TIME AND LAND LOSSES WITH ELECTRIC TOWERS IN AGRICULTURAL FIELDS[1]

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Received 17 February 1982.

Fortin, J.-M. and **C. Vigneault.** 1982. Time and land losses with electric towers in agricultural fields. Can. Agric. Eng. 24: 103–108.

Since 1978, the Agricultural Engineering Department (Université Laval, Que.) has been studying time and land loss around electric towers in agricultural fields. Following surveys and trials in the field, a computer program (APL) was set up to calculate time and land loss under various conditions. This program was conceived to sketch a diagram of land losses in each operation of any production; by superposition of land losses with each machine, the real land loss is obtained. Time losses are defined as supplementary time required for turning around towers plus, in some cases, time for supplementary functions.

Depuis 1978, le Département de Génie rural (Université Laval, Que.) a entrepris des études sur les pertes de terrain et de temps occasionnées par la présence de pylônes de transmission électrique dans les champs cultivés. A la suite d'enquêtes et d'essais sur le champ, il a été possible de préparer un programme d'ordinateur (APL) qui permet de calculer les pertes de terrain et de temps dans la plupart des conditions rencontrées. Ce programme prévoit l'impression du diagramme des pertes pour chaque opération d'une production; par superposition, on obtient la perte réelle de terrain en fonction des machines utilisées. Quant aux pertes de temps, elles représentent les temps supplémentaires qu'exigent les contournements et, dans certains cas, le temps de fonctions supplémentaires.

INTRODUCTION

Time and land loss due to the presence of an electric tower in an agricultural field is becoming more important with the use of larger, more efficient and more expensive farm machines. Moreover, the higher costs of labor, energy and agricultural products cause farmers to consider the adverse economic effects of electric towers in their fields.

This study deals with the interaction between farm machines and electric towers which results in a certain amount of land loss for crop production and supplementary time for turning around.

REVIEW OF LITERATURE

Very few investigations have been reported on the interaction between machine operations and electric towers in agricultural fields. Ontario Hydro (1977) has been a leader in this respect; the first reports by Bomfort (1974) and Genge (1977) were useful in initiating the present study.

Since 1978, Gustafson and Meyer (1980), using the technique of low altitude photography, have been working on an evaluation of land loss.

Technical and economic data were obtained from ASAE Yearbooks (Anonymous 1970–1978), Implement and Tractor Red Books (Anonymous 1971–1981), Manufacturers literature, Quebec statistics (Anonymous 1975–1976) and Quebec Technical and Economical References in Agriculture (Anonymous 1977–1981).

SURVEY AND PRELIMINARY STUDIES

A survey of 60 farms, in 1978, where different types of electric towers are situated showed extreme variations from one case to another, so it is impossible to establish uniform standards on land and time loss for agricultural production. This trend is also shown in the results of Gustafson and Meyer (1980) (Table II).

The preliminary studies have involved exhaustive research on the various farm machines used on Quebec farms; 130 farm machines were studied to define parameters which were used in computer analysis.

The operation of farm machines is related to agricultural production, so it is possible to analyze time and land loss in almost every situation. Table I gives technical and economic data for some machines used on Quebec farms.

MATERIALS AND METHODS

Simulation in the Field

In these trials, 10 farm machines were used around actual size towers to simulate plowing, seeding, planting, harvesting, etc. in the field. Land losses were measured where the machines were ineffective (land would not produce a crop) and where the machine had to make two or more trips on the same land to avoid the tower (reduced yield by compaction; this land is assumed to be fully lost in this study).

Another increasing cost factor is the supplementary time needed to travel around towers. This time loss is the difference between working the same area with or without a tower in the field.

Simulation in the Laboratory

On a large table in the laboratory, it was possible to simulate every field operation with 1/16th-scale implements and towers. With proper care, it is possible to reproduce field data accurate to within 10%. However, time loss is not considered in this simulation.

Graphic Projections

From the data obtained in the field and in the laboratory, graphic projections of land loss around towers are drawn on paper (Fig. 1). The use of these geometric figures, associated with the study of various parameters such as turning radius, length and width of machines, and type, size, angles and location of towers, makes it possible to set up a computer program (APL). Table II compares the average land and time losses measured or calculated by various methods.

The first program (1978) helps to calculate land and time loss in individual operation only, which means many calcula-

[1]A study sponsored by Quebec-Hydro The authors are grateful to the Conseil des Recherches et Services Agricoles du Quebec for supporting this publication.

TABLE I. TECHNICAL AND ECONOMICAL DATA OF FARM MACHINES USED ON QUEBEC FARMS (A FEW OF THE 130 MACHINES STUDIED)†

Machines	Size range (m)	Speed (km/h)	Efficiency (%)	Average capacity ($ha \cdot h^{-1} \cdot m^{-1}$)	Custom rate (1981) ($\$ \cdot min^{-1} \cdot m^{-1}$)
Moldboard plow	0.67 – 3.48	5.6	80	0.45	0.282
Cultivator (vibro)	2.34 – 6.20	5.6	80	0.45	0.073
Grain drill	2.31 – 4.27	6.5	75	0.48	0.113
Corn planter	1.52 – 6.10	6.5	65	0.43	0.100
Mower-conditioner	2.13 – 4.27	8.1	75	0.60	0.136
Forage harvester (corn)	0.76 – 3.05	4.2	65	0.30	0.740
Combine (grain)	3.66 – 7.32	4.8	70	0.33	0.270
Combine (corn)	3.05 – 6.10	4.8	70	0.33	0.400

†Implement and Tractor Red Books (Anonymous 1971-1981); Manufacturers' technical data; Quebec technical and economical data (Anonymous 1971-1981); Kepner et al. (1978).

tions to find the real land and time losses in a specific crop production system.

SYSTEM MODEL

Objective

The objective of the 1981 study was to determine the land and time loss around an electric tower by a complete computer program including all pertinent parameters for each crop production system.

Operations

Thirty-four agricultural and horticultural crop systems were studied and the type and number of operations are noted for each of them. Each system needs from five to ten operations which may be repeated in a few cases. Table III shows the operations needed in six agricultural and horticultural crops.

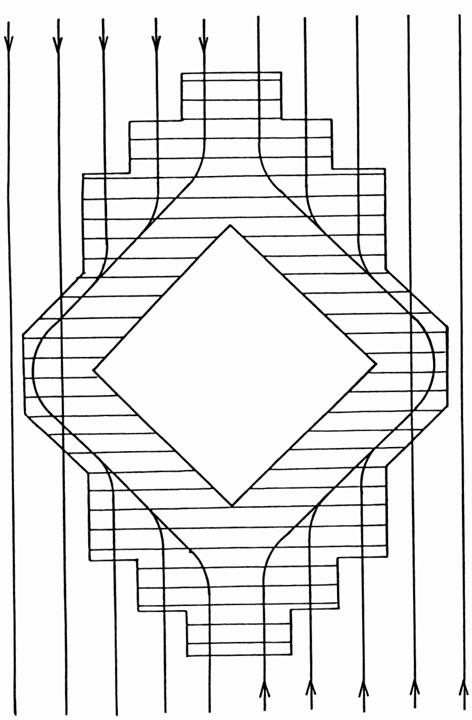

Figure 1. Graphic projection of land lost under and around electric towers.

The operations identification and the machine size ranges that can be used in each operation are given in Table IV. For each operation 0–1, 0–2, . . .), a machine is chosen (M^{-1}, M^{-2}, . . .). For this purpose, a machine bank contains parameters on 130 machines. Table V gives an example of the machine bank with specific application to a shelled corn production (A-9). A provision is made in this bank for self-propelled machines (T = 0); in this case LAT ≠ 0 and RB ≠ 0.

If the machines are operated by a tractor (T ≠ 0), there is a choice between 15 tractor sizes, from 20 to 170 kW. Parameters given in the tractor bank (Table VI) are

TABLE II. LAND AND TIME LOSS VERSUS TOWER TYPES (MEAN) (FS = 0.6 m)

Towers	Land loss: Mean (m^2)	Land loss: Range (m^2)	Time loss (min)
Wood	68†	(5.0-324.0)	0.52†
frame	25‡	(5.0-370.0)	0.30‡
(120 kV)	70§	(2.1-632.1)	—
	15¶	(7.5-32.5)	—
Lattice	158†	(57-472)	1.17†
(7.62 m × 7.62 m;	126‡	(58-343)	1.19‡
230 kV)	189§	(7.2-709.9)	—
	175¶	(67-415)	—
Lattice	278†	(92-918)	1.98†
(12.2 m × 12.2 m;	273‡	(107-688)	1.96‡
735 kV)	288¶	(161-838)	—

†Computer, (1978). (five locations, 25 operations, 53 machines, 32 crops).
‡Field trial, (1978). (five locations, 10 operations, 10 machines).
§Gustafson and Meyer, (1980). Low-altitude aerial photographs.
¶Survey, (1978). 57 towers.

TABLE III. AGRICULTURAL AND HORTICULTURAL CROP SYSTEMS: OPERATIONS NEEDED (EXAMPLES)

Crops†		Operation number
A-2.	Cereal	0- 1 (1)‡, 0- 2 (2), 0- 4 (2), 0- 5 (1), 0-11 (2) , 0-20 (1)
A-9.	Shelled corn	0- 1 (1) , 0- 2 (2), 0- 3 (2), 0- 4 (1), 0- 8 (1) , 0-10 (1), 0-12 (4), 0-14 (1), 0-21 (1)
B-1.	Bean (Dry)	0- 1 (1) , 0- 2 (3), 0- 4 (3), 0- 8 (1), 0-10 (3) , 0-12 (2), 0-14 (1), 0-20 (1)
B-2.	Sweet corn	0- 1 (1) , 0- 2 (3), 0- 4 (3), 0- 8 (1), 0-10 (3), 0-12 (4) , 0-13 (2), 0-14 (1), 0-22 (1)
C-3.	Carrot	0- 1 (1) , 0- 2 (3), 0- 4 (3), 0- 9 (1), 0-10 (8), 0-11 (10) , 0-13 (1), 0-14 (1)
C-8.	Strawberry	0- 1 (1) , 0- 2 (3), 0- 4 (3), 0- 6 (1), 0-10 (12), 0-12 (16) , 0-13 (2), 0-14 (1)

†A-1, A-2 . . ., field husbandry crops; B-1, B-2 . . ., canning crops; C-1, C-2 . . ., fruit and vegetable crops; 0-1, 0-2 . . ., type of operation (Table IV).
‡Numbers in parentheses are numbers of repetitions.

TABLE IV. OPERATIONS AND MACHINES IDENTIFICATIONS

Operation	Machine size range†
O–1 Moldboard plow	M-1 to M-16 2 V, 0.36 m–8 V 0.46 m
O–2 Disk harrow	M-1 to M- 8 16–84 disks
O–3 Cultivator (vibro)	M-1 to M- 8 2.6–6.9 m
O–4 Harrowing	M-1 to M- 4 1.8–7.2 m
O–5 Grain drill	M-1 to M- 8 13 × 0.18 m–24 × 0.18 m
O–6 Transplanter	M-1 to M- 3 1–4 R
O–7 Broadcast seeder	M-1 to M- 3 1.52–7.30 m
O–8 Corn planter	M-1 to M- 4 2–8 R
O–9 Other planters	M-1 to M- 6 1–4 R
O–10 Weeder	M-1 to M- 7 1.22–7.31 m
O–11 Sprayer (field)	M-1 to M- 3 5.48–12.18 m
O–12 Sprayer (row crop)	M-1 to M-8 2–24 R
O–13 Spreader (chemicals)	M-1 to M- 2 2.44–9.14 m
O–14 Manure spreader	M-1 to M-12 5.29–14.10 m³
O–15 (Open)	5.600–12.000 L
O–16 Mower conditioner	M-1 to M- 8 2.13–4.27 m
O–17 Hay baler	M-1 to M- 4 2.13–4.27 m
O–18 Corn harvester (silage)	M-1 to M- 4 1–4 R
O–19 Forage harvester	M-1 to M- 4 1.83–3.66 m
O–20 Combine (grain)	M-1 to M-4 3.66–7.32 m
O–21 Combine (corn)	M-1 to M-3 4–8 R
O–22 Corn picker	M-1 to M-2 2–3 R
O–23 Tobacco harvester	M-1 5 R
O–24 Potato digger and harvester	M-1 to M- 2 2 R
O–25 Beet harvester	M-1 to M- 2 3–4 R
O–26 Asparagus harvester	M-1 4 R

†O = operation; M = machine; V = plow base; R = row.

the average length (LOT), width (LAT) and turning radius (RB without brakes) for each class. The land lost before and after the tower is directly proportional to the turning radius of a tractor or a self-propelled machine. For instance, with the same row-crop implement (3.05 m), a 95-kW tractor will generate a land loss of about 80 m² larger than a 35-kW tractor, when working around a 12.2-m × 12.2-m tower.

The parameters found in the machine bank (Table V) are defined as follows:
LU = useful working width (m); represents 90–95% of the machine's nominal size, except the row-crop machines (100%).
LAT = exterior tracking width for self-propelled machines (m). If a tractor is used, LAT is found in the tractor bank.
TYM = this refers to the location of the working rig in relation to the tractor. Offset machine type = 1 (mower, trailed combine ...); others = 0 (plow, harrow ...).
RB = turning radius for self-propelled machines (m).
VM = average working speed (km/h).
TS = supplementary time per run; when a stop is needed to lower or raise the implement (min).
TYO = operation type; row-crop = 1, others = 2.
LOI = machine overall length (m). 0 = front or mid-mounted implement.
REM = with trailed wagon = 2; without = 1.
CM = cost factor − custom rate (1981) applied for each minute lost. This is the custom rate in Table I multiplied by the machine nominal width ($/min).

From the data included in the machine and tractor banks, some other parameters are calculated:
LN = harmful width of the machine (m). In most cases, LN = LAT. For row-crop operations, LN = LU, if LU > LAT (m).
PAV and PAP = supplementary lengths of land allowed, respectively, before and after the tower in a complete run (m). These parameters are related to the type of operation (TYO) and the length (m) of any combination of tractor-machine (REM = 1) or tractor-machine-wagon (REM = 2) (m). It is a compensation for the lengthening of the turning radius when using trailed equipment.

Tower

Two types of electric towers are studied in the program: a lattice tower which represents a square projection and a wood frame which shows a rectangular projection on the ground.

For each tower, the orientation is given in relation to the direction of the working travel line. The situation in relation to fences (corner, end and side borders) is also introduced in the program. All pertinent parameters are shown in Figs 2 and 3 and are so defined:
LT = tower overall width, perpendicular to the working travel line at zero degree (m).
PT = tower overall length parallel to the working travel line at zero degree (m).
ANG = angle made by PT with the working travel line (degrees).
TB = perpendicular distance between the tower center and the fence parallel to the working travel line (m).
DTC = parallel distance in the working travel line between TB and the corner of the opposite fence (m).
ACC = internal angle at the corner between the two fences (degrees). (N.B.

TABLE V. MACHINE BANK (EXAMPLES OF NINE MACHINES IN SHELLED CORN PRODUCTION)†

	Machine	Parameters§									
		LU (m)	LAT (m)	TYM	RB (m)	VM (km/h)	TS	TYO	LOI (m)	REM	CM ($/Min)
0–1 Plow‡	M-7 (4V 0.36 m)	1.35	0	0	0	5.6	0	2	3.5	1	0.40
0–2 Disk	M-4 (40–50 disks)	3.90	0	0	0	7.2	0	2	5.2	1	0.48
0–3 Vibro	M-4 (4.1 m)	3.70	0	0	0	5.6	0	2	5.2	1	0.30
0–4 Harrow	M-3 (7.2 m)	6.48	0	0	0	8.1	0	2	3.65	1	0.48
0–8 Planter	M-2 (4R 0.76 m)	3.05	0	0	0	6.5	0.5	1	3.97	1	0.30
0–10 Weeder	M-3 (4R 0.76 m)	3.05	0	0	0	5.6	0.25	1	0	1	0.27
0–12 Sprayer	M-2 (4R 0.76 m)	3.05	0	0	0	6.6	0.5	1	3.65	1	0.25
0–14 Spreader	M-4 ($10.57 m^3$)	3.37	0	0	0	6.6	0	2	5.90	1	0.45
0–21 Combine	M-1 (4R 0.76 m)	3.05	2.64	0	6.90	4.8	0.5	1	8.73	1	1.22

†Implement and Tractor Red Books (Anonymous 1971-1981); Manufacturers' technical data.
‡Parameters are defined in the text.
§0-1, 0-2 . . . Operations (Table III) A-9; M-1, M-2 . . . Machines (Table IV).

Fences in above parameters refer to any kind of border.)

Security Factor (FS)

The security factor is the distance (m) that must be maintained between any part of the tower and any part of the machine used.

Time Loss Determination

Time loss is defined as the supplementary time needed to operate a machine when a tower is present over the regular time to make the same job when no tower is there. It accounts, more or less, for the time taken to make turning paths over straight line paths; so, it is the difference between accumulated lengths travelled in running around a tower and the accumulated straight lengths if no turning has to be done. Including speed of operation (VM) and supplementary time in some cases (TS), it is possible to calculate the time loss. Applying the cost factor (CM), it is possible to determine the value of time loss for each crop.

TABLE VI. TRACTOR BANK†

Tractor size (kW)	Parameters‡		
	LOT (m)	LAT (m)	RB (m)
20– 29	3.02	1.90	3.15
30– 39	3.22	1.93	3.15
40– 49	3.53	1.93	3.88
50– 59	3.74	2.07	3.88
60– 69	4.19	2.87	4.50
70– 79	4.19	2.87	4.57
80– 89	4.19	2.87	4.57
90– 99	4.20	3.04	4.67
100–109	4.32	3.04	4.77
110–119	4.32	3.15	4.77
120–129	4.32	3.15	4.94
130–139 (4–W)	4.37	3.30	5.33
140–149 (4–W)	4.45	3.30	5.78
150–159 (4–W)	4.49	3.53	6.10
160–169 (4–W)	4.70	3.55	6.32

†Implement and Tractor Red Books (Anonymous 1971-1981); Manufacturers' technical data.
‡Parameters are defined in the text.

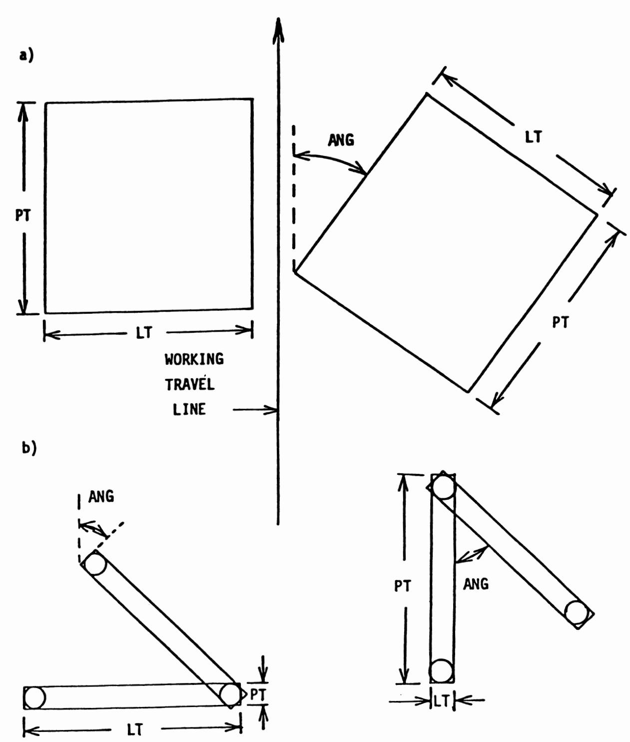

Figure 2. Two types of electric towers: (a) square (lattice towers), left, at 0°, right, up to 45°; (b) rectangular (wood frames) left, projection of the poles (circles) is perpendicular to the travel line or at any angle up to 45°; right, projection is parallel to the travel line or at any angle up to 45°.

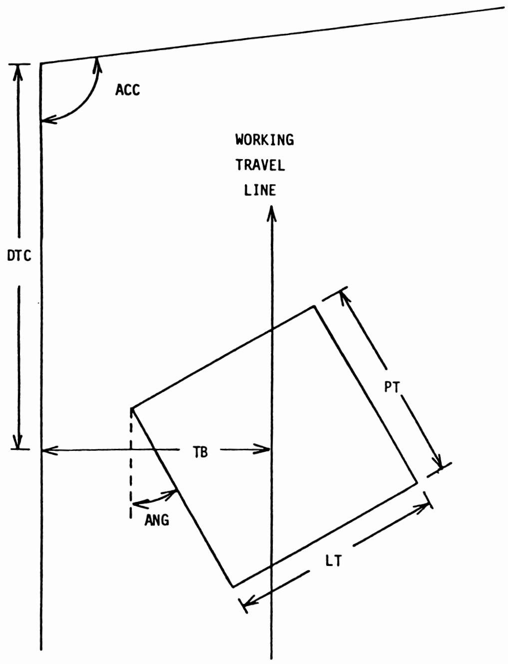

Figure 3. Tower position in the field. Center position happens when DTC and TB are large enough to allow free travel of farm machines around the tower.

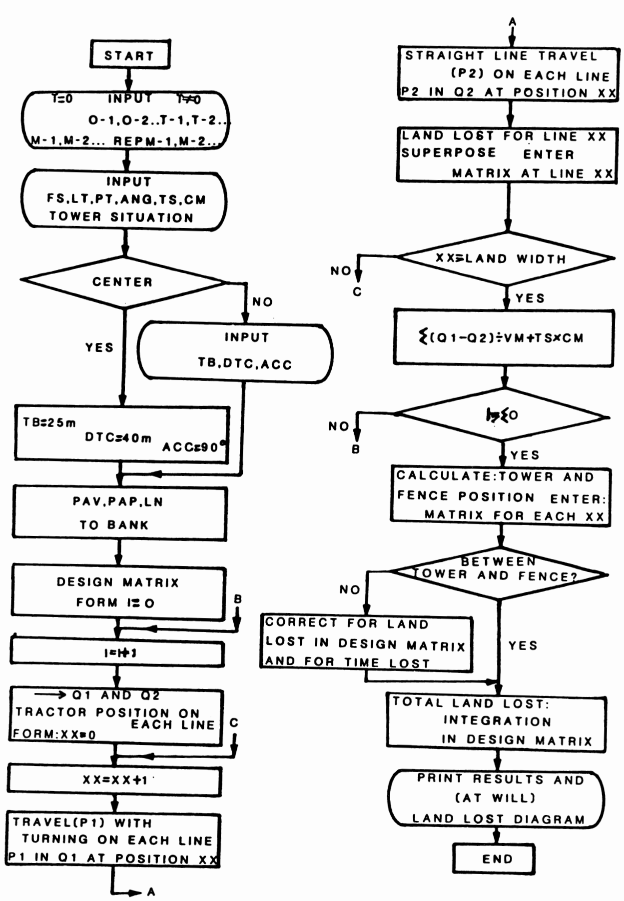

Figure 4. Flow chart for each production.

Flow Diagram

The flow diagram for the main program is shown in Fig. 4. The program starts with operation, machine, tractor and tower parameters. For land losses, the program calculates them for each machine in succession and gives the maximum value. For time loss, the cost is calculated for each machine and is cumulated for crop. The program also superimposes the land loss diagram of each machine, gives a complete land loss diagram and prints the real value of land loss obtained by integration for each crop.

Example Run

In a shelled-corn production (A-9), there are nine operations required (Table III) from plowing to harvesting. There is a lattice tower supporting a 735-kV line in the center of the field and this tower makes a 30° angle (ANG) with the working line (tower dimensions are: PT = 12.2 m and LT = 12.2 m).

For this example, machine parameters are in Table V and the tractor chosen is in the 50- to 59-kW class, in Table VI. For this particular case, the factor of security is set at 3 m. (FS = 3 m).

The following results are obtained: maximum land loss: 780 m^2, in planting with a 4-R, 0.76-m, corn planter; real land loss: 854 m^2, by integration (Fig. 5).

The maximum land loss refers to the individual machine which has the highest land loss in a particular crop system. The real land loss is obtained by superimposing all individual diagrams of maximum land loss by each machine in the system. Therefore, the real land loss is always equal to or higher than the maximum land loss by a single implement of the system.

Total time-loss cost = $17.86 per year (1981).

CONCLUSION

Following surveys and trials in the field in 1978, a computer program (APL) was set up to calculate time and land loss caused by the presence of an electric tower in an agricultural field. This program can sketch the diagram of land loss for any agricultural or horticultural production in which a combination of machines and tractors is given. The real land loss is obtained by integration for each production. The program also calculates the annual cost of time loss.

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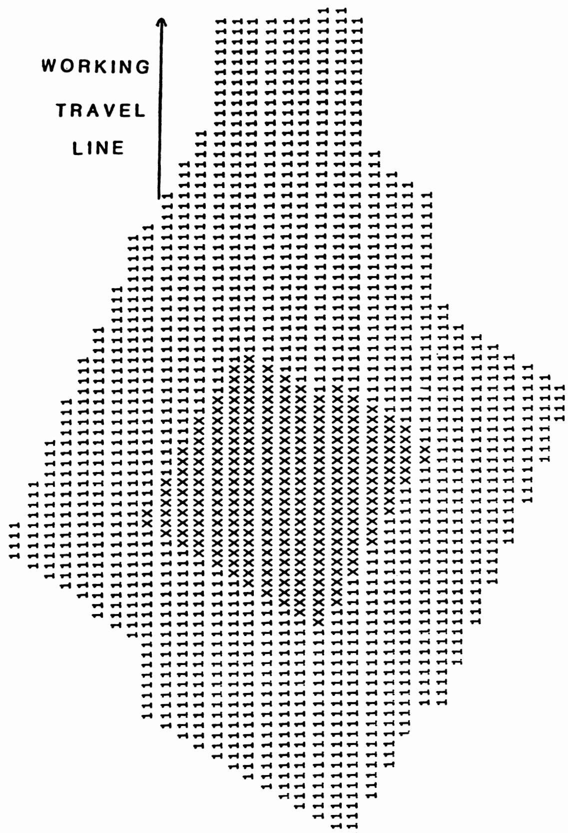

Figure 5. Land lost (11) around a tower (XX) in a shelled corn production with standard farm machines (tower in a center position at 30°).

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