

SIMULATION MODEL FOR GRASS HARVESTING

by Arne Hilmersen

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The decision problem

The agricultural production of the modern farmer is to a large extent dependent on the many decisions he has to make annually, monthly, even daily and hourly. The character of these decisions varies from the short-termed, minor ones to important decisions that have bearing upon the economic situation on the farm for years ahead. It is of vital interest that the decisions made by the farmer are as good and as rational as possible. To achieve this it is necessary for him to have sufficient and relevant information as to alternative solutions and their consequences in the future. It is within this field that research and advisory service are able to better his decisions.

Manual and mechanized labor accounts for approximately 50 % of the production costs in Norwegian agriculture. The importance of good labor-planning systems is therefore evident. The Netherlands and Germany have contributed much of the fundamental work done in this connection (2, 3).

For detailed labor planning every farm requires tailor made output figures. In most agricultural work time consumption, capacity etc. vary often more than 50 % from farm to farm, and mean figures are therefore of minor interest to the individual farmer on his individual farm. To cut the variation, many variable factors have to be accounted for and in a complex planning situation it is of great advantage to have access to modern computing equipment.

A possible solution for the labor planning problem is therefore to establish elementary labor data banks and further to combine these data through computerized labor models to reliable and meaningful figures for the farmer. On this basis he will be able to improve his decision capability.

Introduction to the system

This paper will demonstrate how the process of harvesting grass for silage-making may be synthesized for use in a labor planning system. The system may be constructed either starting with elementary data and then proceeding to the model building or the reverse, starting with building a model suitable for the computer. The author prefers the later procedure.

The following paragraphs describe the development of a grass-harvesting model having the form of a digital simulation model. Further an example of acquiring operational data for the model will be demonstrated. The development of this grass harvesting planning system is based on the following keystones:

Pre-determined time systems (4), system theory (5), simulation theory (6), the use of digital computers.

A case-study is included to demonstrate the practical use of the planning system.

The process of harvesting grass

The harvesting system used for the pilot work is described below.

Equipment in the field:

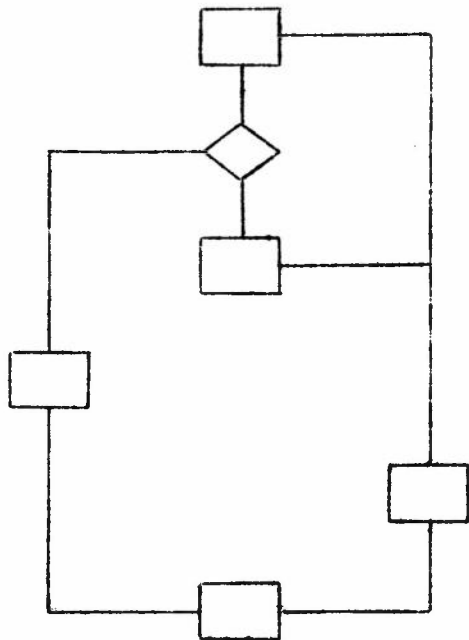
Tractor with direct-cutting forage harvester and a two wheeled trailer hitched to the tractor.

Equipment for transport:

Tractors with two-wheeled trailers. The number can be varied from 1 to 3.

Work method for the process:

FIELD WORK



Cut and load side (by side by driving clockwise around the field).

Is the trailer full?

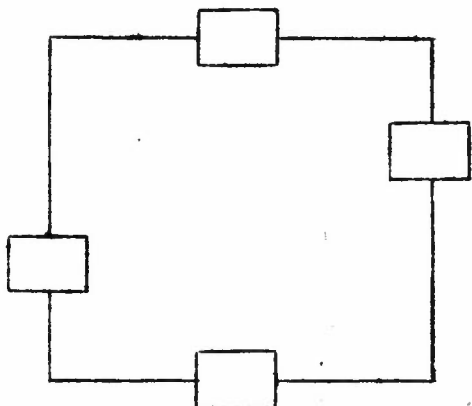
Turn at the corner.

Drive from the edge of the grass to exchange place with the full trailer.

Drive from exchange place to grass with empty trailer.

Unhitch the full trailer.
Hitch an empty trailer.

TRANSPORT WORK



Unhitch an empty trailer.
Hitch a full one.

Drive to the unloading site.

Drive from silo to field.

Unload the trailer
(tipping, selfunloading etc.)

The harvesting model

The model for the field work is by far the largest and the most complex component of the total harvesting model. The sequence of work-elements in the model and in actuality correspond indentically. This simplifies the model logically, but requires a great number of computations and a relatively large core capacity of the computer. The field model is limited to quadrilateral and horizontal fields. The transport capacity of the trailer may be treated as a stochastic variable and accordingly generate results characterized by both the mean time and the variance. The transport model is fairly simple, calculating the time requirements for transport, unloading and the exchange of trailers. The simulation model for grass harvesting is programmed in the FORTRAN IV language and has been run on an IBM 360/40 digital computer. The field model was originally written in ALGOL and run on a UNIVAC 1107 computer, for documentation, see literature (7).

Input/output data

The harvesting model requires the following input data:

- The size and form of the fields i.e. the coordinates for the four corners.
- The coordinates for the place of exchanging trailers.
- Speed of transport driving, in the field and on roads.
- Speed of cutting and loading.
- Nominal and actual cutting width.
- Time for turning in corners.
- Time for exchanging trailers.
- Capacity of the trailer, mean and standard deviation.
- Size of the crop.
- Length of roads, different categories.
- Time for unloading a trailer.

For the time being the following output data are given:

- Total time for cutting, turning, transport driving in the fields and exchange of trailers.
- Total number of trailer-loads.
- Waiting time in field and transport.
- Total time required to harvest the given field under given conditions.

An example of preparing input data.

At every corner of the field the harvesting equipment has to turn and in most cases the angle between the two adjacent sides differs from corner to corner. The time used to turn will accordingly have a tendency to differ depending on the angle of the corner and on the turning pattern.

A series of time studies was conducted to obtain reliable data for use in the simulation model. These studies were carried out with the harvesting equipment described above. The results showed that turning around in a left-handed loop was favorable for corner-angles of less than 82° , the time used per loop was 0.34 min. For greater corner-angles turning should be done by simply driving forward and turning to the right as sharply as possible. For corners between 82° and 150° the time used is;

$$\bar{y} = 0.33 \cos a + 0.29, \quad \text{where } a \text{ is the corner angle.}$$

Turning at corners greater than 150° took no extra time. These results are valid for a forward speed of approximately 90 m/min.

A case study

Farm A has nine hectares of grass to be harvested. The farmer drives the field tractor with a 110 cm wide forage harvester. His neighbour takes the trailers to silo, unloads and drives back to the field. A lay-out for the farm and the four grass-fields is given in figure 1.

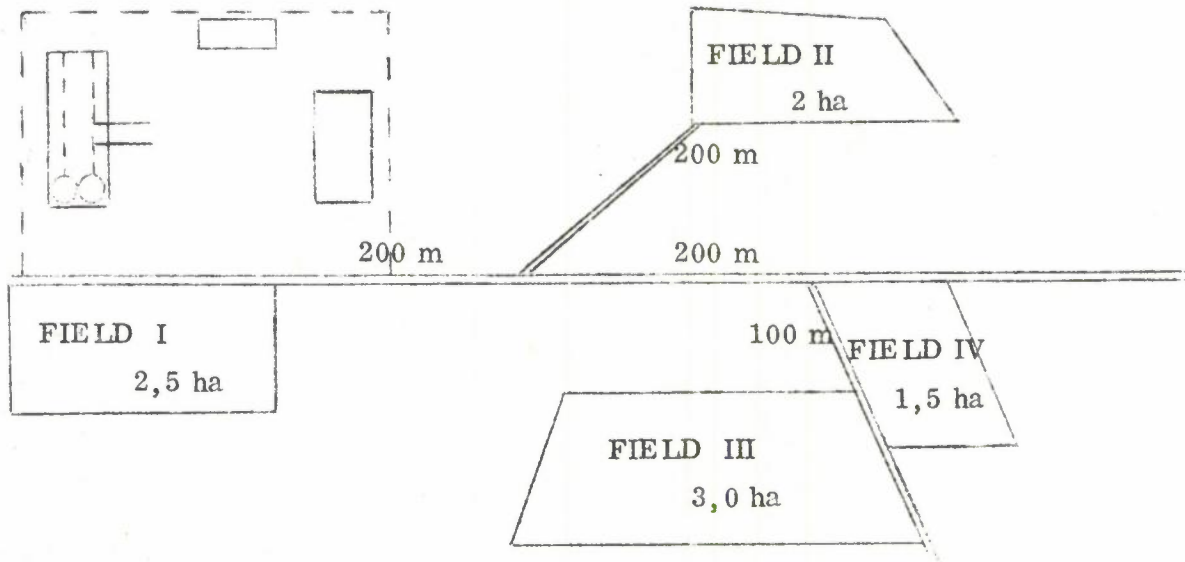


Figure 1 : Farm A and the four grassfields.

The main question is how to rationalize the harvesting. Four possible solutions are discussed:

- Buy a 135 cm wide forage harvester.
- Buy trailers that can load 2000 kg of grass instead of 1000 kg.
- Refine the equipment and method for faster exchange of trailers i.e. cut the time consumption per exchange from 1 to 0.5 min.
- Refine the equipment and method for faster unloading, cut from 4.0 to 2.5 min.

The time consumption for these alternatives together with the old method were assessed by using the grass harvesting simulation model. The standard deviation of the capacity of the trailers was defines as 0 and thus the stochastic process was not used in this case study.

In addition to the information given above and by the farm lay-out, the results are based on the following data:

Forward cutting speed	105 m/min
Transport speed, field	130 m/min
" " field road	200 m/min
" " farm road	300 m/min
Size of the crop	20 tons/ha

The results of the simulation are given in table 1 on the next page.

Table 1.

Results from the grass-harvesting simulation. The time is given in minutes.

	Old method	New harvester	New trailers	Faster exchange	Faster unloading
<u>Input data</u>					
Harvest. width	110 cm	135 cm	110 cm	110 cm	110 cm
Trailer capa.	1000 kg	1000 kg	2000 kg	1000 kg	1000 kg
Trailer exch.	1,0 min	1,0 min	1,0 min	0,5 min	1,0 min
Unloading	4,0 min	4,0 min	4,0 min	4,0 min	2,5 min
<u>Output data</u>					
Harvesting time					
Field I	492	435	416	464	492
Field II	374	366	302	353	357
Field III	620	577	497	587	602
Field IV	328	300	283	310	325
Total time	1814	1678	1498	1714	1776
Saved min	0	136	316	100	38

It should be emphasized that these figures are based on a certain set of assumptions and must be evaluated as such. This means that they should be used with reservation. They will not be fulfilled 100 % in reality. Nevertheless the results may give the farmer valuable information. Combination of the cost of alteration in his harvesting system together with the time saved means that the cost per saved time unit may be calculated, see table 2.

Table 2.

Maximum time saving and the additional cost pr. saved time unit. Cost in Norwegian kroner (kr).

Alternative	Additional cost per season	Max time saving	Cost/saved time
Existing method	0	0	0
New harvester	kr 5400 : 2 : 5	2 h 16 min	kr 3.97/min
New trailer	kr 6000 : 5	5 h 16 min	kr 3.80/min
Faster change	kr 500 : 5	1 h 40 min	kr 1.00/min
Faster unloading	kr 500 : 5	38 min	kr 2.63/min

On the basis of the information given in table 2 many of the consequences of the different alterations will be made evident to the farmer and it is hoped they will enable him to plan his grass harvesting in a fairly rational manner.

Comments

Models give a simplified view of reality. If this were not the case the models would be identical to the actual situation and their use of no benefit. Simulation with models is experimenting with a simplified part of the real world. In this connection one is able to perform experiments that are often impossible in reality, e.g: harvesting grass in the middle of the winter. According to these statements it is very important, however, to treat the results in the same way. They are figures that are derived from simplified assumptions and need to be adjusted for use in real situations.

One is confident that the use of models is going to increase and that in solving the labor planning problems, we have an excellent tool in production models. Banks of elementary data, simulation models and computer facilities form a system with great potential use in agriculture in the future and represent an inspiring challenge.

Literature

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