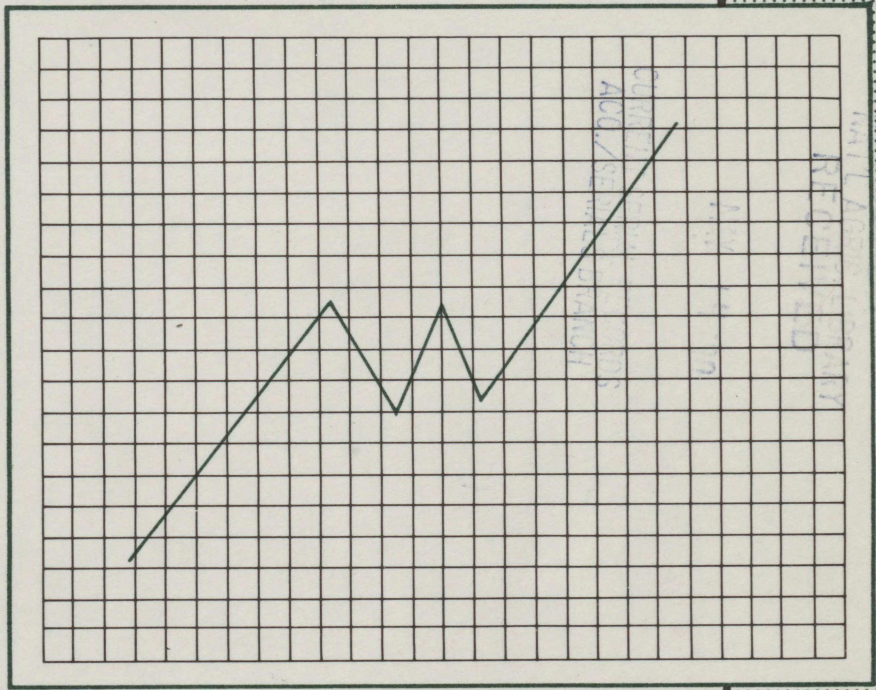

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FINANCIAL EVALUATION OF TILLAGE SYSTEMS FOR MAIZE ON SANDY SOILS IN THE NORTH-WESTERN FREE STATE*

by J. HOUGH and J.A. GROENEWALD**

ABSTRACT

Various tillage systems (including conventional and top-layer practices) were identified and financially analysed by determining income and cost effects of the systems. Net margin analyses provided illuminating rank-order shifts.

The rip-on-row methods are the most economic tillage systems in the North-Western Free State. The best three systems (all top-layer systems) performed on average 111% better than the conventional systems in respect of net margin per R100 of capital invested.

INTRODUCTION

In the Report on Maize (1984 and 1985) the Maize Board speculated that South Africa, as one of the world's 10 largest maize-producing countries, contended with the poorest production conditions. The Republic of South Africa's average yield per hectare from 1977 to 1983 also fell among the lowest of these 10 countries.

According to Mallet (1981), the technology for maize production in South Africa is fairly well developed and the soil's growth season temperatures do not provide insuperable problems in the most important maize-producing areas. The relatively low yield per hectare should, according to him, be ascribed, among other things, to unfavourable conditions for moisture provision. Mallet states, "Any technique that can be economically introduced to make better use of our limited and often unreliable moisture supplies must therefore be encouraged. Tillage promises to be able to make a positive contribution in this area".

Cultivation costs have increased considerably over the past few years. The estimated percentage increase in machinery costs in maize production in the centre of the maize-producing areas increased as follows in the production years 1973/74 to 1982/83 (the working committee on the economic position of the farmer and agricultural financing in general, 1983: Table 5.2):

		%
Fixed costs	-	1 251
Fuel	-	691
Repairs	-	286
Hired services	-	200

It is therefore important to identify the most economic tillage systems.

Seven different tillage systems (including top-layer and conventional tillage) were evaluated over seven years in respect of yield, gross income, production cost, net margins and net margins per

TABLE 1. The world's most important maize-producing countries, 1977-1983

Country	1977	1978	1979 Average yield per hectare (t)	1980	1981	1982	1983	Average yield per hectare over 7 years (except Russia: over 6 years
USA	5,69	6,34	6,88	5,71	6,90	7,21	5,20	6,28
France	5,26	5,29	5,22	5,33	5,73	6,35	5,43	5,52
Yugoslavia	4,25	3,56	4,48	4,23	4,25	4,96	4,73	4,35
Roumania	3,03	3,21	3,75	3,39	3,39	4,06	3,59	3,49
Argentina	3,57	3,10	2,57	3,71	3,33	2,90	3,27	3,21
Russia	-	3,53	3,15	3,18	2,37	3,24	3,30	3,13
China	1,91	2,80	2,97	3,00	3,01	3,26	3,38	2,90
RSA	2,12	1,80	2,34	3,11	1,79	0,99	1,12	1,90
Brazil	1,30	1,44	1,74	1,77	1,77	1,76	1,80	1,65
Mexico	1,22	1,28	1,21	1,28	1,38	1,17	1,46	1,29

Source: Maize Board, 1984. Report on maize
Maize Board, 1985. Report on maize

*Based on an M.Sc. (Agric.) thesis

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R100 of capital invested. The tillage trial was carried out in the Wesselsbron Magisterial District on a Clovelly type soil with a clay percentage of 3 % in the A horizon and 8 - 10 % in the B horizon.

THEORETICAL BACKGROUND

Analyses of soil tillage methods or systems should logically be based on a review of the purpose and effect of such methods. The analysis of core principles in respect of soil tillage is an important starting point.

Purpose of soil tillage

Behr (1983) emphasises the purpose of soil tillage in terms of the improvement of soil structure and also emphasises that tillage should be applied only where it benefits the natural phases of root development and distribution. According to the John Deere Company (1976), the purpose of soil tillage is to create a suitable environment for seed germination, root growth and the control of weeds, erosion and moisture.

Boshoff (1983) also emphasises that soil tillage aims at creating a condition in which the crop that is cultivated will realise the highest net income. This does not necessarily mean attaining maximum physical yield.

Kuipers (1963) maintains basically the same point of view and adds that an additional tillage is financially justified only if the expected economic benefit is greater than the cost.

Effect of soil tillage on soil compaction and conditions

Soil compaction can be brought about by internal or external forces (Cohron, 1971). Shrinking (Gill, 1959), freezing and swelling (Larson & Allmaras, 1971) are internal forces which can compact soil. External forces include the movement of animals (Tanner & Mamoril, 1959), tractor tyres (Chancellor, 1977), implements (Willat & Wallis, 1965) and irrigation (Du Preez *et al.*, 1981).

According to Raney (1971), the soil conditions most affected by compaction are those that are responsible for the control of the content and absorption of water, air, heat and nutrients.

Henning (1984) maintains that soil strength may be regarded as the most important factor determining the penetration of roots. This will therefore have a great effect on plant growth and consequently on yield.

It is therefore clear that compaction limits and restricts root development. Schuurman *et al.* (1974), Veen & Boone (1981) and Bennie & Burger (1980) corroborate this statement.

Theory analysis

The term "top-layer tillage" has many meanings and has caused much confusion among researchers, extension officers and farmers. The Soil Conservation Society of America (1982) has a definition, which reads as follows:

> "Conservation tillage is any tillage system that reduces loss of soil or water relative to conventional tillage; often a form of noninversion tillage that retains protective amounts of residue mulch on the surface".

The statements of Le Roux (1983), Siemens & Oschwald (1978) and Els (1983) support this.

For the purposes of this analysis, top-layer tillage will refer to any tillage system with the minimum of soil disturbance to be sufficient for root growth, fertiliser distribution, weed control and planting.

Conventional tillage is summed up as follows by Koch (1982): The plough-share, followed by two to seven secondary (shallow) tillings. These tillings are occasionally preceded by a disc tillage and/or deep ploughing methods.

INCOME EFFECTS

Table 2 reflects the various tillage systems practised over seven years in experiments in the North-Western Free State. The tillage depths are also indicated.

Systems 2, 3 and 7 are classified as top-layer systems and systems 4, 5 and 6 as conventional systems. System 1 is by definition neither a

TABLE 2. Tilling systems over seven years, 1978/79 - 1984/85

System no.	1978/79	1979/80	1980/81	1981/82	1982/83	1983/84	1984/85
1	N	N	N	N	N	N	N
2	N	AR	AR	AR	AR	AR	AR
3	N	ROR1	ROR1	ROR1	ROR1	ROR1	ROR1
4	N	P(W)	P(W)	P(W)	P(W)	P(W)	P(W)
5	DP(W)	DP(W)	DP(W)	DP(W)	DP(W)	DP(W)	DP(W)
6	P(S)	P(S)	P(S)	P(S)	P(S)	P(S)	P(S)
7	ROR2	ROR2	ROR2	ROR2	ROR2	ROR2	ROR2

Explanation of codes

N - Nardi with tillage depth of 540 mm
CR - Complete ripping with tillage depth of 480 mm
ROR1 - Rip-on-row with tillage depth of 510 mm
P(W) - Ploughing in winter, with tillage depth of 270 mm
DP(W) - Deep-ploughing in winter, with tillage depth of 390 mm
P(S) - Ploughing in summer, with tillage depth of 270 mm
ROR2 - Rip-on-row with tillage depth of 470 mm

TABLE 3. Yield (kg) and gross income* (R) per hectare over seven years

System no.		1978/79	1979/80	1980/81	1981/82	1982/83	1983/84	1984/85	Average	Position
1	(kg)	6 273	6 671	7 082	6 415	6 242	4 150	3 201	5 719	1
	(R)	1 346	1 432	1 520	1 311	1 340	891	687	1 218	
2	(kg)	6 273	6 359	6 469	6 267	4 301	4 368	4 255	5 470	4
	(R)	1 346	1 364	1 388	1 345	923	937	913	1 174	
3	(kg)	6 273	6 490	6 465	6 435	4 858	4 670	4 737	5 704	2
	(R)	1 346	1 393	1 387	1 381	1 043	1 002	1 017	1 224	
4	(kg)	6 273	5 885	6 045	5 025	2 907	1 653	1 799	4 227	6
	(R)	1 346	1 263	1 297	1 078	624	355	386	907	
5	(kg)	5 802	5 572	5 609	6 008	3 815	2 957	2 957	4 674	5
	(R)	1 245	1 196	1 204	1 289	819	635	635	1 003	
6	(kg)	5 072	4 807	4 231	2 337	2 375	2 209	1 765	3 257	7
	(R)	1 088	1 032	908	502	510	474	379	699	
7	(kg)	5 752	5 831	6 250	6 341	5 458	5 060	4 754	5 635	3
	(R)	1 234	1 251	1 341	1 361	1 171	1 086	1 020	1 209	
Average total (kg)		**5 960**	**5 945**	**6 022**	**5 547**	**4 279**	**3 581**	**3 353**	**4 955**	
Average total (R)		**1 279**	**1 276**	**1 292**	**1 190**	**918**	**768**	**719**	**1 063**	

*Maize price = R214,50/t

conventional method nor a top-layer method.

Yield and gross income vary with tillage depths.

Table 3 shows the various yields (kg) and gross income (R) per hectare over seven years.

It is clear that system 1 produced the largest average yield and greatest gross income per hectare.

System 3 has second place on the list. The annual deep-ripping methods may here give rise to higher yield. System 3 again shows the beneficial effect of annual ripping methods on sandy soils.

The conventional systems attained the last three places on the list.

An important conclusion from Tables 2 and 3 is the relation between yield increase and increase in tillage depths. The trend of higher yields and deeper tillings is clear (graph 1) and confirms the research of Snyman (1983).

No straight regression relation was found such as in Snyman (1983), however, but rather an exponential relationship to a depth of 540 mm.

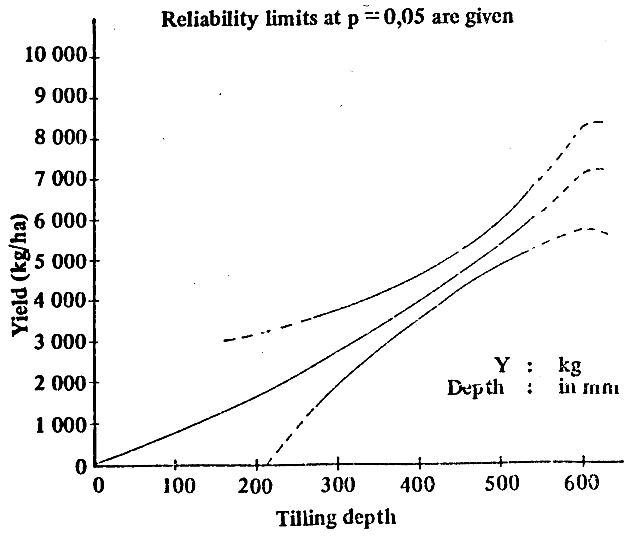
The variance analysis shows the same F values in yield and gross income, i.e. F = 22,059 for years and 14,11 for treatments (tillings). The LSD (gross income) at 0,01 is 208, 54 and 154,992 at 0,05.

It is therefore clear that there are significant gross income differences between the tillage systems at the 1 % and 5 % levels of reliability.

Table 4 sums up the significant differences in yield between the seven tillage systems.

$$Y = -0{,}12069685986 + 1{,}72616914234 \times \text{Depth}^{1{,}2961}$$

Reliability limits at p = 0,05 are given



GRAPH 1. Relation between yield increase and tillage depth

TABLE 4. Levels of significance for indicating differences in yield between seven tilling systems

	1	2	3	4	5	6	7
1	.	NS	NS	,01	,01	,01	NS
2		.	NS	,01	,05	,05	NS
3			.	,01	,01	,01	NS
4				.	NS	,05	,01
5					.	,01	,05
6						.	,01
7							.

NS: Not significant

COST EFFECTS

Procedures

Forty-nine separate budgets were drawn up to calculate the production costs (material costs and machinery costs) of each cultivation system in each separate year. Prices of inputs and outputs were used as at 1 July 1985.

Material costs are the same for all the systems and the machinery costs vary directly from system to system. Various formulas were used to establish a machinery complement for the calculation of the cost of machinery: Machine hours per hectare (Oklahoma State University, 1979; Nel & Groenewald, 1978, fuel and repair costs, depreciation and interest rates per hour (Department of Agriculture and Water Supply, 1985). Full information can be obtained from Hough (1986).

Total production costs per tillage system

Table 5 shows the material costs and machinery costs per tillage system.

TABLE 5. Total production costs per tilling system

System no.	Material costs	Machinery costs R/ha	Total production costs
1	260,84	185,12	445,96
2	260,84	150,71	411,55
3	260,84	131,01	391,85
4	260,84	133,38	394,22
5	260,84	147,25	408,09
6	260,84	122,72	383,56
7	260,84	121,67	382,51
Average	**260,84**	**141,69**	**402,53**

Production costs vary from R382,51 per hectare for system 7 to R445,96 per hectare for system 1.

NET MARGINS

Definition

Net margins are defined here as gross income minus total production costs as set out in Table 5.

Net margins per tillage system

Table 6 shows the net margins per hectare for the various tillage systems on a cultivated surface of 400 hectares.

From the composition of the ordering system it appears that system 3 (with the highest net margin) is R5,18 per hectare better than system 7, which has the second highest margin. The deeper Nardi method therefore produced an average of only R5,18 per hectare larger net margin in 1978/79 over seven years. It is also interesting to note that in system 3 the beneficial Nardi method had a more positive yield and net margin effect than system 7 from 1978/79 until 1981/82. From 1982/83 to 1984/85, however, system 7 performed better.

There is therefore strong competition between system 7 and system 3, since system 3 takes position 2 in respect of yield, position 3 in respect of total machinery costs and position 1 in respect of net margins. System 7 takes positions 3, 1 and 2, respectively.

Systems 1 and 2 also show favourable net margins, but systems 4, 5 and 6 are clearly not in the same class. Although system 6 is the second cheapest in terms of production costs, the system performs the worst in respect of net margins.

Capital investment in machinery per tillage system

Table 7 shows the capital investment in machinery per hectare. This capital investment represents the average investment in machinery - i.e. (purchase price + scrap value)/2, where scrap value is taken as 10 % of the purchase price. The positions show that system 7 is again the most beneficial system in terms of capital investment.

System 1 requires 103 % more machinery capital than system 7 and remains by far the most capital-intensive system.

Net margins per R100 of capital invested

The capital investment referred to here includes investments in land and machinery. High potential maize lands (3 tons of maize or more) are valued at R1 500 per hectare (Van Zyl, 1985). The net margins per R100 of capital invested are given in Table 8.

Interesting position shifts occurred from Table 6 to Table 8. System 7 now takes first place, followed by system 3. Systems 1 and 2 have also exchanged places, but systems 4, 5 and 6 have retained their positions.

TABLE 6. Net margin analysis per tillage system per hectare

Tilling system	No.	1978/79	1979/80	1980/81	1981/82	1982/83	1983/84	1984/85	Average	Order
Nardi (7x)	1	898,44	982,57	1 069,40	928,45	891,89	449,70	249,10	781,36	3
Nardi (1x) complete rip (6x)	2	898,44	955,54	978,79	936,09	520,53	534,70	510,81	762,13	4
Nardi (1x) rip-on-row 1 (6x)	3	898,44	1 007,10	1 001,80	995,46	662,12	622,38	636,55	831,98	1
Nardi (1x) ploughing (W) (6x)	4	898,44	870,88	904,70	689,10	241,41	-23,65	7,21	512,58	6
Deep ploughing (W) (7x)	5	833,38	784,77	792,59	876,92	413,38	232,03	232,031	595,01	5
Ploughing (S) (7x)	6	699,03	643,02	521,27	120,93	128,96	93,87	0,02	315,30	7
Rip-on-row 2 (7x)	7	851,50	868,20	956,77	976,00	789,36	705,23	640,55	826,80	2
Average net margin		**853,95**	**873,15**	**889,33**	**788,99**	**521,09**	**373,46**	**325,18**	**660,74**	

TABLE 7. Capital investment in machinery per tilling system per hectare

Tilling system	No.	1978/79	1979/80	1980/81	1981/82	1982/83	1983/84	1984/85	Average	Order
Nardi (7x)	1	792,06	792,06	792,06	792,06	792,06	792,06	792,06	792,06	7
Nardi (1x) complete rip (6x)	2	792,06	583,28	583,28	583,28	583,28	583,28	583,28	613,11	6
Nardi (1x) rip-on-row 1 (6x)	3	792,06	390,23	390,23	390,23	390,23	390,23	390,23	447,63	2
Nardi (1x) ploughing (W) (6x)	4	792,06	452,23	452,23	452,23	452,23	452,23	452,23	500,78	5
Deep ploughing (W) (7x)	5	454,64	454,64	454,64	454,64	454,64	454,64	454,64	454,64	4
Ploughing (S) (7x)	6	452,23	452,23	452,23	452,23	452,23	452,23	452,23	452,23	3
Rip-on-row 2 (7x)	7	390,23	390,23	390,23	390,23	390,23	390,23	390,23	390,23	1
Average capital investment		**637,91**	**502,13**	**502,13**	**502,13**	**502,13**	**502,13**	**502,13**	**521,53**	

TABLE 8. Net margin per R100 capital

Tilling system	No.	1978/79	1979/80	1980/81	1981/82	1982/83	1983/84	1984/85	Average	Order
Nardi (7x)	1	39,20	42,87	46,66	40,51	38,91	19,62	10,87	34,09	4
Nardi (1x) complete rip (6x)	2	39,20	45,87	46,98	44,93	24,99	25,67	24,52	36,02	3
Nardi (1x) rip-on-row (6x)	3	39,20	53,28	53,00	52,66	35,03	32,93	33,68	42,83	2
Nardi (1x) ploughing (W) (6x)	4	39,20	32,29	33,54	25,55	8,95	-0,88	0,27	19,85	6
Deep ploughing (W) (7x)	5	30,85	29,05	29,34	32,46	15,30	8,59	8,59	22,03	5
Ploughing (S) (7x)	6	35,81	32,94	26,70	6,19	6,61	4,81	0,00	16,15	7
Rip-on-row 2 (7x)	7	45,05	45,93	50,62	51,63	41,76	37,31	33,89	43,74	1
Average net margin/R100 capital		**38,36**	**40,32**	**40,98**	**36,28**	**24,51**	**18,29**	**15,97**	**30,67**	

CONCLUSION

It therefore appears that the rip-on-row methods emerged as the most economic tillage systems in the North-Western Free State. The best three systems, i.e. 7, 3 and 2, are also all top-layer tillage systems. These top-layer systems are (with regard to net margin per R100 of capital invested) an average of 111 % better than the conventional systems.

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