USE OF MATRIX TABLES TO DESCRIBE SUGARCANE PRODUCTION AND INTERACTIONS BETWEEN SOIL, PLANT, CLIMATE AND MANAGEMENT FACTORS IN THE LOWVELD OF ZIMBABWE

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Abstract

Sugarcane production involves many factors which must include interactions between climate, soil, plant, management and advances in new technology. The system chosen is often a compromise and changes should be anticipated with the introduction of new technology and as constraints or opportunities occur. A matrix may be used to help understand the interactions and compromises that may be made. This paper describes the use of matrices in the production system in use in Zimbabwe. It also shows the impact that the use of chopper harvesters will have on the various components of the production system. The matrix can be expanded to include financial, environmental and other considerations for analysis. A matrix quickly highlights differences in the components of the production system and can also pool a lot of information. It can be adapted to meet specific objectives or needs and should be considered as being very versatile, flexible and user friendly. The biggest challenge is to find appropriate short words to describe the interactions or effects within the matrix. To some extent, this makes them user-specific when the background information is not understood. In this paper the information in the Zimbabwe Sugarcane Production Manual is used to supply the information needed. This paper outlines how the large inflow of technological information presented at SASTA can be collated into matrices used to describe different systems of production. The matrices can be adapted to meet the specific needs of researchers, extension workers and growers and can be expanded to include financial considerations.

Introduction

The Zimbabwe Sugarcane Production Manual (ZSPM), and all the new technology included in it, highlighted the need to examine the choices available when a system of production for an estate or individual field is selected. A matrix was used to do this in the section of the ZSPM titled 'Systems of Production' and that forms the basis of this paper. The system of production chosen must take into account climate, soil, plant and management interactions. The introduction of new technology often affects the current production system and modifications may be required to ensure that full benefit is achieved. The matrix is useful as it explains the rationale used in simple terms, and it can be used to describe the system as it is and can track changes. Matrices show how many options there are and how significant some of the interactions can be. The number of options available is increasing and assimilation of all the new technology is a challenge even to technologists. The matrix is a simple method of presenting the information. It was used in a paper describing choices available for different systems of coffee production in Zimbabwe which could be considered in Hawaii (Clowes, 1997). This paper describes the use of matrices in the sugarcane production system in Zimbabwe, and the impact the introduction of chopper harvesters will have on the system. A matrix is used to compare the effects of hand harvesting and chopper harvesting on the system.

Materials

Matrices require information to be reliable and complete. The Zimbabwe Sugarcane Production Manual (Clowes and Breakwell, 1998) is used here to illustrate the use of a matrix to describe the interaction between components of the production system, including the use of new technology. Matrices were developed to compare the interaction of climate, soil, plant and management factors on the production system.

Approach

This paper is divided into two parts to help show how matrices can be used in different situations. The first part, encompassing Tables 1-6, describes major components of the management system; while the second (Table 7) considers the impact new technology can have on the total system. The matrices help highlight changes that are recommended to ensure that the full benefits are derived. The information in the section 'Systems of Production' in the ZSPM uses matrices to highlight management choices available to producers, in order to help gain a better understanding of the system of production as a whole rather than as separate disciplines. The matrices help to determine the areas requiring further research as well as the interaction of one factor with another. The latter is not always known or appreciated when new technology is introduced into an existing system of production. This method of holistically examining the system of production should be of great benefit to those wanting to understand the impact of different conditions on the system, or to those making comparisons.

Examples

The wide choice of factors involved in the system of production and the effect some of these factors have on each other are shown in the following matrices:

Table 1 shows the effect climate and management have on the different stages of plant growth and the susceptibility or sensitivity to different factors. One can add or alter the factors depending on the prevailing conditions. An important factor indicated in the matrix for Zimbabwe is that stalk elongation occurs only when mean daily temperatures exceed 18°C (i.e. from mid-August onwards). This has a strong impact on irrigation management. The emphasis, when water is either scarce or expensive, is to reduce irrigation in winter and to ensure full irrigation when stalk elongation occurs during the hotter summer months.

The matrix shown in Table 2 helps with the selection of variety (five are available in Zimbabwe). It gives the characteristics of the variety and sensitivity to management. If mill distance is great, variety CP72-1312 would be suited to early and mid season harvesting. Late season harvesting would be avoided due to its sensitivity to Yellow Leaf Syndrome (YLS). This variety also has high tolerance to Hot Water Treatment (HWT). Response to ripener still has to be ascertained and this indicates an area where work is needed.

This matrix (Table 3) classifies the soil on the basis of texture (soil and clay%) and shows the effects of the type of soil on different management operations. Soil type in the south east Lowveld ranges from heavy black basalt, with over 50% clay, to coarse sands with over 85% sand. Texture has a great impact on soil and field operations. Timing of planting, harvest and cutting must all take cognisance of soil type and topography. The heaviest transport load is at harvest, when most damage can be done to the soil and to subsequent operations (e.g. damage to sub-surface drip equipment, particularly if buried too shallow). Soils can be too wet at harvest and equipment may be unsuited to wet conditions (e.g. tyres). Ripping is sometimes practised after harvesting ratoon crops. The matrix indicates that soils at opposite ends of the texture range are unlikely to benefit from ripping but for different reasons. The basalts are self churning whereas the coarse sands seldom need ripping as they tend to compact less. Soil type impacts on nutrition, weeds and pests as indicated in Table 3.

The data in Table 4 show the variability over 40 000 hectares of soil in the south east Lowveld. It covers distinguishing characteristics and factors affecting irrigation, from permeability to depth, as well as the likelihood of salinity and sodicity hazards. The matrix helps to pinpoint management differences based on soil type.

Table 5 shows the choice of conservation tillage system based on different soil conditions, residue cover and irrigation method. It shows that mulching is not suited to cold wet soils but is appropriate for warm dry soils. Mulching is also not appropriate for furrow irrigation, whereas it is appropriate for the other systems. The advent of the chopper harvester and the need to chop green cane is likely to favour conservation tillage systems wherever furrow irrigation is not practised.

Table 1. The plant growth/climate and management matrix.

	GROWTH STAGE					
CLIMATE	Setts	Germination	Canopy	Stalk elongation	Growth	Maturity and ripening
Heat	very hot, fast germination and pre-plant irrigate	beneficial, irrigate often	shorter time to canopy	after mid-August >18°C	requires irrigation + heat	apply ripeners for sucrose accumulation
Waterlogging	rot	poor germination	slows growth	slowed	slowed - population reduced	not desirable
Cold	slow germination	emergence spread out	slows growth	not <18°C	slow	natural ripening
	MANAGEMENT					
Drainage	+	+	+	++	++++	+
Tilth	+++	+++	+			
Irrigation	pre-irrigation	if crust, irrigate at emergence	+	+++	++++	Dry off - if ripeners used, irrigate pre-application.
Nutrition	P and S pre-plant	N and K	N and K	Nil	Nil	Nil
Weed control	remove perennials before planting	pre-emergence (Gramoxone pre-emergence cane)	pre- or post-emergence herbicides	hand weed, spot spray eg Shamva* and Watergrasses**	Nil	Nil
Roguing for Smut*** and Shamva grass	remove volunteers	remove volunteers	essential	essential for Shamva grass	Nil	Nil

*Shamva grass = *Rottboellia cochinchinensis* (was *exaltata*) **Watergrasses = *Cyperus* spp. ***Smut = *Ustilago scitaminea*

Table 2. Variety/growth/management matrix.

CHARACTERISTIC	VARIETY				
	NCo376	N14	CP72-1312	ZN1L	ZN2E
GROWTH					
Seed	100%	124%	122%	115%	119%
Emergence	Good	+	++	+	+
Plant	Good	+	+	+	+
Ratoon	Good	+	+	+	+
Stalk pop/ha	146 000	118 000	117 000	130 000	122 000
Canopy cover	Good	=	+	=	+
Stalk height	Good	+	++	+	–
Lodging	Good	–	+	+	+
ERC%	100%	101%	109%	101%	112%
Cane t/ha	100%	106%	102%	105%	91%
ERC t/ha	100%	108%	112%	105%	102%
Flowering	Intermediate	+	–	–	–
Tolerance to HWT	Good	Good	Excellent	Poor	Very poor
DISEASE					
Smut susceptibility	Very	Tolerant	Tolerant	Most tolerant	Most tolerant
YLS visual signs	Slight	Moderate	Severe	None so far	Negligible
RSD infection	High	Very high	High	High	Very high
Leaf scald	Tolerant	Tolerant	Tolerant	Tolerant	Intermediate
MANAGEMENT					
Harvest season	All year	Best early to mid	Early - avoid YLS	Best late	Best early
Green cane	Suitable	Not as suitable	Most suitable	Suitable	Not as suitable
Nutrition	Standard	Higher N & K	Higher N & K	?	?
Water	Hardy	High requirement	High requirement	High requirement	High requirement
Herbicide	Tolerant	Leaf scorch	Tolerant	Tolerant	Tolerant
RIPENER					
Ethrel	1,5 L/ha	Nil	?	?	?
Fusilade Super	0,3 to 0,45 L/ha	0,45 to 0,6 L/ha	?	?	?

Table 6 gives the recommended primary conservation for different conditions (e.g. slope, soil depth, level of mechanisation, use of grass strips and type of irrigation). This will be of particular importance to the LOMAZ scheme proposed for the Bindura and Shamva areas, which have higher annual rainfall and steeper topography than the Lowveld.

The matrix in Table 7 shows the impact of chopper harvesting sugarcane which is currently hand harvested in the south east Lowveld. It shows that the introduction of the chopper harvester will force changes to be made to the present production system. The following are considered to be the most significant:

- Mills and transport systems will have to be adapted to cope with cane billets.
- Mill breakdowns will have serious consequences on chopper harvested cane. The two mills would benefit from close liaison and co-operation. Growers would have to stop harvesting immediately when a mill breakdown occurs, and all cane harvested would be delivered to the one mill in operation (fortunately only 25 km apart).
- Change from planting in the furrow to the ridge (with some evidence of crop loss).
- Removal of stones essential to reduce breakdowns (chopper harvester and mill) and to maximise throughput.
- Redesign furrow layout to produce longer rows.
- The labour structure for harvesting will be different: higher grades and more skill.
- Greater fuel and equipment costs; fewer general labour but more skilled labour.
- Mobile and fully equipped mechanical back-up required in the field.

Table 3. Soil/management matrix.

	Sand	Loamy sand	Sandy loam	Sandy clay loam	Clay	Basalt
Sand % Clay + silt %	>85% <15%	80-85% <25%	>50% >20%	>50% 20-30%	<50% 30-50%	 >50%
Drainage	good	good	good	good	poor	poor
Wet areas**	not common	not common	sometimes needed	more common	required	Required
LAND PREPARATION						
Planting						
Ripping	not needed	seldom needed	sometimes needed	more common	often needed	not needed - as self mulching
Ploughing*	not necessary	normal	normal	normal	normal	normal
Land planing	essential - for furrow irrigation	essential - for furrow irrigation	essential - for furrow irrigation	essential - for furrow irrigation	essential - for furrow irrigation	essential - for furrow irrigation
Harrowing	common	common	common	common	common	common
Rolling***	not needed	not needed	not common	not common	not common	not needed
Tilth	not applicable	sometimes applicable	required	required	required	not necessary
Ratoon						
Trash parting	on each ridge beneficial	on each ridge beneficial	on ridge every 5-8 rows for furrow	on ridge every 5-8 rows for furrow	on ridge every 5-8 rows for furrow	on ridge every 5-8 rows for furrow
Re-ridging	most beneficial	most beneficial	common	common	common	common
Ripping	not needed	not needed	generally not needed	generally not needed	sometimes advisable	not advised
IRRIGATION						
Furrow <2% slope	unsuitable	mostly suitable	suitable	suitable	suitable	Most suitable
Drip	suitable	suitable	suitable	suitable	suitable	suitable
Overhead	suitable	suitable	suitable	suitable	low application rates	low application rates
Dry-off	short	short	normal	normal	normal	normal
Over-irrigate	leaches	leaching possible	avoid - except removal salts	avoid - except removal salts	avoid - except removal salts	avoid - except removal salts
Stress	most sensitive	most sensitive	less sensitive	less sensitive	least sensitive	least sensitive
N	split x 3	split x 2	split x 2	split x 2	split x 2	split x 2
P – appl once/ann	not always needed	as needed	normally needed	normally needed	normally needed	normally needed
K	split x 2	normally needed	normally needed	normally needed	normally needed	normally needed
S	adequate in SSP†	adequate in SSP	adequate in SSP	adequate in SSP	adequate in SSP	adequate in SSP
Trace elements	ferrous sulphate anthill	ferrous sulphate anthill	ferrous sulphate anthill	ferrous sulphate anthill	ferrous sulphate anthill	ferrous sulphate anthill
Gypsum	sodic soils	sodic soils	sodic soils	sodic soils	sodic soils	sodic soils
LIME						
Calcitic	preferred	preferred	preferred	optional	optional	optional
Dolomitic	not required	not required	not required	optional	optional	optional
WEEDS	remove	remove	remove	remove	remove	remove
Hand weeding	suitable	suitable	suitable	suitable	suitable	suitable
Herbicides	follow label	follow label	follow label	follow label	follow label	follow label
Volunteers	remove	remove	remove	remove	remove	remove
Roguing	smut/shamva grass	smut/shamva grass	smut/shamva grass	smut/shamva grass	smut/shamva grass	smut/shamva grass
INSECT PESTS						
Nematoides	consider treatment	seldom treat	no treatment	no treatment	no treatment	no treatment
BMB	common	common	common	common	common	common
Termites	most common	sometimes a problem	not common	not common	not common	not common
PLANTING						
Furrow	preferred	preferred	preferred	optional	optional	ridge
Ridge	not suitable but can split ridge after planting	not suitable but can split ridge after planting	not suitable but can split ridge after planting	optional	optional	optional

* Rip and heavy harrowing can be equivalent to a ploughing
** Wet areas often result from topography, old watercourses and sometimes impervious layers in the subsoil
*** Rolling facilitates upward movement on cloddy soils and is recommended for drip at planting
† SSP = single superphosphate.

Table 4. Soil properties of the sugarcane industry in the South East Lowveld.

Soil series	Soil parent material	Colour and texture: Topsoil Colour	Topsoil Texture	Subsoil Colour	Subsoil Texture	Depth cm	Physical properties: Permeability	Salinity sodicity hazard	Intake rate	Total available moisture: Depth cm	mm
Triangle PE 1	Basic gneiss	Reddish brown	SaCL	Red	SaC	60-120	Adequate but more restricted in lower horizon of deep soils	Moderate to high	Moderate	0-60 0-75 0-90 0-105	78 100 120 135
Triangle P 1	Siliceous gneiss	Brown	SaL	Yellowish red	SaCL	30-80	Adequate in upper horizon, rapidly becoming restricted with depth	Moderate to high	Moderate to rapid	0-30 0-60 0-75	36 72 90
Triangle P 2	Siliceous gneiss	Brown	LSa	Yellowish red	SaL	20-70	Adequate in upper horizon, rapidly becoming restricted with depth	Moderate to high	Moderate to rapid	0-30 0-60	27 63
Triangle P 3	Acid siliceous gneiss	Greyish brown	Sa	Pale brown	Sa/LSa	20-70	Rapid in soil horizon, severely restricted below	Moderate to high	Rapid	0-30 0-60	24 45
Triangle P 4 (Mopane soils)	Siliceous gneiss	Dark brown	SaL	Reddish brown	SaCL/ SaC	40-100	Moderate in upper horizon, very restricted below	High	Moderate	0-40 0-80 0-100	48 96 120
Triangle PE 2 (Mopane soils)	Basic gneiss	Dark red-dish rown	SaCL	Red-brown	SaC	40-100	Moderate in upper horizon, very restricted below	High	Moderate	0-40 0-80 0-100	48 96 120
Triangle PE 3	Basic gneiss	Dark brown	SaC	Black	C	60-90	Relatively impermeable	High	Slow	0-30 0-60 0-90	42 84 126
Triangle P 5	Siliceous gneiss	Greyish brown	LSa	Black	SaC/C	20-70	Relatively impermeable	Very high	Slow	0-30 0-60	27 60
Nyamandhlovu K 1	Sandstone	Brown	Sa	Brown	Sa	100	Adequate	Low	Rapid	0-30 0-60 0-90	20 40 60
Chisumbanje B 1	Basalt	Black	C	Black	C	60-150	Restricted	Moderate to high	Initially rapid, then very slow	0-60 0-90 0-120	64 128 192
Alluvial soils Sabi series	Alluvium	Brown	Variable LS/ SaCL	Brown	Variable SaL/ SaCL	50-150	Adequate	Low	Rapid	Variable depends on texture	Variable

Key to Texture: Sa = Sand; SaCL = Sandy Clay Loam; SaL = Sandy Loam; SaC = Sandy Clay; LSa = Loamy Sand; C = Clay
Source: Sugarcane Irrigation Handbook (1982) KE Cackett and ZSPM (1998)

Table 5. Conservation/tillage matrix.

CONDITIONS	TYPES OF CONSERVATION TILLAGE: Mulch	Ridge	Strip Cropping (for rainfed break crop)	Potholes
SOILS				
Cold/wet	NA	Ap	NA	NA
Warm/dry	Ap	Ap	Ap	Ap
RESIDUE COVER				
> 30%	Ap	NA	IS	NA
< 30%	NA	Ap	IS	NA
IRRIGATION				
Drip	Ap	Ap	NA	Ap
Sprinkler	Ap	Ap	NA	Ap
Centre pivot	Ap	NA	NA	Ap
Furrow	NA	Ap	NA	NA

Ap = Appropriate; IS = In strips NA = Not appropriate
Source: ZSPM (1998) Conservation Tillage; HE Elwell

Table 6. Matrix for primary conservation works.

CONDITIONS	TYPE OF PRIMARY CONSERVATION				
	Skeletal works	Irregular layout	Parallel layout	Broad based contours	Bench terrace
LAND SLOPES					
< 2%	Ap	NA	NA	NA	NA
2-10%	NA	Ap	LSU	Ap	NA
> 10%	NA	OIC	NA	NA	OIC
SOIL DEPTH					
Shallow	Ap	Ap	Ap	NA	NA
Moderate	Ap	Ap	Ap	Ap	D
Deep	Ap	Ap	Ap	Ap	Ap
OPERATIONS					
Hand	Ap	Ap	Ap	Ap	Ap
Machine	Ap	NA	Ap	Ap	Ap
GRASS STRIPS (Not shallow soils)	OIC	OIC	D	NA	D
IRRIGATION					
Drip	Ap	D	Ap	Ap	D
Sprinkler	Ap	Ap	Ap	Ap	D
Centre pivot	Ap	NA	NA	D	NA
Furrow	D	D	Ap	NA	NA

Ap = appropriate; D = difficulties encountered; LSU = (if) land shapes uniform; NA = not appropriate; OIC = only in conjunction with conservation tillage
Source: ZSPM (1998) Conservation; HE Elwell

There could also be impact from:

- Yield decline and the effect of monoculture.
- Varietal suitability to mechanised harvesting (many aspects from soil, pest and disease and mechanical effects) and the need to breed varieties for this (approximately 13 years at present).
- Crop loss (direct and indirect).
- Vigour measured as number of ratoons and yield decline over time.

The matrix shows at a glance the impact of the change. The effects of the various factors can be quantified and the information included in the matrix.

Discussion

This paper illustrates the use of a simple matrix to help define interactions between any two components in the system of production. It is important that the new technology is properly integrated into the production system, and that choices are made on the basis of the information available and also adapted as and when needed. The production of the ZSPM in separate sections based on discipline, tended not to interface all the data from other sections. The section titled 'System of Production' was therefore included. It was made up of matrices so that the information contained in earlier sections could be seen as part of the whole production system. The rationale could be followed up by referring back to the relevant sections.

Increase in choices of available technology has been covered in the matrices presented in the paper, with reference to:

- **Variety** - with early, late and all year round and with specific attributes suited to specific conditions.
- **Irrigation system** - furrow, sprinkler, centre pivot, drip and floppy.
- **Mechanisation** - land preparation, cane loading, transport and harvesting innovations are increasing.

Only selected information has been included as the interaction of herbicide/soil type/type of weed/irrigation system lends itself to simple examination in one or more matrices. In addition, the following changes which impinge on the system and economics of production must be considered:

- **Irrigation** cost and availability (climate change).
- **Pest and disease threats** (e.g. Black Maize Beetle and YLS). Note: Eldana borer present only adjacent to cane in Zimbabwe.
- **Skills** required to make full use of the new technology.
- **Training and back-up needed** to ensure full use of the technology.

All these have to be considered and can be built into matrices to describe the needs, costs and availability to the production system. Matrices have been used to define our current state of knowledge and how it has been incorporated into the production system. Matrices could be used as an extension tool to determine whether or not the choices given have been made and, if not, whether there was good reason not yet understood which could then be added to the matrix.

The matrices are useful in describing the changes taking place. The information presented in the paper shows a basic matrix design; but more complex matrices could be produced and they could include financial implications. This paper shows that there are many factors involved in the system of production and that matrices can help show how all the factors interrelate, and how different conditions could affect the choices made in a positive or negative way.

Table 7. Matrix showing the impact of the change from hand to chopper harvesting (CH).

Component	Hand	Mechanical (CH)*	Comment
RESOURCE USE			
Labour use	High	Low	5 t/day cf 60 t/hour
Skill level	Low	High	CH operators learning curve
Fuel	Minimal	High	Devaluation favours labour use
Housing	High	Low	Higher grade CH
Workshop and spares	Minimal	High	Including mobile unit
Training needs	Low	High	Quite different
Training intensity	High	High/low	CH higher initially
MODIFICATIONS REQUIRED			
Mill reception	Nil	One mill 1999	Triangle cannot yet accept CH
Transport	Nil	Modify for billets	Trailers need modification
Planting	Versatile	Ridge only	Convert back to planting on ridge
Stones	Versatile	Must remove	A major threat in Lowveld
Irrigation furrow	Versatile	i) Longer rows	Improve throughput
		ii) Modifications	For movement and turnaround
Centre pivot	Versatile	Straight lines	Straight lines preferred for CH
SENSITIVITY			
Wet weather – operation	Versatile	Bogged down	Not for long periods
Wet – deterioration	Slower	Faster	Delays increase losses
Wet – Irrigation	Flexible	Vulnerable	Subsurface drip vulnerable
Mill breakdown	Less	Rapid	Deterioration
Labour availability	More	Less	HIV impacting on productivity
Yield decline	Less	More	Not measured less dry winter
Sugar losses	Less	More	Adequate labour and supervision
Variety	Less	More	Select suitable varieties
Pest and disease	Less	More	Mainly soil/stem
Crop vigour	More	Less	If pests and diseases build up
Crop deterioration	Less	More	Pre and post rains - hot

*CH is introduced when cutters are scarce or costly, producivity is low or when green cane harvesting.

Research and extension must impact on the system of production in a positive way for it to be effective. Any system of production tends to be a compromise with trade-offs which must be understood for full benefits sometimes to be realised. This will be increasingly important as further varieties are introduced. Some may have failings that may not become apparent for some time, or perhaps only when a change is made (e.g. new herbicide introduced).

Examples in Zimbabwe have been: variety CP72-1312 has been changed from an all year round variety to an early and mid season harvest variety due to YLS. Variety ZN2E and, to a lesser extent, ZN1L have not performed as well as NCo376 in the diffuser. The diffuser (change in milling process) may not be as well suited to the varieties we are tending to produce with high quality and low fibre, which may have the wrong characteristics or bulk density. This makes it essential to include all factors in the system of production as well as milling when appropriate. We could also quantify the amount of change that is occurring in terms of hectares or persons putting technology into practice.

The use of matrices helps to show the choices available and the interactions that take place between the climate/soil/plant and management factors. It has been shown that milling and other factors can sometimes be included to advantage.

Conclusion

Matrices can be used to pool technology from different disciplines and to incorporate it into an understanding of the system of production and to show the compromises that are made. It also shows where information is missing and where further work is required. The matrix is a simple tool which can help in understanding complex situations, monitor changes and also forecast future trends and changes that are likely to take place. It is a useful way of presenting information and testing its relevance over time. The challenge is to find words that are short and specific enough to describe the interface. It can limit the use of the matrix to those who have sufficient understanding of the information it contains. Research and extension can be guided by the interactions contained in the matrices. The increasing amount of technology available can easily be incorporated into the matrix to help gain an understanding of possible effects and interactions on the components of the production system. The matrices provide a more holistic understanding of the production system in a user friendly way.

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