cattle	**28**	**-6**	**29**

Source: Derived from Teagasc National Farm Survey

absolute farm incomes, the attractiveness of farming as a career for younger people, even on good-sized farms, is diminished by instability in the flow of income and the related insecurity in the conditions for investment.

Direct income subsidies

The low farm incomes on cattle and sheep farms include a substantial component of direct or 'non-price payments (as livestock headage and premia payments). These payments have increased in number and in volume in recent years and are expected to account for over 40 per cent of all farm incomes by 1996 [Fingleton et al 1992; Kearney 1995a]. Sheep farmers have been the greatest beneficiaries, in that the subsidies already represent over 80 per cent of their FFI. The corresponding proportion on cattle system farms is in the order of 50 per cent (Table 11). However, comparison of Tables 8 and 11 will show that

Table 11

Direct income subsidies by selected farm systems and percentage of family farm income[1]

Year	Dairying		Cattle		Sheep		All farms	
	£	%	£	%	£	%	£	%
1989	428	2.7	762	40.5	2860	64.4	1082	14.9
1990	450	3.5	1210	50.0	4630	88.9	1740	26.0
1991	405	3.3	1142	50.0	4159	93.4	1591	26.3
1992	830	5.4	1850	62.9	4582	94.6	2165	30.2
1993	879	5.1	1339	52.3	4682	80.4	2158	26.7

[1]Most of the 1993 subsidies were not paid until 1994

Source: Derived from Teagasc National Farm Survey

the increases in the absolute levels of subsidies have not had a commensurate impact on the level of FFI in cattle and sheep farms. Their effect apparently has been to maintain the level of subsistence incomes on these farms and thus cover-up a real decline in the market income component of their earnings. It is necessary to note here that part-time farming allows a proportion of drystock farmers to supplement their low earnings from farming.

Simply stated, the current position in regard to direct income payments in Irish agriculture is that, given the relatively high incidence of cattle and sheep farms in the total farm population and the high percentage of their incomes coming from direct payments, a majority of Irish farms now depend on non-price payments for most of their family farm income.

Economic viability of farms and farm households

At farm level the viability of a holding is determined mainly by two sets of factors: its economic performance as a business and its human resources, the latter reflected in the household structure and the operator's managerial capabilities. To survive economically and sustain a farming household, as such, a farm must have the potential and the opportunities to generate a socially acceptable level of income and to provide some surplus for re-investment in the farm business. Of course farm households can be sustained by having other sources of income. The 1991 Census of Agriculture showed that 27 per cent of farm operators had other gainful economic activity, although the proportion ranged from 9 per cent on dairying-type farms to 29 per cent on the mixed grazing livestock farms.

Teagasc's National Farm Survey (NFS) operationally defines the economic viability of a farm as (i) its capacity to remunerate family labour at the average agricultural wage, and (ii) its capability of giving an additional 5 per cent return on non-land assets. The NFS uses two other variables to classify farms: (iii)

Table 12

Number and percentage of farms in different viability categories

Category	1991		1992		1993	
	No.	%	No.	%	No.	%
Viable	**40,000**	**24**	**51,200**	**31**	**47,000**	**29**
Large viable	28,300	17	33,000	20	34,600	21
Small viable[1]	11,700	7	18,200	11	12,400	8
Non-viable	**125,000**	**76**	**113,800**	**69**	**118,300**	**71**
Jobs	30,000	18	29,700	18	36,400	22
Good Demog.	58,300	36	51,200	31	38,100	29
Poor Demog.	36,700	22	33,000	20	33,800	20
Total	**165,000**	**100**	**165,000**	**100**	**165,000**	**100**

[1]Viable within the definition adopted but with less than .75 of a standard labour unit.

Source: Derived from Teagasc National Farm Survey

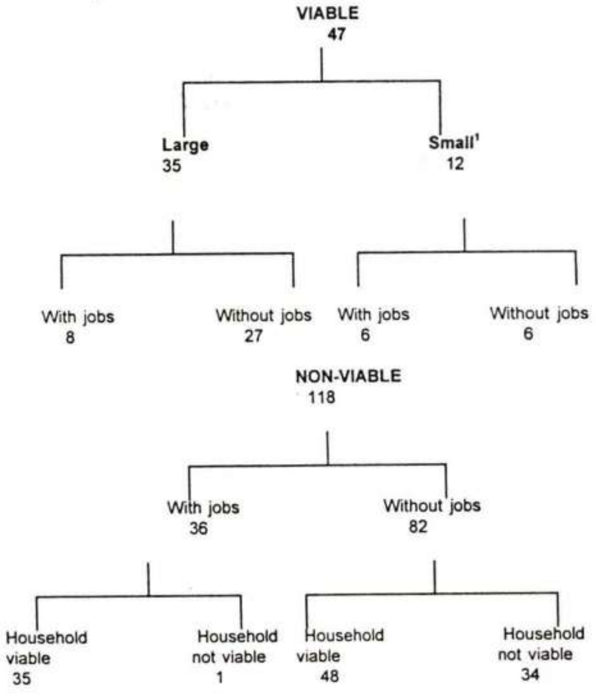
'demographically non-viable' households where the holder is over 55 years of age and where there is nobody else under 45 years in the household; and (iv) 'other activity status', to take account of whether or not the farm operator and/or spouse has a non-farm job.

From what has already been said about the year-to-year variability of farm incomes it will be understood that the numbers of viable farms, as defined, will vary somewhat from year to year. An analysis for the three years 1991-1993 shows that this number ranges in the order of 40,000 to 50,000 (Table 12).

Table 12 indicates that the viable category may be subdivided into a 'large' and a 'small' group, the latter comprising farms with less than 0.75 of a labour unit. When this sub-category of small farms is subtracted out it can be seen that the estimated number of viable farms remained fairly stable during 1991-1993 in the 28,000 to 35,000 range.

It will also be noted from Table 12 that the other relatively stable category in numbers was at the opposite end of the spectrum, i.e., those on non-viable farms, with no other gainful employment and with 'poor household composition. Their numbers fell within the 33,000-37,000 range.

Using the four NFS viability variables already noted we may classify the national farm population of 1993 (taking 165,000 farms as the total) by the general orders of magnitude in the diagram below. The proportion of the viable



[1]Viable within definition used but with less than 0.75 of a standard labour unit.

category associated with demographically non-viable households was relatively small and these are not therefore identified separately.

Reference to Table 12 and to the diagram will show that in regard to the absolute number of farms, there are four major categories of interest. The main structural characteristics of each of these are presented in Tables 13 to 16. The data in the Tables are mostly self-explanatory but the key points for present purposes are summarised here.

Major categories of farms by viability criteria

Category 1- Viable Farms: These 47,000 farms account for 29 per cent of the total and for 44 per cent of AAU. However, the 'small-viable' sub-category (viable mainly because of the return to their low input of family labour) are in most respects similar to the non-viable groups as regards income, resources, farming system, and household composition. Half of these households have other gainful employment. A more rigorous definition of viability would most likely exclude a large proportion from the viable category. For instance, adopting a £12,000 FFI and a 5 per cent return on non-land assets as the criteria for viability (as of 1993) would reduce the national proportion of viable farms to

Table 13

Selected characteristics of viable farms, 1993 (Category 1)

	Viable Large			Viable Small[1]		
Characteristics	No Jobs[2]	Jobs	Total	No Jobs[2]	Jobs	Total
% of all farms	15	5	21	2	4	8
Family farm income (£)	25,818	21,169	24,113	7,590	6,236	6,827
Sales/receipts (£)	70,865	59,518	66,170	13,416	11,414	11,579
Subsidies (£)	3,867	5,414	4,134	1,718	1,637	1,673
AAU (ha)	52	52	51	19	17	20
ESUs	50	44	47	10	8	9
Net new investment (£)	4,271	4,315	4,098	1,260	389	740
Costs/£100 output (£)	64	66	64	46	46	46
Labour units	1.8	1.5	1.7	0.7	0.5	0.6
% in dairying	75	57	71	24	26	20
% drystock	15	25	18	70	60	68
% in tillage	8	16	10	6	14	11
No. dairy cows	32	20	29	3	1	2
Age of holder	48	43	48	47	49	48
H'hold size	4.7	5.0	4.6	3.8	4.1	3.5
% H'holds with pension	29	26	27	52	11	27
% H'holds with unemployment	3	0	2	45	9	21
% on good soil (Type 1)	61	63	61	31	50	47

[1]Viable within the definition adopted but with less than 0.75 of a standard labour unit

[2]A small proportion with poor demography not included: neither operator nor spouse has a job

Source: Derived from Teagasc National Farm Survey.

16 per cent (see Table 17), and correspondingly increase the non-viable categories - mainly Categories 2 and 3 as these are described below.

The more rigorous classification means that there are now somewhat less than 30,000 'vanguard' farms in the country, mostly in dairying and on good soils, being operated at high levels of intensity by 'young' households. Most of the new investment is taking place on those farms but it is of interest to note that operating costs per £100 output are lower than for the other major categories. Family farm incomes at £25,000 to £30,000 are comparatively high but when account is taken of the labour involved the returns are not much different from the average industrial wage.

'Large viable' households have two similarities with the 'non-viables'. They earn direct subsidies (more in absolute amounts than relative to their FFIs), a fact related to the retention of young cattle in the dairying areas and the inclusion of about 6,000 drystock farms in this category. In fact when the returns for the sub-category of drystock farms were analysed separately they showed that viability on those farms was in great part attributable to direct subsidies, these accounting for half of their FFI of £16,700. A proportion also have incomes from non-farm employment, mainly because of the occupations of wives and the self-employment of farm operators.

Table 14

Selected characteristics of non-viable farms where operator and/or spouse has non-farm job, 1993 (Category 2)

Characteristics	Small dairying	Drystock	Total
% of all farms	4	16	22[1]
Family farm income (£)	5,665	2,530	3,196
Sales/receipts (£)	21,108	7,983	10,855
Subsidies (£)	1,337	1,851	1,814
AAU (ha)	26	20	21
ESUs	20	7	9
Net new investment (£)	2,534	1,075	1,321
Costs per £100 output (£)	73	71	74
Labour units	1.4	0.9	1.0
% in dairying	100	0	19
% in drystock	0	100	76
% in tillage	0	0	5
No. dairy cows	14	0	3
Age of holder	46	47	47
H'hold size	4.9	4.5	4.6
% H'holds with pensions	36	21	23
% H'holds with unemployment	11	15	14
% on good soil (Type 1)	32	36	36

[1]Small proportion excluded

Source: Derived from Teagasc National Farm Survey

Table 15

Selected characteristics of non-viable farms where operator and/or spouse has no other job and household composition is 'Good', 1993 (Category 3)

Characteristics	Small dairying	Drystock	Total
% of all farms	11	17	29
Family farm income (£)	6,464	3,480	4,631
Sales/receipts (£)	20,114	10,843	14,452
Subsidies (£)	1,273	2,165	1,877
AAU (ha)	24	24	25
ESUs	18	9	12
Net new investment (£)	1,815	850	1,321
Costs per £100 output (£)	68	67	67
Labour units	1.3	1.1	1.2
% in dairying	100	0	38
% in drystock	0	100	59
% in tillage	0	0	3
No. dairy cows	13	0	5
Age of holder	52	56	55
H'hold size	4.0	3.7	3.8
% H'holds with pensions	54	54	54
% H'holds with unemployment	20	31	27
% on good soil (Type 1)	30	41	37

Source: Derived from Teagasc National Farm Survey

Category 2 - Non Viable Part-Timers: The great majority of part-timers, however, are on non-viable farms with smaller than average holdings. These 36,000 part-timers comprise 22 per cent of all farm households and have 17 per cent of all AAU. A minority (6,600) are in small-scale dairying (average 14 cows) and are not in most cases' on the better soils. While there is some new investment on these dairy farms they are operated with a relatively high cost structure.

Category 3 - Non-Viable with 'Good' Household Structure: This is the largest single category (48,000 households) comprising 29 per cent of all households and accounting for 26 per cent of total MU. They have close to the average size of farm in the country whether in terms of MU or ESUs. In many respects, but particularly from the viewpoint of earning an acceptable level of living for a household of today, this is the main problem category in Irish farming. Analysis of NFS on a three-year period (1991-1993) returns on the basis of the viability criteria used here showed this category to be the most variable in size, and the most sensitive to the vagaries of farm incomes. Their incomes and levels of new investment can vary considerably. Clearly, there is a proportion of this category who may be 'temporarily' non-viable or who are otherwise in a transition stage probably to Category 4 (see below). About 18,000 are in small-scale dairying (average 13 cows), again with only a minority on the better soils.

For the greater part these households depend on low income drystock farming. About 40 per cent of their FFI comes from direct subsidies. They also manage to survive through dependence on State income transfers as evidenced by the fact that over half of these households have pension incomes, most likely paid to a surviving member from an earlier generation. They also benefit from Smallholders' Unemployment Assistance.

Category 4 - Non-Viable with 'Poor' Household Structure: This is a residual category of some 34,000 households of older people on small farms, operated at low levels of intensity. They represent 20 per cent of all farm households and have 13 per cent of AAU. A small number are in dairying (average 6 cows). Subsidies account for nearly half of FFI. Household income is also dependent on pensions but because of their older age structure they do not benefit from Smallholders Unemployment Assistance to the same extent as Category 3.

Dynamics of structural change

The foregoing analysis is a static picture of the structure of farming in that it depicts viability categories for one point in time (i.e. 1993). A more exhaustive analysis would seek to track the process of entering or falling out of different categories by examining the annual records of the same set of farms for, say, a 10 year period.

Leavy [1995] studied the performance of some 300 farms which remained in the NFS from 1984 to 1990. Using economic and socio-demographic variables

Table 16

Selected characteristics of non-viable farms where operator and/or spouse has no other job and household composition is 'Poor', 1993 (Category 4)

Characteristics	Small dairying	Drystock	Total
% of all farms	3	16	20
Family farm income (£)	3,087	2,378	2,490
Sales/receipts (£)	10,039	6,403	6,967
Subsidies (£)	730	1,162	1,118
AAU (ha)	17	17	17
ESUs	9	5	6
Net new investment (£)	246	259	312
Costs per £100 output (£)	68	62	63
Labour units	1.0	1.0	1.0
% in dairying	100	0	14
% in drystock	0	100	83
% in tillage	0	0	3
No dairy cows	6	0	1
Age of holder	64	67	66
H'hold size	1.6	1.6	1.6
% H'holds with pensions	30	59	54
% H'holds with unemployment	26	10	13
% on good soil (Type 1)	21	35	33

Source: Derived from Teagasc National Farm Survey

Table 17

Selected characteristics of non-viable farms using a £12,000 plus Family Income Criterion[1], 1993

Characteristics	Total
% of all farms	16
Family farm income (£)	28,523
Sales/receipts (£)	77,999
Subsidies (£)	4,190
AAU (ha)	56
ESUs	55
Net new investment (£)	5,197
Costs per £100 output (£)	64
Labour units	1.9
% in dairying	77
% in drystock	12
% in tillage	9
No dairy cows	34
Age of holder	49
H'hold size	4.9
% H'holds with pensions	27
% H'holds with unemployment	2
% on good soil (Type 1)	61

[1]And also a 5 per cent return to non-land assets.

Source: Derived from Teagasc National Farm Survey

to identify expanding and contracting farms/households he designated four clusters of homogenous groups as follows:

(i) **'Entrepreneurs':** These represented less than 10 per cent of the total; they were mostly the large dairy and cattle farms which expanded their businesses over the 7-year period. They were young, farmed intensively and efficiently, had no surplus labour capacity, and had good contact with the various support services.

(ii) **'The Pressurised':** Constituting about 15 per cent of the total, these were mainly small dairy farmers whose businesses tended to decline or remain static although they had surplus labour capacity. They were farming reasonably efficiently but had difficulty in expanding from their existing position.

(iii) **'Part-timers':** Approximately 30 per cent of the total, mostly with cattle and sheep enterprises but also with a limited number in small dairy enterprises. They farmed extensively and despite having off-farm employment they still had surplus labour on their farms.

(iv) **'Declining - At Risk':** These accounted for 45 per cent of the total and their business size had declined over 1984-90. Almost all were in cattle and sheep enterprises on limited areas of land; they farmed extensively and had a considerable surplus of labour on their farms.

Leavy's classification corresponds broadly with that presented here. His fourth grouping ('declining-at-risk') would largely coincide with Categories 3 and 4 as identified from the 1993 NFS data but his criteria for business expansion limit the 'vanguard' farms to a select group of 10 per cent of the total.

Leavy's conclusion is that despite the fact that most farmers are under-utilising their labour and to a lesser extent their land resources, their farm businesses are not expanding.

IV DETERMINANTS OF STRUCTURAL CHANGE AND THEIR IMPLICATIONS FOR THE FUTURE

Irish agriculture has been firmly on a trajectory of pronounced structural change for at least three decades. The data presented here show that change has accelerated over the 1980s. This is confirmed by other analyses [Matthews 1994] showing that projected downward trends in the numbers of farms in six enterprises for 1900-2000, and which were based on 1975-85 changes, were already surpassed in 1991 – except in the case of the sheep enterprise where the numbers of sheep exceeded the numbers projected.

Structural change over the longer term is marked by decline in the number of farms, decline in the farm labour force (referred to in more detail below), growth of part-time farming, concentration of production on larger farms and in the more commercially viable farming regions, a clear retreat into low-intensity low income cattle and sheep production in a large part of the country with greater diversity of enterprises in the other part, endemic failure to achieve economic and socio-demographic viability in many rural areas, and the increasing reliance of farming households on the non-market component of family farm income.

To summarise, the outcome of this process of change is a current structure containing four main categories of farm which are differently positioned to meet the challenges of the future. Using Teagasc definitions of farm and farm household viability there are now at most 47,000 economically viable farm units in the country, but more rigorous and indeed realistic concepts of viability would reduce this number to 30,000 or thereabouts. Of the economically non-viable units there are 36,000 where the farm operator and/or spouse has another source of income. Another 82,000 farm households do not have such incomes; of these 48,000 are 'young' households on average sized farms while the remaining 34,000 are 'older' households on poorer farms and unlikely to survive into another generation as separate units.

The questions therefore are: what forces have been driving this pattern of change? Will these forces persist for another decade and are there any unprecedented developments likely to emerge? If so, what will be their impact on the structure we have described?

The argument being made here is that while future change will be determined by many factors - some of which have not been experienced in the past three decades - there is no combination of factors in prospect that will substantially alter the established pattern of structural change from its present course.

Technology

Agricultural restructuring is not a simple outcome of any single set of forces but derives from the interactions of technology, markets and policy on the one hand with regional, local, individual farm and household circumstances on the other. Increasingly, however, the modernisation of farming is propelled by factors external to the procedures themselves, to the sector, and, indeed, to any single country. The 'globalisation of agriculture' is a term now used to denote the increasing integration of the sector into the international and world economy, together with the formulation of agricultural policies in the context of global trade agreements.

With no apparent reduction in the expenditure on agricultural research in the advanced economies it seems reasonable to assume that technological advances and their transfer across national boundaries will continue to increase the productive potential of agricultural resources, possibly at an increasing rate as new sets of innovations come on stream in the late 1990s [Commins and Higgins 1987; Alexandratos 1990:15]. The commercial applications of new technology will have to respect environmental management, health and safety, as well as animal welfare considerations, and also the overall limits to production dictated by lack of effective demand (see below). In the past, technology for farming has not been scale-neutral and the successful adoption of further technologies - most likely cost-reducing practices - in conditions of environmental and market constraints will call for levels of knowledge, skill and managerial ability found mostly among those farm categories which are currently enterprising or viable. With the closer linkage of farming to the agri-industrial sector and food-chain - which has its own imperatives for rationalisation and technological development - the pressures for innovation will continue at farm level, e.g. to produce according to prescribed and more exacting quality standards.

The impact of these technological forces will be expressed most directly within the commercial farming sector - typically the Category 1 farms, especially those just surviving in this category. But the international policy and related market environment will have implications for all categories except perhaps those at the lower end of the spectrum. The present authors cannot claim expertise in policy analysis but we draw upon the views of a number of economists to provide at least a partial vision and a degree of consensus as to the prospects ahead.

External policy and market environment

Following implementation of the CAP reforms over 1993-96 and the ratification of the GATT decisions covering the years 1995-2000 the policy context for the rest of the 1990s is basically settled. This is not to say that the eventual impact on Irish agriculture can be accurately discerned. Concerns expressed at the time of the proposed reforms seemed justified but the actual measures agreed differed substantially from the proposals, while there was also an unexpected devaluation of the green pound. Increases in direct payments for the commodities affected have offset price reductions and the economic situation in the sector is now quite buoyant [Kearney 1995b]. Indeed later analyses of the agreed reforms anticipated this. But the fact remains that the opportunities for expanding production have been curtailed while the extent to which production controls are tightened or relaxed in the future will depend very much on the evolution of agricultural markets and the expected balance between global supplies of food and the global demand for food [Matthews 1994]. Specifically on the dairy sector Fingleton [1994] notes that although changes consequent on CAP reforms have had minimal impact to date, commitments on trade liberalisation required under GATT are likely to result in significant restrictive adjustments to current prices and quota arrangements before the end of the 1990s.

One obvious effect of such a development will be the further exit of smaller producers from milk production. The data presented here (Tables 14 to 16) suggest that there are a number of small and economically vulnerable dairy farmers among the non-viable categories identified.

Consideration of the next GATT round post-2000 has already begun with a growing acknowledgement of the irreversibility of the trend towards greater trade liberalisation [Kearney 1995b]. Further GATT-imposed cuts in agricultural protection can be anticipated following the completion of the current round, bringing the competitive capacity of Irish agriculture even more strongly into focus within the EU and in world terms [Lucey 1995]. Reviewing FAO projections for global agricultural production and food demand until 2010, Matthews [1995] concluded that these do not hold out the prospect of global demand and supply being sufficient to reverse the long-standing downward trend in world food prices and to lead to a more remunerative outlet for Irish and European farm produce. Matthews adds that the best estimate is for the decades-long imbalance between production capability and market demand to continue.

The other issue of relevance here is the enlargement of the European Union towards the central and eastern European countries. This prospect holds threats for Ireland in relation to the degree to which the EU will provide market access for the agricultural products of these countries as part of the process of EU integration. Enlargement eastwards may also put pressure on the EU agricultural budget [Kearney 1995b]. However, Arnold [1995] concludes that these countries offer not only threats but also marketing opportunities, depending on their rate of economic recovery.

While these various matters are of direct concern to the viable category of Irish farmers the large numbers currently depending on non-price subsidies may be faced with changes in these payments. The principles underlying such payments have come into question. The report [CEC 1994] of the expert group convened by the EU's Directorate General for Economic and Financial Affairs to assess EU agricultural policy made a number of recommendations for further reform of the CAP. These included: (i) the separation of the two aspects of policy, that of market competition and economic efficiency on the one hand, and that of social and environmental aims on the other, (ii) the gradual phasing out of the EU financing of compensatory payments and the devolution of responsibility for such funding to the Member States; (iii) the use of EU regional, social and cohesion funds as accompanying measures to support structural change and rural development.

Such a fundamental approach to CAP financing will not find easy political acceptance. A compromise is likely to be found in the more specific targeting of payments to those farmers in need, the decoupling of payments from production, and their more direct linkage to social, environmental and perhaps structural objectives.

An arrangement of this kind together with the availability of schemes such as the Rural Environmental Protection Scheme (REPS), will ensure the continued existence of a large category of low-intensity drystock farms in Ireland. In fact, more so than in the past this sector will continue to be a refuge for the exits from the market-oriented category.

Alternative farm enterprises

This conclusion about the continuing residual nature of much drystock production is reinforced by the progress to date with alternative enterprises. Evidence suggests that their adoption will be slow in relation to the magnitude of the target numbers, and selective as to kinds of farmers diversifying from conventional production.

A study by Leavy [1995] concludes that several factors inhibit the widespread adoption of alternatives to conventional farm enterprises - despite the availability of land and labour on the part of those farms displaced from the viable commercial farming of existing enterprises. The obstacles include lack of funds for investment, the absence of well-established systems of institutional support in promotion, marketing and training (in contrast to the back-up which, e.g. dairying had), and the low level of human capital - as reflected in poor household composition, old age and negative attitudes to novel ideas. However, the enterprise which requires least departure from existing practices is forestry as it is not so demanding of management skills or of marketing systems - at least in the short-term. Indeed forestry has accounted for perhaps the major shift in land use in recent years, with planting rates of over 20,000 ha per year and private landowners taking up over half of this area.

Yet, other studies show that, paradoxically, those farm owners who applied for afforestation grants during 1988-1991 did not come, even proportionately, from the poorer farming regions [Hannan and Commins 1993:68]. The regional pattern of forestry applications conformed more closely to the distribution of tillage and dairying than to the regional pattern of small-scale and low income farming. Data from the 1991 Census of Agriculture confirm this association of forestry with commercial farming. In the 'large-farm' counties (see Section II of this paper) 13.7 per cent of farms had woodland compared to 4.1 per cent in the small-farm counties, with the percentages in the other categories of county being in the intermediate range. It is true, however, that sales of land for afforestation (i.e. 'non-farm' forestry) occur more frequently in the poorer farming regions than in commercial farming counties.

The limited data in the 1991 Census in regard to other income earning activities on farms (e.g. bed and breakfast, recreational activities for tourists, crafts, etc) also show a relatively higher incidence in the more prosperous farming regions.

Evidently, the adoption of alternative farm enterprises, not unlike survival in conventional farming, is associated with younger people having capital, enterprising attitudes and a willingness to change. Progress in this form of diversification will make only slow inroads into the large numbers of non-viable farms in the poorer regions.

The domestic economy: Non-farm employment

To an increasing extent persistent low-farm incomes on small holdings have been offset by earnings from non-farm employment. Employment conditions are expected to improve appreciably over the coming years but it remains doubtful whether the geographical distribution of new jobs will be as widespread as in the expansionary years of the 1970s - before world recession hit Irish industrial employment.

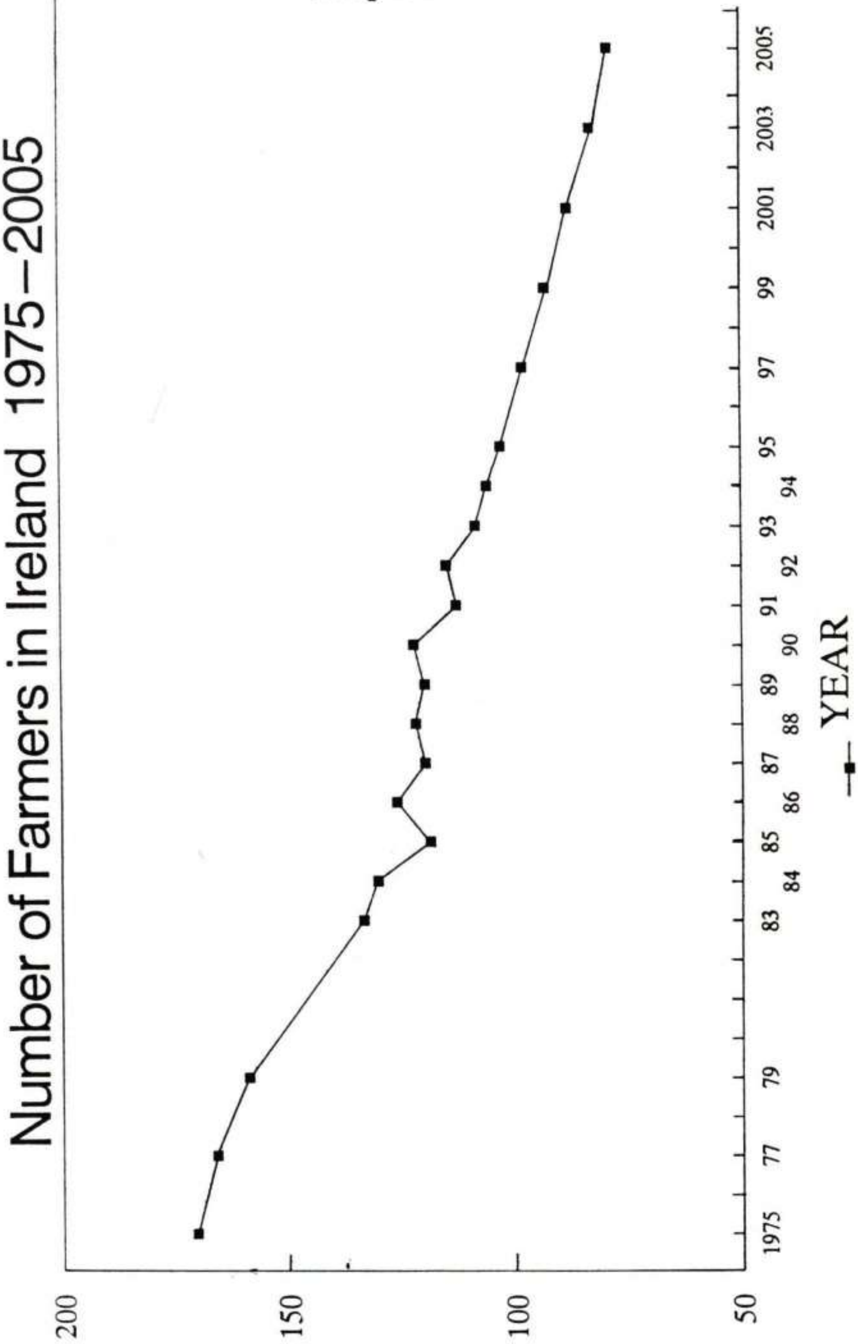
In any event, given the difficult market environment which economists see as facing farming over the next ten years, it can be assumed that the trend towards part-time farming will continue, absorbing greater numbers of the operators of non-viable holdings. Apart from continuing difficulties in generating employment in locations accessible to the remoter rural areas, the only factors to inhibit the growth of part-time farming are deficiencies in training and skills on the part of farm operators. However, these are unlikely to present insuperable constraints given the extensive system of job training now available around the country.

Labour force changes and farmer replacement

Decline in the farm labour force is the outcome of past structural change while the size and composition of the current labour force will dictate future adjustments. Over the past few decades decline in the Irish <u>farm labour force</u> proceeded steadily within a range of 2.5 per cent to 3.5 per cent per annum. There is nothing to suggest that this trend will change direction or scale. It may even intensify as retirements, deaths and exits for other jobs rise in relation to the numbers of entrants. A continuation of current trends would take the present farm labour force down from 150,000 to 100,000 persons by 2005.

Decline rates among <u>farmers</u> have been lower than for those in the total farm labour force. Recent OECD projections for Ireland estimate 90,000 farmers in the country (not the same as 'landholders') by 2001 [OECD 1994]. A straight trend projection of the Labour Force Survey estimate of 109,000 farmers in 1993 would suggest a figure of 79,000 farmers by 2005 [see Graph 2]. Here, it is reasonable to assume that the younger segments of the present generation of farm families will not be prepared to stake their future in farming to the same extent as their predecessors.

Graph 2


Number of Farmers in Ireland 1975–2005
'000 Farmers
200
150
100
50
1975
77
79
83
84
85
86
87
88
89
90
91
92
93
94
95
97
99
2001
2003
2005
YEAR

Fewer numbers, however, will be associated with better quality human resources, as the numbers receiving basic career training in recent years have remained steady. However, there is again a clear association between the incidence of formal training, farm size and region. Between 1986 and 1994 the annual number of recipients of the Teagasc Certificate in Farming [CIF] was 863. When this was expressed as a ratio of the estimated numbers of farms over 20 hectares changing hands annually the number of CIF recipients per 100 new farm operators varied from 47.6 in the large farm counties to 23.2 in the small farm counties (as these groupings were identified in this paper).

Land structure

While the better-trained young people are now coming into farming at the higher farm size levels it is also the case that other well-qualified aspirants to farming (such as those with farm apprenticeship training) are finding it difficult to establish a career on the land if they are not farm inheritors. In the past the exodus of labour from farming did not result in corresponding degrees of farm consolidation, reductions in the numbers of holdings and opportunities for non-inheritors to get access to the land. In the 1970s there were public discussions, committee reports and official declarations of intent to deal with the rigidities in the Irish land structure and allow for greater mobility of land between one set of occupiers and another. But this momentum came to very little and with surplus production building up land policy in this sense went off the agenda. Changes in the structure of production and in the farm labour force took place without commensurate change in the structure of farms apart from formal and informal lettings and the outcomes of transactions occurring in a limited land market.

What evidence there is of land structure changes again suggests a regionally differentiated pattern [Hannan and Commins 1993:71]. In the 'north-west' where substantial 'land retirement' has occurred whether into part-time farming or 'refuge farming' - sales of agricultural land as a ratio of holding numbers have been relatively low. In these areas land mobility occurs through sales for afforestation, through informal lettings or transfer to absentee owners. By contrast sales rates have been highest in areas of high average farm size, good soil quality and high use intensity.

As for the future, there is little in the current policy menu or in any foreseeable set of measures which would suggest a new momentum in land structural change. One unknown factor is the strength of their attachment to land on the part of those who have it. This is probably weakening at least to the extent that landholders are willing to surrender managerial control rather than ownership. The provisions of the Early Retirement Scheme, by which the successor must expand the transferor's holding, will also give some impetus to land rental by young people. However, on balance, policies and initiatives now in position could induce smaller-scale farmers to accept, and become accustomed to, a pattern of living in which income is not dependent on active farming but is enhanced simply by retaining farm occupancy and making limited use of the land.

V CONCLUSION

Looking 10 years ahead we envisage two phases of structural change in the farm sector. Up until the year 2000 there could be some moderation in past rates of adjustment, with the exception of a continuation of decline in the numbers of dairy farms. The revised methods of enumeration in the 1991 Census of Agriculture eliminated in the statistical sense over 30,000 marginal farms so there is likely to be a time-lag before high rates of decline appear among the remaining 170,000 farms. While real farm prices will fall, the rising volume of direct payments (now making up one-third of farm income, a proportion expected to increase further) will cushion the more marginal producers against income loss. The main blocks of agricultural policy and the related national Programme for Agriculture, Rural Development and Forestry are in position until the end of the century. Prospects are improving for non-farm employment, thus increasing the opportunities for part-time farming.

The relative calm of the next five years seems certain to be followed by a period of turbulence, to 2005 at least. There have been no policy shifts in recent times of the scale and magnitude likely under GATT trade liberalisation, EU enlargement and changes in EU budget commitments. There is, therefore, little by way of precedent for assessing the possible directions for Irish farm structure. To undertake such an assessment would in itself be a major research task. But it seems reasonable to suggest that on the evidence of past trends structural change will gather momentum with outcomes mirroring the pattern of adjustment described earlier in this paper. That is to say, there will be a high degree of volatility in farm incomes in the context of reductions in market protection, increasing pressures on high-cost producers and consequent difficulties for them to remain viable, further and perhaps more rapid depletion of the number of economically viable producers. A population of 80,000 farmers by 2005 - and this is a conservative enough estimate based on a non-turbulent phase of change - could mean having no more than 30,000 viable farms then, without using rigorous definitions of viability. As is the case at present these would co-exist with a large number of part-time farmers and another large residual category of fulltime drystock farmers. The latter will continue to depend on direct income supports but if Brussels is to continue to pay these, after political bargaining, they will be more tightly targeted to achieve social and environmental objectives.

This vision of a three-track farming system is based on the assumption that the pathways for future adjustment are already fixed by the structure which has evolved over three decades and by the limits set by the external market and policy environment. An alternative scenario would see this prospect as too passive a stance to take for a country which is so dependent on its natural resources. It would claim that the shaping of structural change in farming is not altogether dictated by inevitable and external forces. It would argue for the full manipulation of those levers that we in Ireland can control for ourselves in the pursuit of a model of development best suited to our own circumstances. It might see possibilities in having research and development capacity more expressly focused around the different sets of problems of different regions in the country. And it would seek a more optimal balance than at present between palliative income support measures and the required supports for resource development.

There is need for more systematic thought and study on these or other options for the future of farming and rural resources.

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APPENDIX

Table A1

Per cent of farms with different enterprises and size of enterprise, by category of county, 1991

Enterprise	Large farm counties	Medium-to-large farm counties	Medium-to-small farm counties	Small farm counties
		Per cent of farms with		
Crops	37.6	23.3	14.4	22.0
Dairy cows	40.8	35.0	33.8	13.7
Other cows	40.6	41.1	54.8	69.5
All cattle	84.5	86.4	92.2	90.4
Sheep	31.6	24.8	23.8	41.9
		Average size: hectares/animals[1]		
Crops	14.6	18.7	3.5	1.7
Dairy cows[2]	35.9	31.9	20.9	14.3
Other cows[2]	11.0	10.8	9.4	7.1
All cattle	66.8	61.2	41.8	26.3
Sheep	221.9	188.8	139.5	131.8

[1]Of farms with the particular enterprise

[2]including heifers-in-calf

Source: Derived from Census of Agriculture, Table 11

APPENDIX

Table A2

Changes in the percentage share of crops and livestock (animals and hectares) by categories of county

Year	Crops	Dairy cows	Other cows	All cattle	Sheep	Pigs
			Large farm counties			
1960	46.9	34.7	34.7	31.0	28.9	49.5
1980	56.2	43.3	21.8	33.0	31.0	45.8
1991	58.9	46.3	23.2	35.3	33.1	38.9
			Medium-to-large farm counties			
1960	19.9	20.6	20.6	21.8	13.4	15.8
1980	25.4	22.0	13.9	20.3	10.2	13.5
1991	29.9	22.8	15.0	20.6	14.2	16.8
			Medium-to-small farm counties			
1960	15.6	24.4	24.4	24.3	13.8	23.9
1980	8.4	23.6	23.3	23.9	14.1	30.6
1991	5.6	22.2	26.5	23.7	15.8	37.4
			Small farm counties			
1960	17.5	20.4	20.3	22.9	43.9	10.8
1980	9.9	11.1	41.0	22.8	44.8	10.1
1991	5.6	8.7	35.2	20.4	36.8	6.9

Source: Derived from Census of Agriculture, various tables

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