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A Search for Strategies for Sustainable Dryland Cropping in Semi-arid Eastern Kenya

Proceedings of a symposium held in Nairobi, Kenya, 10–11 December 1990

Editor: M.E. Probert

Co-sponsors:

Kenya Agricultural Research Institute
Australian Centre for International Agricultural Research (ACIAR)
Commonwealth Scientific and Industrial Research Organisation (CSIRO), Australia

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Foreword

The population of Sub-Saharan Africa will have more than doubled between 1985 and 2010. More than half of this tropical region is semi-arid, and most rural people living in such areas must depend on small-scale dryland agriculture. However, in many areas the fertility of the farmed land has fallen as the pressure of human population has increased. Farm productivity has fallen and farmers have found themselves sliding into poverty.

In 1983 the Kenyan National Council for Science and Technology and ACIAR jointly hosted a symposium in Nairobi aimed at identifying how Australia, with its lengthy experience of agricultural research in its own tropical region, might contribute to solving the agricultural development problems of Eastern Africa. The difficulties of farmers in semi-arid cropping areas in eastern Kenya emerged as a high priority. Consequently, a joint project, sponsored by ACIAR and centred on the Katumani Research Station (now the National Dryland Farming Research Centre) and on farms in the Machakos and Kitui Districts, commenced in 1985. The project involved close collaboration between research staff from the Kenya Agricultural Research Institute (KARI) and the Tropical Crops and Pastures Division of CSIRO, Australia's national research organisation.

The results of nearly six years of research were presented to 64 Kenyan government administrators and researchers, and representatives of national and international development aid donor agencies, at another two-day symposium sponsored by KARI, ACIAR and CSIRO, and held in Nairobi during December 1990. These proceedings present the 15 papers delivered. Shortly, ACIAR will also be publishing a companion digest of the results.

A major difficulty that confronts researchers investigating agricultural problems in semi-arid tropical regions is the variability of the climate. This poses special problems when interpreting experimental results and formulating sound crop husbandry recommendations for farmers. The KARI/ACIAR dryland farming project has used a maize crop model to tackle these issues. Consequently, a tool now exists that can explore the interactions between water supply, nitrogen nutrition and such agronomic practices as adjusting the time of planting and planting density of crops, and simulate crop performance using historical weather data.

As well as describing the development and application of the model, the papers support the theme that a strategy of augmenting traditional soil fertility maintenance practices (such as applying manure) with modest amounts of commercial fertiliser provides the best prospects for food security and sustainable agricultural development in heavily populated semi-arid tropical lands. This view runs contrary to previous popular wisdom that prevailed when the land was less degraded. The level of interest among participants at the symposium was most gratifying. Equally gratifying is the fact that the approaches advocated are already being applied successfully by a few farmers in the Machakos and Kitui Districts.

ACIAR and the scientists involved in the project believe that the approaches and strategies developed could do much to improve the lot of poor farmers living in semi-arid areas of Kenya and other tropical African countries.

The project and the symposium could not have succeeded without the enthusiastic support of the Directors and staff at the Katumani Research Station, and the interest shown by Mr G.Muhoho, Minister of Research and Technology, and other Kenyan Government ministries is gratefully acknowledged. The contributions of the late Mr Peter Kusewa, who was Director of the Katumani Research Station during the formative stages of the project until his untimely death in 1990, and Mr Benson Wafula, who subsequently became acting Director, deserve special mention.

Mr Neil Huth of the CSIRO Division of Tropical Crops and Pastures did much of the hard work needed to bring the papers delivered at the symposium to the high standard of presentation in these proceedings.

G H L Rothschild
Director
ACIAR

Preface

Developing countries in Africa struggling to increase food production face a dilemma in the form of limited essential physical resources, such as land, water, nutrients and energy, and lack of proper technologies. This situation is exacerbated by high population growth rates, which make it even more challenging for governments to achieve the elusive goal of alleviating poverty and suffering.

Kenya is one of these countries that is short of arable land (20% only). Four-fifths of the country consists of arid and semi-arid lands (ASAL), which are characterised by a bimodal rainfall pattern that ranges from very low to 800 mm per annum. This rainfall is extremely variable and unpredictable, which leads to frequent crop failures. Physical features include large areas of flat land and gently rolling hilly areas as well as steep and ragged hills and valleys. Elevations range from 700 m to 1800 m above sea level, and slopes can be as high as 30% or more, making large areas prone to erosion.

The ASAL received prominence during the 1979–83 Fourth National Development Plan in response to the plan theme of poverty alleviation. They, in particular, have come under increasing pressure. The ASAL areas are inhabited by small-scale farmers, farming mostly at the subsistence level. They have the greatest population change, with a natural rate of increase of 3.5–4.0% per annum, and a higher actual growth rate due to migration from the crowded fertile areas of the highlands. Farm sizes range from 1.5 to 17 ha.

The area under crops in the ASAL is usually smaller than the area under grazing. However, due to the rapid increase in population, an increasing proportion of the grazing area is being put under cultivation. Migrant populations have brought with them farming technologies developed for the well endowed high-potential areas that are inappropriate to their new settlements. Inevitably, this has led to recurrent crop failures, hunger and suffering, which can be alleviated only by costly famine-relief operations. Even more serious is the problem of rapid resource degradation in this fragile environment, which is leading to declining productivity and possible eventual permanent barrenness.

The needs of the high-potential areas of Kenya have to a significant extent been met through research and the application of new technologies. The ASAL have, however, not received sufficient research attention, and therefore traditional production systems have benefited little or nothing from research-tested innovations. This gap became acutely apparent during the early and mid-1970s, when many parts of Kenya experienced a series of years with poor rainfall that coincided with population migrations from high-potential to marginal areas.

It was during this period that research scientists in the Ministry of Agriculture and the former East African Agricultural and Forestry Research Organisation (EAAFRO) began to give serious thought to strengthening research in rainfall-deficient areas. The initial thrust was to be in the Machakos and Kitui Districts of Eastern Province — populous parts of the country where crop failures and famine are virtually endemic.

The first positive action taken was the gradual strengthening of Katumani Research Station by the Ministry of Agriculture, culminating in its elevation in status to the National Dryland Farming Research Station (NDFRS) in 1980, with responsibility for planning and coordinating dryland research activities throughout Kenya. Financial constraints made initial program development slow. In 1979, however, technical assistance was secured from UNDP/FAO, and Project Document No. Ken/74/017, entitled 'Dryland Farming Research and Development', was endorsed by the Kenya Government and the donor agencies.

At an earlier date, UNDP/FAO and the Kenya Government had signed a Project Agreement (KEN/74/016), 'The Kenya Sorghum and Millet Development Project', a major objective of which was to develop sorghum and millet for the dry lands of Eastern Province. Though administratively separate, this project complemented KEN/74/017.

While the latter project was still in progress, bilateral negotiations in 1979 between USAID and the Kenya Government resulted in the formation of Project No. 615–0180, 'Dryland Cropping Systems Research Project', based administratively at KARI, Muguga, but with field studies carried out at the NDFRS, Katumani. Special care was taken at the project design level to ensure complementarity and collaboration between KEN/74/017 and Project No. 615–0180. The approach was multidisciplinary, and involved both expatriate and Kenyan scientists.

The two donor projects were due to end in early 1984. A symposium on Dryland Farming Research in Kenya which would bring together the results achieved during their rather short 4–5-year lifetime in a form easily available for reference was therefore convened in November 1983. Meanwhile, following the establishment of the Australian Centre for International Agricultural Research (ACIAR) by the Australian Government in June 1982, efforts were being made to identify major agricultural problems and priorities in eastern Africa where the Australian agricultural research community, with its experience of research in Australia's own tropical and subtropical regions, might effectively be applied in collaborative programs. A highly successful consultation between senior scientists and scientific administrators from Australia, seven eastern African countries, and international research and development organisations took place in Nairobi in July 1983, sponsored by ACIAR and the National Council for Science and Technology of Kenya.

A Memorandum of Understanding for scientific and technical cooperation between the Government of the Republic of Kenya and ACIAR was signed in June 1984, the year when most parts of Kenya were experiencing a drought of a severity not recorded for many decades. Arising from this agreement, the joint Australian–Kenyan Government project entitled, 'Improvement of Dryland Crop and Forage Production in Semi-Arid Regions of Kenya' (ACIAR Project No. 8326), and centred on the NDFRS, Katumani, commenced in 1985. The project involved collaboration between the Kenya Government, ACIAR and the Tropical Crops and Pastures Division of CSIRO, Australia's national research organisation.

The main emphasis in the first phase of the project was in support of some of the activities of the NDFRS, Katumani — namely socioeconomics, forage legume evaluation, climatic risk analysis and management, soil and water management and soil fertility management.

The project concluded on 30 June 1987. The Government of Kenya/Donor Appraisal Mission of the National Agriculture Research Project (NARP), in which Dr R.K. Jones the ACIAR co-project leader participated, took place in October–November 1986. It was timely as well as essential for consideration of the future of Project No. 8326, which was due for review in April 1987. All parties were anxious to ensure that the follow up project's objectives remained consistent with the priorities which emerged in the formulation of the NARP.

The follow up ACIAR project (No. 8735), entitled 'Improvement of Dryland Crop and Forage Production in the African Semi-Arid Tropics', commenced in January 1988 and was due to be concluded in June 1991. It was favourably reviewed in December 1990 with a recommendation that it continue for a further 2–3 years. The project involved close collaboration between research staff of the Kenya Agricultural Research Institute (KARI) and the CSIRO Division of Tropical Crops and Pastures. Immediately before the review, the two-day KARI/ACIAR/CSIRO symposium covered in these proceedings was convened at the International Centre of Insect Physiology and Ecology (ICIPE), Duduville.

Modern published scientific works are rarely the result of a single intellect. Often they involve a mixture of individuals with different attitudes and aptitudes. The proceedings of this symposium owe their success to dozens of dedicated scientists and policymakers. ACIAR deserves special mention for defraying the cost of sponsoring the symposium and the publication of these proceedings. Much of the coordinating responsibility was shouldered by Dr J.R. Simpson, ACIAR Joint Project Leader, and Dr B.W. Ngundo, KARI Assistant Director.

Special mention is also due to the late Mr P.K. Kusewa, who was the Director of the National Dryland Farming Research Centre, Katumani, during the formative stages of the project until his untimely death in 1990. The Australian High Commissioner, His Excellency D.C. Goss, and the Deputy Director of ACIAR, Dr J.G. Ryan both delivered special tribute speeches at the farewell dinner function in honour of the late Mr Kusewa for his contribution to the project. The Minister for Research, Science and Technology, the Hon. George Muhoho, who delivered the closing speech at this function also made a special tribute to the late Mr Kusewa.

The technical sessions were ably and voluntarily chaired by Dr B.W. Ngundo, Assistant Director, KARI; Dr F. J. Wang'ati, Secretary, National Council for Science and Technology; Dr B.M. Ikombo, Acting Director, NDFRC, Katumani; Dr A.M. Kilewe, Director, NARC, Muguga; Dr R.L. McCown, CSIRO Division of Tropical Crops and Pastures; Dr F.N. Muchena, Director, NARL, Kabete; and Dr J.G. Ryan, Deputy Director, ACIAR. Their contributions were much appreciated. The cost of this symposium was minimised through the generous offer of the excellent facilities of ICIPE by the Director, Professor Thomas R. Odhiambo.

C G Ndiritu
Director
KARI

Appendix 1. Standard Inputs and Assumptions Used in the Modelling Analysis

Standard Inputs

The analysis assumes that pests, weeds and nutrients other than nitrogen are not limiting.

Unless otherwise specified, the following inputs were assumed. The maize cultivar, Katumani Composite B was simulated at a plant population of 4.4 plants/m^2. The standard soil profile used was that of a chromic luvisol which is typical of the region (Table A1).

Planting was assumed to occur once onset of the season was detected. Onset was defined as the receipt of in excess of 40 mm of rain within an 8-day period with no more than one consecutive dry day (0 mm). Onset windows during which planting could take place were defined as from calendar day 276 to 320 and calendar day 62 to 120 for the SR and LR, respectively. Planting was simulated at the end of the onset window in those seasons when onset according to these rules was not detected.

The standard soil profile had an organic carbon content of 1.1% in the surface layer, an initial mineral N content of 54 kg/ha at the beginning of the onset window and an available water-holding capacity of 173 mm over its 130 cm depth. Soil water was initialised at one-fifth of the available range and initial values of mineral N are given in Table A1. The fertiliser response investigated was to 0, 10, 20, 40, 80 and 160 kg N per ha applied at planting as calcium ammonium nitrate. Each season was modelled independently of other seasons with reinitialisation of input parameters at the start of the onset window unless otherwise specified.

Gross Margin Calculation

In situations when the scenarios simulated involved different input costs, yield output was converted to a gross margin in Kenyan shillings (Kshs/ha), using the following assumptions. Grain was valued at 3 Kshs/kg and fertiliser was assigned a value of 16.3 Kshs per kg N. Seed costs varied with plant density and gross margins were adjusted to reflect this, assuming that seed for planting was valued at 4 Kshs/kg and two seeds of average weight of 0.32 g are planted per planting position, prior to thinning to one plant. Planting, harvesting and weeding costs were not likely to be influenced in any predictable way by the scenarios investigated and these costs have been excluded.

Table A1. Profile information for the standard soil used in the case study.

DLAYR is the layer depth in cm, LL is the lower limit of plant extractable soil water (volumetric), DUL and SAT are the corresponding drained upper limit and saturated water contents respectively, WR is a weighting factor for root growth, BD is the layer bulk density in g/cm^3, C is the organic carbon (%), NH_4 and NO_3 are the ammonium and nitrate mineral-N (in µg/g) at onset of the season.

DLAYR	LL	DUL	SAT	WR	BD	C	NH_4	NO_3
10.0	0.140	0.250	0.300	1.00	1.35	1.10	1.0	2.0
10.0	0.140	0.250	0.300	0.86	1.35	1.10	1.0	3.0
10.0	0.140	0.290	0.320	0.64	1.35	1.00	1.0	3.0
20.0	0.150	0.300	0.330	0.47	1.40	0.80	1.0	2.0
20.0	0.170	0.300	0.340	0.35	1.40	0.70	1.0	1.0
20.0	0.170	0.310	0.350	0.25	1.40	0.65	1.0	1.0
20.0	0.170	0.310	0.360	0.15	1.40	0.60	1.0	1.0
20.0	0.170	0.310	0.370	0.08	1.40	0.60	1.0	1.0

Whole profile properties :
SALB, the soil surface albedo = 0.13
U, the soil evaporation coefficient for stage 1 = 9 mm
SWCON, the whole profile drainage coefficient = 0.50
CN2, the runoff curve number = 60

Prospects for Improving Maize Productivity Through Response Farming

B.M. Wafula,* R.L. McCown† and B.A. Keating§

STRATEGIES considered in the previous paper involved management practices that were fixed, irrespective of seasonal prospects. In contrast, farmers frequently vary their management either consciously or subconsciously in response to their perceptions of the rainfall prospects for the current season. 'Response farming' was a scheme developed in Kenya to forecast the potential of the pending growing season using rules based on time of season onset and early cumulative rainfall (Stewart and Hash 1982; Stewart and Faught 1984; Stewart 1988, 1991). The scheme included tactical responses, such as adjustments in crop densities and nitrogen fertiliser, to better match agronomic management with seasonal potential. In seasons forecast as having a high yield potential, high plant populations and nitrogen fertiliser side-dressings were recommended. In seasons forecast as having low yield potential, recommendations were to thin plant stands to reduce demand for soil resources and not add additional nitrogen fertiliser.

Although the concepts embodied in response farming are intuitively attractive, there had been no means by which its value in terms of increased productivity or reduced risk could be assessed. This is because the value of response farming can not be determined experimentally, given the interseasonal variability in rainfall that characterises semi-arid Kenya. Stewart and Kashasha (1984) present the results of an evaluation conducted on seven farms in one season. Clear benefits of nitrogen fertilisation were obtained, but it is not possible to separate the value of fertilisation from the value of the response farming forecast per se. In addition, it is impossible to derive general conclusions on the value of response farming from one season's experimentation. The availability of a model that simulates maize growth in relation to climate, soil and management factors provided a unique opportunity to quantify the value of response farming. With the model, we can separate the value of fertilisation from the value of the response farming forecast and can assess variability in response over the historical rainfall record.

The details of response farming and our evaluation have been extensively reported elsewhere (Stewart 1988, 1991; Stewart and Hash 1982; Stewart and Faught 1984; Wafula 1989; McCown et al. 1991; Keating et al. 1992). In this paper we attempt to summarise the key outcomes of our analysis.

General Methods

The standard inputs used and assumptions made throughout the simulation study have been described in detail elsewhere (Keating et al., Exploring strategies for increased productivity, these proceedings; McCown et al. 1991). Briefly, all simulations were conducted using daily rainfall data for the National Dryland Farming Research Centre, Katumani, Machakos, Kenya (lat. 1°35'S; long. 37°14'E; alt. 1601 m). In general, conditions selected are those thought to be typical of current practice or recommendations. Two crops per year were simulated over the 1957–1988 period. The short rains (SR) occur from October to January and the long rains (LR) from March to July.

Onset of the long rains season was deemed to occur when 40 mm of rain was recorded within an 8-day period, with no more than one contiguous dry day. The onset rule for the short rains was similar but based on 30 mm instead of 40 mm. Onset periods or 'windows' were defined from calendar days 289 to 327 and 38 to 106 for the SR and LR, respectively. Unless specified otherwise, sowing was assumed to take place immediately season onset was detected within the window. If onset was not detected in any particular season, the crop was assumed to have been sown into dry soil at the end of the onset window. These onset criteria are based on the agroclimatic analysis of Stewart and Faught (1984) but are to some degree arbitrary and bound to be specific to regions. Nevertheless,

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the concepts of planting windows and minimum rain needed to initiate planting activity are consistent with farmer behaviour in this region (Ockwell et al. 1992) and are likely to be more generally applicable.

The maize cultivar, Katumani Composite B, was simulated throughout this study. The standard soil profile assumed was that of a chromic luvisol, which is typical of the region. This soil has an organic carbon content of 0.8% in the surface layer, an initial mineral-N content of 54 kg/ha and a potential available water content of 173 mm over its 130 cm depth. Each season was modelled independently of other seasons with reinitialisation of input parameters at the start of the onset window.

The performance of alternative fixed and response farming strategies involving different input levels (for example, studies involving different rates of fertiliser) were compared using gross margin per hectare. The assumptions made in terms of prices of inputs and outputs are given in McCown et al. (1991). Monetary values are in Kenyan shillings (Kshs) and as a guide, 100 Kshs is equivalent to US$4. Variable costs included seed, fertiliser (30 Kshs per kg N) and harvest costs. The price assumed for nitrogen is twice the purchase price, to allow for variable costs of transport, application and additional weeding costs. A constant sale price of 3 Kshs/kg for maize grain was assumed.

Strategies Examined

Fixed. Rates of N fertiliser (ranging from 0 to 80 kg N per ha) applied at sowing as calcium ammonium nitrate were examined. Other studies have shown that plant population needs to be varied to match nitrogen supply if optimum production is to be achieved (Keating et al. 1991). Hence, these N rates were combined with plant populations ranging from 22 000 to 55 000 plants/ha (Table 1a).

Response farming. The schema devised by Stewart and Faught (1984) incorporated two levels of predictor. Predictor I was based solely on date of onset of the rainy season. Predictor II used date of onset together with a second stage predictor, consisting of the cumulative rainfall over the 30 or 35 day period following onset. Analyses reported elsewhere (McCown et al. 1991) have indicated that the second stage predictor is of limited incremental value only in the short rains (SR) season. For simplicity, this paper will focus on an evaluation of Predictor I, the date of season onset.

Seasons in which onset occurred before 18 March (calendar day 77) and 2 November (calendar day 306) for the long rains and short rains, respectively, were classified as early. Seasons starting after these dates within the defined onset windows were said to be late. These definitions of early and late onset were those developed by Stewart and Faught (1984). In the period studied, 47% of seasons started early, 53% were late. Two levels of management were evaluated, each with specific tactics for early and late onset (Table 1b). No low input level was considered since tactics are only relevant when at least some inputs are in use. The tactics evaluated can be thought of as a reduction in N fertiliser rate and plant population when a poor season is forecast on account of a late onset.

Table 1. Nitrogen fertiliser and plant population levels used in the simulation study of (a) fixed strategies, and (b) response farming strategies using forecasts based on season-onset date.

(a) Fixed strategies

Fixed strategy	Plant population ('000 plants/ha)	N rate (kg/ha)
S1	22	0
S2	27	15
S3	33	30
S4	37	45
S5	44	60
S6	55	80

(b) Response farming strategies

Strategy	Predictor onset date	Plant population ('000 plants/ha)	N rate (kg/ha)
R_1 – medium inputs	Early	33	30
	Late	33	0
R_2 – high inputs	Early	44	60
	Late	33	30

Results

Performance of the Predictor

Three classes of season (good, fair and poor) were identified by Stewart and Hash (1982) and Stewart and Faught (1984) in terms of rainfall amount (Table 2a). Stewart and Faught (1984) showed that the date of season onset was negatively correlated with the amount of rainfall received, particularly in the long rains (Fig. 1). This is a reflection of the phenomenon that the date of cessation of the rains is less variable than that of onset, making season duration dependent mainly on date of onset. As a consequence, the prospects for the different classes of season are influenced by the date of onset predictor (Table 2b). For example, while 37 percent of all long rains seasons were rated as good using Stewart's criteria (Table 2a), the probability of a season that starts early being good, rises to 65 per cent. Likewise, while 15 per cent of all short rains seasons were poor in terms of seasonal rainfall, the probability that a season that starts late will be poor is increased to 25 per cent.

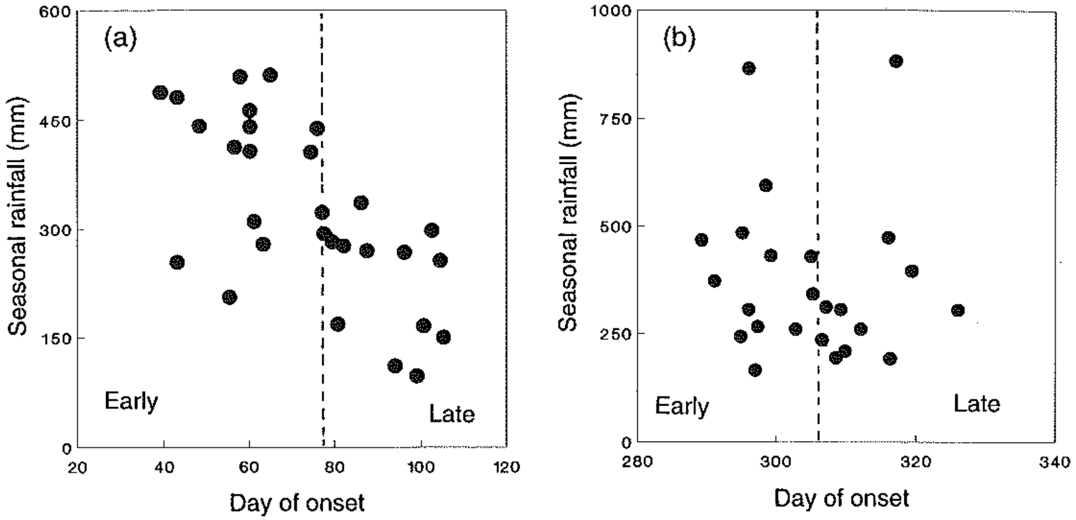

Fig. 1. The relationship between total seasonal rainfall for (a) long rains and (b) short rains), and date of rainy season onset. Classification into early and late onset based on the criteria of Stewart and Faught (1984).

McCown et al. (1991) have examined forecasting rules devised by Stewart and his colleagues in more detail than is possible here. They conclude that the rules developed for Katumani are close to optimal and that they substantially reduce uncertainty in the prediction of seasonal rainfall. Predictor II (early season rainfall and onset date) provided an improvement over Predictor I (onset date alone) in the accuracy with which good seasons were forecast, particular in the short rains. Poor seasons were predicted little better by Predictor II than by Predictor I.

Table 2a. Classification of season classes based on rainfall received between season onset and maize maturity.

Season class	Rainfall between season onset and maize maturity (mm) Long rains	Short rains
Good	>280	>330
Fair	150–280	230–330
Poor	<150	<230

Table 2b. Performance of the first-stage predictor (date of onset) for the long (LR) and short rains (SR) at Katumani over the 1957–1988 period. Proportion of seasons in different rainfall classes (specified in Table 2a) over all seasons, and when classified according to date of onset.

Season	Rainfall class	Percent of seasons All seasons	Early onset	Late onset
Long rains	Good	37	65	0
	Fair	41	29	58
	Poor	21	5	42
Short rains	Good	40	53	25
	Fair	44	40	50
	Poor	15	7	25

The Impact of Response Farming on Productivity

Large increases in the productivity of maize production were found to be associated with the use of nitrogen fertiliser and appropriate plant populations, for both fixed and response farming strategies (Fig. 2). Simulated grain yields averaged over both seasons and over 1957–1988 increased from 1106 to 2794 kg/ha as the input level in the fixed strategies increased from S_1 to S_6. Mean gross margin was maximised at N rates of 45 kg N per ha and a plant population of 37 000 plants/ha (S_4 — Fig. 2).

For the same input cost, averaged over the period studied, the response farming strategies (R_1 and R_2 on Fig. 2) linking fertiliser use to onset dates resulted in gains in the expected gross margin. However, the average size of these gains was small (300–500 Kshs/ha) in comparison with the large impact of the unconditional use of fertiliser (up to 2500 Kshs/ha).

The Impact of Response Farming on Risk

While the overall impact of the tactics examined on average profitability was small, reductions in the risk associated with fertiliser use also need to be assessed.

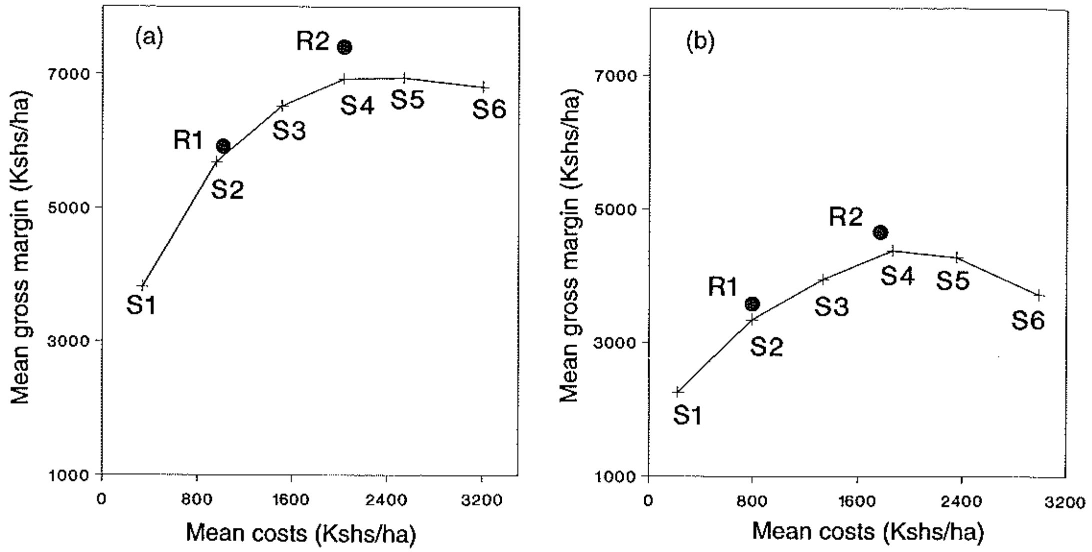

Fig. 2. Average gross margin and costs over the 1957–1988 period simulated at Katumani for a range of fixed (open symbols) and response farming (R_1,R_2) strategies specified in Table 1. (a) Long rains and (b) Short rains.

The high input conditional strategy (R_2) provided benefits over and above a comparable fixed strategy (S_4) in 67% of seasons simulated, but had a negative impact in the remainder of seasons. Such negative effects arose mostly from situations when an early onset was indicative of a good season and inputs were increased accordingly, but subsequent response to these additional inputs was poor.

Efficiency frontiers in Mean (E)–Standard Deviation (SD) space. McCown et al. (1991) have compared conditional strategies with fixed strategies in terms of E–SD space. The technique portrays production in terms of the long-term average gross margin (E) and risk in terms of the standard deviation of gross margin (SD) over the historical period simulated (Fig. 3). Compared with a corresponding set strategy (S_4), the high input conditional strategy (R_2) resulted in higher mean returns with the same or slightly reduced risk, insofar as standard deviation is an adequate measure of risk. The strategy using moderate input levels conditional on onset-date (R_1) fell below the efficiency frontier generated by fixed strategies and is of no further interest. A 2:1 rule of thumb has been suggested (Ryan 1984) as a first approximation to the attitudes of farmers on smallholdings to incurring added risk in conjunction with increased gross margin; that is, such farmers would not be averse to using inputs or technologies provided they did not increase the standard deviation of the gross margin more than twice the increase in mean gross margin. Such a rule would suggest that the S_2, S_3 and S_4 fixed strategies and the R_2 conditional strategy are realistic options for risk averse farmers. The E–SD plot also highlights the large gains in efficiency achievable through the use of inputs (S_4 vs S_1) and conversely, the small benefits of tactics associated with their conditional use (for example, comparing R_2 with S_4).

Stochastic dominance analysis. The cumulative distribution functions (CDF) for the gross margin (Fig. 4a) compare the low-input (S_1) and high-input (S_4) fixed strategies with a high-input conditional strategy (R_2). A closer examination of the lower third of the probabilities for gross margin (Fig. 4b) highlights the large increase in risk of a negative gross margin associated with use of fertiliser inputs (S_4 compared to S_1) and the significant reduction in this risk that was achieved with a conditional strategy using information on date of season onset as a predictor (R_2 vs S_4).

Safety first (mean (E)–negative deviation (ND) space). The desire of farmers to achieve some threshold production level needed for survival is easily envisaged. In the case of decisions concerning fertiliser inputs, the desire of farmers not to lose money (that is, to avoid recording a negative gross margin) can be viewed as a requirement for financial survival or 'safety-first' goal- setting. Strategies can be assessed in terms of such goals by plotting the expected returns against the probability weighted sum of deviations below some target, in this case, below a gross margin of zero (Fig. 5). Such a plot in mean–negative deviation space (E–ND) (K.A. Parton, University of New England, Australia, unpublished data) has obvious parallels to E–SD space considered earlier (Fig. 4). E–SD space uses all variability in returns as an indicator of risk (that is, deviations both up and down) while E–ND space considers only the down-side risks. While response farming raised expected returns slightly, it had little impact on risk as assessed in the E–SD plot (Fig. 3). Tactics linked to an onset-date

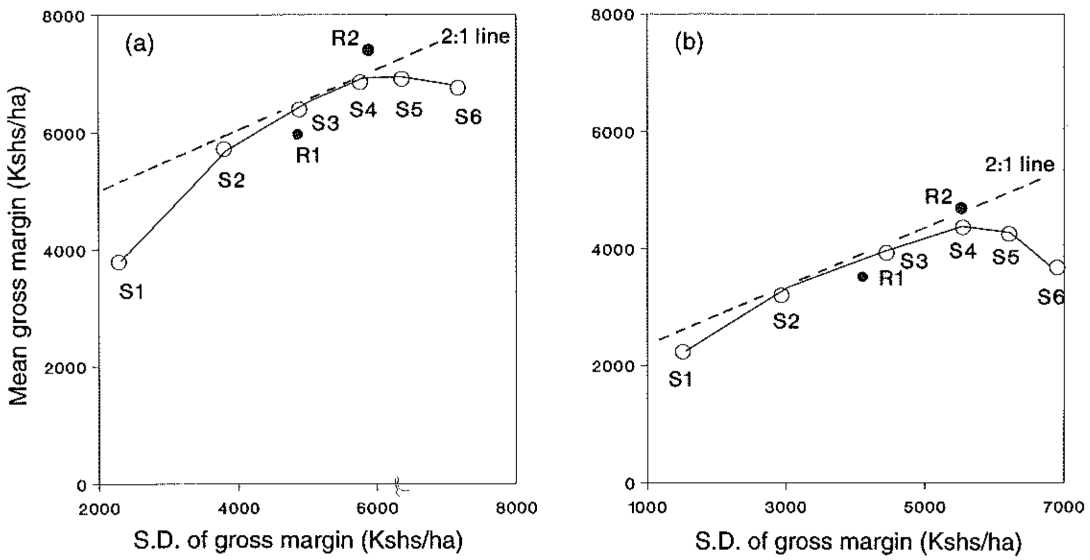

Fig. 3. The outcome of various fixed (open symbols) and response farming (R_1, R_2) strategies, specified in Table 1, plotted in mean-standard deviation space. The broken line represents the slope of the 2:1 line. (a) Long rains and (b) Short rains.

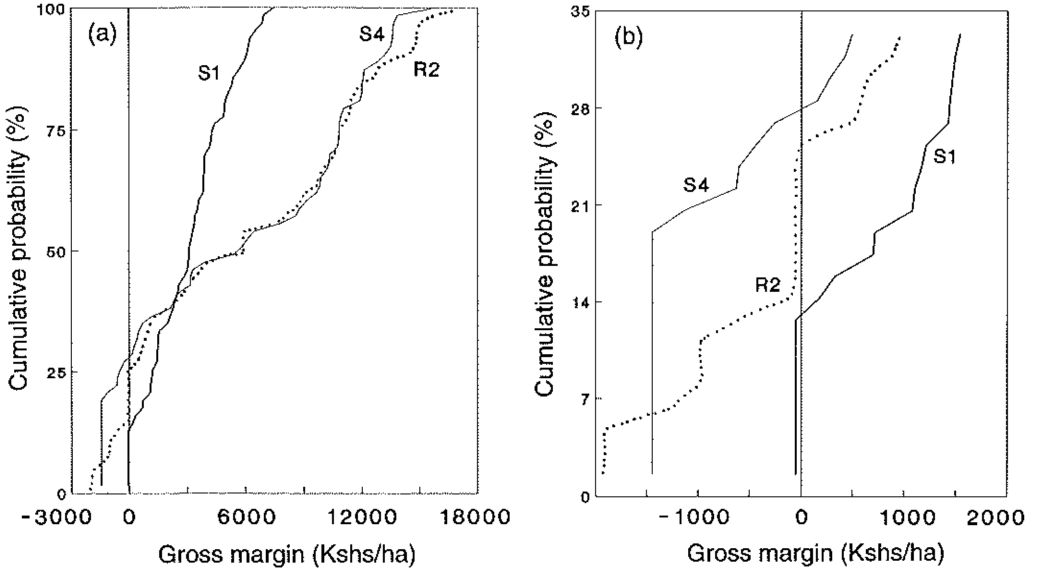

Fig. 4. Cumulative probabilities of gross margin for fixed (S_1, S_4) and conditional (R_2) strategies of N fertilisation over both long and short rains. Details of strategies are given in Table 1.
(a) Full range of gross margin.
(b) Lower 33% of the range in gross margin.

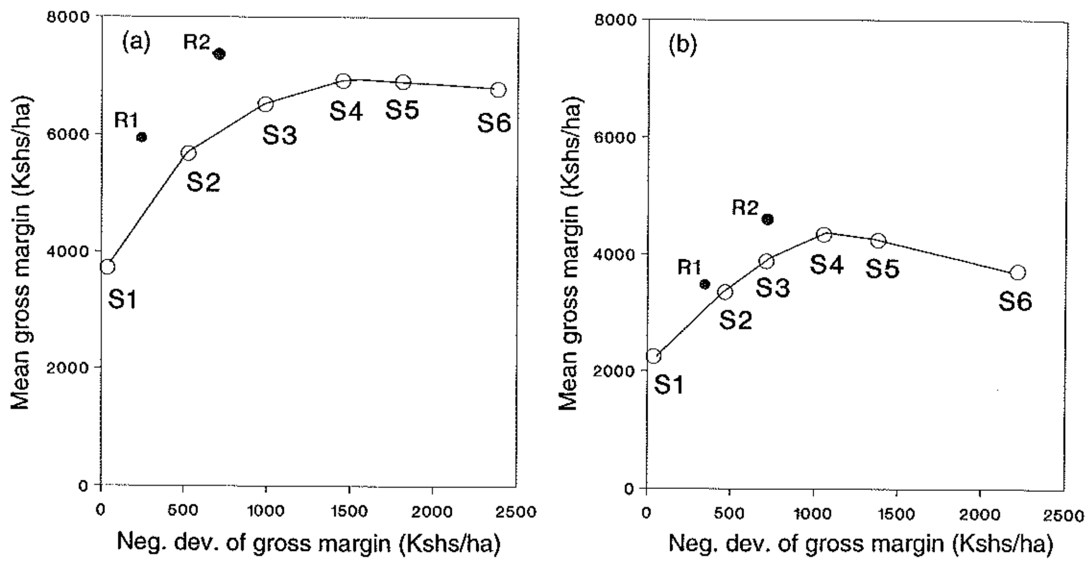

Fig. 5. The value of various fixed (open symbols) and response farming (R_1, R_2) strategies, specified in Table 1, plotted in mean–negative deviation space. The negative deviation refers to outcomes with a gross margin less than 0 Kshs/ha. (a) Long rains and (b) Short rains.

forecast did however have a substantial benefit in reducing negative deviations (Fig. 5) and may be attractive to farmers pursuing strong 'safety-first' goals.

Discussion

The date of the start of the rains at Katumani can be a useful predictor of potential yield, and hence of the capacity of crops to respond to inputs. Adjustment of N input levels and plant populations to better match the season potential is a logical response with a sound biological basis. How much value to place on the forecast is more difficult to assess. In terms of average returns, its value is small relative to the large benefits from using fertiliser irrespective of a forecast. In terms of minimisation of risks, it can be of value, substantially reducing the number of occasions when fertiliser is purchased and rainfall is insufficient to obtain a return in the year of application.

Information presented elsewhere (Keating et al., these proceedings) on variability in rainfall and response to fertiliser additions shows that anything less than 20 to 30 years would not provide an adequate picture of the variability in net benefits associated with a particular tactic. Experimental evaluation of the conditional management strategies (examined in this paper using simulation) would not have been feasible.

Recognising that farmers change their practices incrementally, the results indicate that the most important step is increased use of nitrogen fertiliser, irrespective of any formal system to forecast seasonal potential. While this and earlier studies (Keating et al., these proceedings) in the region highlight the potential economic value of fertilisers, we observe few farmers using them. Possible reasons are considered in other papers in these proceedings (Muhammad and Parton; McCown and Keating).

References

Keating, B.A., Godwin, D.G., and Watiki, J.M. 1991. Optimising nitrogen inputs in response to climatic risk. In: Muchow, R.C., and Bellamy, J.A., ed., Climatic risk in crop production — models and management for the semiarid tropics and subtropics. Wallingford, CAB International, 329–357.

Keating, B.A., McCown, R.L., and Wafula, B.M. 1992. Adjustment of nitrogen inputs in response to a seasonal forecast in a region of high climatic risk. In: Penning de Vries, F.W.T., and Teng, P.S., ed., Systems approaches to agricultural development. Dordrecht, Netherlands, Kluwer, in press.

McCown, R.L., Wafula, B.M., Mohammed, L., Ryan, J.G., and Hargreaves, J.N.G. 1991. Assessing the value of a seasonal rainfall predictor to agronomic decisions: the case of response farming in Kenya. In: Muchow, R.C., and Bellamy, J.A., ed., Climatic risk in crop production — models and management for the semiarid tropics and subtropics. Wallingford, CAB International, 383–409.

Ockwell, A.P., Parton, K.A., Nguluu, S.N., and Muhammed, L. 1992. Relationships between the farm household and adoption of improved technologies in the semi-arid tropics of eastern Kenya. The Journal of Farming Systems Research – Extension, in press.

Ryan, J.G. 1984. Efficiency and equity considerations in the design of agricultural technology in developing countries. Australian Journal of Agricultural Economics, 28, 109–135.

Stewart, J.I. (1988). Response Farming in Rainfed Agriculture. Davis, California, The Wharf Foundation Press, 103 p.

— (1991). Principles and performance of response farming. In: Muchow, R.C., and Bellamy, J.A., ed., Climatic risk in crop production — models and management for the semiarid tropics and subtropics. Wallingford, CAB International, 361–382.

Stewart, J.I. and Faught, W.A. 1984. Response farming of maize and beans at Katumani, Machakos District, Kenya: recommendations, yield expectations, and economic benefits. East African Agricultural and Forestry Journal, 44, 29–51.

Stewart, J.I., and Hash, C.T.T. 1982. Impact of weather analysis on agricultural production and planning decisions for the semi-arid areas of Kenya. Journal of Applied Meteorology, 21, 477–494.

Stewart, J.I., and Kashasha, D.A.R. 1984. Rainfall criteria to enable response farming. East African Agricultural and Forestry Journal, 44, 58–79.

Wafula, B.M. 1989. Evaluation of the concepts and methods of Response Farming using crop growth simulation models. MAgSci thesis, Melbourne University.