Silage

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THE SELECTION OF SILAGE MAKING SYSTEMS

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1. Introduction

The problem of selecting the best system of silage making is on many farms difficult to resolve. Recent increases in herd size and the continuation of upward movements in the cost of labour and feeding stuffs have made it necessary to acquire larger and more expensive machines in order to produce a greater quantity of better quality silage. Further expansion in silage making capacity can be obtained by extending the harvesting period but any savings in capital investment by adopting such a policy have to be weighed against the increased likelihood of conserving a greater proportion of material with a low digestibility and also of running greater risks with the weather. In order to choose the best, or cheapest system, it is necessary to measure the costs, not only of different machinery complements, but also the changes in expected returns with variation in silage quality. Furthermore, in choosing a system it is imperative to make sure that all the machines involved are not only matched with each other, but also with the farm labour supply.

2. The effect of the machinery system on silage quality

The system of silage making affects silage quality in two ways. Firstly, the capacity of the machines affects the potential output of the system and the time at which harvesting takes place. Secondly, the type of machines can influence the extent of losses at all the stages involved in conservation.

The well known association between the stage of grass growth at which cutting takes place,and the quantity and quality of the grass conserved is depicted in Figure 1. Thus, the larger the capacity of the machinery system, the greater the proportion of grass which it is possible to harvest at the "correct" stage of growth. This fact is, of course, well appreciated by farmers; a recent survey of 24 Cheshire farmers [1] showed that all but two cut their grass either before or at the early flowering stage. The ultimate test of quality is the performance of the animals eating the silage and there is some experimental evidence [2] as well as practical experience to show that stage of growth has an economically significant effect for both milk and beef production.

It is more difficult to quantify the effect of machinery type on conservation efficiency. Chopping and laceration produce a better fermentation [3] and reduce losses in the silo [4] as well as increasing the dry matter intake of self fed animals [2] and making the silage easier to handle in the winter. It is also suggested that rapid filling of a silo helps to improve the fermentation process [5].

The most difficult material to ensile is young leafy grass with a high crude protein and moisture content, but low in sugars. There is a strong positive correlation between the crude protein content of grass and the resultant acidity of the silage, such that one of two measures needs to be taken to ensure a reasonable fermentation. One alternative is to wilt such material [6], the other is to use additives. Both these procedures, especially wilting, have an effect on the design of the silage making system. Wilting increases the effective capacity of both trailers and the silo, reduces the amount of effluent produced and also improves the dry matter intake of the animals eating the silage. The disadvantages of wilting, such as the greater reliance on fair weather and consolidation problems, can be avoided by the use of additives. A review of their use is shown in Table 1. Experiments carried out at Liscombe Experimental Husbandry Farm have demonstrated the worth of additives for use with problem crops, if not for all direct cut crop crops [7].

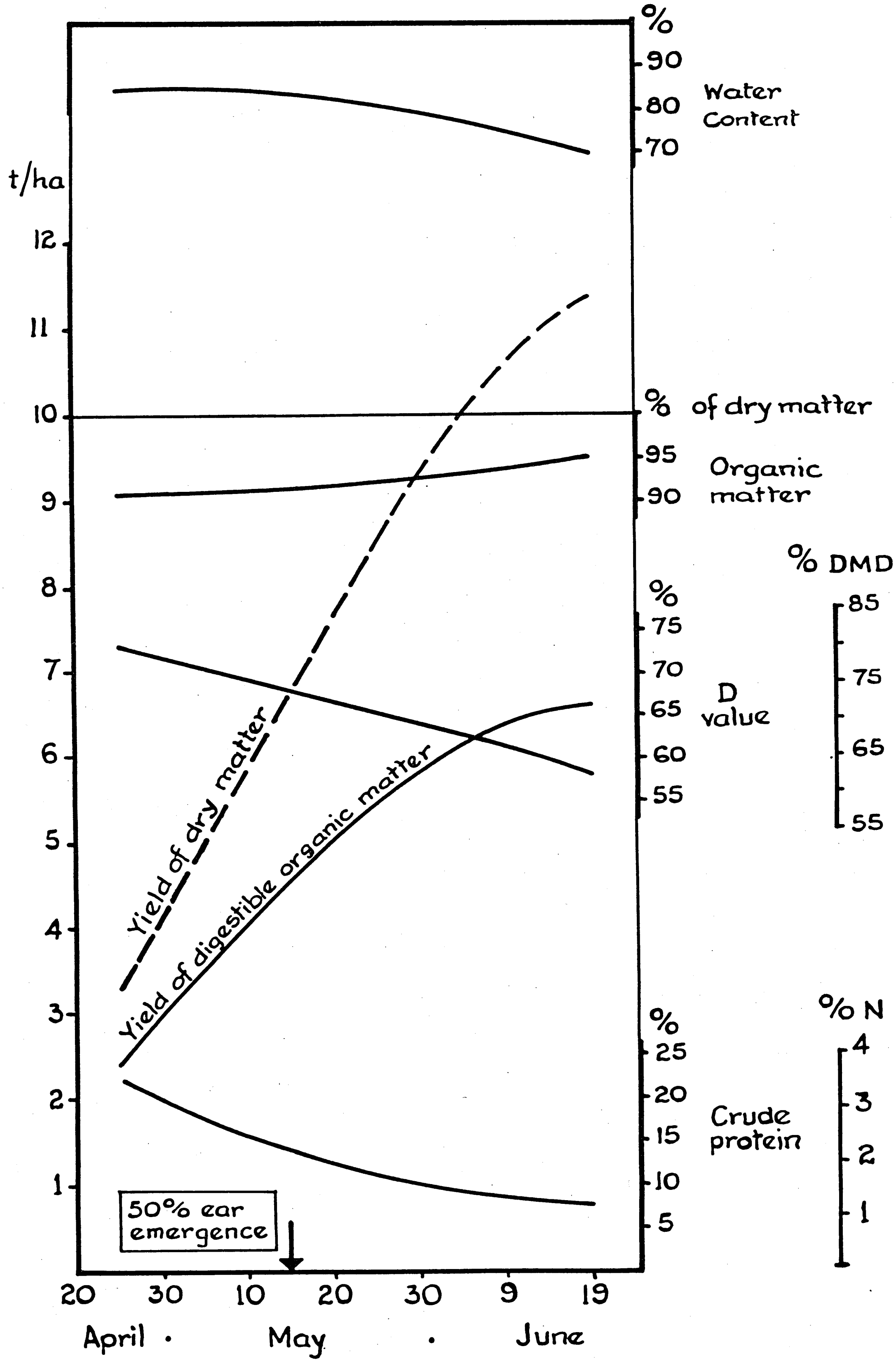
3. The effect of weather on available harvesting time

Rainfall records provide an approximate guide to the likelihood of receiving a particular number of operating days within a season. Table 2 shows the frequency in percentage terms of the number of "dry" and "pick up" days which occurred in the Nantwich area of Cheshire between the 16th May and the 7th June (21 days) in the years 1948 to 1966. "Dry" days are defined as days on which there was less than 0.04 inches of rain; "pick up" days as days which follow a "dry" period of at least 24 hours.

The Table shows the importance of the degree of risk a farmer is prepared to take on the required capacity of a harvesting system. Furthermore, assuming a direct cut system can operate only on dry days and a wilting system only on pick up days, then there is a

FIGURE 1

TYPICAL DIAGRAM SHOWING THE METHOD OF RELATING STAGE OF DEVELOPMENT TO YIELD AND QUALITY OF S24 PERENNIAL RYEGRASS DURING PRIMARY GROWTH.



Source:- Green, J.O., Corral, A.J. and Terry, R.A. Grass Species and Varieties. Grassland Research Institute. Technical Report No.8. Feb. 1971.

considerable reduction in the available working time caused by operating a wilting system for a similar degree of risk. For example, a farmer who plans his system on the basis of 10 working days between the 16th May and 7th June would have received at least 10 dry days in 100% of the years but 10 pick up days in only 84% of the years. A dramatic increase in risk occurs at the point where 13 "pick up" days are required in the same 21 day period.

TABLE 1

Summary of Types of Additive

Additive	Ingredients	Principle	Application Rate	Method of Application	Estimated Cost	Other Comments
MOLASSES SUPPLIERS: Various, e.g. British Sugar Corporation.	LIQUID % by weight Sucrose - 60 Mineral - 25 Salts Water - 15	Production of lactic acid by fermentation of sugar by bacteria.	1-3 galls. per ton of green material, depending on the leafiness and wetness of the crop.	(a) applied to mown swath (b) forage harvester attachment; (c) sprinkled on clamp. 50:50 water solution.	Allowing for feeding value of molasses, about £0.24/ton @ 3-gallon rate.	Difficult to distribute uniformly, particularly on clamp. Improved palatability of silage. Innocuous. Not very popular at present.
ADD-F SUPPLIERS: B.P. Chemicals International Ltd., Devonshire Hs., Piccadilly, London W1X 6AY.	LIQUID Formic Acid - 85% Water - 15% (approximate figures)	Direct acidification - lowers pH immediately.	4 pints/ton of green material.	By applicator on forage harvester.	£0.30/ton of green material.	Corrosive. May blister skin. Therefore always wear protective clothing. Keep water available. Very popular. Has been proven effective in trials at independent research centres.
SILAGE SHIELD SUPPLIERS: Feed Services (Livestock) Ltd., Hartham, Corsham, Wiltshire.	LIQUID Formic Acid. Proprionic Acid. Citric Acid. Lactic Acid. Antioxidants and flavouring	Direct acidification to lower pH. Also aims to produce a more palatable end product.	Normally 2 lbs/ton of grass. Increasing to 3 lbs/ton where conditions of high moisture content and/or high nitrogen content apply.	Pressure sprayed from applicator on forage harvester, powered by electric motor and compressor run from tractor battery.	£0.34/ton of green material at 2 lb/ton rate.	Potentially corrosive but claimed to be less of a problem than other standard formic acid formulations. Caution is still necessary.
SILAGE MASTER SUPPLIERS: Agil Ltd., Fishponds Close, Wokingham, Berkshire.	LIQUID Propan - 20L, Proprionic Acid, Propane 1, Phosphoric Acid, Benzoic Acid, Antioxidants and flavouring.	Activates lactic fermentation. Inhibits mould development. Also aims to produce a more palatable end product.	2 lbs/ton of green material.	Mini applicator which automatically pressure mists chemical into the forage harvester.	£0.40/ton of green material	Claimed to non-corrosive. Requires sensible care in handling but acid potential is less in comparison with other products.
SYLADE SUPPLIERS: I.C.I.Ltd., P.O. Box 1, Billingham, Teeside, TS23 1LB.	LIQUID 40% solution of formaldehyde gas (61.3% formalin), 14.5% sulphuric acid. Polymerisation inhibitors. Corrosion inhibitors.	Preservation without the production of lactic acid.	½ - 1 gallon/ton of green material.	By applicator on forage harvester.	£0.30/ton of green material @ ½ gallon rate.	Claimed to be less corrosive. Can be unpleasant to use. Always wear protective clothing and keep water available. Feeding trials at Hurley have shown increase in D.M. intake over that produced by normal silage making.
KYLAGE EXTRA SUPPLIER: Pan Britannica Industries Ltd., Britannica House, Waltham Cross, Hertfordshire EN8 7DY.	SOLID Calcium formate, Fermentable sugars, Sodium Nitrite, Trace Elements.	Inhibits putrefying bacteria. Stimulates desirable lactic acid forming bacteria.	3-4 lbs/ton of green material.	By applicator on forage harvester or by hand.	£0.21/ton of medium protein crop. £0.28/ton of high protein crop.	Safer to handle - non-corrosive powder.

Source: Information compiled from manufacturers and research literature.

TABLE 2

Frequency, expressed as a percentage, of dry and pick up days in the Nantwich area of Cheshire between the 16th May and the 7th June for the years 1948 - 1966

	Number of days													
Type of day	6	7	8	9	10	11	12	13	14	15	16	17	18	19
						%								
Dry, < 0.04"	100	100	100	100	100	95	89	84	79	73	58	53	35	16
Pick up	89	89	89	89	84	79	73	53	47	32	26	16	11	1

Those farmers who are more stringent and prepared to harvest only on days of nil rainfall can expect increased levels of risk as shown by Table 3. It also follows that those farmers who wish to concentrate harvesting into a shorter overall period must be prepared either to increase system capacity to maintain reasonable harvesting safety margins or be prepared to accept more risk. For example, if one wished the harvest to span a maximum of 14 calendar days, then on average one would expect to receive (from Table 3) dry days 79% of the available time, which is equivalent to only .79 x 14 = 11 dry days.

TABLE 3

Frequency, expressed as a percentage, of dry and pick up days in the Nantwich area of Cheshire between the 16th May and the 7th June for the years 1948 - 1966

	Number of days													
Type of day	6	7	8	9	10	11	12	13	14	15	16	17	18	19
						%								
Dry, nil	100	100	95	95	84	79	73	68	53	47	26	21	16	11
Pick up	84	84	84	79	63	53	31	21	21	16	16	5	5	0

4. Designing a silage making system

The essential processes to be carried out during silage making can be listed as follows:- cutting, collection, transport and ensiling. Some machines, such as a forage harvester or a buckrake, can be used to combine two processes into a single operation, thereby reducing the number of combinations of machines, or systems, to be considered. Theoretically, a very large number of technical systems are possible. For example, in Table 4 for the machines shown and ignoring differences in design, size, make and the possibility of having more than one machine at each stage, some 480 (8 x 5 x 3 x 4) combinations are possible. However, not all the combinations need to be considered because some machines do not fit together in a single system, such as ensiling by means of a dumpbox and blower without having chopped the grass. A particular system may, also, not produce silage in a suitable form for an appropriate silo emptying and feeding system. Nevertheless, the example in Table 4 does illustrate the existence of silage making systems, other than the conventional ones. Changing prices and technology could well cause completely new systems to be developed and adopted in the near future.

TABLE 4

Possible combinations

of machines

involved in silage making

Process	Machine	Number of machines
Cutting	Finger bar mower, Finger bar mower + conditioner, Flail mower, Rotary mower, Rotary mower + conditioner, direct cutting with single chop, double chop or precision chop harvesters.	8
Collection	Buckrake, single chop, double chop or precision chop forage harvester, self loading trailer.	5
Transport	Buckrake, tipping trailer, forage box	3
Ensiling	Rear mounted buckrake, front mounted buckrake, forage blower, dump box and blower.	4

The performance of a system can also be influenced by the method of management and a careful matching of design features and sizes of machines. In Table 5, the effect of wilting, in terms of the number of full trailer loads of grass produced per acre, is compared with direct cutting for different harvester types and trailer sizes. Both wilting and chopping are shown to reduce the amount of transport necessary, so that the benefits of larger trailers are proportionately greater the denser and drier the crop when carted from the field.

TABLE 5

The effect of wilting, harvester type used for pick up and trailer size on the trailer loads per acre

		POUNDS (total)	POUNDS D.M.	LOAD WEIGHT (CWT)				LOADS PER ACRE OF 2-ton D.M. CROP			
		wt.per cu.ft	per cu.ft.	360* c.ft	504* c.ft	576* c.ft	630* c.ft	360* c.ft	504* c.ft	576* c.ft	630* c.ft
DIRECT CUT	Single chop	7	1.4	22	31	36	39	9.0	6.3	5.6	5.0
20% D.M.	Double chop	15	3.0	48	67	77	84	4.5	2.9	2.6	2.4
WILTED	Single chop	7	2.1	22	31	36	39	6.0	4.3	3.8	3.4
30% D.M.	Double chop	13	3.9	42	58	66	73	3.2	2.3	2.0	1.8
	Precision chop	15	4.5	48	67	77	84	2.8	2.0	1.7	1.6

Source - Adapted from 'Silage Making Systems'. A.D.A.S., 1972.

* Trailer Dimensions -	Cubic Capacity (cu.ft.)
10' x 6' x 6'	360
12' x 7' x 6'	504
16' x 6' x 6'	576
16' x 6.6' x 6'	630

Planning the organisation of a silage making system is a task of equal importance to that of selecting individual machines. The number of available men is a restriction on the way in which a particular system can be operated. Typical outputs for different man unit systems, assuming a yield of eight tons of grass cut per acre, are shown in Table 6.

TABLE 6

Typical, average and target outputs for selected systems based on man units

SYSTEM	ACRES HARVESTED PER HOUR		POTENTIAL OUTPUT (ACRES) FROM 10 DAYS HARVEST - 8 HOURS PER DAY		ANNUAL GRASS TONNAGE BASED ON 30 DAYS OF HARVESTING	
	AVERAGE	TARGET	AVERAGE	TARGET	AVERAGE	TARGET
One man direct cut	0.25	0.38	20	30	480	720
Two man direct cut	0.31	0.45	25	36	600	944
Three man direct cut	0.75	1.12	60	90	1440	2160
Four man wilting	1.50	1.87	120	150	2880	3600
Five man wilting	2.00	2.50	160	200	3840	4800

Source - data taken from I.C.I. and M.A.F.F. Surveys 1970/71

A whole set of factors will control the system output in any particular situation, including the cutting and loading rate, the distance from the silo to the field, the speed and size of transport units, silo loading arrangements and delays caused by breakdowns or by poor matching of the relative capacities of different machines within the system. Furthermore, it is rare to find machines used to their full theoretical field capacity*, average estimates of the field efficiency** of silage making equipment varying from 65% to 95%, as shown in Table 7.

TABLE 7

Field efficiencies for individual machines

MACHINE	PER CENT		
	Poor	Average	Good
Mowers - cutter bar	70	75	80
Mowers - flail	80	85	90
Mowers - rotary	80	85	90
Swath Turner/Side Rake	80	85	90
'Flail' Forage Harvester	55	65-70	85
'Precision' Chop Harvester	55	65-70	85
Buckrake	85	90	95
Trailer	92	95	98

Source - C. Culpin (1969). Profitable Farm Mechanisation.

Utilising equipment as fully as possible is doubly important where machines service each other in series, as in silage making. Thus, if each machine in a system of four has a field efficiency rating of 85%, and it is assumed that when one machine stops, the whole system ceases to operate***, then the overall efficiency of the set of machines is reduced to 52%, as calculated below:

$$\text{System efficiency} = 100 \times \frac{85}{100} \times \frac{85}{100} \times \frac{85}{100} \times \frac{85}{100} = 52\%$$

This example stresses the need at the design stage to plan a system that is well integrated in order to avoid delays which can have a serious effect on the total system output. The way in which a system might be planned is illustrated below, using the following assumptions:

a) yield of first cut grass = eight tons per acre;

b) average total travel distance = one mile;

c) average speeds:

(i) flail harvester 3 m.p.h.

(ii) transport 10 m.p.h.

* Theoretical field capacity is the rate of field coverage that would be obtained if a machine were performing its function for all the available time at the ideal forward speed and always using all the rated width.

** Field efficiency is defined as the ratio of the actual rate of coverage to the theoretical field capacity expressed as a percentage.

*** The effect would probably not be quite so dramatic since there is usually some spare capacity in some of the stages of a system.

d) effective day length = eight hours;

e) three man direct cutting system;

f) dry matter content when direct cutting = 20%;

g) 48" in line single chop harvester fitted with laceration plate;

i) density of cut and lacerated grass approximately 9 lbs per cubic foot;

j) two trailers 16' x 6' x 6' - capacity of each approximately two tons of lacerated grass;

k) one push-off buckrake;

l) three tractors.

It is necessary to work out the potential output at each stage of the harvesting process, namely, cutting and loading, transport from field to silo and filling the silo. In this example, it is assumed that the buckrake has adequate capacity for filling so that only the first two stages are considered.

The potential cutting and loading rate per day is calculated from the equation:-

$$\frac{W \times D \times L \times E}{A}$$

where W = harvester cutting width in feet;

D = distance travelled per hour in feet;

L = length of working day in hours;

E = system efficiency, per cent;

A = area units per acre in square feet.

Thus, for the example in question the potential number of acres cut per day

$$= \frac{4 \times 3 \times 5280 \times 8 \times 65}{9 \times 4840 \times 100} = 7.6 \text{ acres/day.}$$

The potential transport rate in acres per day is calculated from the equation:-

$$\frac{L \times C \times E}{(T + O + U) \times W}$$

where L = length of working day in minutes;

C = trailer capacity in tons;

E = system efficiency, per cent;

T = travel time in minutes;

O = trailer changeover time in minutes;

U = trailer unloading time in minutes;

W = weight of grass to be transported per acre in tons.

The rate of transportation is calculated for two trailers with a capacity of two tons each, assuming that one trailer will always be with the forage harvester as follows:

$$\frac{8 \times 60 \times 2 \times 65}{(6 + 1.5 + 2.5) \times 8.5 \times 100} = 7.3 \text{ acres per day}$$

If the trailer capacity was 2.5 tons, the potential transport rate as calculated from the above equation would be 9.2 acres per day.

In pratice it is not possible to match the capacity of trailers and forage harvesters on the basis of average rates of work. This is because of variation in performance caused by, say, heavier crops, longer transport distances, failure to fill trailers completely and reduced travelling speeds. A plan, using a trailer with a capacity of

$2\frac{1}{2}$ tons, can on average transport 9.2 acres of grass per day with the assumptions made and this might at first sight appear to be adequate to service a forage harvester capable of cutting 7.6 acres of grass per day. However, a change in performance by either machine might with such a margin of extra transport capacity, result in delays occurring.

A bottleneck can occur at the silo, if there is no room to tip additional loads of grass when it arrives more quickly than usual, or the buckrake fails to keep up. A conventional "push-off" rear mounted buckrake can achieve loading rates of 15 to 20 tons per hour when skilfully operated and would normally be adequate for the machinery sizes quoted in this example.

Similar calculations to the one outlined have been carried out for different systems, assuming a yield of 13.5 tons per acre of fresh cut grass (15% dry matter) or eight tons when wilted (25% dry matter) for three sizes of trailers and three transport rates. The results are summarised for direct cutting in Table 8 and for wilting in Table 9. The Tables illustrate the interdependence of trailer size, transport rate and the number of men and implements in their effect on total system output.

5. Costing quality differences

The capital cost of silage making machinery can be spread over more acres by extending the harvesting period but not without increasing the proportion of poorer quality grass conserved. Conversely, it is perhaps technically possible to harvest all the grass on the day when it is at its biologically optimum stage of growth, but not without incurring the costs of a large capacity system. Thus, to decide on the optimum size of silage making equipment and the optimum harvesting period, it is necessary to quantify the cost of producing lower quality silage in terms of lower production. This is a difficult exercise but the following attempt has been made in the belief that some kind of formal estimate may be better than complete reliance on experience. Furthermore, although the absolute levels of silage value may be erroneous, the differences in value can still be quite accurate.

The assumption has been made that only S 24. perennial ryegrass is to be harvested and that all the silage is valued in terms of milk production. The latter assumption is based on the reasoning that differences in silage quality will have a marginal effect on milk production. The potential annual output per acre, £ Yp, is calculated from the following equation for 11 cutting stages:

$$Yp = \frac{D_i \times Y_i \times M_r \times E_1 \times E_2 \times F \times R \times P}{100 \times M_i}$$

where D_i = % digestible organic matter in dry matter (D.O.M.D.)

Y_i = yield of dry matter in lbs per acre

M_r = metabolisable energy of silage, K calories/lb D.O.M.

M_i = K calories required per lb of milk production

E_1 = % potential loss of dry matter

E_2 = % potential loss of metabolisable energy in remaining dry matter

F = % decrease in dry matter intake for silage made from grass cut after May 10th

R = yield adjustment factor for scientific data

P = price per gallon of milk

The values for digestibility, D_i, and the yield of dry matter per acre, Y_i, have been taken from a report on grass species and varieties published by the Grassland Research Institute [9]. However, because the yields are based on experiments and seem high in relation to those commonly occurring in practice, they have been reduced by 40% in the equation, that is R = 0.6.

The energy content of milk, M_r, varies according to its composition. These calculations are based on a gross energy value of milk of 320 K calories, which assumes that the milk contains 3.5% fat, 3.3% crude protein and 4.5% carbohydrate [10,11].

TABLE 8

Factors contributing to the organisation of labour and machinery and their effect on actual work rate when operating 'direct cut' harvesting systems

	DIRECT CUT GRASS																	
MACHINE USED	SINGLE CHOP									DOUBLE CHOP								
SYSTEM FACTORS: 3 TRAILER SIZES: A = 360 cu.ft.approx. B = 504 cu.ft.approx. C = 576 cu.ft.approx.	A			B			C			A			B			C		
YIELD-LOADS/ACRE	9			6.5			5.5			4.5			3.2			2.8		
HARVESTER POTENTIAL - LOADS/HOUR	5			3.6			3.0			5.0			3.6			3.0		
TRANSPORT RATE:																		
(a) MINUTES/LOAD	8	12	20	8	12	20	8	12	20	8	12	20	8	12	20	8	12	20
(b) LOADS/HOUR	7.5	5	3	7.5	5	3	7.5	5	3	7.5	5	3	7.5	5	3	7.5	5	3
POTENTIAL WORK RATE ACRES/HR	0.55	0.55	0.33	0.55	0.55	0.46	0.55	0.55	0.55	1.10	1.10	0.66	1.10	1.10	1.0	1.10	1.10	1.10
ORGANISATION OF LABOUR & MACHINERY FOR MAXIMUM OUTPUT																		
TRANSPORT MAN	1	1	2	1	1	2	1	1	1	1	1	2	1	1	2	1	1	1
HARVESTER MAN	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
BUCKRAKE MAN	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
NO.OF TRACTORS	3	3	4	3	3	4	3	3	3	3	3	4	3	3	4	3	3	3
NO.OF TRAILERS	2	2	3	2	2	3	2	2	2	2	2	3	2	2	3	2	2	2
MIN.GANG SIZE	3	3	4	3	3	4	3	3	3	3	3	4	3	3	4	3	3	3

Source: adapted from information provided by I.C.I. Farm Advisory Service (1972)

TABLE 9

Factors Contributing to the Organisation of Labour and Machinery and their Effect on Actual Work Rate When Operating 'Wilting' Systems.

WILTED GRASS

3 TRAILER SIZES: A=360 cu.ft.(Approx); B=504 cu.ft.("); C=576 cu.ft.(")

MACHINE USED	SINGLE CHOP								
3 TRAILER SIZES:	A			B			C		
YIELDS - LOADS/ACRE		6			4.3			3.8	
HARVESTER POTENTIAL - LOADS/HOUR		7			5			4.4	
TRANSPORT RATE:- (a) MINUTES/LOAD	8	12	20	8	12	20	8	12	20
(b) LOADS/HOUR	7.5	5	3	7.5	5	3	7.5	5	3
POTENTIAL WORK RATE (ACRES/HR)	1.16	0.83	0.50	1.16	1.16	0.70	1.16	1.16	0.80
ORGANISATION OF LABOUR AND MACHINERY FOR MAXIMUM OUTPUT									
TRANSPORT MEN	1	2	3	1	1	2	1	1	2
HARVESTER MAN	1	1	1	1	1	1	1	1	1
BUCKRAKE MAN	1	1	1	1	1	1	1	1	1
MOWER MAN	1	1	1	1	1	1	1	1	1
SIDERAKE MAN	0	0	0	0	0	0	0	0	0
NO.OF TRACTORS	4	5	6	4	4	5	4	4	5
NO.OF TRAILERS	2	3	4	2	2	3	2	2	3
MIN.GANG SIZE	4	5	6	4	4	5	4	4	5

MACHINE USED	DOUBLE CHOP								
3 TRAILER SIZES:	A			B			C		
YIELDS - LOADS/ACRE		4			3			2.5	
HARVESTER POTENTIAL - LOADS/HOUR		4.5			3.2			2.8	
TRANSPORT RATE:- (a) MINUTES/LOAD	8	12	20	8	12	20	8	12	20
(b) LOADS/HOUR	7.5	5	3	7.5	5	3	7.5	5	3
POTENTIAL WORK RATE (ACRES/HR)	1.12	1.12	0.75	1.12	1.12	1.00	1.12	1.12	1.12
ORGANISATION OF LABOUR AND MACHINERY FOR MAXIMUM OUTPUT									
TRANSPORT MEN	1	1	2	1	1	2	1	1	1
HARVESTER MAN	1	1	1	1	1	1	1	1	1
BUCKRAKE MAN	1	1	1	1	1	1	1	1	1
MOWER MAN	1	1	1	1	1	1	1	1	1
SIDERAKE MAN	0	0	0	0	0	0	0	0	0
NO.OF TRACTORS	4	4	5	4	4	5	4	4	4
NO.OF TRAILERS	2	2	3	2	2	3	2	2	2
MIN.GANG SIZE	4	4	5	4	4	5	4	4	4

MACHINE USED	PRECISION CHOP								
3 TRAILER SIZES:	A			B			C		
YIELDS - LOADS/ACRE		3			2.2			2.0	
HARVESTER POTENTIAL - LOADS/HOUR		6			4.4			4.00	
TRANSPORT RATE:- (a) MINUTES/LOAD	8	12	20	8	12	20	8	12	20
(b) LOADS/HOUR	7.5	5	3	7.5	5	3	7.5	5	3
POTENTIAL WORK RATE (ACRES/HR)	2.00	1.66	1.00	2.00	2.00	1.30	2.00	2.00	1.50
ORGANISATION OF LABOUR AND MACHINERY FOR MAXIMUM OUTPUT									
TRANSPORT MEN	1	2	3	1	1	2	1	1	2
HARVESTER MAN	1	1	1	1	1	1	1	1	1
BUCKRAKE MAN	1	1	1	1	1	1	1	1	1
MOWER MAN	1	1	1	1	1	1	1	1	1
SIDERAKE MAN	1	1	1	1	1	1	1	1	1
NO.OF TRACTORS	5	6	7	5	5	6	5	5	6
NO.OF TRAILERS	2	3	4	2	2	3	2	2	2
MIN.GANG SIZE	5	6	7	5	5	6	5	5	6

Source - Adapted from information provided by I.C.I. Farm Advisory Service (1972)

The efficiency of utilisation of metabolisable energy varies according to the quality of the diet. Lower efficiency values are usually associated with a reduction in percentage crude protein and an increase in fibre in the diet [10, 11], so that the efficiency has been varied according to the stage of cutting, using available data sources [11,12] as shown in Table 10.

TABLE 10

Metabolisable energy requirements

per lb of milk produced

as affected by stage of harvesting

HARVESTING DATE	CRUDE PROTEIN % OF D.M. OF S 24. RYEGRASS	UTILISATION EFFICIENCY %	METABOLISABLE ENERGY REQUIRED/lb OF MILK.K cal/lb
10th May	15	69	464
15th May	14	68	470
20th May	12.5	67	476
25th May	11.0	66	485
30th May	10.0	65	492
4th June	9.0	65	492
9th June	8.5	64	500
14th June	8.0	64	500
19th June	7.5	64	500
24th June	7.4	64	500
29th June	7.2	64	500

Timeliness of cutting is only one factor affecting the quality of silage produced. Conservation losses also have a marked effect on quality differences caused either by losses in dry matter, E_1, or a loss of metabolisable energy in the remaining dry matter, E_2. Two levels of conservation efficiency are investigated here, using values of 90% and 87.5% loss for E_1 and E_2 respectively in the high efficiency case and 80% and 70% in the low efficiency case.

A further factor to be taken into account is the fact that as the digestibility of a food falls, so does the dry matter intake of the animals with a consequent lowering of production. To calculate the 'F' factor, it has been assumed that material harvested on the 10th May has an 'F' value of 100%. Values for 'F' for material harvested later in the season, with lower digestibility, have been calculated from a regression equation derived by Crabtree [13] and are shown in Table 11.

TABLE 11

The effect of harvesting date and conservation efficiency

on the potential output of S 24. grass silage

1	2	3	4	5	6	7	8	9	10	11	12
Harvest date	D Value %	Yield of DOM tons /acre of 1st cut.	Metabolisable energy requirement. K cal/ lb of milk	F %	Yp for 1st cut. High conservation efficiency. £/acre	Yp for 1st cut. Low conservation efficiency. £/acre	Yield of * aftermath DOM ton/ acre.	Yp for 1st cut and aftermath. High efficiency £/acre	Loss in output from 20th May. £/acre.	Average loss in output/ acre/ day from 20th May. £/acre	Difference in output for high and low efficiency. £/acre
10 May	69.0	2.4	464	100	144.03	102.15	.750	256.13	8.17	4.08	74.98
15 May	68.0	2.7	470	98.9	157.93	112.01	.675	258.81	5.49	2.74	75.70
20 May	66.5	3.0	476	97.1	174.64	123.86	.600	264.30	0	0	77.24
25 May	65.0	3.4	485	95.7	179.30	127.16	.525	257.74	6.56	3.28	75.28
30 May	64.0	3.7	492	94.6	188.83	133.92	.450	256.05	8.25	4.13	74.73
4 June	62.5	4.0	492	93.0	192.56	136.57	.375	248.56	15.74	7.87	72.49
9 June	61.0	4.2	500	92.0	194.93	138.25	.300	239.73	24.57	12.29	69.88
14 June	59.5	4.4	500	90.0	194.36	137.85	.225	227.96	36.34	18.17	66.41
19 June	58.0	4.6	500	88.2	193.55	137.27	.150	215.95	48.35	24.18	62.88
24 June	56.5	4.7	500	86.5	190.62	135.19	.075	201.82	62.48	31.24	58.73
29 June	55.0	4.9	500	84.9	187.61	135.06	0	187.61	76.69	38.35	54.55

Sources : Grassland Research Institute, Hurley [9]; I.C.I. Farm Survey [14].

* Not reduced by 40% and converted to Yp using a metabolisable energy requirement of 457 K cal/lb milk.

Finally, in order to express Yp in value terms, a winter milk price of 24p per gallon has been assumed. The potential financial output, as shown in Table 11, surprisingly, for the first cut, increases with delay in harvesting. The main reason for this is that the yield of subsequent cuts has not been taken into consideration. According to experimental evidence from the G.R.I. (9), and confirmed by an I.C.I. farm survey (14), a delay of some five days in taking the first cut results in a loss of some .075 tons of D.O.M. in the second cut. Modifying the expression for Yp, to include the additional yield for subsequent cuts, produces the financial output shown in column 9 of Table 11. The Table also shows in column 10 the potential losses in output due to cutting delay and how substantial they can become in terms of lost milk production, especially after the middle of June.

The final column of Table 11 compares the financial consequences of high and low conservation efficiency. It can be seen that in the early part of the season, conservation efficiency is several times more important than any delay in cutting. Even in the second week in June, it is possible to lose almost twice as much potential output through poor conservation efficiency than it is through untimely harvesting.

The effects of poor quality silage can be ameliorated by the feeding of additional energy, either in the form of more concentrates or by increasing their energy concentration. However, unless concentrates are fed at very high levels, there will be a lowering in the energy concentration of the total diet, which must result in a lowering of the potential yield of the cows. Kettleborough (1) has shown elsewhere that any additional concentrate costs are small in relation to losses in output which still occur despite supplementation.

6. Selecting the least cost system

All the factors previously described in this report, along with the peculiar circumstances of an individual farm, have to be considered when selecting the least cost system. Several major assumptions have been made in this section, namely, the allocation of machine overhead costs to the first cut of silage; that direct cut systems operate for 2/3rds of the number of calendar days; that wilting systems can be carried out for only 13/23rds of the available days; that differences in the required number of tractors by systems of different sizes is reflected in the hourly charge for tractors; that silage making is confined to one variety of ryegrass, which yields eight tons of first cut fresh grass per acre and that the cutting of grass begins for all systems when the "D" value is 69%. In a real situation, all the factors depicted in figure 2 would be taken into account. The analysis which follows merely demonstrates a method for making a choice and provides in relative terms an indication of the important parameters affecting choice. Ten systems have been considered and these are described in Table 12. Most of the systems are in common use, except for system 2, which is a one-man wilting and precision chop system, and system 9, which requires five men to operate a direct cutting system using a self-propelled precision chop forage harvester.

Each system can be screened, before the financial analysis proceeds, to investigate the degree of integration within the system and to check on the capacity of the system in relation to the requirements of the farm in question. This has been done according to the method outlined in section 4 for each of the 10 systems for two levels of system efficiency. The results are described in Table 13. A system efficiency of 60% is normally attainable in practice, that of 80% being difficult to achieve.

Annual machinery costs for each system are set out in Table 14 and these, when converted to an acreage basis (Table 15), have been added to the average untimeliness costs shown in column 11 of Table 11 to produce the total harvesting costs per acre for different lengths of harvesting period as set out in Table 16. Silage making is assumed to begin on May 20th.

The calculation of the total harvesting costs assumes that average weather conditions prevail, so that for a direct cutting system 2/3rds of the available time has been assumed to be rain free. For the case of wilting systems, only 13/23rds of the available time has been taken as suitable for operation. Thus, for system 1, a direct cutting system, the total harvesting cost per acre on day 10 has been worked out as follows:-

Time worked = 2/3 of 10 days = 6.66 days.

Machinery costs per acre for 6.66 days (from Table 15) at 60% of field efficiency = £17.23.

Average untimeliness cost per acre for day 10, or the period up to May 30th (From Table 11, column 11) = £3.28.

Total harvesting cost per acre = £17.23 + £3.28 = £20.51.

The data in Table 16 has been used to construct capacity costs curves for each of the ten systems and these are drawn in figure 3.

Figure 2

Factors to be taken into account in planning a silage making system

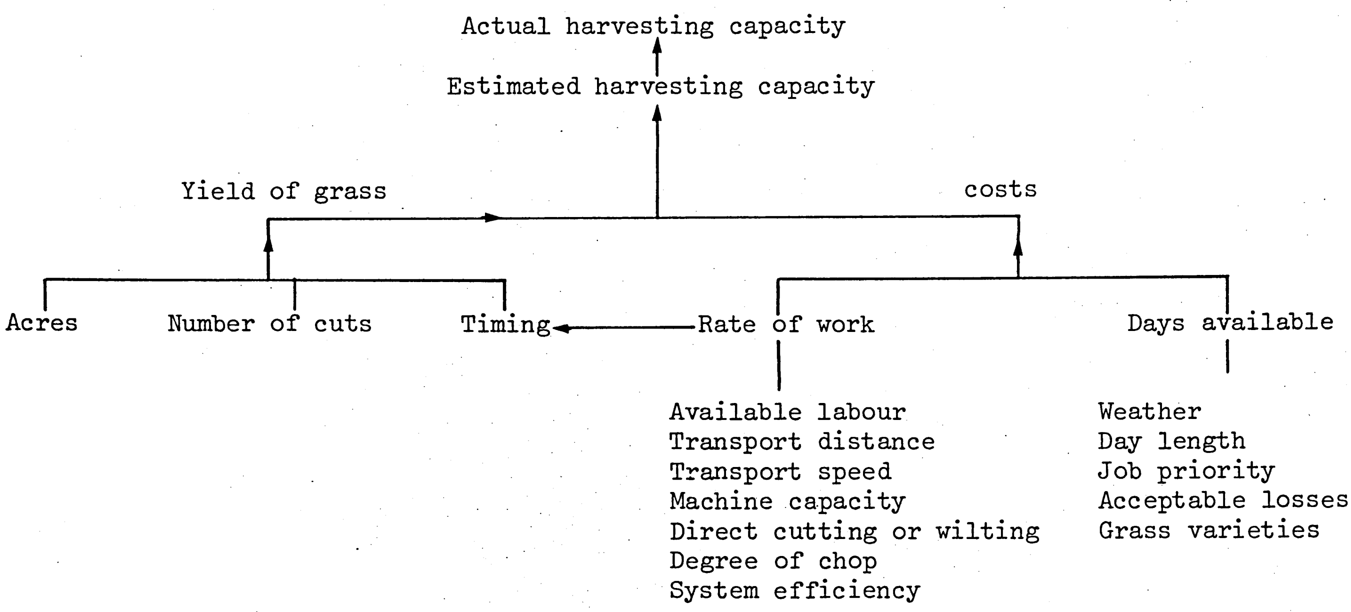


TABLE 12

Equipment Required by Each of Ten Harvesting Systems.

SYSTEM NUMBER	1	2	3	4	5	6	7	8	9	10
TRACTORS - 50 - 60 b.h.p.		1	1	1	2	2	3	3	2	3
65 - 75 b.h.p.	1	1	1	1	1	1	1	1	2	2
MOWER - NO CONDITIONING (INNER SWATH BOARDS)										
- CUTTER BAR				1						
- ROTARY		1				1		1		1
P.T.O. SWATH TURNER										1
FORAGE HARVESTERS										
IN-LINE FLAIL - 48"			1	1						
SIDE MOUNTED FLAIL - 44"	1									
DOUBLE CHOP - 60"					1	1	1	1		
SIDE MOUNTED PRECISION CHOP-51" PICK UP		1								
TRAILED PRECISION CHOP-60" PICK UP										1
SELF PROPELLED DIRECT CUT									1	
TRAILERS - 10 x 6 x 6 ft.		1								
12 x 7 x 6 ft.	1		1	1	2	2		2		2
12 x 6 x 6 ft.							2		3	
DUMP BOX									1	
FAN/CONVEYOR UNIT									1	
PUSH OFF BUCKRAKE	1	1	1	1	1	1	1	1		1

TABLE 13

Maximum Feasible Output of each of Ten Systems at Two Levels of Efficiency.

NO. SYSTEM	SYSTEM EFFICIENCY RATED AVERAGE AND TARGET	POTENTIAL LOADING RATE - ACRES PER DAY	TRAILER SIZE (ft) AND CAPACITY (tons)	POTENTIAL TRANSPORT RATE PER DAY		MAXIMUM FEASIBLE SYSTEM OUTPUT				OBSERVATIONS
						PER DAY		PER HOUR		
				ACRES	TONS D.O.M.	ACRES	TONS DOM.	ACRES	TONS DOM.	
1 ONE MAN-DIRECT CUT	60	6.4	12x7x6 1.75	6.3	6.3	2.6	2.6	0.32	0.32	Assumes that 1.25 hrs is required for buck-raking at silo.
	80	9.0	12x7x6 1.75	8.8	8.8	3.5	3.5	0.43	0.43	Assumes that 1.5 hrs is required for buck-raking at silo.
2 ONE MAN-WILTING	60	8.7	10x6x6 2.00	11.0	11.0	3.5	3.5	0.43	0.43	If mowing can be undertaken outside the normal working day feasible output is increased by approx. 85%
	80	11.6	10x6x6 2.00	14.5	14.5	4.5	4.5	0.56	0.56	
3 TWO MAN DIRECT CUT	60	7.0	12x7x6 1.75	6.3	6.3	3.5	3.5	0.43	0.43	This system does not fully occupy the second person unless a second tractor and trailer is introduced.
	80	9.3	12x7x6 1.75	8.4	8.4	4.5	4.5	0.56	0.56	
4 TWO MAN WILTING	60	8.7	12x7x6 1.75	9.1	9.1	4.6	4.6	0.57	0.57	Second person is responsible for mowing and buckraking. Note that trailer capacity is not limiting as in '3'.
	80	11.6	12x7x6 1.75	12.2	12.2	6.0	6.0	0.75	0.75	
5 THREE MAN DIRECT CUT	65	8.7	12x7x6 2.50	9.0	9.0	8.7	8.7	1.10	1.10	This is one of the most popular direct cutting systems.
	85	11.6	12x7x6 2.50	12.0	12.0	11.6	11.6	1.45	1.45	
6 THREE MAN WILTING	65	10.4	12x7x6 2.50	13.0	13.0	10.1	10.1	1.20	1.20	This system assumes that mowing can take place outside the normal 8 hour working day.
	85	13.6	12x7x6 2.50	17.0	17.0	13.6	13.6	1.70	1.70	
7 FOUR MAN DIRECT CUT	65	9.6	16x6x6 3.50	13.6	13.6	9.6	9.6	1.2	1.2	Trailers are towed alongside forage harvester. 12' x 7' x 6' trailer would have been adequate
	85	12.3	16x6x6 3.50	17.8	17.8	12.3	12.3	1.5	1.5	
8 FOUR MAN WILTING	65	11.2	12x7x6 2.50	13.0	13.0	11.2	11.2	1.4	1.4	Fourth man is only concerned with mowing. Trailers are towed behind the forage harvester.
	85	14.4	12x7x6 2.50	17.4	17.4	14.4	14.4	1.8	1.8	
9 FIVE MAN WILTING	60	17.0	16x6x6 4.0	14.4	14.4	14.4	14.4	1.8	1.8	Direct cutting overloads the transport system in this instance.
	80	23.0	16x6x6 4.0	19.2	19.2	19.2	19.2	2.4	2.4	
10 FIVE MAN WILTING	65	13.0	12x7x6 2.50	13.0	13.0	13.0	13.0	1.6	1.6	It is wise to carry excess trailer capacity. Is assumed that one person can mow and row swathes in.
	85	16.5	12x7x6 2.50	17.4	17.4	16.5	16.5	2.1	2.1	

TABLE 14

Total annual machine costs and tractor operating costs allocated to each of ten harvesting systems.

SYSTEM NUMBER	1	2	3	4	5	6	7	8	9	10
MACHINERY PRICES MOWER	-	330*	-	165*	-	330*	-	330*	-	330*
SWATH TREATMENT	-	-	-	-	-	-	-	-	-	250***
FORAGE HARVESTER	325	825*	490	490	725*	725*	725*	725*	10,500* **	1350* **
TRANSPORT	350	250	350	350	700	700	1000	700	1500	700
SILO LOADING	220	220	220	220	220	220	220	220	1400* **	310
TOTAL INITIAL CAPITAL £	895	1625	1060	1225	1645	1975	1945	1975	13400	2940
ANNUAL COSTS *** DEPRECIATION - 10%	-	-	-	-	-	-	-	-	-	25
- 15%	134	244	159	184	247	296	292	296	225	201
- 20%	-	-	-	-	-	-	-	-	2380	270
INTEREST-10% ON HALF INITIAL CAPITAL	44	82	53	62	82	99	97	99	670	147
HOUSING/INSURANCE etc. 2½%	21	41	26	31	41	49	48	49	335	74
MAINTENANCE/REPAIRS-5%	44	23	53	53	46	46	61	46	75	48
-7½%	-	87	-	11	54	76	54	76	892	149
TOTAL ANNUAL COSTS £	243	477	291	344	470	566	552	566	4577	914
TRACTOR OPERATING COSTS £ PER HOUR	0.95	1.05	2.05	2.05	3.00	3.75	3.95	3.95	4.50	5.05

% OF INITIAL CAPITAL FOR SELECTED ITEMS:- * - 7½% - MAINTENANCE AND REPAIRS, e.g. Precision Chop Harvester.

** - 20% - DEPRECIATION, e.g. Precision Chop Harvester.

*** - 10% - DEPRECIATION, e.g. Equipment for swath treatment.

TABLE 15

The machinery costs/acre harvested by each of ten systems for 1 - 30 days

(Average Yield = 8 tons/acre)

SYSTEM		EFFICY	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	23	25	28	30
1	A	60	99.0	51.6	34.5	26.5	22.0	18.7	16.5	14.8	13.4	12.1	11.5	11.2	10.7	10.1	9.5	9.2	8.5	8.2	8.0	7.6	7.0	6.7	6.3	6.0
	B	80	72.0	38.0	25.7	19.0	16.3	14.0	12.3	11.0	10.0	9.0	8.6	8.1	7.6	7.2	6.9	6.6	6.3	6.1	5.9	5.6	5.2	5,0	4.7	4.5
2	A	60	141.0	72.0	48.6	37.2	30.4	25.5	22.4	19.9	17.9	16.4	15.1	14.2	13.2	12.4	11.8	11.2	10.7	10.2	9.8	9.5	8.5	8.0	7.5	7.1
	B	80	108.0	55.1	37.4	28.6	23.2	19.6	17.2	15.5	13.7	12.6	11.6	10.9	10.2	9.6	9.1	8.6	8.2	7.9	7.6	7.5	6.6	6.2	5.7	5.5
3	A	60	89.3	46.6	32.9	25.9	21.6	18.8	17.1	15.5	14.1	13.2	12.4	11.7	11.3	10.8	10.4	10.0	9.7	9.4	9.2	9.0	8.5	8.3	7.8	7.5
	B	80	68.6	35.8	25.3	20.0	16.6	14.5	13.2	11.7	10.9	10.1	9.5	9.1	8.7	8.3	8.0	7.7	7.5	7.3	7.1	7.0	6.8	6.6	6.0	5.8
4	A	60	79.9	41.3	28.7	22.6	18.6	16.1	14.3	13.0	12.0	11.1	10.5	9.9	9.4	9.0	8.6	8.3	8.0	7.7	7.5	7.4	6.9	6.7	6.3	6.1
	B	80	60.1	31.4	21.8	17.1	14.2	12.3	10.9	9.9	9.1	8.4	7.9	7.5	7.2	6.8	6.5	6.3	6.1	5.9	5.8	5.6	5.2	5.0	4.7	4.5
5	A	65	56.1	29.3	20.4	16.1	13.4	11.6	10.4	9.4	8.6	8.1	7.6	7.1	6.8	6.5	6.3	6.1	5.8	5.7	5.5	5.4	5.1	4.9	4.6	4.5
	B	85	42.6	22.3	15.5	12.2	10.2	8.8	8.2	7.1	6.5	6.1	5.9	5.4	5.1	4.9	4.7	4.6	4.4	4.3	4.2	4.1	3.9	3.7	3.5	3.4
6	A	65	62.0	32.6	22.8	17.8	16.5	12.9	11.6	10.5	9.7	9.0	8.6	8.3	7.5	7.3	7.1	6.8	6.6	6.4	6.2	6.1	5.7	5.5	5.2	5.1
	B	85	43.8	23.1	16.1	12.6	10.5	9.1	8.2	7.4	6.8	6.3	6.0	5.6	5.3	5.1	4.9	4.8	4.6	4.5	4.4	4.3	4.0	3.8	3.7	3.5
7	A	65	60.8	32.0	22.4	17.6	14.8	12.9	11.5	10.1	9.7	9.1	8.9	8.1	7.7	7.4	7.1	6.9	6.6	6.4	6.2	6.1	5.8	5.6	5.5	5.0
	B	85	48.6	25.6	17.9	14.1	11.8	10.3	9.2	8.1	7.7	7.2	6.8	6.5	6.2	5.9	5.7	5.5	5.3	5.2	5.0	4.9	4.6	4.4	4.2	4.1
8	A	65	53.4	28.0	19.7	15.4	13.6	11.2	10.1	9.1	8.4	7.8	7.4	7.1	6.6	6.4	6.3	5.9	5.7	5.6	5.4	5.3	5.0	4.8	4.5	4.3
	B	85	41.5	21.8	15.3	11.9	10.1	8.7	7.8	7.1	6.6	6.1	5.7	5.5	5.1	5.0	4.8	4.6	4.5	4.4	4.3	4.2	3.9	3.7	3.4	3.3
9	A	60	320.2	161.4	108.6	81.9	66.1	55.4	47.9	42.3	37.8	34.3	31.4	28.9	27.0	25.2	23.7	22.3	21.2	20.7	19.2	18.4	16.0	15.2	13.8	13.0
	B	80	240.2	121.0	81.4	61.3	49.4	41.6	35.9	31.7	28.4	25.7	23.5	21.7	20.2	18.9	17.7	16.7	15.9	15.1	14.4	12.9	12.0	11.4	10.4	9.7
10	A	65	66.6	38.8	26.9	21.0	17.4	15.0	13.4	12.0	11.1	10.3	9.6	9.0	8.6	8.3	7.9	7.6	7.2	7.0	6.8	6.7	6.3	6.0	5.7	5.5
	B	85	50.7	29.6	20.5	16.0	13.5	11.4	10.2	9.2	8.4	7.8	7.3	6.8	6.6	6.3	6.0	5.7	5.5	5.3	5.2	5.1	4.8	4.6	4.3	4.2

TABLE 16

The cost/acre of operating ten harvesting systems in the Nantwich area for first cut S 24. Silage cut at 5-day intervals, assuming average weather risk, and harvesting beginning on May 20th.

SYSTEM NUMBER	System efficiency %	Day 5 (3.3)* (2.8)**	Day 10 (6.6)* (5.7)**	Day 15 (10)* (8.5)**	Day 20 (13.3)* (11.3)**	Day 25 (16.6)* (14.1)**	Day 30 (20.0)* (17.0)**	Day 35 (23.3)* (19.8)**
1 *	60	31.9	20.51	16.23	18.37	21.35	25.77	38.24
2 **	60	45.28	30.25	23.03	22.70	24.63	28.87	33.92
3 *	60	30.60	21.50	17.33	19.01	22.19	27.17	32.68
4 **	60	31.22	20.14	16.63	18.19	21.25	26.17	31.58
5 *	65	18.97	14.08	12.23	14.57	18.19	23.57	29.28
6 **	65	24.76	17.28	14.23	16.37	19.59	24.77	30.28
7 *	65	20.87	15.24	13.23	15.47	18.99	24.27	29.98
8 **	65	21.36	15.20	12.88	15.17	18.69	23.87	29.48
9 *	60	99.70	53.68	38.43	32.57	33.85	36.57	40.08
10 **	65	27.16	17.40	15.68	17.27	20.55	25.37	30.88

Note = * effective days when operating direct cutting systems;

** effective days when operating wilting systems.

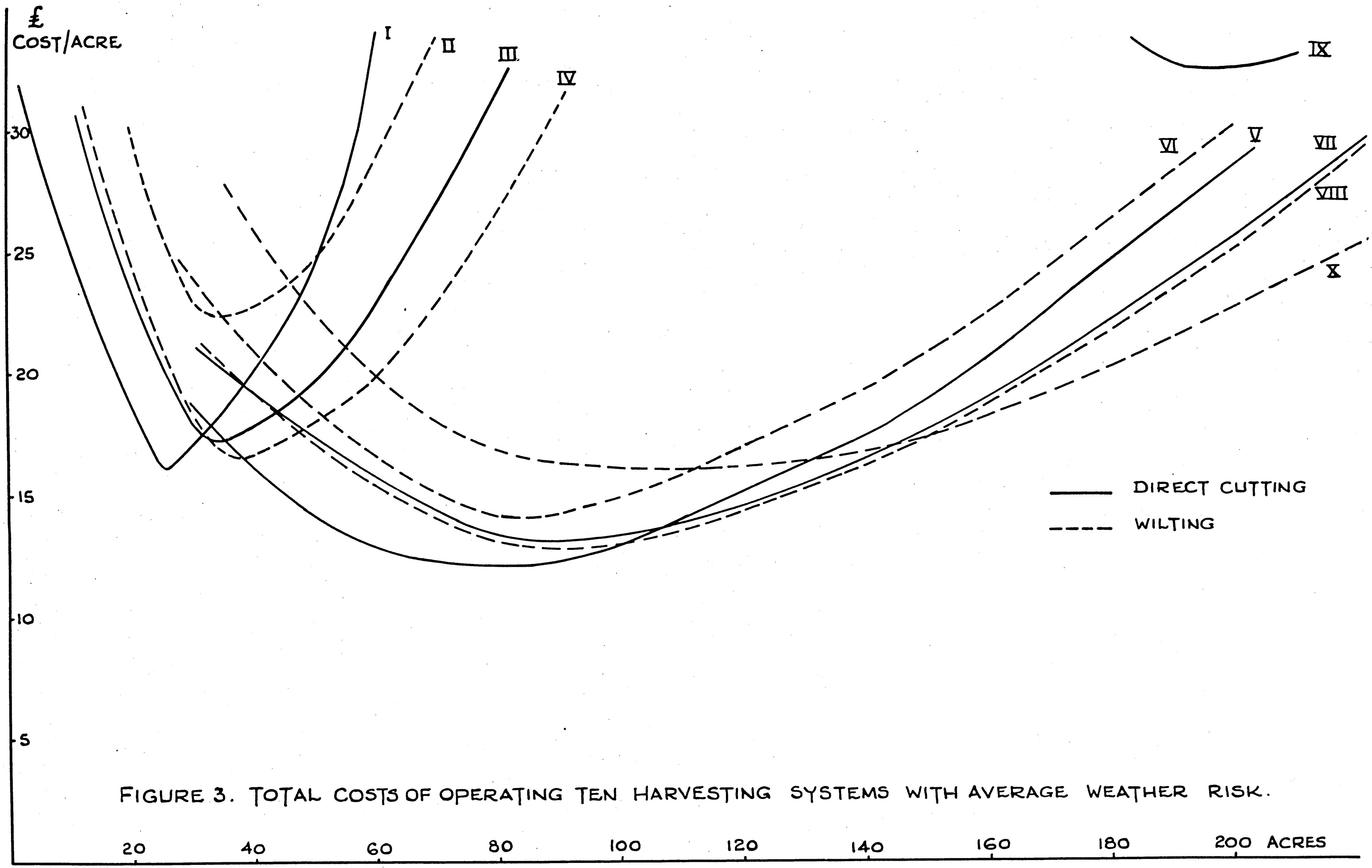


FIGURE 3. TOTAL COSTS OF OPERATING TEN HARVESTING SYSTEMS WITH AVERAGE WEATHER RISK.

7. Conclusions

Any conclusions drawn from the analyses are of course highly dependent on the assumptions made. However, the least cost systems for particular acreages, which can be identified in figure 3, are for the most part systems commonly encountered in practice. Thus, for example, system 5, which is the cheapest system over the range 40 to 100 acres is the popular three man direct cutting system using a 60 inch double chop forage harvester.

The results are inconclusive about the benefits of wilting, differences in costs being very small, especially for systems 7 and 8. It would seem that the higher costs of untimeliness for wilting systems are balanced out by the savings in machinery costs due to faster rates of work. The very large discrepancy between systems 9 and 10 is due to the fact that the throughput of system 9 is restricted by trailer capacity, so that any comparison of the two systems is invalid. The curve for system 9 does, however, illustrate the importance of obtaining a high throughput with a self-propelled forage harvester. The decision about wilting would seem to rest on evidence concerning the efficiency of conservation and the degree of acceptable weather risk. Thus, for example, if it could be shown that much better silage can be made by wilting as opposed to direct cutting with additives, then system 8 could be a much cheaper system than system 7.

It may be that systems other than those investigated could be found which are cheaper to operate, especially for larger acreages. The close agreement with the systems identified as being least cost and conventional systems gives some confidence for extending the analysis for a greater number of systems at larger acreages. Furthermore, the costs shown in figure 3 have been worked out at 5-day intervals, and to obtain more accurate estimates, particularly at cross-over points, it would be necessary to use a shorter interval. The use of a shorter interval would also be beneficial in identifying more closely the optimum length of the harvesting season. In Table 16, it can be seen that for most systems, costs begin to turn upward around day 15, or June 4th, which corresponds to a "D" value of 62.5%.

The total harvesting costs have been worked out assuming that silage making begins on May 20th. However, the average untimeliness costs quoted in Table 11, column 11, show that it is probably cheaper to start harvest earlier than this, since by doing so the average untimeliness costs can be reduced. Furthermore, by starting silage making early in May, there is greater time flexibility in that high untimeliness costs are not incurred until the beginning of June. This conclusion is, of course, dependent on the locality of the farm, the variety of grass and the availability of resources in terms of the needs of the whole farm. It is also pertinent to remember that the level of conservation efficiency is more important than timeliness of harvesting.

Choosing a silage making system is a complicated job and it could well be that experience within the farming industry can produce equally good or better answers at less cost than those provided by the analysis presented here, especially for conventional acreages. The aim of this paper is to show how a system can be chosen in a systematic way, especially in a new situation. As such, the analysis could be improved in several ways, but not without adding to the detail and complexity of the calculations. Firstly, more thought needs to be given to the definition of suitable weather conditions and also to develop suitable methods for investigating the effect of weather variation on the performance of systems. Secondly,more research is required in quantifying differences in the quality of silage and the value of such silage when harvested by different methods at different times. The value of the silage depends to a large degree on the type of animal to which it is fed, which in turn depends on the grazing, conservation and livestock policy of the whole farm. The analysis presented here is also partial in another sense in that decisions about the availability of tractors and men for silage making must also be made in a whole farm context. Finally, at a more detailed level, there is still much work to do in choosing the right conbination of machines for silage making, given that the performance of the whole system changes according to variation in rates of work of individual machines, transport distances and breakdowns.

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