CROP PRODUCTION AND FERTILIZATION IN THE RSA: A FUTURISTIC VIEW

DR DM SCOTNEY, Soil and Irrigation Research Institute

Background

It is appropriate to briefly review some issues concerning population growth, land utilization and fertilizer usage.

Population growth is one of the most important factors that will affect future crop production. This includes changes in the demand for selected agricultural products and the purchasing power of a large percentage of the population. The total population will almost double 25 years hence and to keep pace with demand, food production will need to increase from the present 2,5% to over 4% per annum. Spies (1987) concludes that future markets for agricultural commodities will be determined largely by demands from the Black population.

Land utilization data reflect that of the 107 million ha of the RSA (excluding 16 million ha for TBVC and self governing States) 85% is used for agriculture. This excludes 3% under small-holdings and 1% under forestry. According to Terblanche (1986) the agricultural land comprises 87% natural veld, 11% (10 million ha) dryland cropping, just over 1% planted pasture and almost 1% under irrigation. The areas planted to important field crops and their gross values for 1975/76 and 1985/86 are shown in Table 1.

The complete dominance of maize (58%) is clearly reflected and together, maize, wheat and sugarcane occupy 75% of the total area planted to the crops shown in Table 1. Their combined gross value is 62% of the total. There is little evidence of recent horizontal expansion except for some crops such as cotton. However, Burger (1983) reported an annual increase of 0,5% for the area planted to maize. Gross values have risen significantly and certain crops (e.g. tobacco) show high gross values for the area planted.

Information of this kind tells nothing of the ecological implications of the crop production nor the standards of agronomic practice. Closer examination of yield data reflects large annual fluctuations which Schoeman and Scotney (1987) ascribe mainly to erratic rainfall and poor soil selection. With the exception of sugarcane which shows a steady annual increase in yield ha^{-1} ($\pm$ 1 ton) over a 30-year period (Wood, 1987) average yields of other major crops are generally low and highly variable. Analyses of yield data (1969/70-1985/86) for major production areas reflect average yields of 2,2 ha^{-1} and 1,3 t ha^{-1} for maize and wheat respectively.

Data presented by Kassier *et al* (1987) show that fertilizer (NPK) usage reached a peak ($\pm$ 900t) in 1981 only to be followed by a sharp decline to lows in 1983 and 1984, with a slight upturn predicted for 1987. Lime has followed a similar trend. It is of interest to note that years of highest and lowest yields coincide with the fertilizer usage. According to Burger (1983) almost 60% of all fertilizer used is applied to maize and blanket applications to soils of varying potential have led to much over- and under-fertilization. It is also clear that much crop production takes place in high risk areas. Despite this, overall production has remained well ahead of the demands for food and has allowed for substantial exports.

Potential for crop production

In 1971 the Department of Agriculture and Water Supply initiated a countrywide land type survey aimed to

TABLE 1. Extent planted and gross value of selected field crops

Crop	Extent planted (100 ha)		Gross value R10^6	
	1975/76	1985/86	1975/76	1985/86
Maize	4548	4044	500	2014
Wheat	1944	1925	273	744
Sugarcane	341	430	232	578
Sunflower	288	323	45	106
Groundnuts	159	221	29	66
Cotton	26	126	13	96
Tobacco	36	34	56	195
Drybeans	65	67	21	67
Soyabeans	22	30	2	14
Total	7429	6979	1171	3880

(Source: Abstract Agric. Statistics, 1987) providing an inventory of soils, terrain forms and climates (MacVicar, 1986). Such an inventory allows reliable assessments of potential to be made and, when matched to crop requirements, provides the best means for classifying land suitability (FAO, 1978). The land type survey has enabled several assessments of agricultural potential to be made at regional level of which that of the Highveld Region is particularly valuable (Scheepers *et al*, 1984). Although not yet complete the land type survey provided the basis for Schoeman and Scotney (1986) to make a tentative and general assessment of the rain-fed cropping potential of the White areas of the RSA, as shown in Fig. 1.

land use in each region suggest a great need for adjusting cropping pattern to available potential. Recent studies in the Highveld suggest that 1,7 million ha maize is grown on marginal land (Dept. Agric., 1986). Similar adjustments appear necessary in the Free State region.

Ignoring the issue of individual farm viability Schoeman and Scotney (1986) found that if maize in the main production areas were planted according to soil potential, a total crop exceeding the 1984/85 level could be reaped from an area one third smaller than the area planted in that season. Similarly the total area presently planted to maize in the Highveld region (3,6 million ha) could be

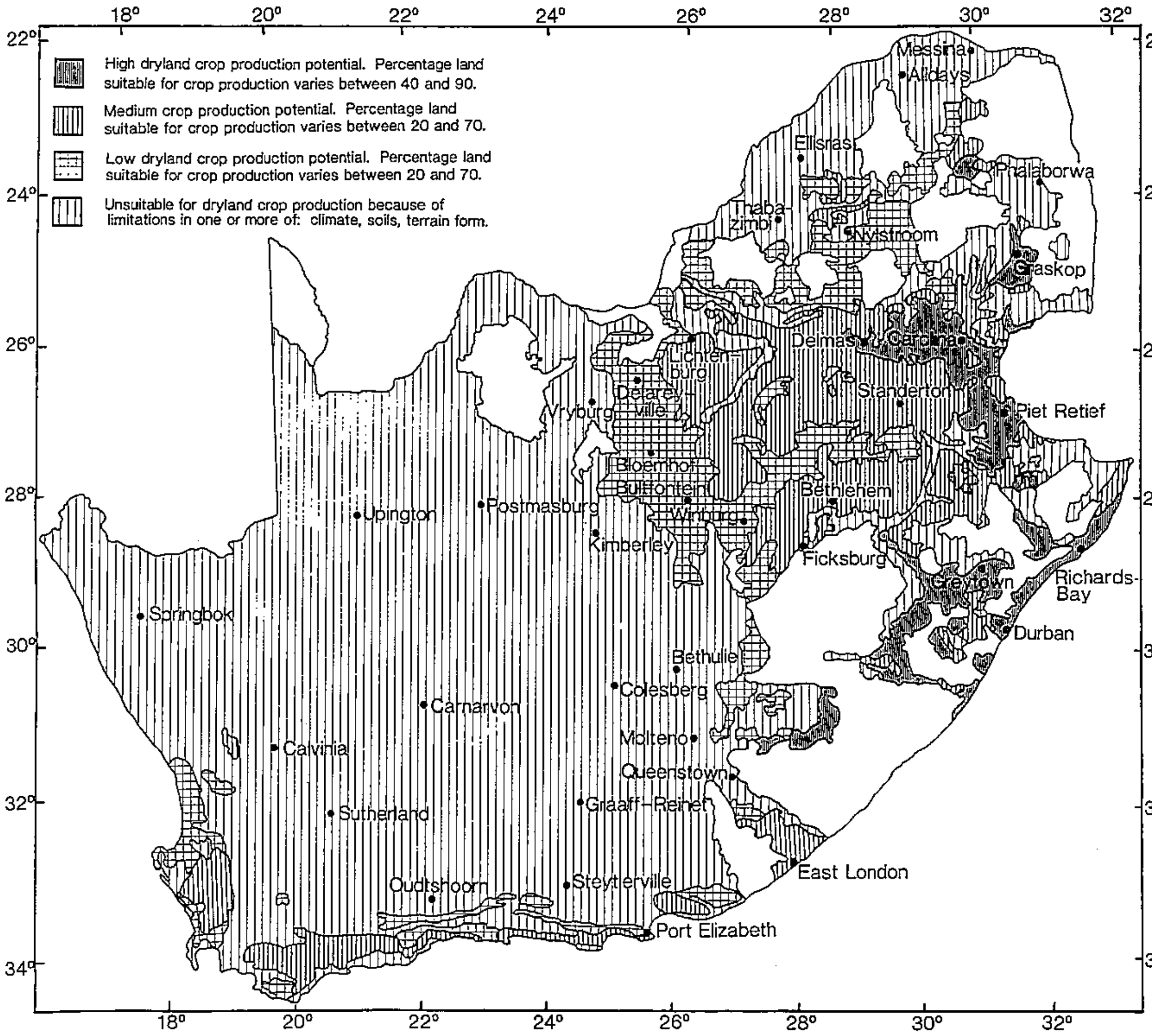

Fig 1. Rainfed cropping potential in the RSA (after Schoeman and Scotney, 1986)

Estimates of the nett productive areas of each potential class in various agricultural regions are presented in Table 2. The study shows that 13,5% (14,2 million ha) is suitable for crop production with only 3% (3,1 million ha) found to be of high potential. Most of this land lies in the Natal and Transvaal regions. Comparison of these data with the present extent of cultivation shows that an area of 1,3 million ha is available for horizontal expansion. The assessments when viewed against present

accommodated on medium and high potential land. A national target of 6 million t could be comfortably realized if totally restricted to high potential land.

Inherent natural resource features can greatly influence fertilization and liming practice. Highly weathered dystrophic soils characterize most of the high potential land. Substantial inputs of fertilizer and lime are required but will vary according to crop and pasture type.

TABLE 2. Crop production potential of white farmland — RSA (after Schoeman & Scotney 1987)

Agricultural Region	Rainfed crop production potential						Total ha x 1000	Region/ RSA %
	High		Med		Low			
	ha x 1000	%	ha x 1000	%	ha x 1000	%		
Transvaal	1 199	7,9	890	5,8	1 043	6,8	3 131	20,5
Natal	1 539	26,4	440	7,5	70	1,2	2 049	35,1
Highveld	190	1,6	4 440	38,3	1 316	11,4	5 947	51,3
Free State	–	–	68	0,4	946	4,6	1 014	5,0
Winter rain	–	–	912	6,6	583	4,2	1 495	10,8
E. Cape	194	3,6	241	4,5	176	3,3	612	11,4
Karoo	–	–	10	0,03	10	0,3	20	0,06
Total RSA (105 373 400 ha)	3 122	3,0	7 001	6,6	4 644	3,9	14 268	13,5
Present cultivation							12 915	
Potential expansion							1 353	

Surveys made of the distribution of acid virgin topsoils show that 5,0 mill. ha (5,5%) and 10,9 mill. ha (12,1%) of the country are strongly acid (pH KC1 < 4,5) and moderately acid (pH KC1 4,5-5,5) respectively (Pedology staff, 1980).

General assessments are of little value at the farm level where far more resource information is needed. Soil properties, such as available moisture capacity and effective depth together with local climate are important features that determine landuse options. Even in high rainfall areas shallow rooting depth caused by aluminium toxicity can result in moisture stress and crop failure. For instance, Mallett *et al*, (1985) found the placement of lime to a depth of 550 mm necessary to avoid the adverse effects of dry spells.

Possible influences on future crop production and fertilization

Future development in the agronomic field will be influenced by issues such as market demand, price policies, the impact of research and the success of technology transfer. Short and longterm strategies will differ and forecasts over the longterm are difficult. According to Spies (1987) 'dit is nie moontlik om die langtermyn vraag na landbouprodukte te voorspel nie'. Despite this, some possible influences and trends are noted.

Demand for annual field crops

Future production should be aligned to the available cropping potential and the demands for self sufficiency and trade. It is appropriate to compare the present average production and consumption of selected commodities as presented in Table 3. From this it would appear that the demands are largely being met.

Denny (1986) predicts that by the year 2000 the likely demand for protein will be approximately 894 500 t. Total production, mainly of plant origin, should exceed this amount.

The demands of the livestock industry could provide additional outlets for the crop farmer. The total feed requirements for livestock estimated by Denny (1986) exceed 9,6 mill. t giving a shortfall of 66 000 t mainly comprising wheaten bran, cotton cake and fishmeal. Sophisticated ration formulation allows considerable flexibility in matching supplies to demand but substitutes for fishmeal create a special challenge. Snyman (1986) has stressed the need to increase food production at prices commensurate with the purchasing power of the potential market. In his view, even a conservative aim of 7,5 mill. t *maize* is well within reach but any production above local demand (± 6 mill. t) could force prices down.

The problem of replacing maize on marginal land with crops such as grain sorghum and sunflower is not only complex but will demand higher levels of managerial skill from the farmer.

While *grain sorghum* is likely to expand onto heavy textured soils, increasing *wheat* production at a rate commensurate with population growth and changing preferences offers considerable prospect. The current annual production of 1,8 mill. t will have to be increased to 3,8 mill. t by the year 2000 (4% per annum). Wheat could replace maize in some areas provided soils are carefully selected.

The prospects for oil seed crops are reasonably bright with an annual growth in production of 3% to 5% needed. In the case of *sunflower* the estimated demand will

TABLE 3. Average production and consumption of selected commodities in the RSA (after Le Roux, 1987).

Commodity	Production $Tx10^6$	Consumption $Tx10^6$
Maize	10,7	5,5
Wheat	1,8	2,1
Grain sorghum	0,7	0,6
Groundnuts	0,25	0,8
Sunflower seed	0,33	0,23
Soyabeans	0,04	0,038
Dry beans	0,084	0,06
Beef and veal	0,60	0,64
Mutton	0,220	0,227
Pork	0,11	0,11
Poultry	0,507	0,520
Dairy products	0,113	0,131

1 normal season assumed

be of the order of 720 000 t, much of which could be achieved by raising current yield levels to 1,5 t ha^{-1}. However, some horizontal expansion will be necessary. According to Snyman (1986) current *groundnut* production is plagued with high input costs, yield variability and inadequate management. No major changes in production are expected. There are definite prospects for *soyabean* production, especially in the eastern Highveld and Free State areas. Although this could make good shortages in fishmeal the extent is unclear. While prospects for *drybeans* are good, the current demand of 62 600 t is easily met and unless other markets develop normal increases will suffice.

There is good potential for expanding *cotton* production, especially in the TBVC States. Current production is close to 300 000 bales (200 kg) with a likely demand of 400 000 bales (Snyman, 1986). Increasing local production could provide major savings in foreign exchange. *Tobacco* provides high financial returns but the declining demand does not suggest much scope for expansion.

Independant states and self-governing territories

Any crop production strategy for the RSA should be seen in context with the demands and production of neighbouring territories as well as other Southern African countries. Although Avery (1985) presents an optimistic view of world food production, the 20 percent decline per capita food production in Sub-Saharan Africa between 1960 and 1983 noted by Brady (1986) gives cause for concern.

The independant and self-governing territories total 16,3 mill. ha. Tomlinson quoted by Terblanche (1986) suggests that these areas possess 23% of South Africa's total agricultural potential and could feed almost twice the present population (15,4 mill.). At present about 5% of agricultural production takes place in these areas which can meet the needs of about 2,5 million people (Terblanche, 1986).

In the TBVC States the potential for expanding dryland and irrigation production appears to exceed one million ha (DBSA, 1987) but more accurate assessment of both present and potential production is urgently needed. Likewise, data on fertilizer usage are virtually non-existent. It should be appreciated that 'fertilizers can unlock dramatic increases in productivity. Proper use of appropriate fertilizers could increase yields by 50% -60% in developing countries. A ton of fertilizer often translates into 10 tons of grain' (IFDC, 1985).

Pasture production

The National Grazing Strategy could greatly influence crop production and fertilizer usage. Raising stocking rates through veld reinforcement and replacement by pastures is the best means of overcoming the problem of veld degradation. Pastures will also play a vital role on marginal land where the introduction of livestock enterprizes can provide stability to farming systems.

The present extent of pasture production is shown in Table 4. Over the past 10 years the area under pasture has increased by 75% and at present carries 2 million animal units (Pieterse, 1986). Yields of irrigated pasture are 30% to 40% higher than those for dryland.

The potential for pasture production in South Africa is vast and estimates have ranged from 12 to 24 million ha. According to Edwards and Booysen (1974) 12% of the country is suited to total replacement of the veld and 23% to reinforcement techniques. Most of the available potential lies in the frost-prone summer rainfall areas.

By way of example the vast potential of the Highland Sourveld of Natal (1,8 mill. ha) alone for providing low-cost beef production systems has been clearly demonstrated (Theron *et al*, 1974; Harwin and Theron, 1975). Estimates show that the current stocking rate could be increased by 400% through radical veld improvement techniques. Since the soils are mostly

TABLE 4. Extent of cultivated pastures grown in South Africa (after Pieterse, 1987)

Cultivated land (ha)		Pasture production (ha)	% Pastures
Dryland Irrigated	11 570 990 1 149 213	1 676 025 276 539	14,4 24,1
Total	12 720 000	1 952 564	15,3

dystrophic, exploitation of the inherent potential of this bioclimatic group alone would demand large quantities of lime and fertilizer.

According to Pieterse (1986) raising livestock numbers from the present 14 mill. AU to a requirement of 25 mill. AU at the turn of century will require an annual pasture establishment rate of 520 000 ha. This is six times the current rate of approximately 83 000 ha per annum. A target of between 12 and 15 mill. ha by the year 2010 is not unrealistic and is well within the limits of potential.

Legume-based pastures could play a major role in the future. Strijdom and Wasserman (1984) argue that all marginal land and 25 percent medium and high potential cropland (i.e. ± 17 mill. ha) could be established to such pastures without affecting crop production. The contribution to soil enrichment by nitrogen is reflected in their estimate of 434 464 t N being added to non-arable (290,263 t) and arable (144,201 t) soils. This amount compares favourably with the total of N fertilizers currently applied.

Afforestation

In 1985 afforestation totalled 1,1 mill. ha most of which was in the Transvaal (52%) and Natal (36%). Additional plantations in Transkei, Ciskei and Venda covered 60771 ha, 6077 ha and 5581 ha respectively.

According to Weys (1985) new afforestation amounts to 15 600 ha per annum (85% conifers). Supply of hardwoods has not kept pace with demand so that future developments in the industry could be considerable. New aforestable areas comprise 774 500 ha good land with 404 500 ha of marginal suitability. A further 180 000 ha are located in the Black areas. The total, together with existing plantations, amounts to an eventual target of 2 557 000 ha, or a doubling of the present area.

Afforestation however competes with crop production for high potential arable land and water supplies. For instance, almost 20% of the afforestated area in Development Region F is deemed to be high potential land (Schoeman and Scotney, 1986). Similar examples occur in the related Midlands (Scotney, 1970).

Schönau (1983) reported that research on fertilization began with wattle in the 1920's, pines in the 1930's and eucalypts in the 1950's. Response to fertilizers may be sustained for up to 10 years. Fertilization can be the most economically beneficial sylvicultural operation provided that it goes hand in hand with other practices, especially weed control. Despite likely benefits to short duration stands the use of fertilizer by the industry is not likely to amount to large quantities. Estimates of future use by Schönau (1983) are presented in Table 5 and are probably conservative.

Sugarcane production

The area under this important crop is 430 000 ha. Since 1950 a technological revolution has helped maximize yields ha^{-1} which have almost doubled, mainly as a result of fertilization (Wood, 1987). Average annual increases of almost one t ha^{-1} are reflected in Fig. 2 and bear witness to impressive technological advancement in an industry where the research-extension-practice adoption sequence serves as a fine example.

A total of 79 576 t fertilizer was used in 1984 comprising 36 602 t N, 9696 t P and 33 278 t K. After a long history of applications of P-fertilizer and filtercake few fields are deficient in P (Thompson, 1987). However, recent research shows that levels in excess of normal recommendations are economically justified on high P-fixing soils of the Natal Midlands and, in certain cases, broadcast applications are also justified.

Nitrogen recommendations have recently been amended with requirement being inversely related to the capacity of soils to supply N (Meyer *et al*, 1986). The soils of the industry have been grouped into four classes according to their potential to mineralize N from soil organic matter. Soil and climate have also been found to affect the reliability of K recommendations (Wood and Meyer, 1986).

'Whole-cycle' recommendations are available to the farmer, many of whom claim that high rates of fertilizer may be justified since costs of weed control and re-establishment are reduced. The fertilizer advisory service allows the farmer to choose whether he wants maximum return on investment in fertilizer or return per hectare of crop (Thompson, 1980).

Fertilizer use is likely to follow yield increases and, apart from new irrigation schemes or projects in Black areas, no major expansion is foreseen.

TABLE 5. Estimated annual fertilizer use for forestry (after Schönau, 1983).

Species	Extent (ha)		Fertilizer type	Amount (t)
	New plantings	Re-established		
Wattle		15 000	Superphosphate (10,5%)	4 000
Eucalypts	12 000		Ammoniated superphosphate (16)	2 100
		15 000	Mixture 3:2:1 (25)	2 200
Pines	27 000	20 000	Mixture 2:3:2 (22)	10 000
Sub Total	39 000	50 000		
Total	89 000			18 300

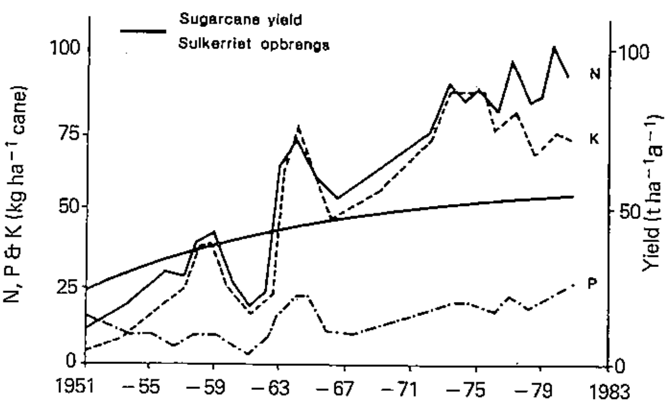

Fig 2. Average amounts of NPK used (kg ha^{-1}) and average yields (t $ha^{-1}a^{-1}$ in the sugar industry (after Wood, 1987)

Irrigation practice

With 65% of the country receiving less than 500 mm annual rainfall, irrigation will play a vital role in stabilizing production. Details of the current and potential areas of irrigation given by Schoeman (1987) are shown in Table 6.

The almost 1,2 mill. ha currently irrigated comprises annual crops (45%), pastures and permanent crops (32%) and orchards, vineyards and vegetables (23%). Irrigation is practised on private farms (58%), board schemes (23%) and state schemes (19%). The annual growth rates for these categories are 3,43%, 1,47% and 1,55% respectively. Future expansion is likely to be limited by water availability and it is estimated that a maximum of 16 000 m³ per annum will be available by the year 2010. Underground supplies mainly in the drainage areas of the eastern escarpment could also support 430 000 ha (Van der Merwe, 1986).

Emphasis in the future is likely to be given to high value crops (e.g. horticultural crops), and perhaps wheat, soyabeans and pastures. On some new schemes crops such as rice could become important. While future projections for the irrigation-fertilizer relationship are unclear, yield increases over dryland production of 30 to 50 percent will substantially increase fertilizer demand (Cooke, 1975).

Technological advancement

Scientific endeavour could have a marked influence on the future. Advances in biotechnology and genetic

TABLE 6. Extent of current and potential irrigation (After Schoeman, 1987)

Agricultural Regions	Area irrigated (1 000 ha)				Potential (1 000 ha)
	State schemes	Board schemes	Private	Total	
Transvaal	78	141	182	401	20
Natal	18	34	63	115	50
Highveld	9	6	16	31	0
Free State	78	16	72	166	80
Cape	18	13	48	79	41
Winter Rain	23	152	40	25	50
Karoo	23	29	89	141	15
	247	391	510	1 148	256

engineering could, as some claim, create a second 'green revolution'. Productivity gains from the use of computers, efficient information systems, robotics and automated environments could also result in profound economic and structural changes in agriculture over the next 20 years.

It has been recently suggested that such advances could result in the total area under cereals in the UK falling from 3,87 mill. ha to between 1,75 and 2,0 mill. ha by the year 2015 assuming demand remains the same and the crop is restricted to the best soils. The impact of similar trends in South Africa would be immense. However, some reservation of the eventual benefit of biotechnology, largely concerning the economic benefits to the farmer is justified until local research has made more progress.

Environmental degradation

Environmental issues will continue to influence agronomic practice. Estimated soil losses amount to roughly 300 mill. t per annum, or 2,5 t ha^{-1} (Adler, 1985). Considering that over 80% of the land surface is covered by natural vegetation, such losses are excessive. Exceptionally high losses have been recorded and research has shown that these may exceed 60 t $ha^{-1}a^{-1}$ on unprotected pineapple lands (Kieck, 1986). In the case of wind erosion, losses of 40 t $ha^{-1}a^{-1}$ have been recorded on vulnerable soils in the western Free State (Van der Westhuizen, 1986). Such losses far exceed tolerance levels and the estimated rate of soil formation of 0,31 t $ha^{-1}a^{-1}$ given by Du Plessis (1986).

Soil erosion implies nutrient losses. Annual losses of N (3 3 000 t), P (26 400 t) and K (363 000 t) and valued at R365 million have been estimated (Du Plessis, 1986). With quality of life studies receiving increasing attention, the potential hazard of pollution from fertilizers will need careful monitoring. Chemical-related degradation is already important and, for example, an area of over 100 000 ha is deemed to be brak and/or waterlogged (Du Plessis, 1986).

Inherent soil acidity has already been noted but there are also indications of increasing acidity on cultivated land (Burger, 1983). This matter deserves attention and it should be noted that soil acidity is fast becoming a major agronomic problem in Australia where an estimated 2 mill. ha are already showing reduced yields from this cause.

Soil compaction is also a potential hazard in soils with less than 15% clay and may reduce yields by as much as 30% to 40%. This problem is associated with almost 2 mill. ha of land (Du Plessis, 1986).

On the positive side, fertilizer is a major ally in combating erosion by ensuring rapid plant growth soon after planting and providing maximum canopy cover when rainfall energy is highest. Applications of phosphogypsum have also been shown to reduce soil losses.

Organic fertilizers

Growing livestock and poultry enterprises together with mounting municipal waste and sewerage, suggest that organic fertilizers could become important notwithstanding difficulties of handling and distribution. Buys (1985) estimates that approximately 3 mill. t a^{-1} of cattle and poultry manure together with guano are currently available but that only 20% of this amount is used as fertilizer. Although guidelines of the NPK content of the various materials are given, accurate assessments of the future impact of organic fertilizers are not yet available.

In a detailed study of sludges as a soil amendment Du Plessis (1977) estimated that sludge could reduce the amount of inorganic fertilizer used by about 10%. This would, however, depend on many factors and although sludge could provide good results as a soil amendment its limitations would have to be fully assessed.

Practices such as stubble mulching, no-till and ley cropping will all affect the long-term fertility status of cultivated land and are to be encouraged. These, together with additions of other organic materials, could enhance fertility and provide for much greater soil stability.

Meeting the challenge

The future presents many challenges. Some of the more important of these are noted.

Horizontal and vertical expansion

Despite the 1,3 mill. ha of reserve land available for expansion, scarcity of such resources over the long term is of concern. Adler (1985) stressed that cultivated land per capita will decrease from 0,5 ha to 0,2 ha by the year 2020. In the self-governing territories comparable values are already between 0,1 and 0,2 ha per capita (Roos and Lubbe, 1986). Viewed against the accepted norm of 0,4 ha per capita the scope for horizontal expansion is clearly limited.

In addition, the loss of agricultural land to competing uses such as township development, roads, mining and industries will counteract the potential for expansion. Estimates of annual losses vary between 20 000 and 35 000 ha so that at least 500 000 ha could be lost 20 years hence excluding that required for nature conservation and afforestation. In the light of such estimates it is clear that the country cannot afford to pay lip service to the call for reserving high potential land for agricultural purposes. The need to promote vertical expansion in crop production is clear and presents a special challenge if the 45% increase in food production suggested by Terblanche (1986) is to be achieved.

Judicious fertilization, in addition to rational soil use, will continue to play a major role in raising production. Arnon (1978) stressed the important role of fertilizer in modernizing agriculture in developing countries where the nutrient status of most fields lies on the steep part of the response curve. In such instances fertilizer is a lead practice *par excellance.*

Crop production strategy

The need to develop a comprehensive and dynamic crop production strategy emerges a major challenge as assessments of cropping potential become clearer, resource degradation increases and demands change (Schoeman and Scotney, 1986; Terblanche, 1986). Such a strategy must be based on detailed studies of soil-climate-crop relationships in which reliable crop models play an important role. Isolated attempts for specific areas and crops have already been made but a co-ordinated effort is needed to provide a national strategy. Useful concepts in the development of such a strategy are noted in the ecological zones project of the FAO (1978).

According to Burger (1983) massive financial benefits to the maize industry would result from switching to more appropriate crops according to soil potential in the summer rainfall area. This approach can, however, create problems at farm level over the short term where changing from an existing system may be rendered difficult by investments in specialized machinery, fixed improvements and so forth. Despite this, even without switching to new crops, benefits will result from adjusting inputs such as fertilizer according to soil potential.

Inputs and outputs

Implementation of a 'profits up, inputs down' philosophy on each and every farm presents another important challenge. Kassier (1987) notes that the only way of overcoming the price squeeze is either to improve output or to decrease input or both. In world-wide context it has been claimed that 'farmers have become victims of their own huge successes in raising productivity and output at a time of stagnating demand' (Le Roux, 1987). Low input: low output systems are thus being called for, but where high population growth rates are predicted, lower output objectives could have serious repercussions over the long-term. Such systems are also best applied by farmers with low debt burdens and demand high levels of management.

Much attention is now being given to reducing inputs of fertilizers, seeds, chemical weedicides and tillage operations. Exploitation of excessive levels of soil P and K is justified provided fields are carefully monitored by efficient soil testing, the results of which are professionally interpreted. Under high rainfall conditions Farina and Channon (1987) have shown that soil P test values can drop by as much as 10 mg 1^{-1} in just two years. Optimizing soil potential can provide to high yields and lower costs per unit of production.

In meeting this challenge general recommendations will be of limited value since each farm, each enterprise and each field needs its own production strategy.

Systems approach

Adoption of the systems approach with multi-disciplinary actions has not yet made satisfactory progress in South Africa. Making good this shortcoming presents a real challenge to both researcher and adviser. The usefullness of the approach in agriculture was noted by Harwin and Theron (1976) and Jones (1978) and is embodied in the 'whole-problem' or 'whole-farm' approach proposed by Le Roux (1984). It has special application in crop production where simulation modelling holds great promise. In order to farm well with fewer chemical inputs it is impossible to separate the crop from the rest of the environment. Total systems for crop production will mean implicit soil testing for nutrients and nematodes, pest scouting, accurate seeding rates, correct tillage operations and efficient conservation. So-called 'prescriptive farming' based on computer weather monitoring and predicting times of planting, harvesting, disease outbreaks and topdressings needs more attention.

Learning to farm with risk

There is great need to ensure that future crop production takes place with a clearer understanding of the risks involved. Much of the hardship and failure of the past has been a direct result of farmers and advisers neglecting this important aspect. An example of the future challenge is given by the promising research initiated by the Grain Crops Research Institute in co-operation with the University of the Orange Free State.

In these studies 100-year theoretical daily rainfall data were generated for selected stations and maize yields determined using the PUTU model. Risk is defined as the chance of occurrence (expressed as %) of a yield less than the corresponding value indicated on derived risk — yield graphs. The risk taken in attaining any given yield can be assessed and related to required inputs such as fertilizer (De Jager, 1978, personal communication).

Provisional risk-yield graphs resulting from this research are used simply as examples in comparing selected localities with different cropping potentials (Fig. 3). Model-derived yields compared to hypothetical planning yields are presented in Table 7. The yield-risk graphs show clearly that high risk characterizes Lichtenburg while the planned yield for Cedara is considerably less than the accepted 50% risk level.

Fertilizer costs may also be evaluated on the basis of risk analyses. The approach offers farmers and advisers far better understanding of the likely consequences of their decisions and holds much promise once crop models prove reliable over a wide range of resource situations.

Research and extension

Numerous challenges face research and extension and both need greater impetus. Without attempting to elaborate on the many fields of possible research it can

TABLE 7. Planning and model-derived (50% risk) yields with a comparison of risk (%) for selected localities (after De Jager, 1987).

Locality	Cropping potential	Yield (t/ha)		Risk (%)		
		Planned	Model-derived	Planned	Model-derived	Diff.
Schweizer Reneke	Low	3,8	1,4	100	50	+50
Lichtenburg	Med	4,7	2,8	87	50	+37
Cedara	High	5,0	7,5	12	50	−38

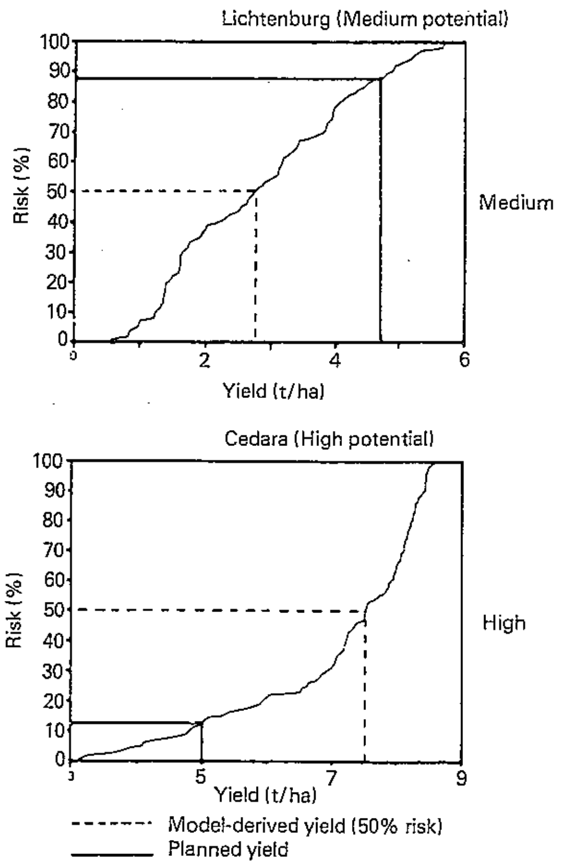

Fig 3. Yield-risk graphs for selected localities (de Jager, 1987 personal communication)

be stressed that the clients of tomorrow will be high-level managers demanding research of the highest order (Snyman, 1986). Greater emphasis will need to be given to low-cost production systems, especially in high risk areas, and the development of crop production 'packages' to meet farmer needs.

Other important needs are drought prediction, crop modelling and the expansion of fertilizer calibration studies on carefully selected bench mark soils. Establishing response surfaces for specific crop-soil-climate situations is a high priority and will provide the means to formulate the most profitable fertilizer recommendations for the farmer and his financial standing. An approach similar to that described by Farina (1975) is advocated. At the same time steps must be taken to improve fertilizer advisory services and every effort made to standardize methods, promote quality control and eliminate all weaknesses in the soil testing system, including poor soil sampling.

Under the present circumstances there is great need for effective extension with appropriate bias to financial management and the formulation of correct 'messages'. The role of whole-farm demonstrations is seen to be of particular importance. Co-ordinated action will be needed to intensify counselling on improved production techniques and maximising profit.

Farmer responsibility

The South African farmer is resilient and capable of facing the future challenges. He needs to appreciate that all final decisions, including those concerning crop choices and fertilizer use, are his alone. He also needs to review these in the light of calculated risk. He should appreciate that managerial inputs of the past have not always met the demands of optimal resource utilization. Every decision to introduce new enterprizes (crop or livestock) or lower inputs, will demand higher levels of management. The farmer carries the responsibility for adopting a more rational approach to land use planning.

Co-ordinated actions

There are many public and private bodies rendering a service to the farming community. Co-ordination of effort and avoiding duplication presents a formidable challenge. In fertilizer-related activities alone there is much scope for closer co-operation. The Fertilizer Society, representing over 95% of the local industry, has a key role to play in co-ordinating research effort, providing the link with State and other institutions and bringing reliable and appropriate information to the farming community. Much information concerning fertilizer use is available and needs careful interpretation for the benefit of the farmer.

Criticism that the farmer 'is being bamboozled with pseudo-science' must be avoided. Creation of a data bank reflecting the rise and fall of the nations soil fertility status is seen as an important need. Co-ordinated actions should also encourage closer ties with the Black States and self-governing territories.

Conclusions

The immediate need for most farmers, especially in high risk areas will be to lower input costs. Achieving this, and where appropriate adjusting cropping patterns, will demand higher levels of management.

Although local and export markets will largely dictate future crop production, the importance of relating it to available resource potential, both nationally and at farm level, must be fully appreciated. The limited extent of high potential agricultural land draws attention to the need for a dynamic crop production strategy based on sound ecological principles. The strategy will need to take account of developments in the Black States and elsewhere in Southern Africa.

Positive steps will have to be taken to rationalize land use. Areas planted to maize may decline but not to the detriment of total production. Wheat and other crops such as soyabeans are likely to increase in importance. In addition to vertical expansion features likely to influence fertilizer demand include agricultural resource potential, pasture production and developing agriculture.

The limited reserve of agricultural land, when viewed against continuing losses to non-agricultural uses, is cause for concern. This implies that the demands of the rapidly growing population will need to be met largely through yield increases. In this respect it appears safe to assume that production will keep pace with demand, at least until 2010, provided the rate of technological advancement and standard of farm practice increases.

Co-ordinated actions involving research and extension should aim to provide appropriate and clear 'messages' for the farming community. In this respect the Fertilizer Society has a key role to play since fertilizer is one of the most important and costly of all the production factors. United effort is the only way in which the agricultural ship will once again find its course and sail full steam ahead.

The farmer will need to consider his responsibilities towards rational land use, risk assessment and resource conservation, especially when making decisions concerning crop production and fertilization.

It is appropriate to quote Fitts (1978) who stated 'a farmer's greatest interest is in maximizing his return while minimizing his risks. Proper use of chemical fertilizers will greatly influence his ability to increase yields and to achieve his goal of profitable farming. This will involve fitting the fertilizer to the soil, crop and climatic conditions. Nutrient balance, as well as nutrient deficiencies, should be equated to crop varieties and climate. It is not a matter of scattering a little fertilizer over wide areas and hoping the response obtained will fall on the steep part of a curvilinear response curve, but of ascertaining the limiting factors that will influence the yield plateau that can be attained with greatest efficiency'.

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