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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

Looking Forward: Finding a Path for Sustainable Farm Development

R.L. McCown* and B.A. Keating†

THE challenges ahead in agricultural development for Kenya, in particular its semi-arid regions, are enormous. In real terms, population pressure on the land is among the most severe in the world. While Kenya ranks much lower than both Bangladesh and India (Binswanger and Pingali 1988) in terms of people per hectare, if land area is weighted by its potential productivity, the rankings change dramatically. Figure 1 expresses population pressure as people per million kilocalorie potential production and includes only people who work in agriculture: Kenya comes near the top. Pressure on land in the Machakos-Kitui districts of Kenya is particularly severe (Higgins et al. 1982).

The options for response to this problem, which have been presented in the introductory paper (McCown and Jones, these proceedings), are compared in Figure 2. Option A, out-migration to urban centres, generally precedes successful implementation of B or C. Remittances from urban workers provide security for the household and possible capital inputs to farm production. The future contribution of this option as a means of relieving pressure on land depends on the rate of employment growth relative to population growth.

The expansion of cropping into the dry marginal areas (Option B) can be expected to continue in the future, but certain trends are predictable. Because the carrying capacity of land available for settlement declines as the most productive land is settled first, the efficacy of this option declines proportionately. The downward spiral (Fig. 3 in McCown and Jones, these proceedings) ensures that without other options operating effectively, it is only a matter of time before the low-level state is reached again and another shift must be considered. As drier zones are settled, crop production becomes increasingly hazardous and relevant crop selection and breeding frontiers press up against biological limits. Remittances from urban workers will become increasingly crucial for financial security.

Option C concerns implementation of yield-improving technology that is necessary for making continuously-cultivated systems sustainable. The most important question concerning the production side of the problem of future food-security is whether yield-improving technologies are, or can be made, economically feasible. A number of technologies (new genetic attributes and various agronomic management strategies) have been examined by earlier papers in this volume. In general, new technologies do not bring about significant improvements unless the soil infertility constraint is first relieved. Our research findings indicate that chemical fertiliser of the appropriate type and amount is an ingredient of the management strategy which is economically optimum and consistent with risk preferences of many farmers in this region, in spite of climatic limitations (Keating et al. and Wafula et al., these proceedings). This is reinforced by our observation that a few farmers rely upon chemical fertiliser to augment traditional soil fertility maintenance strategies, and do so very profitably.

Analysis of Supply and Demand for a Fertiliser-augmented Soil Enrichment Technology

Why do so many farmers choose to retain a farming strategy that seems to be so far below the optimum for them? A helpful approach to analysis is provided by the model of induced innovations (Ruttan and Hayami 1984) which is portrayed in its simplest form in Figure 3 (simplified from de Janvry and Dethier 1985). New technology comes about as the result of demand 'pull' and supply 'push', but the rate and direction of technological change is strongly influenced by relative prices of land, labour, capital and associated risks. Comparative information available to the decision-making process of both users and suppliers of technology can be considered as a payoff matrix. This comparative information includes that concerning the costs, benefits, and risks of the

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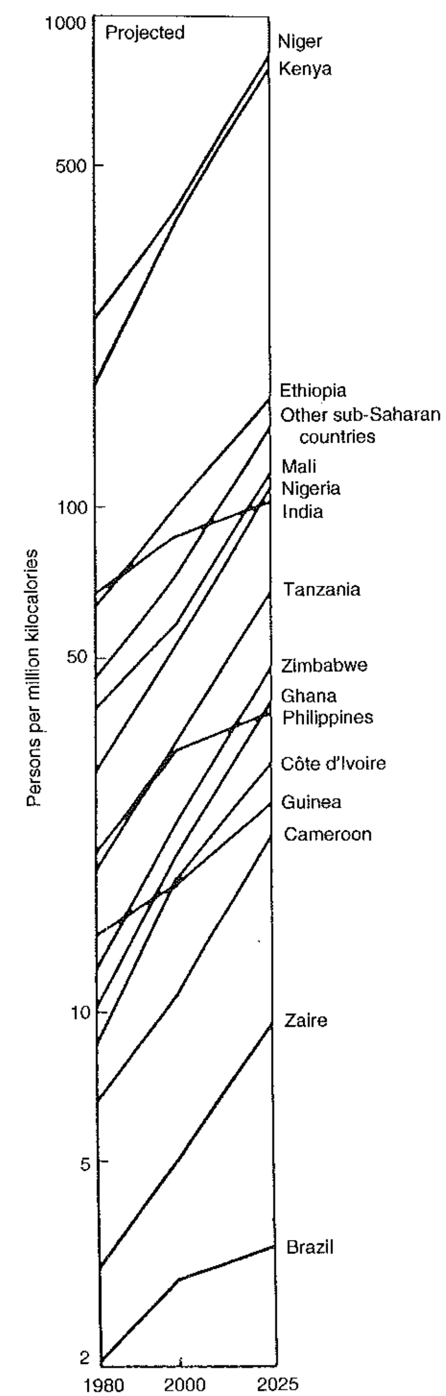

Fig. 1. Population pressure forecast in terms of rural people per million kilocalories of potential production, on a log scale (after Binswanger and Pingali 1988).

available alternative technologies. Not only does this influence producer choice, but it impacts upon supply of technologies by influencing research priorities; research institutions are rewarded for aligning research priorities with expected payoffs. From the demand side, the technology options are weighed against other options, for example, migration, or investment outside agricultural activities. The more variable the climate, the more difficult it is to compare alternatives in the payoff matrix and the more important it is to consider alternatives in the context of climatic risk.

From the fact that most farmers do not use fertiliser (even though it is available) it might be presumed that most farmers at present do not judge fertiliser as a contributor to the most profitable option in the expected payoffs matrix. Correspondingly, there is a strong tendency for Kenyan potential suppliers of innovations (researchers, extension workers) to accept this verdict. However, considering the human and ecological consequences of present technology remaining static as pressure of population continues to increase and soil fertility and production continues to decline, it is crucial that the option with the best technical prospects for sustaining yields is not dismissed prematurely.

Figure 4 shows a more comprehensive version of the induced innovation flow diagram. This 'structuralist model of induced innovations' (de Janvry and Dethier 1985) allows us to examine factors interfering with the market forces that underlie the supply of and demand for innovations. The elements corresponding with supply and demand in Figure 4 are qualified as 'latent' and the payoff matrix as 'expected'. Since we are focusing on the apparent lack of demand for a technology that we hypothesize is the optimum, we will begin with those factors that might influence latent demand (that is, what farmers think about this option) and the actual payoff matrix (that is, what they are able to do in implementing it). We believe that there are good reasons why many farmers would have an inaccurate perception of the probable benefits of this option because of the few opportunities for access to such information. This problem is compounded by the variability in yield response, often caused by variable seasonal water supply.

There is presently no well developed 'package' of recommendations for improving yields via soil enrichment through augmentation of scarce supplies of boma manure with chemical fertiliser. Even if a farmer realises the value of integrating fertiliser application into the existing system to avoid adverse effects on the soil (McCown and Jones, these proceedings), there may be supply constraints, including lack of capital to purchase fertiliser and poor access to supplies. These problems are compounded by any perception of investment risk due to poor rainfall, inadequate skill with the technology, or untimely supply.

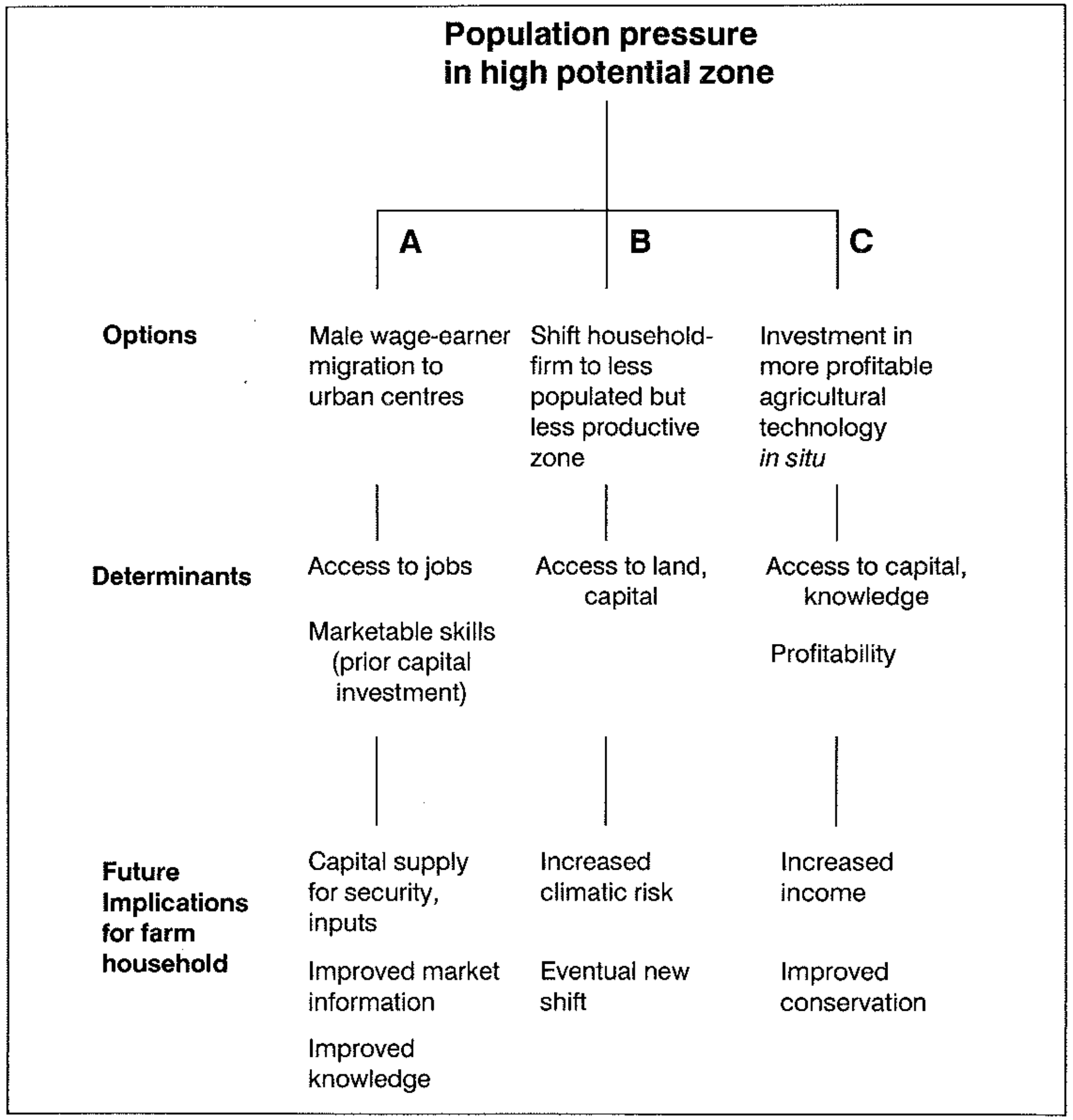

Fig. 2. Options open to farmers when faced with pressure for sustention induced by population growth, and their implications (after Mortimer and Tiffen, pers. comm.).

So far we have used Figure 4 to examine possible non-market explanations for non-adoption of fertilisers. We have not considered social payoffs from technological change and have not considered the state as a client of technology suppliers. It seems reasonable to question whether policymakers have either a realistic perception of the potential benefits of a fertiliser-augmented soil enrichment (FASE) strategy in Zone 4 (McCown and Jones, these proceedings), or of the risks and limitations of migration into the drier Zone 5. To date, agricultural science has provided little assistance to those seriously considering the policy option of encouraging fertiliser use. Information is needed on the potential of fertiliser use to increase incomes and improve food security for the highly populated, degraded areas in Zone 4, and on the risks that confront new settlers in yet uncultivated areas of the drier Zone 5 (Option B, Fig. 2).

An important result of this project is the placing of the FASE option in the expected payoff matrix in a more credible way. The requirement that, to be useful, credibility of FASE must be available in advance (ex ante) means that predictive tools are needed. Simulation

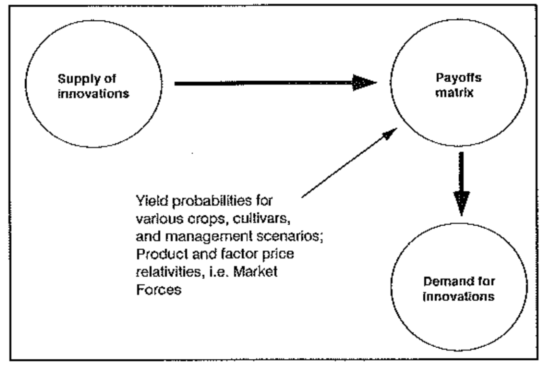

Fig. 3. Supply and demand for technological innovations (after de Janvry and Dethier 1985).

models, properly tested and validated, are a powerful tool for this purpose. Many of this project's resources have gone into field experimentation which provided such a tool for maize. This now provides the source of estimated yields for a wide range of relevant alternative production technologies. These are the data that enable economic analysis of costs and benefits for the expected payoff matrix. Economic analyses are shown in the lower left corner of Figure 4 in McCown and Jones (these proceedings) as the final task of the project.

Of the two potential beneficiaries of this research—farmers and policymakers—Figure 4 indicates that, in the usual situation where there are influences which distort market forces, policymakers are, in terms of action, 'upstream' of farmers. Government policy can be a tool for alleviating or compensating for factors which prevent farmers from adopting this technology. Ruthenberg (1980, p. 176) concluded that the fertiliser-driven soil enrichment option could be feasible in this farming system, but probably only if aided by some policy intervention . Mudahar (1986) indicated that this was likely to be in a form other than government fertiliser subsidies.

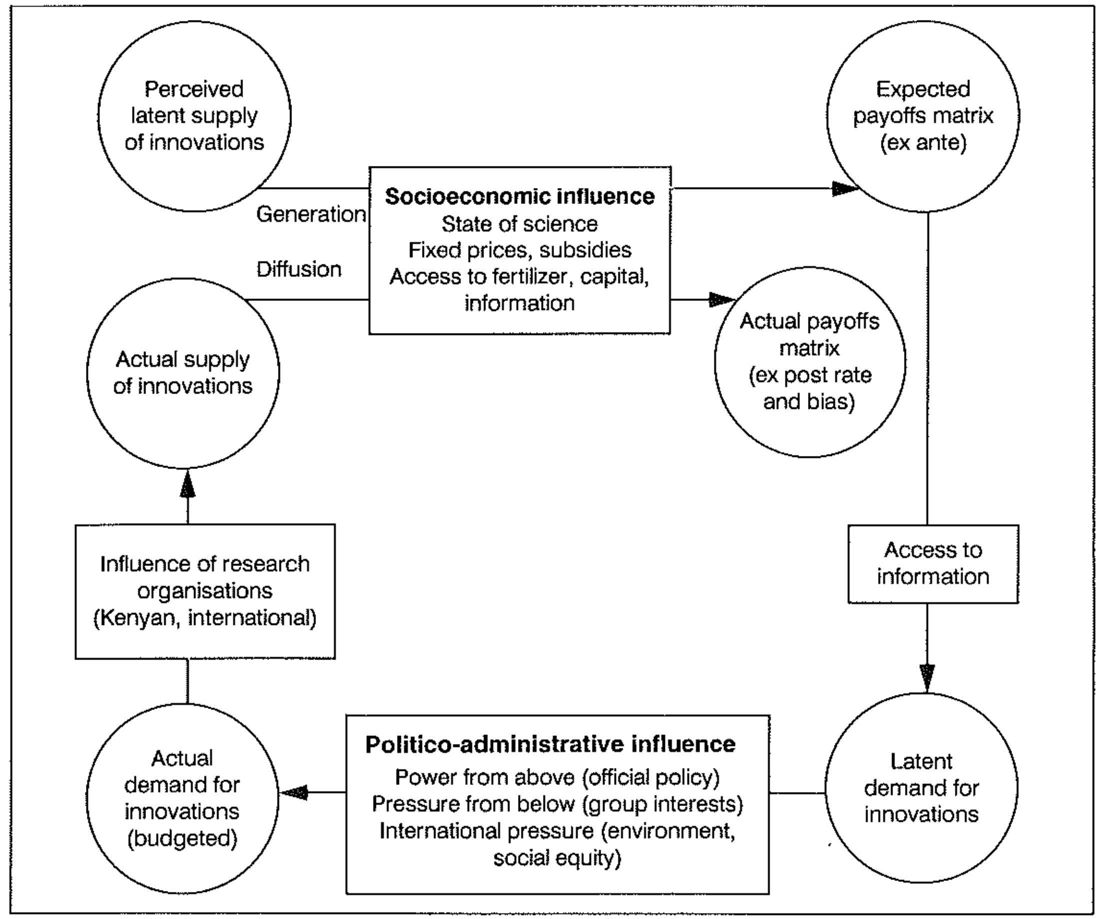

Fig. 4. Factors that interfere with the supply and demand for innovations within the context of induced innovations (after de Janvry and Dethier 1985).

Moving Towards a Sustainable Agriculture

There is a conflict that arises in the tailoring of a fertiliser strategy to a semi-arid environment. On the one hand, for a chemical fertiliser input to be technically efficient and not contribute to accelerated soil degradation, it needs to be part of a relatively complex package. On the other hand, as both the capital and management requirements of the package and the climatic risks are sufficiently large in relation to the expected improvement in returns, farmers are likely to resist adopting the entire package at once. In general, technology transformation attempts have a very poor success rate (Dommen 1988). Thus, it is necessary to conceptualise the ideal package in stages that can be implemented gradually without too much loss in total benefits.

In this, we have again turned to predictive models to examine the incremental progress that might be made from implementing different levels of inputs. These steps combine improvements in crop nutrition through N fertiliser application with improvements in crop water supply through return of crop residues. Plant population was optimised for each step (Table 1). While such steps would be, in reality, part of a progressive improvement in soil management, they are discrete for this analysis, since the long-term effects of fertilisation and residue return on soil fertility, structure and erosion losses are not considered. Neither have we explicitly modelled the impact of the return of crop residues on runoff, but have altered curve numbers within the model so that reductions in runoff of the magnitude shown in Table 1 were assumed. Effects of this magnitude are considered realistic (see Okwach et al., these proceedings).

Average maize yield at Katumani over the 1957–1988 period is predicted to increase from 970 kg/ha to 2740 kg/ha as inputs and associated management practices change from step 1 to step 4 (Figure 5).

Step 1 is a scenario that approximates the present system. Maize is grown at low plant populations without fertiliser nitrogen and with high runoff losses in the absence of the return of crop residues. The mean grain yield simulated (970 kg/ha) is on the upper side of the average reported for the region (700–900 kg/ha; Jaetzold and Schmidt 1983) but in our case we have not considered losses due to poor management, such as delayed planting, weeds or pests.

Step 2 involves small inputs of nitrogen fertiliser (10 kg N per ha), some increase in plant population and return of the 'additional' stover produced (that is, over and above Step 1) to the soil surface (Table1). Step 3 involves further increases in nitrogen fertiliser (20 kg N per ha), plant population and return of stover.

Step 4, with optimal N fertilisation (40 kg N per ha) and plant population (4.4 plants/m^2) and little runoff, is a scenario that approaches the production potential for this environment with excellent management (2740 kg grain per ha).

This analysis suggests that useful gains could be made with modest inputs of nitrogen, residue return and appropriate crop management (compare, for example, step 2 with step 1).

Being Realistic

We realize that to even suggest that a fertiliser-based strategy for smallholders in a climatically risky region might be feasible appears to many as naive. Nevertheless, we are faced with the certainty that the yields of a farming system which has increasing numbers of people continually taking more from the soil than they replace will not only decline to low levels, but also will respond little to any investment except soil enrichment. We argue that it may be even more heroic (or naive) to plan systems of production which increase intensity of cropping with no tested plan for compensating for additional extraction rates. For example, the nominal 'plan' for fertility maintenance in the Makueni project was for farmers to use manure, rotations and grass leys (Lynam 1978), and it has taken only about 20–30 years for the unsustainability of the strategy to become clear. Illusions of sustainable production of farms settled later may last longer, but the decline to a low-level equilibrium (Fig. 3 in McCown and Jones, these proceedings), is avoidable only by higher rates of replacement of nutrients than occurs with present technology.

Table 1. Management inputs and parameters of the soil water balance for the simulation of four possible steps towards enhanced productivity (see Fig. 5).

Step	Fertilizer N	Plant population	Soil organic matter %	Runoff curve no.	Mean seasonal runoff	Soil evap. coefficient
	(kg/ha)	(per m^2)	(0–15 cm)		(mm)	(mm)
1	0	1.6	0.9	80	62	9
2	10	2.2	1.0	70	40	7
3	20	3.3	1.1	60	23	5
4	40	4.4	1.2	50	12	4

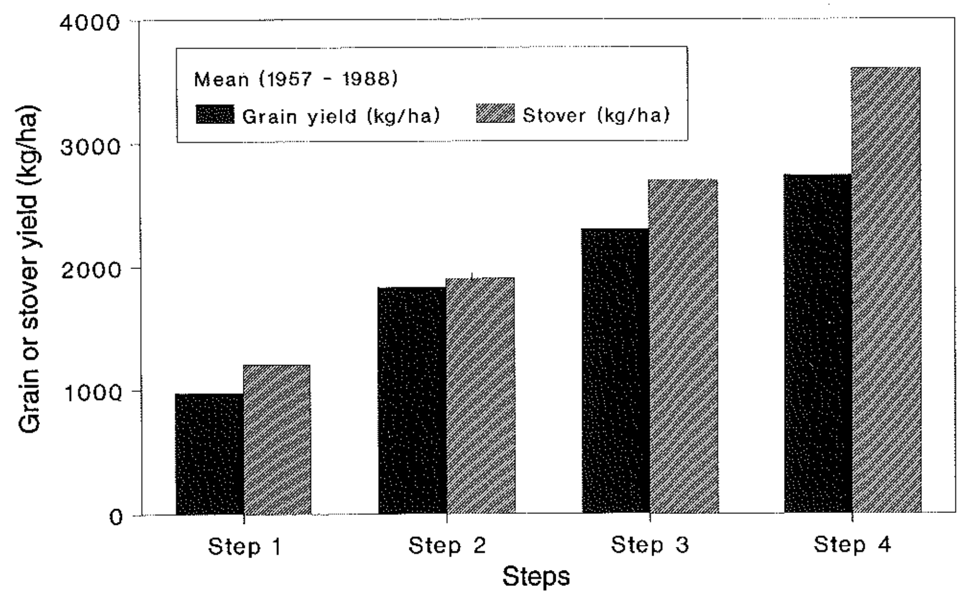

Fig. 5. Mean maize yields simulated for Katumani weather over the 1957 to 1988 period with increasing levels of inputs (details given in Table 1).

Even if it is evident that FASE is the optimal strategy for some farmers, we recognise that it will not be so for all. Farmers within this farming system differ enormously in the climate, soil and financial resources available to them and in their knowledge and abilities. Statistics from other tropical cropping regions show that fertiliser use is highest where incomes are highest and risks are lowest, such as in fertile irrigated regions (Anon. 1989). It is significant, however, that fertiliser use is increasing in dryland areas (Anon. 1989), and favourable economics are increasingly being demonstrated (McIntire 1986). A policy to encourage fertiliser use in the Machakos-Kitui Districts might bring criticisms from those especially concerned with social equity in development. However, there is a growing case that adoption of FASE by farmers with sufficient means is preferable to a continued shared slide into deeper regional poverty and food insecurity. Due largely to present or past off-farm earnings, a sizeable proportion of farmers in the Machakos–Kitui area would often enough have the means to buy a bag of fertiliser if they believe the returns to be great enough (Lutta Muhammad, pers. comm.). If the economics of FASE prove to be favourable, this initial injection of capital is the key to escape from the trap in Figure 3 of McCown and Jones (these proceedings) by initiating a gradual recovery of system productivity and income.

Although fertiliser supply is a major problem in much of the African SAT, in Machakos–Kitui, supply infrastructure is in place to serve the coffee-growers in agroecological zone III. However, little service in supplying information and advice is provided from retailers, because fixed prices limit their profits and hence their incentive to market aggressively (Abbott 1983). A further problem is that all fertiliser in Kenya is imported, and except for that which arrives as international aid, its acquisition requires foreign currency expenditure. Even if it is demonstrated that fertiliser is important in the economically optimum production strategy in the medium-potential area of Machakos–Kitui, it is possible that this would be a suboptimal policy from a national perspective. Returns may be greater in higher potential zones, especially under conditions of limited supplies and problems of negative balance of payments. However, such a comparison should not be prejudged; it should be made in the light of the best estimate of the payoffs from a FASE strategy, including effects on reduction of costly food relief for the region.

The implementation of a FASE strategy requires research on integrating a new input with the existing system. Because the marginal income benefits will be less than in wetter climates, it is important that recommendations be efficiently tailored for local circumstances. The knowledge base for this would need to be acquired from research on a considerable number of interactions with other practices, soil type, and plot history. This can be justified only if the outcome of the ex ante study indicates that the expected benefits warrant it. The primary investment of this project is in ascertaining if a FASE strategy is economically feasible. If it proves to be so, a major new research initiative will be required to develop, in conjunction with farmers, the specific recommendations for a wide range of circumstances, including farmers' attitudes and beliefs concerning risk, that occur within this region.

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