IMPACT OF CAPITAL ON THE GROWTH PROCESS OF A SUGARCANE FARM IN MPUMALANGA

BO Haile, B Grové & LK Oosthuizen[1]

Abstract

The research was conducted for a representative 50 ha farm in the Onderberg region in Mpumalanga province, where farmers use a combination of centre-pivot, drip, and dragline systems of different sizes to grow sugarcane. The main intention was to establish a multi-period linear programming model capable of economically evaluating a farm's expansion decision-making process for farmers faced with investment decisions in alternative irrigation systems, taking into account the available initial capital of the farm. A linear programming (LP) model was used to assign a mainline for a total of twelve irrigation system combinations based on the assumption that the farmer wishes to start with a 30 ha centre-pivot investment. The Generalized Algebraic Modelling System (GAMS) was used to formulate the farm growth model as mixed integer dynamic linear programming (MIDLP) for a 15-year planning horizon. Based on the results, farmers are initially forced to invest in lower-cost irrigation systems when they lack capital to start a farm business due to the time value of money. They only consider lowering operating costs by investing in capital intensive irrigation systems when they have more own capital or borrowing capacity.

1 INTRODUCTION

Investments decisions about irrigation systems create their own economic problems (McCarl & Musser, 1985; Rae, 1977). Hence, for uninformed farm managers, irrigation system investment decisions are often more difficult than decisions relating to expenses in the short term. Firstly, evaluating the relationships between variables that determine the investment decision, for instance, between investment cost and operating cost required for the irrigation system, is not an easy task. In the short-term, the lower capital cost system might seem attractive. However, over the long –term, this system might have higher operating costs, which finally determine the outcome of a farmer's cash flow in later years. There are also conceptual problems involved in investment decisions, such as estimating the investment amounts and expected benefits, conflicting results of various financial selection criteria, and the diversity of opinions when determining the results. Lastly, the investment

[1] *Graduate Student, Lecturer and Professor respectively, Department of Agricultural Economics, University of the Free State.*

costs are incurred now for potentially higher profits in the future (Bender *et al*, 1992). Then, the challenge for the producer is to evaluate the tradeoffs between the investment cost and operating cost of the systems as related to the other decision variables, since there are many alternative design choices available. The capital cost of the irrigation system is related to the cost of the systems, the mainline to convey water, and the pump required to move water from the source to the fields. One of the factors that affect operating costs is the kilowatt requirement to drive water. The kilowatt requirement of a given system or a combination of systems is dependent on both the quantity pumped and the total head (head plus total pressure) the pump is working against. The total pressure is the sum of the system's pressure and frictional loss. The frictional loss, in turn, is dependent on the pipe size of the mainline (Radley, 2000).

In a given situation, a farmer cannot change the head of his farm. Keeping this factor constant, he is left with the problem of deciding which type of system to invest in and what the pipe size should be for the mainline. Hence, the overall investment cost and operating cost are dependent on the irrigation system combinations and the design of these combinations for mainlines. Should a farmer choose a suitable pipe size and pump size to expand the current system, or a large size pipe and pump, taking future expansion in another system into account? Should he expand from irrigation system A to irrigation system B and then to C, or to irrigation system C then to B? Thus, designing the irrigation system and the ways it can expand have implications on the capital cost and operating cost of the systems.

Given the capital cost of an irrigation system, it is important to determine the extent to which variables such as liquid capital at hand, tax deductions, borrowing capacity, operating cost, and time value of money affect the development of the irrigated farm. Hence, the problem immediately facing the farmer in relation to the interaction that exists among these important variables is the type of system to invest in, where to allocate surplus cash, how much to borrow to supplement internally generated funds, and what direction to take the farm business through new investments.

Such problems can only be addressed appropriately by a multi-period mathematical procedure. Applications of dynamic linear programming (DLP) models in South Africa and internationally are not new. Some of the applications to problems of irrigated agriculture include optimal water management strategies which benefit irrigation outcomes (Oosthuizen & Van Zyl, 1995; Akhand *et al*, 1995); optimal management strategies under variable water supply (Symington & Viljoen, 1997); optimal production strategies and financial compensation for sustainable irrigation (Viljoen & De Jager, 1997).

Other applications of DLP include the determination of the structural effects of subsidizing farmers to change from land under cash crop production to pastures for beef considering production risk (Van Zyl & Vink, 1989); optimal varieties selection (Willis & Hanlon, 1976); and optimal variety mix in a range of market prices (Kearnev, 1994). However, in South Africa, there is no model specifically devoted to the irrigation system investment problem. In almost all the models, the capital budget was compiled outside the model, and it is only used to optimize the cash flow of the farm. Such approaches are difficult for studying the timing of a farm growth process. Hence, they pay less attention to farmers who are faced with the problem of deciding about irrigation system expansion.

The main objective of this study is, therefore, to determine the optimal irrigation system expansion choice and timing given a certain amount of capital available for a farm business. To achieve this objective, a mixed integer dynamic linear programming (MIDLP) model is developed to evaluate the optimal system combinations in the growth of the farm.

2. METHODOLOGY

2.1 Data collection

The model and data needs are based on a representative farm in the Onderberg area in Mpumalanga province, South Africa. Farmers in this region use different combinations of centre-pivot, drip and dragline systems in different sizes to grow crops such as sugarcane (National Department of Agriculture, 2002; Oosthuizen & Grové, 2001). To generate reasonable alternatives, this study assumes that the farmer has 50 ha of land to expand. To simplify the possible combinations, a further assumption was needed, namely that the farmer will expand 30 ha of sugarcane under centre-pivot irrigation system (block 1) initially. Then, the farmer will expand the remaining 20 ha of farmland. Since irrigation systems are purchased in lumpy sizes, the 20 ha farm to be developed is divided into two blocks of 10 ha land (block 2 and block 3). The combinations resulted are named as C1 (centre-pivot and 20 ha dragline), C2 (centre-pivot and 20 ha drip), C3 (centre-pivot, 10 ha dragline, and 10 ha drip), and C4 (centre-pivot, 10 ha drip, and 10 ha dragline). Then, sound scenarios of the expansion path that can be followed by the farmer in mainline selection were formulated as follows:

(a) *Dependent expansion path*: Here, the farmer invests in the optimal mainline, taking into account possible future expansion. Since the pipe size (diameter/thickness) and the friction loss between water and the pipe are inversely related, the choice of pipe size has a significant effect on the investment and operating cost of the systems. The thicker the pipe size, the higher the investment cost and the lower the kilowatt needed, and vice versa. This expansion path can be further divided in two by the way he supplies energy for driving the water, giving two expansion paths named A and B: (i) Single pump for all the irrigation systems in the combination (expansion path A); and (ii) each irrigation system with its own pump when expanding (expansion path B).

(b) *Independent expansion path*: In this alternative, the farmer invests in the optimal mainline needed only for the irrigation system being expanded currently, not considering future development. Hence, even though he incurs low cost for the pipe for the time being, he will increase the cost of energy needed to overcome the overall frictional loss when he expands to another irrigation systems due to the pipe that he invested in earlier, which will not be optimal when another irrigation system is added to the farm. This expansion path is named C, and the irrigation systems can be provided with their own pump when expanding.

Once the four irrigation system combinations were identified, each system combination was designed properly using the spreadsheet model developed by Radley (2000), and mainline and pump size were assigned using the linear programming model developed by Radley (2000). Then, inter-temporal enterprise budgets were prepared for the entire alternative for sugarcane (Rae, 1977). Technical data regarding mechanization for the budgets and physical quantities of the inputs for the life cycle of the crop are taken from the COMBUD (1998) data. All input prices and investment cost were expressed for 2002.

2.2 Model specification

The farm expansion model is formulated and structured as a MIDLP using GAMS (General Algebraic Modelling System) (Brooke *et al*, 1998) to develop and evaluate a farm expansion decision problem. The model's basic structure resembles that of the other growth models (e.g. Barry & Willmann, 1976; Boehlje & White, 1969; Hazell & Norton, 1986) developed in terms of multi-period linear programming. The GAMS model consists of the following basic components: (a) the objective function of the model, which is to maximize the present value of net worth of a 50 ha sugarcane farm business at the end of a 15 year planning horizon, (b) decision variables such as irrigation system investments, long-term loans, production loan, off-farm investment, tax, tax deductions, tax deduction transfers, cash transfers and crop planting, and (c) technical constraints regarding the availability of land, capital, and borrowing capacity which are related to the fixed resources of the model. Since the GAMS formulation was lengthy, it was not possible to present it in this paper; hence, it can be referred from Haile (2003).

The model assumes that the farm operator chooses from a set of irrigation systems to plant sugarcane and that all prices and technical coefficients are constant. The model contains 647 rows and 1 033 columns. It is evident that resource constraints will determine a farmer's choice of expansion. For this analysis, long-term borrowing with a 10 year loan term and production loan was included. Living expenses were assumed to be constant at R25,000 per annum. The overhead cost required by the farm was assumed to be R15,000 per annum. Tax activity was also included at a marginal tax rate of 35%. An off-farm investment activity is included for money deposited in a bank at an interest rate of 5%. The nominal interest rate on borrowed capital was assumed to be 17% with inflation at 8%, and the cash flow associated with them was expressed in real terms. When a farmer starts a farm, he needs security to borrow money. Thus, the farmer has initial property worth R200,000, and 60% was set as the proportion of net worth that can be borrowed. The sugarcane life cycle is considered to be 7 years, and further, it is assumed that the farmer continues with this cycle of replacement for the planning horizon.

3. RESULTS AND DISCUSSION

To demonstrate how a change in the resource base affects the timing of irrigation system expansion and the timing of the area planted using the irrigation systems, the MIDLP was solved for different initial liquid capital levels. The growth process observed, where initial capital is parameterized, is discussed in three sub-sections. The first section includes the initial capital range where the time horizon for the centre-pivot was too short to generate enough money to expand. The second section includes an initial capital range allowing expansion from centre-pivot to the next 10 ha. The last section is the case of high initial capital for the centre-pivot to expand to the full 50 ha land.

3.1 Development of 30 ha farm land

Table 1 show that with less capital at hand to start farming, the only possible expansion within this 15 year period of time is in a centre-pivot system in year 1, which is in block 1 with 30 ha farm land. It occurs because the time horizon is too short for the centre-pivot to generate surplus cash for further expansion. The area of sugarcane planted is expressed as a percentage of the area of the centre-pivot. To observe the effect of capital, the initial capital was varied for R15,000 intervals.

At R215,000, the centre-pivot in combination C1 with expansion path C is selected in year 1. The capital is so low that the farmer has to choose a thin pipeline, leading to an overall lowest investment cost. However, he has to incur a higher operating cost to generate income. With this choice, he needs 10 years to fully develop the 30 ha land with sugarcane. Specifically, 55% of the land is developed within the first six years, and 45% of the land is developed in year 9 and 10, to get a net worth of R1,681,705. With R230,000 starting capital, he still has to choose the centre-pivot in combination C1, but with expansion path B. It means that he selects an investment cost which is a little more expensive but has a lower operating cost. In this case, he only needs 9 years to fully develop the whole land with sugarcane, of which 47% of the area is developed in 5 years time, and 53% of the land is developed in year 9 to earn a net worth of R1,739,574. At R245,000, the choice is still the same, but the increase in capital has an impact on the area of crop that can be planted within the short time. Accordingly, 45% of the area can be planted in the first four years, while the remaining 55% is planted in year 9, significantly increasing his net worth.

Table 1: Summary of the mixed integer dynamic linear programming results for 30 ha centre-pivot farm (2002)

Starting Liquid Capital (R)	Irrigation System Selected				Sugarcane Establishment (% of total area of the irrigation system)								Net worth in Present Value (R)
					Year								
	System Type	Combi-nation Type	Expan-sion Path	Expan-sion Time² (Year)	1	2	3	4	5	6	9	10	
215 000	Pivot¹	C1	C	1	30	1	1	4	3	16	37	8	1 681 705
230 000	Pivot¹	C1	B	1	31	2	2	8	3		53		1 739 574
245 000	Pivot¹	C1	B	1	25	8	1	10			55		1 799 179
260 000	Pivot¹	C4	B	1	20	14	1	10			54		1 839 764
285 000	Pivot¹	C3	A	1	13	21	1	10			54		1 891 100

Notes:
1) First block expansion (30 ha).
2) Time period of initiation of the irrigation system expansion.
C1 (30 ha centre-pivot, 20 ha dragline).
C3 (30 ha centre-pivot, 10 ha dragline, 10 ha drip).
C4 (30 ha centre-pivot, 10 ha drip, 10 ha dragline).
A–dependent: single pump.
B-dependent: each system with its own pump.
C-independent: each system with its own pump.

At R260,000, the farmer chooses combination C4 for a centre-pivot with expansion path B. The choice gives a lower operating cost, and the area planted with sugarcane will be within the first four periods, increasing the area planted by 1% more than the previous R245,000 initial capital, and planting 54% of the land in year 9. When the capital is increased to R285,000, the farm operator is willing to incur a higher investment cost for a centre-pivot, which is combination C3 with expansion path A. This choice will further lower his operating cost to generate more net worth. However, he will plant a smaller area of crops (13%) in the first year, and plants a greater area (21%) in the second year. The rest of the area is planted in year 3 and 4 (1% and 10% respectively), while he can plant 54% in year 9. These results show that with more initial capital, he can choose a higher investment for the mainline to lower operating cost. It significantly reduces the crop area panted in year 1 (e.g. compare R260,000 and R285,000 as starting capital); however, he can plant more in year 2, and the reduction in operating cost can improve the net worth of the farming activity.

Therefore, it is possible to conclude that when cash available to start a farm business is low, it takes a long time to generate surplus cash to expand from a centre-pivot irrigation system to other irrigation systems in order to farm additional land. The crop area is developed incrementally over time.

3.2 Development of 40 ha farm land

When the farmer increases his starting capital above about R287,000, the growth model starts to expand to the next 10 ha land to block 2. The results summarized in Table 2 are for initial capital increased by amounts of R40,000. Accordingly, the farmer has the ability to expand to centre-pivot and drip within the 15-year period. Both are high capital cost investments and more efficient regarding water application, but with a lower operating cost than would be the case if he had expanded to dragline. In all the capital ranges, the farmer chooses combination C2 in year 1.

Referring to Table 2, at starting capital R290,000, the farmer is following expansion path C for the combination C2. It means that he has to select a mainline with a thinner pipe if he has to expand to 40 ha farm land, thereby incurring higher operating costs to enter the business quickly. However, if he has the ability to increase his initial capital to a higher level to as much as R440,000, he will incur higher investment costs now in order to reduce the operating cost in the following years. For starting capital ranging from R320,000 to R440,000, the choice of the farmer will be expansion path A, which means investing on the optimum mainline. This is a thicker pipe size, and the frictional loss is reduced significantly to the extent that the energy consumption of the whole 40 ha land is low. The amount of starting capital available influenced crop-planting activities significantly. The area under drip irrigation is developed fully (10 ha) in the first year in all the cases of initial capital. It is because the yield of the drip irrigation system is high compared to centre-pivot, and if it is fully developed, replacing it in year 8 is easy, because it is a small area compared to that of a centre-pivot. However, planting of sugarcane is done incrementally for the centre-pivot in year 2, year 3, and then year 9 to develop the total area of 30 ha. The impact of capital is then to increase the early planting of sugarcane under the centre-pivot irrigation system. Hence, when capital is increased, the area planted in year 2 increases from 2% to 34% and the area of sugarcane planted in year 3 increases from 16% to 59%, while the area of sugarcane planted in year 9 decreases from 82% to 7%. The net worth increases from R2,652,316 at starting capital R290,000 to R2,893,116 at starting capital of R440,000.

Table 2: Summary of the mixed integer dynamic linear programming results for 40 ha irrigation farm (2002)

Starting Liquid Capital (R)	Irrigation System Selected				Sugarcane Establishment (% of total area of the irrigation system)				Net worth in Present Value (R)
	System Type	Combination Type	Expansion Path	Expansion Time[3] (Year)	Year 1	2	3	9	
290 000	Pivot[1]	C2	C	1		2	16	82	2 652 316
	Drip[2]	C2	C	1	100				
320 000	Pivot[1]	C2	A	1		8	23	69	2 685 987
	Drip[2]	C2	A	1	100				
350 000	Pivot[1]	C2	A	1		15	33	52	2 741 302
	Drip[2]	C2	A	1	100				
380 000	Pivot[1]	C2	A	1		21	42	37	2 792 276
	Drip[2]	C2	A	1	100				
410 000	Pivot[1]	C2	A	1		28	50	22	2 842 696
	Drip[2]	C2	A	1	100				
440 000	Pivot[1]	C2	A	1		34	59	7	2 893 116
	Drip[2]	C2	A	1	100				

Notes:
1) First block expansion (30 ha).
2) Second block expansion (10 ha).
3) Time period of initiation of the irrigation system expansion.
C2 (30 ha centre-pivot, 20 ha drip).
A–dependent: single pump.
C-independent: each system with its own pump.

Hence, it can be concluded that there are certain initial capital ranges within which it is possible to expand from centre-pivot to another 10 ha, for the farm to cover 40 ha in total. Besides, within this capital range, the results show that it is best to expand to a drip irrigation system than to dragline irrigation systems which are efficient regarding water application and have a longer useful economic life than draglines. Besides, it shows that the drip system has a higher average gross margin, which demonstrates that the farm manager should not have started farming with a centre-pivot as his initial investment, as the centre-pivot is not generating enough surplus money within this planning horizon.

3.3 Development of 50 ha farm land

Using Table 3, when the farmer has enough money to start a farm, he will expand to develop the 50 ha land fully. This is because his borrowing capacity will increase. In all cases of the observation, he will choose a centre-pivot and 20 ha of drip (combination C2) with expansion path A. This alternative irrigation system combination is expensive in terms of investment but has a lower operating cost. The drip irrigation systems in each block expansion are purchased in year 1.

Planting sugarcane with the drip irrigation systems is all done in year 1, while the farmer starts to develop the centre-pivot irrigation system in the second year when initial capital is parameterized from R450,000 onwards. The reason for delaying sugarcane planting under centre-pivot is that drip irrigation systems outperform centre-pivot in yield variability by first-degree stochastic dominance (Haile, 2003). Besides, the crop area planted in the centre-pivot depends on available initial capital. For instance, at R450,000, 6% of the area of centre-pivot is planted in year 2, then 86% is planted in year 3 and the remaining 8% in year 9 to get a net worth of R3,633,594. With increasing capital, the whole area of the centre-pivot is planted in year 2 and year 3, and with enough capital, it is developed in year 2 at an initial capital level set to R630,000. Increasing initial capital also increases the net worth of the farm activity at the end of the planning horizon. The reason why the farmer does not develop the total crop in year 1 is that the life cycle of sugarcane is the same for all, and it was assumed that the farmer will continue planting and replacing sugarcane if it is initiated once. Hence, it is not wise to plant all 50 ha in year 1 because it has to be replaced in year 8, implying a huge amount of establishment cost while no income is generated in that year.

Therefore, from the results observed, it can be concluded that when the farm operator has enough capital, he is able to expand his sugarcane crop to the full 50 ha land. In addition, the irrigation system combination chosen and the alternative expansion path followed will tend towards the more expensive one, reducing the operating cost of the irrigation systems in the coming years.

When he has less initial capital, he is forced to invest in the systems sub-optimally due to the time value of money.

Table 3: Summary of the mixed integer dynamic linear programming results for 50 ha irrigation farm (2002)

Starting Liquid Capital (R)	Irrigation System Selected				Sugarcane Establishment (% of total area of the irrigation system)				Net worth in Present Value (R)
	System Type	Combination Type	Expansion Path	Expansion Time[4] (Year)	Year 1	2	3	9	
450 000	Pivot[1]	C2	A	1		6	86	8	3 633 594
	Drip[2]	C2	A	1	100				
	Drip[3]	C2	A	1	100				
480 000	Pivot[1]	C2	A	1		27	73		3 705 720
	Drip[2]	C2	A	1	100				
	Drip[3]	C2	A	1	100				
510 000	Pivot[1]	C2	A	1		43	57		3 753 388
	Drip[2]	C2	A	1	100				
	Drip[3]	C2	A	1	100				
540 000	Pivot[1]	C2	A	1		58	42		3 799 149
	Drip[2]	C2	A	1	100				
	Drip[3]	C2	A	1	100				
570 000	Pivot[1]	C2	A	1		73	27		3 843 771
	Drip[2]	C2	A	1	100				
	Drip[3]	C2	A	1	100				
600 000	Pivot[1]	C2	A	1		87	13		3 887 094
	Drip[2]	C2	A	1	100				
	Drip[3]	C2	A	1	100				
630 000	Pivot[1]	C2	A	1		100			3 928 111
	Drip[2]	C2	A	1	100				
	Drip[3]	C2	A	1	100				

Notes:
1) First block expansion (30 ha).
2) Second block expansion (10 ha).
3) Third block expansion (10 ha).
4) Time period of initiation of the irrigation system expansion.
C2 (30 ha centre-pivot, 20 ha drip).
A–dependent: single pump.

4 CONCLUDING REMARKS

The dynamic linear programming model shows that the amount of initial capital available to start an irrigation farm has a significant influence on the type of systems a farmer can invest in, the way crops can be expanded in the area available for the irrigation systems, and the speed of his full development of the farm. That is, with fewer financial constraints, he will invest and plant as early as possible due to the time value of money. When they are faced with financial constraints, farmers consider investments that are less capital intensive but which could imply higher operating costs. It is because they do not have any options, and it is the only option to start the business. However, when there are fewer financial constraints, they will select an investment that is efficient and capital intensive, thereby managing their operating cost significantly and efficiently. The model developed here for the growth process of an irrigated land is a useful model for farm application. The GAMS coding of the model is so generic that it can be adapted for any time horizon by merely changing the time variable. Besides, the procedure developed for modelling the interaction between decision variables such as tax deduction, borrowing, which is expressed as a function of net worth, deferring tax payments until a positive income is generated, and others showed the capability of the model to model the cash flow of the farm growth process more closely to real-life behaviour. A shortcoming of the model is that it ignores risk, and future developments should be directed towards developing procedures to take inter- and intra-temporal correlation between activities into account.

ACKNOWLEDGEMENTS

Financial assistance provided by the Water Research Commission (WRC) is gratefully acknowledged. The views of the authors do not necessarily reflect those of the WRC.

REFERENCES

Akhand NA, Larson DL & Slack DC (1995). Canal irrigation allocation planning model. *Transactions of the-ASAE* 38(2):545-550.

Barry PJ & Willmann DR (1976). A risk-programming analysis of forward contracting with credit constraints. *American Journal of Agricultural Economics* 58(1):62-70.

Bender FE, Kahan G & Mylander WC (1992). *Optimization for profit: A decision maker's guide to linear programming.* New York: Haworth Press.

Boehlje MD & White TK (1969). A production investment decision model of farm firm growth. *American Journal of Agricultural Economics* 51:546-563.

Brooke A, Kendrick D, Meeraus A & Raman R (1998). *GAMS: A user's guide.* New York: GAMS Development Corporation.

COMBUD (1998). *COMBUD Enterprise Budgets*. Directorate of Agricultural Economics, Pretoria, South Africa.

Haile BO (2003). *Development and application of a multi-period linear programming model to economically evaluate the growth process of a sugarcane farm in Mpumalanga*. Unpublished MSc Thesis, Department of Agricultural Economics, University of the Free State.

Hazell PBR & Norton RD (1986). *Mathematical programming for economic analysis in agriculture*. New York: Macmillan.

Kearnev M (1994). *An intertemporal linear programming model for pip fruit orchard replacement decisions*. Technical paper No 94/6, Ministry of Agriculture and Fishers, Wellington, New Zealand.

McCarl BA & Musser WN (1985). *Modeling long-run risk in production and investment decisions*. Proceedings of a Seminar Sponsored by Southern Regional Project S-180, Charleston, SC, March 24-27:129-148.

National Department of Agriculture (2002). *Resource information on the nine provinces of South* Africa. http://www.nda.agric.za, 20 September 2002.

Oosthuizen HJ & Van Zyl J (1995). Economics aspects of the privatization of the Marico-Bosveld government water scheme. *Agrekon* 34(1):23-38.

Oosthuizen LK & Grové B (2001). *Evaluation of the economic efficiency of irrigation systems for large and small-scale farming businesses*. Progress Report for Water Research Commission, University of the Free State, Department of Agricultural Economics, South Africa.

Radley R (2000). *Sagteware vir die ontwerp van besproeiingstelsels: 'n Ondersoek na geskikte pakkette*. Verslag vir LNR Instituut vir Landbou-ingenieurswese, Suid-Afrika.

Rae AN (1977). *Crop management economics*. Crisby Lockwood Staples, London.

Symington HM & Viljoen MF (1997). Optimal management strategies for typical farmer in the Vaalharts irrigation area during conditions of variable water supply. *Agrekon* 36(2):157-180.

Van Zyl J & Vink N (1989). Structural aspects of beef production on pastures in the summer rainfall producing areas of South Africa. *Agrekon* 28(3):19-25.

Viljoen MF & De Jager JM (1997). *Optimal production strategies and financial compensation for sustainable irrigation farming during drought on the Vaalharts Scheme in South Africa*. Sustainable Irrigation in Areas of Water Scarcity and Drought, Proceedings of the International Workshop, Oxford, UK, pp 1-5.

Willis C & Hanlon W (1976). Temporal model for long-run orchard decisions. *Canadian Journal of Agricultural Economics* 24:17-28.