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An Economic and Institutional Analysis of Maize Research in Kenya

by

Daniel David Karanja

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Department of Economics
MICHIGAN STATE UNIVERSITY
East Lansing, Michigan 48824

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AN ECONOMIC AND INSTITUTIONAL ANALYSIS OF MAIZE RESEARCH IN KENYA

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Daniel David Karanja is an Agricultural Economist at the Kenya Agricultural Research Institute (KARI) and is currently a Ph.D. student in the Department of Agricultural Economics, at Michigan State University.

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ABSTRACT

Maize, the most important food crop in Kenya, contributes 44 percent of the per-capita, calorie intake. Increases in maize production over the past three decades have been attributed to the availability and adoption of modern maize techniques, especially fertilizer and hybrid seed. This paper estimates the rate of return to maize research to be 53 to 61 percent, and reveals that his impact was aided by complementary agricultural extension and seed multiplication and distribution programs. The paper describes the institutional framework that may have led to one of Kenya's agricultural research success stories. It also poses challenges to the future of maize production in Kenya.

Daniel David Karanja is an Agricultural Economist at the Kenya Research Institute (KARI) and currently the Deputy Project Leader of the KARI/CIMMYT Maize Data Base Project at KARI Headquarters, Nairobi, Kenya. The views expressed in this paper are those of the author and should not necessarily be attributed to KARI.

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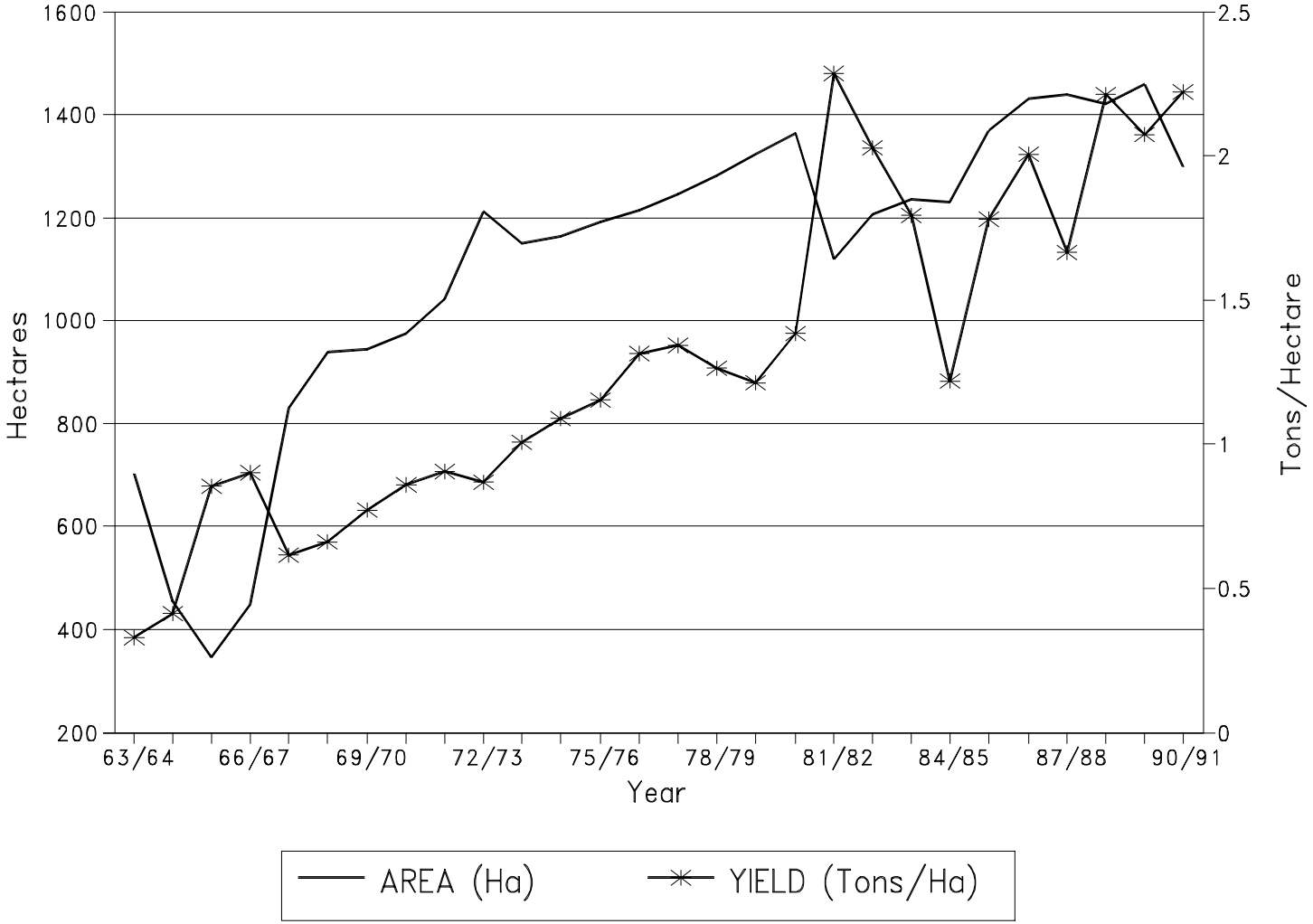
1. BACKGROUND

Maize is the most important food crop in Kenya. It contributes over 20 percent of total agricultural production, 25 percent of total agricultural employment and about 44 percent per capita calories intake (CIMMYT, 1990; Rutto, 1992). Kenya's national food security is often pegged to availability of adequate supplies of maize to meet domestic demand. Currently, per capita consumption of maize is estimated at about 115 kilograms per year (CIMMYT, 1992). The crop is grown in almost all agro-ecological zones on both large and small farms. The latter account for over 70 percent of total production on over 80 percent of total maize area (Karanja, 1990). However, the large-scale farmers account for most of the marketed maize.

Maize was introduced into Kenya at the turn of the century. By 1903 it occupied 20 percent of total food crop area (Meinertzhagen, 1957). In 1989-90, the crop covered 79 percent of cereal crop area (CIMMYT, 1992). Compared with traditional cereals of sorghum and millet, the popularity of maize has been attributed to its ease of cultivation, limited diseases and pests, ease of storage, and utilization in various forms. Figure 1 shows the trends in maize area and yield in Kenya between 1963-90. The increase in maize production is basically attributed to availability and adoption of modern maize technologies, especially hybrid seed and fertilizer. The development of hybrid maize is considered one of Kenya's greatest agricultural research success stories.

The purposes of this paper are to provide quantification of the impact of maize research, and to examine the effects of extension and seed sales on this impact. Additional insights are gained from institutional analysis of maize technology development and transfer.

Figure 1. Maize Area And Yield In Kenya, 1963-1990



Source: Statistical Abstracts (Various issues).

2. MAIZE RESEARCH AND ITS ACHIEVEMENTS

Maize improvement efforts by isolated researchers and farmers date back to the 1920s (Gerhart, 1975). The Government of Kenya, responding to demands from large scale maize farmers, initiated a systematic maize germplasm improvement program in 1955 when it hired a plant breeder, M. N. Harrison, to develop late-maturity maize hybrids for high-altitude regions. The government later expanded the program to develop early-maturing maize for marginal regions in 1957 and medium-maturing varieties for medium altitudes in 1965.[1]

The first Kenyan hybrid maize, H611, is a cross between a previously released synthetic variety, Kitale Synthetic (KS) II, and an Ecuadorian line, Ec 573. Released in 1964, H611 has a 40 percent yield advantage over KS II (Harrison, 1970). Between 1965 and 1989, researchers developed and released eleven high-altitude, maize hybrids. On average, these had a 30 to 53 percent yield advantage over the local maize. Katumani Composite A (KCA) and Katumani Composite B (KCB) were the first improved varieties for the marginal regions. Released in 1966 and 1968, respectively. Although popular in these regions, their yield performance was dismal. Farmers preferred a higher yielding and earlier-maturing variety, Dryland Composite (DC) I, released in 1989, was preferred. The Embu program made an impact with the release of medium-maturing H511 and H512 in 1968 and 1970, respectively. These varieties had a research-yield advantage of 36 percent over the local maize and were widely adopted by farmers in the medium-altitude regions. The coastal maize program triumphed in 1989 with the release of the first coastal hybrid, Pwani Hybrid I, which replaced the previously released Coast Composite, an open-pollinated variety. Table 1 summarizes varietal releases since 1961.

The maize breeding program was augmented by an extensive agronomy program. Although agronomic trials date as far back as 1910, the most notable work was done by Dr. A.Y. Allan starting in 1963. Supported by Rockefeller Foundation and British government, Allan worked closely with breeders at Kitale and evaluated the new hybrids over a wide range of agronomic characteristics. His trials resulted formed basis for specific agronomic recommendations for farmers (Allan, 1971).

Notably, one of the greatest achievements of the maize research team over the years has been its provision of a range of improved maize varieties suitable for different agro-climatic conditions in Kenya. The H600 hybrids are late-maturing varieties suitable for the Kenyan highlands, the medium-maturing H500 hybrids are good for mid-altitude regions and the open-pollinated composites and synthetics are suitable for the drier lowlands. Besides these, some farmers still grow "local" varieties mainly in the cool highlands and western Kenya.

[1] The current maize research program consists of a late-maturity varietal program at Kitale, medium-maturity program at Embu, early-maturity program at Katumani and coastal maize program at Mtwapa. These programs develop varieties suited to different agro-climatic conditions.

Table 2. An Institutional Diagram of Maize Research in Kenya, 1900-1990

STAGE	PERIOD	MAIZE TECHNOLOGY DEVELOPMENT	MAIZE SUPPORT SYSTEMS	POLICY ENVIRONMENT
Pre-Hybrid	1900-63	*Introduction of Maize from U.S. via S. Africa *Scattered Trials/Pre-Selection of Maize Types *Kenya White Complex *Screening Maize Rusts, 1952 *Development of Synthetic varieties, 1950 *Hybrid Research, 1955 *Rockefeller Support, 1955 *Import of Germplasm, 1959 *Dryland Maize Research, 1957 *Agronomic trials, 1963	*Railway Network, 1890s *Farmers' Association, 1919; Renamed KFA, 1923 *Road Networks, 1920s *Agric. Extension, first attempts 1910s; revamped 1954 *Agricultural Credit (Land Bank), 1942 *Kenya Seed Company (KSC), 1956; *Maize Marketing Board, 1959 *Government Contract with KSC, 1963 *Agricultural Finance Corporation, 1963	*European Settlement *Kenya Colony, 1920 *Colonial Tax/Macroeconomic Policies, 1920s-50s *Agricultural Production Marketing Act, 1936 *Increased Production of Crops Ordinance, 1942 *Guaranteed Prices for maize, 1942 *Swynnerton Plan, 1954
Hybrid Revolution	1964-80	*First Hybrid Release, H611, 1964 *Mid-Altitude Maize Research, 1965 *5,000 District Demonstration Trials, 1965 *FAO-Sponsored Fertilizer Trials, 1970s *11 hybrids and 3 OPVs, 1964-80	*Expansion of Agricultural Services *KSC: Increased Seed Output and Distribution *KFA: Expanded Fertilizer and Seed Supply *Expanded Maize Marketing Services, 1970s *Rural Access Roads Program	*Independence in 1963 *Land Transfers and Re-settlement, 1960s *Expanded Credit, Extension, Research, 1965-80 *First oil crisis, 1973/79 *Second oil crisis, 1978/79 *Coffee Boom, Inflation, 1978-80 *Maize Marketing Policies Enhanced, NCPB, 1979 *Declining per capita food production, mid-1970s *Declining economic performance, mid-1970s
Hybrid Plateau	1980-90	*Increased Focus on Farming Systems Research *Focus on Yield Stability and Marginal Areas *Decline in Budget Support to Research *High-Protein Maize (abandoned) *NARP I, 1986 *Reorganization of KARI, 1984-86 *Maize Research Review, 1990 *7 hybrids 1 OPV, 1980-90	*National Extension Project, 1981 *KSC: Expanded Network/Exports *Decreased Loan Facilities: AFC, Commercial Banks *Expanded NCPB's Marketing & Storage Capacity *KSC Research Department, 1980s *Guaranteed Maize Prices and Purchases	*Food Policy Frameworks, 1981, 1986 *Major drought, 1984 *Focus on Smallholder/Marginal regions *Population Pressure/Control Strategies *Declining Economic Performance *Structural Adjustment Program *Restructuring NCPB *Liberalized Input Prices/ *Declining Per Capita Food Production

Table 1. Maize Varietal Releases in Kenya, 1961-1995

VARIETY	YEAR OF RELEASE	MATURITY	ALTITUDE	RESEARCH YIELD (Metric tons/Hectare)
KSII	1961	Late	High	3.4
Kat. SII	1963	Early	Medium	2.0
H611	1964	Late	High	4.5
H621	1964	Late	High	4.1
H631	1964	Late	High	4.5
H622	1965	Medium	High	5.2
H632	1965	Medium	High	4.5
H612C	1966	Late	High	5.9
KCA	1966	Early	Medium	2.3
KCB	1968	Early	Medium	2.8
H511	1968	Medium	Medium	3.6
H512	1970	Medium	Medium	4.1
H611C	1971	Late	High	5.9
H613C	1972	Late	High	6.0
CC	1974	Medium	Low	3.3
H614C	1976	Late	High	6.3
H625	1981	Late	High	6.8
H612D	1986	Late	High	6.4
H613D	1986	Late	High	6.0
H614D	1986	Late	High	6.6
H626	1989	Late	High	6.8
DCI	1989	Early	Medium	2.9
PHI	1989	Early	Low	3.8

Source: Adapted from Karanja (1990).

Farmer adoption of higher-yielding and diverse varieties led to increased maize production through improved farm yields and expansion of maize area. Karanja (1990) indicates that maize area and yield more than doubled, and production increased nearly fivefold between 1955-59 and 1985-88. The area planted to improved seed increased from about 2 percent in 1962-64 to 64 percent in 1985-88. The adoption and spread of hybrid maize contributed to increased household and national food security and improved incomes for maize farmers, maintained food prices at low levels, and momentarily relieved Kenya from making difficult food-policy decisions to guarantee adequate supplies.

3. ECONOMIC ANALYSIS

Karanja (1990) used a production function approach to calculate the rate of return (ROR) to investments in Kenyan maize research for the 1955-88 period.[2] Under Karanja's assumption that research affects area and yield after a lag of ten years, the ROR is defined formally to be that value of r which solves equation 1.

(1)
$$\Delta R = \frac{P_m \times \Delta Q}{(1 + r)^{10}}$$

where ΔR is the change in research expenditure; ΔQ is the resulting change in maize output, and P_m is the maize price (22.58 K£ per ton). To estimate the effect of research or output, Karanja made use of the identity:

(2)
$$\text{OUTPUT} = \text{YIELD} \times \text{AREA}$$

Equations representing maize area and yield as functions of inputs, research and extension expenditures, prices and "weather and external shocks to the economy" variables were estimated using a linear, two-stage regression analysis.[3] With all variables except DUM in natural logarithms, the regression results are:

(3)
$$= 9.05 - 0.57\text{AR} + 0.25\text{RE} + 0.07\text{EX} + 0.08\text{FT} + 0.12\text{HB} + 0.24\text{D}$$
$$R^2 = 0.64$$

(4)
$$= 8.47 - 0.26\text{YD} + 0.49\text{RE} + 0.07\text{EX} + 0.01\text{MP} + 0.02\text{HB} + 0.13\text{I}$$
$$R^2 = 0.86$$

where: YD = Maize Yield in tons/ha; AR= Maize Area in ha; RE= Maize Research Expenditure, lagged 10 years, in K£; EX = Maize Extension Expenditure in K£; FT = Fertilizer Imports in tons; MP= Maize Producer Price in K£/ton; HB= Hybrid Seed Sales by KSC in tons; and DM= Dummy Variable for Weather, External Economic "Shocks".

The results indicate that improvement in maize yield and expansion of maize area are explained by, *inter alia,* increases in research and extension expenditures and the spread of hybrid seed; yield is also positively influenced by fertilizer while higher producer prices influence maize area expansion. The results also indicate that maize research, extension and

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[2] The ROR is a single number that summarizes the pattern of program benefits and costs over time. If the ROR exceeds the cost of obtaining funds for the program, for example as measured by an interest rate on borrowed funds, then the program is deemed successful.

[3] Maize output was split into yield and area components to get a better assessment of differential impacts on output. Since yield and area may be simultaneously determined, for example area expansion onto marginal land may decrease yield, an instrumental variables approach was implemented using two-stage, least squares.

seed programs contribute positively to attainment of higher maize yields and expansion of maize production, and consequently to growth in output.

The regression coefficients show that an increase in maize research expenditure of one percent leads directly to increases in yield of 0.25 percent and area of 0.49 percent after ten years. Interactions between research and area reduce the research impact on output by 0.35 percentage points, at a first-order approximation. Therefore, when adjusted, an increase in research expenditure by one percent raises maize output by 0.40 percent ten years later. This percentage figure is then converted to a change in maize output, and its value in Kenyan Pounds (K£). When used in equation **Figure 3**, a rate of return (ROR) of 68 percent was found.

This information and data was utilized to test the hypothesis that the maize research program was partly successful as a result of the complimentary effects of the extension program of the Ministry of Agriculture and the efforts of the Kenya Seed Company. The values of the exogenous variables, other than research, were set equal to the sample means for those variables. The only exception was the dummy variable representing weather and external economic shocks (DM), which was set equal to zero, so that results corresponded to a "normal" year. The resulting equations are:

(5) $$(YD) = 11.763 - 0.5705 \times \ln(AR) + 0.2529 \times \ln(RE$$

(6) $$\ln(AR) = 9.665 - 0.2623 \times \ln(YD) + 0.4922 \times \ln(RE)$$

The current paper calculates the interactions between yield and area, using an exact solution to the simultaneous yield and area equations (5) and (6). Solving these equations simultaneously to express ln(Y) and ln(A) as linear functions of ln(R) shows that:

(7) $$\partial\ln(AR)/\partial\ln(RE) = 0.5008; \text{ and } \partial\ln(YD)/\partial\ln(RE) = -0.03$$

Since annual maize production, Q, can be expressed as ln(Q) = ln(YD) + ln(AR), it follows that $\partial\ln(Q)/\partial\ln(RE) = \partial\ln(YD)/\partial\ln(RE) + \partial\ln(AR)/\partial\ln(RE) = 0.468$. Thus, a one percent increase in research expenditure raised maize output by 0.468 percent ten years later. This number is known as the *elasticity of maize output with respect to maize research.*

To quantify the effect of research on output in weight terms, the sample average maize production, 1,692,417 metric tons (t) is used. A one percent increase in research expenditure or 1542.59 K£, would increase production by 0.468 percent or about 7920 t. Applying equation **Figure 3** with P_m = 22.58 K£/t gives an ROR of 60.8 percent. The difference between this result and that of Karanja (1990) is due to the more accurate representation of interactions between yield and area in the current paper.

The solutions to equations (5) and (6) allow calculation of the maize quantity, $\hat{Q}$, at the sample means. Multiplying $\hat{Q}$ by the elasticity of output with respect to research (0.468) gives $\Delta\ \hat{Q}$, the predicted change in output from a one percent change in research expenditure. In this case, $\Delta\ \hat{Q}$ = 4460 t, different from the *actual* sample mean in part because of lower ability of equations (5) and (6) to predict the real situation (as explained by their relatively low R^2 values and the nonlinear nature of equation **3**). For this reason, the ROR (at estimated sample means) is reduced to 53.5 percent. Any of the estimated RORs, from 53.5 to 68 percent, indicate excellent returns to investment in maize research compared to alternative investments or prevailing bank interest rates.

To estimate the effect of extension on research impact, a scenario is constructed in which the extension service is assumed to lose one-half of its effectiveness. This is done by halving the estimated coefficient of EX in the yield and area regressions (5) and (6), while those of the other variables are unadjusted. This scenario's yield and area equations, analogous to (5) and (6), are:

(8) $(YD) = 11.397 - 0.5705 \times \ln(AR) + 0.2529 \times \ln(RE)$ a

(9) $\ln(AR) = 0.328 - 0.2623 \times \ln(YD) + 0.4922 \times \ln(RE)$

In this scenario, the projected increase in production due to a one percent increase in research expenditure is 2678 t, a decrease of sixty percent. This is strong evidence of the impact of the extension service on maize production. The elasticity of maize output with respect to maize research remains unchanged. However, the monetary impact of the research is diminished since the same percentage change in output due to research, applied to a lower level of projected output, leads to a lower estimated benefit. Using the lower estimated benefit in equation **Figure 3** results in an estimated a ROR of 46 percent, a decline of about eight percent from the base scenario. A second scenario assumes a one-half-effective seed program and a fully-effective extension service. When the impact of seed on yield and area is halved, the resulting yield and area equations are:

(10) $(YD) = 11.222 - 0.5705 \times \ln(AR) + 0.2529 \times \ln(RE)$; a

(11) $\ln(AR) = 9.586 - 0.2622 \times \ln(YD) + 0.4922 \times \ln(RE)$

The increase in production, ΔQ, due to a one percent increase in research expenditure equaled 2678 t. Using this in equation **Figure 3** results in an estimated ROR of 46 percent. Lastly, a scenario in which each of the extension and seed programs were one-half as effective is used. Thus, the impacts of extension and seed on yield and area were halved. The resulting equations were:

(12) $(YD) = 10.855 - 0.5705 \times \ln(AR) + 0.2529 \times \ln(RE)$; a

(13) $\ln(AR) = 9.249 - 0.2623 \times \ln(YD) + 0.4922 \times \ln(RE)$

In this case, the increase in output from a one percent increase in research expenditure fell to 1644 t, and the estimated ROR to research was 39 percent.

The results indicate that both the seed and extension programs contributed positively and significantly to maize production. These programs have positive interactions with the maize research program. The results indicate diminished impact of research were either, or both, of the complementary programs less effective. In other words, any condition that would have reduced the performance of agricultural extension and/or operations of the Kenya Seed Company would have reduced the impact of research on maize production. This would probably be the case if the extension program undergoes structural changes that reduce the effectiveness of extension message or the proportion of farmers contacted by extension agents. Similarly, a reduction of the efficiency of the maize seed production and distribution system would lower the impact of maize research on production. This is easy to visualize in that even if the research program developed better varieties but, for one reason or another, there was a less effective seed multiplication and distribution program, and/or technology transfer mechanisms, the result would be a reduction in the adoption rate and subsequent effect of the new varieties on overall production. However, despite these interactions between research and complementary programs, the estimated ROR to research remained high in each scenario, indicating a high productivity of maize research over the sample period.

4. INSTITUTIONAL ANALYSIS

Most of Kenya's agricultural development and performance today is heavily influenced by institutions and policies previously established, some dating as far back as the colonial era. Evaluating the performance of institutions today in isolation from the past is difficult. In order to explain the success of hybrid maize in Kenya, this study reviews the evolution of institutional and policy environments surrounding the maize industry from 1900 to 1990.

From the turn of the century to the Great Depression in the 1930s, agricultural development policy was almost entirely European-settler oriented, with scant attention paid to African agriculture. Between 1930s and 1950s, the settlers' interests still dominated policy but government increasingly attended to African farming during World War II. The Swynnerton Plan of 1954 marked a turning point and provided needed attention and impetus for African agricultural development. At independence in 1963, many agricultural institutions and policies were already in place which continue to influence the performance of Kenya's agricultural sector to date. This study highlights important institutions and institutional arrangements that existed in the following periods: (1) The Pre-Hybrid Era: 1900-63; (2) The Hybrid Revolution: 1964-80; and (3) The Hybrid Plateau: 1980-90; and considers the challenges facing the maize research program.

Table 2 presents the development of the maize research program, maize support institutions and key policy environments between 1900-90.

4.1. The Pre-Hybrid Era: 1900-1963

Britain became actively involved in East Africa in the 1870s, assumed territorial responsibilities in 1893 and colonized Kenya in 1920. Britain constructed railway line from the Kenyan coast to Lake Victoria to open up trade between Uganda and Britain. For political reasons and because the railway operation could not cover its costs, the British government encouraged its citizens to settle in Kenya and participate in agricultural production and trade to finance the rail-line and develop the colony. The settlers alienated about 20 percent of Kenya's best arable land, located mainly close to the railway line, imposed taxes on local Africans to obtain cheap farm labor, and established control over all monetary, transport, research and farmer advisory services. Further, the administration banned Africans from growing major cash crops such as tea, coffee and pyrethrum. In this way, African agriculture was relegated to a subsistence level while settler farming became export-market oriented and was aptly protected from competition.

Maize, having been introduced by Arab traders at the coast and moved interior by church missionaries, appeared in exhibitions at the first Agricultural Show in Nairobi in 1902. By 1903 maize covered about 20 percent of the total food crop area (Meinertzhagen, 1957; Huxley, 1958). Many of the introduced maize varieties originated in North America, brought by settlers immigrating from South Africa. The crop became increasingly popular among African farmers

but, since marketing outlets were nonexistent, they had no stimulus to increase production beyond subsistence requirements.

The opportunity for African farmers to increase maize production and participate in the market came in 1942, when the colonial government enacted an Increased Production of Crops Ordinance. This ordinance mobilized all farmers, European and African, to increase production of all food crops, particularly maize and wheat, to feed troops and personnel during the Second World War. To facilitate this, the government established a Maize Control Unit under the Agricultural Production Marketing Act (enacted in 1936) to oversee the purchase of all maize in the colony. A government-appointed farmer association, the Kenya Farmers Association (KFA), formed as British East African Farmers' Association in 1919, assisted in maize purchases, shipments and payments to farmers. Maize prices were guaranteed and for the first time, short-term credit was issued, in the form of Guaranteed Minimum Returns (GMR). Farmers responded by increasing production substantially: the acreage under wheat more than doubled, and maize in the settler areas also nearly doubled (Huxley, 1958).

The Maize Marketing Board (MMB) was established in 1959 to replace the Maize Control Unit. This confirmed the permanency of an organized system of maize marketing in Kenya. The objectives of the MMB were to regulate, control and improve the collection, storage, marketing, distribution and supply of maize and maize products (Huxley, 1958). Before creating its own marketing network, MMB utilized the services of the KFA and various provincial marketing boards set up in the 1950s to reach out to all maize-growing regions. A sharp increase in agricultural production during the war aggravated problems of soil depletion and erosion. The extent of these problems on African farms raised the concern of the colonial government, which pledged to improve African areas and emphasize soil conservation measures. From 1946 to 1954, the government invested substantial resources in soil conservation, livestock improvement, water supply, investigation and experimentation into farming systems, crops, methods of cultivation, fertilizers, and pasture research. A state of emergency imposed in 1952 against the Mau Mau rebellion slowed the recruitment of new settlers and provided the stimulus to accelerating the development of African agriculture. In 1953, the colonial government agreed "to provide employment to displaced Africans, raise agricultural productivity and human and stock-carrying capacity of the land" (Heyer *et al*, 1976). The colonial government then requested the Department of Agriculture to formulate a strategy for developing African agriculture. The response was the release the Swynnerton Plan of 1954, compiled by then Assistant Director of Agriculture, R.J.M. Swynnerton.

The plan outlined a comprehensive scheme for smallholder agricultural development. It proposed a review of the land tenure system to enable consolidation and registration of land and issuance of title deeds which farmers could use to borrow loans, and improvement of agricultural extension, research, credit and marketing services. It argued that African farmers required credit and recommended creation of an agricultural credit bank, the Loan Bank for African farmers. The plan also differentiated between the high-potential and the marginal regions, lifted restrictions on production of high-valued export crops by African farmers, recommended expansion of

agricultural extension and research services to African farmers and decentralization of marketing boards to improve marketing coverage. In response to this plan, the government expanded the agricultural extension program and formed district survey teams to plan and advise farmers on land intensification through farm planning and crop and livestock management. By 1962 the agricultural field staff had expanded to 179 agricultural officers and assistants, 1,107 agricultural instructors and 2,347 assistant agricultural instructors, but the teams could not cope with the demand for extension services. More than three-quarters of the staff were stationed in smallholder farming areas.

The maize research work that started in 1930 at Njoro was abandoned during the Second World War. Large commercial farmers in Trans Nzoia pressed the government to institute research into hybrid maize that was already popular in North America. The government granted their request and employed the first full-time maize breeder at Kitale (Johnson, 1980). Using conventional breeding methods, the breeder developed synthetic varieties from inbred lines developed from the well-adapted Kenya Flat White complex (Gerhart, 1975). One of these synthetic varieties became parent to the first Kenyan hybrid seed, H611, which was commercially released in 1964, about ten years after initiation of a maize germplasm improvement program.

In 1963, with prospects of the first maize hybrid at hand, the government entered into an agreement with Kenya Seed Company (KSC) to produce hybrid seeds and ensure adequate supplies were available to farmers.[4] Under the contract, the KSC multiplied, processed and distributed hybrid seed from the maize research program to farmers. Using the already established marketing network of the KFA, the KSC provided sufficient quantities of improved seed under the projected conditions of a rapidly increasing demand.

4.2 The Hybrid Revolution: 1964-1980

Before Kenya's independence, the British government drew up plans to maintain agricultural output and transfer land to Africans and promised aid for agricultural credit and technological and management services. Kenya's political independence in 1963 was accompanied by an exodus of settlers from large farms and a relatively smooth transition to African farming. The government committed itself to a comprehensive, land-resettlement program. In the first decade after independence, 35,000 families settled on 470,000 hectares (ha) of land from densely populated and resource-constrained African Reserves, at a total cost of £30 million. An additional 16,400 families settled on 168,000 ha in subsequent settlement programs.

The release of the first, Kenyan, hybrid maize in 1964 came at an opportune time because of the looming threat of a decline in the marketed surplus of food production as a result of the vast changes in the farming structure. A survey of African-owned, large, mixed farms in Trans Nzoia in 1967-69 revealed that overall agricultural production fell by 80 percent (Heyer *et al*, 1976). In

[4] Data to support this is rather vague.

response, the government expanded the agricultural extension program, provided credit through the Agricultural Finance Corporation (AFC), and set up training centers for African large-scale farmers.

In 1965, the government expanded the maize research program to cover the medium-altitude maize growing regions on the central highlands. The success of this expansion culminated in the release of medium-maturing maize hybrids that farmers in the region adopted quickly. Between 1963 and 1970, the maize breeding program was augmented by a comprehensive agronomy program funded by British aid and the Rockefeller Foundation. Researchers advanced recommendations on time of planting, spacing, weed management and fertilizer rates to farmers through an aggressive campaign and extensive coverage by the agricultural extension staff of the Ministry of Agriculture. By 1972, the extension service had about 2,600 agricultural and animal-health assistants and 5,500 junior assistants; the latter group worked in direct contact with the farmers. In spite of insufficiently trained frontline staff, low farmer coverage and message-orientation towards large-scale farmers, the extension service did play an important part in putting across the basic message about hybrid maize. In 1965, extension agents planted over 5,000 demonstration plots across the country in major maize-growing districts. In the late 1960s and 1970s, the extension service conducted hundreds of fertilizer demonstrations each year in all maize growing districts of western Kenya. Between 1964 and 1980, the maize program released 14 hybrids and open-pollinated varieties. In a survey on hybrid maize adoption in western Kenya in 1973, about 35 percent of the farmers interviewed indicated that they first heard of hybrids from extension agents and 64 percent said they would go to an extension agent for advice on maize (Gerhart, 1975, p. 9).

The Agricultural Information Centre, established in 1966, facilitated the hybrid campaign by supplying information to farmers and enclosing in every package of seed sold by the KSC printed leaflets in English and Swahili on hybrid recommendations. The KSC responded to high demand for improved maize varieties by expanding its marketing network in the mid-1960s. While relying on the KFA to service the large-scale farms, the KSC contracted provincial marketing boards, farmer cooperatives and Dalgety, a private hides and skins merchant, to reach out to smallholders. The company also appointed small-scale African shopkeepers in almost all trading centers in maize growing regions as hybrid seeds stockists, thereby bringing hybrid seed to within short distances from the farms. In this way, the KSC increased the number of hybrid maize seed stockists from 103 in 1966/67 to 1,171 and 2,541 stockists in 1971/72 and 1975/76, respectively. It also contracted large-scale farmers and government agencies such as the Agricultural Development Corporation to multiply seed; the latter account for about 50 percent of the certified seed (Ndambuki, 1990). Hybrid seed sales increased from an average of 2,100 t in 1966/67 to 6,700 t in 1971/72 and 11,460 t in 1975/76.

Use of fertilizer on maize never matched the adoption of hybrid seed. The reason commonly cited was that fertilizers were more expensive, bulkier and harder to store. Stockists lacked capital, storage and transport to provide sufficient quantities of fertilizers to farmers in a timely fashion.

Table 2. An Institutional Diagram of Maize Research in Kenya, 1900-1990

STAGE	PERIOD	MAIZE TECHNOLOGY DEVELOPMENT	MAIZE SUPPORT SYSTEMS	POLICY ENVIRONMENT
Pre-Hybrid	1900-63	*Introduction of Maize from U.S. via S. Africa *Scattered Trials/Pre-Selection of Maize Types *Kenya White Complex *Screening Maize Rusts, 1952 *Development of Synthetic varieties, 1950 *Hybrid Research, 1955 *Rockefeller Support, 1955 *Import of Germplasm, 1959 *Dryland Maize Research, 1957 *Agronomic trials, 1963	*Railway Network, 1890s *Farmers' Association, 1919; Renamed KFA, 1923 *Road Networks, 1920s *Agric. Extension, first attempts 1910s; revamped 1954 *Agricultural Credit (Land Bank), 1942 *Kenya Seed Company (KSC), 1956; *Maize Marketing Board, 1959 *Government Contract with KSC, 1963 *Agricultural Finance Corporation, 1963	*European Settlement *Kenya Colony, 1920 *Colonial Tax/Macroeconomic Policies, 1920s-50s *Agricultural Production Marketing Act, 1936 *Increased Production of Crops Ordinance, 1942 *Guaranteed Prices for maize, 1942 *Swynnerton Plan, 1954
Hybrid Revolution	1964-80	*First Hybrid Release, H611, 1964 *Mid-Altitude Maize Research, 1965 *5,000 District Demonstration Trials, 1965 *FAO-Sponsored Fertilizer Trials, 1970s *11 hybrids and 3 OPVs, 1964-80	*Expansion of Agricultural Services *KSC: Increased Seed Output and Distribution *KFA: Expanded Fertilizer and Seed Supply *Expanded Maize Marketing Services, 1970s *Rural Access Roads Program	*Independence in 1963 *Land Transfers and Re-settlement, 1960s *Expanded Credit, Extension, Research, 1965-80 *First oil crisis, 1973/79 *Second oil crisis, 1978/79 *Coffee Boom, Inflation, 1978-80 *Maize Marketing Policies Enhanced, NCPB, 1979 *Declining per capita food production, mid-1970s *Declining economic performance, mid-1970s
Hybrid Plateau	1980-90	*Increased Focus on Farming Systems Research *Focus on Yield Stability and Marginal Areas *Decline in Budget Support to Research *High-Protein Maize (abandoned) *NARP I, 1986 *Reorganization of KARI, 1984-86 *Maize Research Review, 1990 *7 hybrids 1 OPV, 1980-90	*National Extension Project, 1981 *KSC: Expanded Network/Exports *Decreased Loan Facilities: AFC, Commercial Banks *Expanded NCPB's Marketing & Storage Capacity *KSC Research Department, 1980s *Guaranteed Maize Prices and Purchases	*Food Policy Frameworks, 1981, 1986 *Major drought, 1984 *Focus on Smallholder/Marginal regions *Population Pressure/Control Strategies *Declining Economic Performance *Structural Adjustment Program *Restructuring NCPB *Liberalized Input Prices/ *Declining Per Capita Food Production

The Challenge Ahead	1990-	*What Emphasis: High/Marginal Maize; Breeding/Agronomy; Small/Large-Scale? *Increased Research Financing? *Strategic Planning/Priority-Setting? *Enhanced Networking: Regional/International?	*Liberalized Maize Marketing? *National Extension Project II? *Agricultural Credit: Orientation Towards Smallholders? *Liberalized Seed Industry? *Input Supply Markets, *e.g.* fertilizer? *Improved Performance of Maize Support Institutions?	*Ef *De *Po *Ec *De *De

But for a long time, the government maintained a price subsidy on fertilizer as an incentive to farmers. As a result, fertilizer use on maize increased substantially.[5]

The Sywnnerton Plan cited Agricultural credit as a critical input for agricultural transformation of African farming. The first government loans to smallholders were made prior to the plan in 1948 by the African Land Utilization and Settlement Board, later the African Land Development Board. The lending activities of these two boards (for African and European farmers) combined in 1963 to create the AFC. Under the AFC, short-term loans such as the GMR were advanced to maize and wheat farmers. The provision of the GMR was coordinated through the KFA which provided farm inputs and deducted their cost from produce delivered at the end of the crop season. The GMR provided loans to both large and small farmers (Gerhart, 1975). A survey indicated that only 1.5 percent of official credit went for maize grown by smallholders as of 1972. Credit from private lending was limited since maize trading was restricted to the official marketing channel.

Ready (official) market and guaranteed government prices facilitated Kenya's maize production boom of the 1964-80 period. The MMB merged with several provincial agricultural marketing boards in 1966 to form a single Maize Produce Board. In July 1979, this board and the Wheat Board of Kenya (established in 1952) merged into the National Cereals and Produce Board (NCPB). Through the various boards charged with the marketing of maize, the government improved the access to markets by increasing the number of purchasing depots and enlarged the national maize storage capacity by constructing more storage silos. Sales of maize to the marketing board increased from about 225,000 t in 1966/67 to 570,000 t a decade later. Between 1975-1980, maize purchases by the board were estimated at about 35 percent of the total marketed maize (deWilde, 1984). Between 1964-1980, maize production increased from about 0.9 million tons in 1964-65 to 1.5 million tons in 1974-75 and 1.65 million t in 1979-80. The increase in production from 1964 to the mid-1970s was attributed more to yield improvement than area expansion; the converse is true from the mid-1970s to 1980 (Karanja, 1990).

4.3. A Hybrid Plateau?: 1980-1990

Kenya's macro-economic environment deteriorated in the 1980s as demand for food increased due to a rapidly growing population, adverse weather in some years led to low output, and poor global economic conditions had deleterious effects on the Kenya economy. This prompted the government

[5] Data to support this is rather vague.

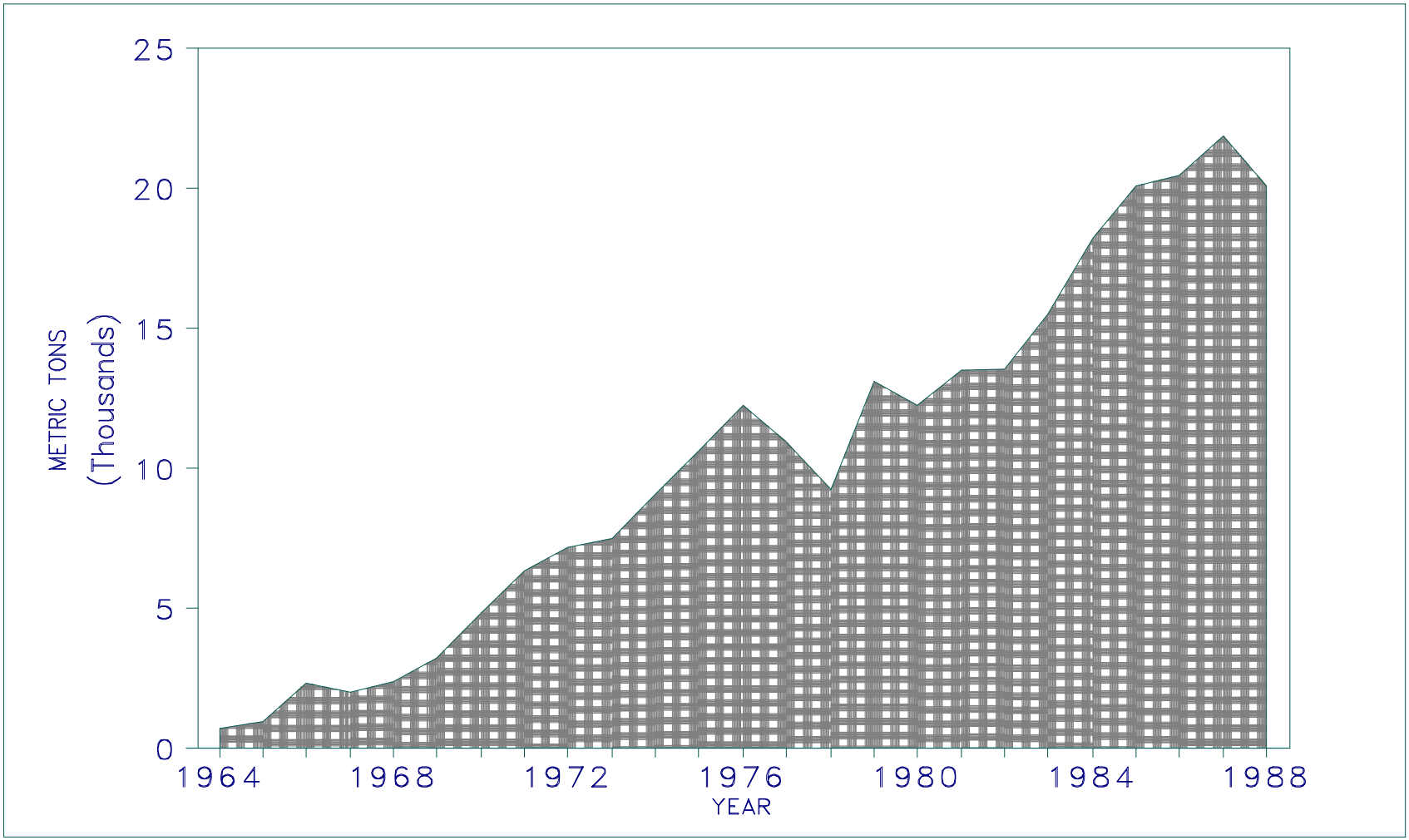
to map out strategies to increase food production to sustainable levels and to foster economic growth. These strategies included: (1) investments in agricultural research; (2) expansion of agriculture into the vast Kenya's low-rainfall region; and (3) reduction of population growth rate.

Despite increases in maize output of about 30 percent, from 1.9 to 2.7 million tons, between 1980-1981 and 1987-1988, the rate of increase in maize area and yield actually declined. Seven improved maize varieties were released to farmers between 1980-1990 period. Agricultural research and extension institutions underwent structural transformation that was meant to make them more effective as vehicles for development and dissemination of agricultural technologies. The government converted the former agricultural research department into a semi-autonomous institution, the Kenya Agricultural Research Institute (KARI), while adopting a new mode of extension, the Training and Visit system, in 1981.

Yields of maize varieties indicated that the newly released varieties in 1989 had smaller yield-advantage over their predecessors than the previously released ones. In other words, the research yields were exhibiting a "plateau effect" (Figure 3). For instance, H611 had a yield advantage of 40 percent over the KS II that it replaced, it was out-yielded by H622 by 16 percent which, in turn, was out-yielded by H611C by 12 percent. The latest release, H626, had a one-percent yield advantage over H625, which was released eight years earlier and is of close parentage. Similar observations can be made for medium-altitude maize and the open-pollinated varieties. It took 15 years after the release of the Coast Composite to release Pwani Hybrid I, which had a 0.78 t/ha yield advantage over previous varieties. This prompts the question: Was maize research yield approaching a peak? And if so, what were the implications on maize production in Kenya?

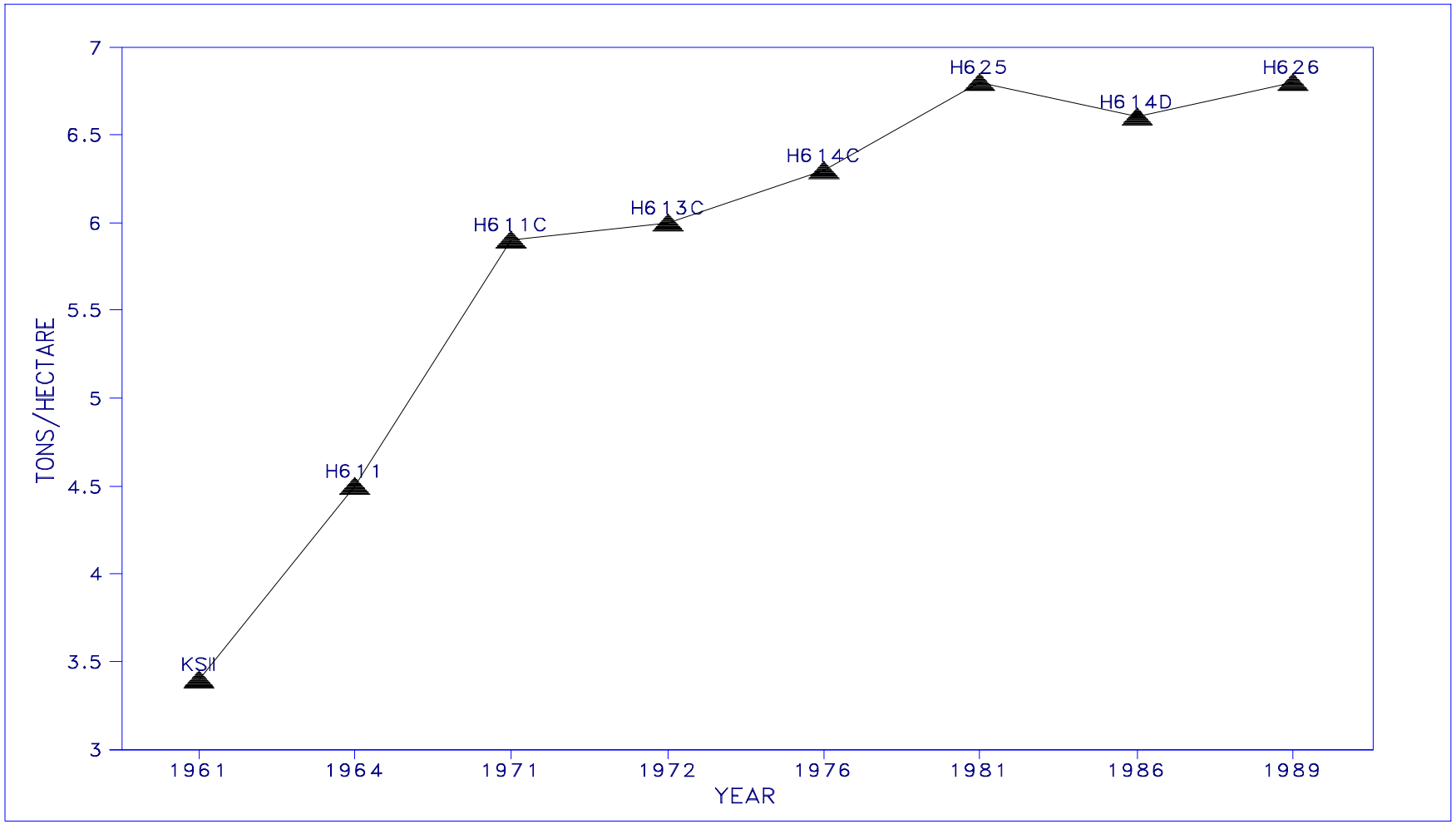
Also disturbing was the trend of KSC hybrid seed sales. Whereas seed sales increased substantially in the 1960s and 1970s, the growth in sales slowed down considerably in the 1980s. Between 1980-1990, the seed sales increased from an average of 12,800 t in 1980/1981 to about 21,000 t in 1988/1989. The annual increase in sales was by 2 percent between 1985-90 compared to a 40 to 70 percent annual increase in the 1960s and 20 to 30 percent in the 1970s (Figure 2 shows trends in maize seed sales between 1964-88). At the same time that yield improvements were diminishing, real (inflation-adjusted) expenditures on maize research were on the decline. Figure 3 presents the trends of maize research expenditure from 1955-59 to 1985-88. From an annual average expenditure of 126,400 K£, in real terms, in the 1960s, maize research expenditure increased to 232,000 K£ in the 1970s and declined to about 133,000 K£ in the 1980s. This decline in funding may have had a negative effect the productivity of the maize research program. Moreover, lack of operating funds has been cited as a major constraint to maize research (KARI, 1992). Reflecting on issues raised in this section, the challenge to increased maize production in Kenya is an uphill task as manifested by decreasing per capita maize production and increasing food demand fueled by a rapid population growth rate.

Figure 2. Maize See Sales in Kenya, 1964-1988.



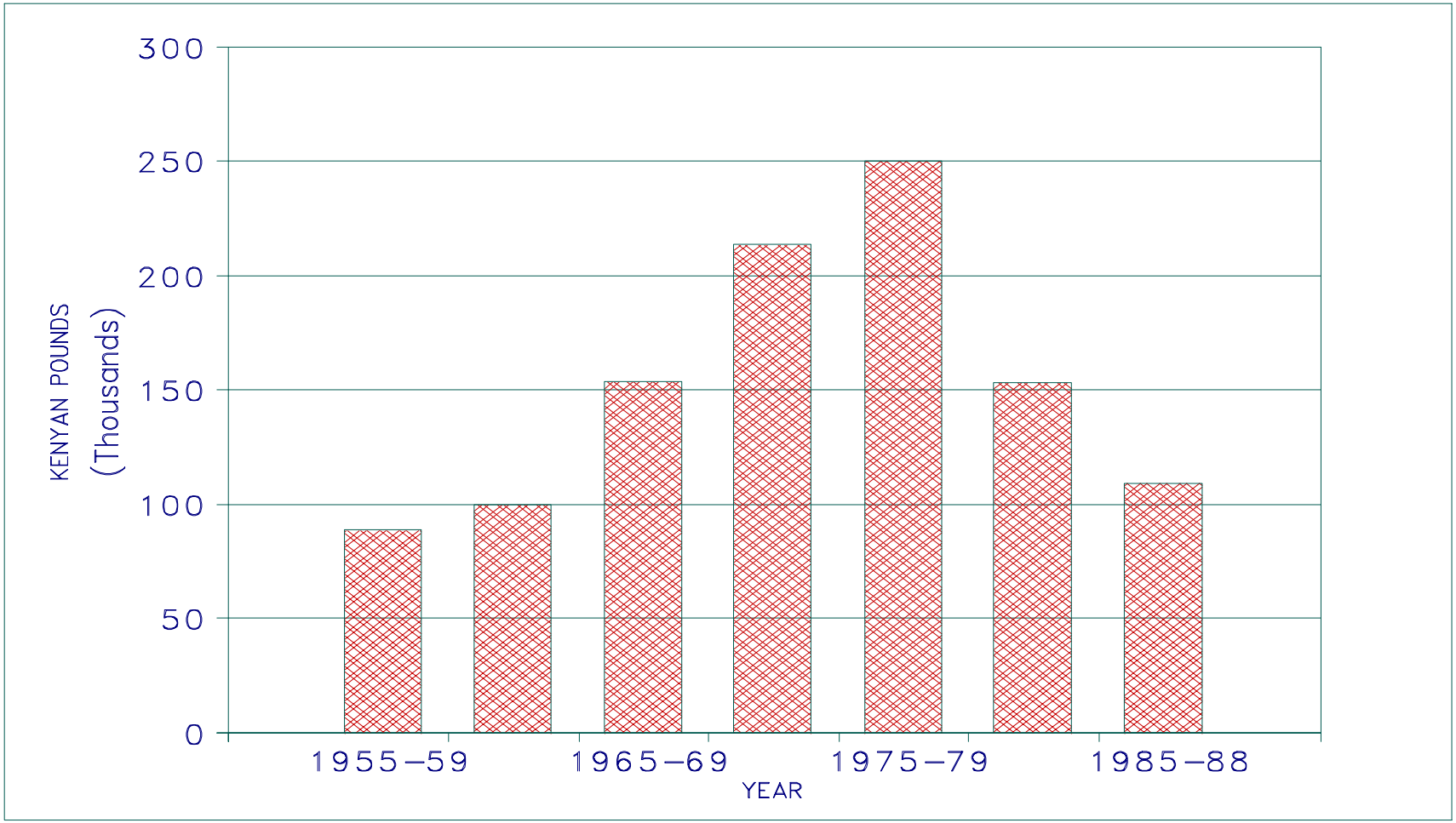
Source: Kenya Seed Company. Unpublished Data.

Figure 3. Late-Maturing Maize Varietal Research Yield Potential.


7
6.5
6
5.5
5
4.5
4
3.5
3
TONS/HECTARE
KSII
H611
H611C
H613C
H614C
H625
H614D
H626
1961
1964
1971
1972
1976
1981
1986
1989
YEAR

Source: Adapted from Karanja (1990).

Figure 4. Deflated Public Maize Research Expenditure in Kenya, 1955-1988. (1971=100).



Source: Karanja (1990).

5. IMPLICATIONS

The findings of this paper, as in Karanja (1990), indicate that maize research was productive over the 1955-88 period. The estimated payoff is high and comparable to investments in agricultural activities elsewhere and confirms that the investment made was worthwhile. Also, through both the economic and institutional analyses, the paper revealed the contributions to the success of the maize research program made by the KSC and the agricultural extension service of the Ministry of Agriculture. No doubt the aggressiveness of the seed and extension programs enhanced the productivity of the research team as evident from the spread and adoption of different maize varieties country-wide. This paper brought to light the importance of the institutional arrangement and policy agenda that existed at the time of the first hybrid release, revealing that Kenya had many of the necessary prerequisites for maize technological take-off. Some of the important factors that led to successful development of the Kenya maize sector are: (1) an effective railway and road network for facilitating farm-input supply and produce marketing already existed; (2) an efficient marketing network for inputs, through the KFA, and produce, through the MMB, was in place; (3) the government provided price guarantees and seasonal credit for maize; (4) an aggressive seed processing and distribution company, the KSC, was also in existence; and (5) the government was committed and had a political will to improve the quality and quantity of maize in Kenya, as is evident from its systematic and procedural creation of institutions and formulation of supportive policies.

Several other important factors led to the success of maize research and technology development in Kenya. These include: (1) the fifty years of local selection and adaptation that preceded hybrid research and provided appropriate parental stock; (2) the yield-advantage of the initial hybrids was overwhelming, leading to high adoption rates of new seed; (3) the demand for hybrids was immediate since it stemmed from the farmers; (4) the researchers' were committed to their work, as exemplified by the judicious importation of new genes from Latin America, using networking to identify appropriate genotype results; (5) the quality and continuity of the maize research program was impressive: from its inception in 1955 to 1973, the breeding program had only two directors, both with a 3-4 years overlapping experience at Kitale where the chief agronomist had more than a dozen years experience in Kenya; the program was also supported by three scientists from the same program (Iowa State) over a period of nine years, each familiar with the others' methods and experience; and (6) the maize research program worked closely with the seed industry, the government extension service and the farmers. The effective participation by farmers in the decision process in the early years was instrumental to the evolution of the hybrid era. The settler farmers insisted on hybrid research in the early 1950s. The government responded almost immediately by recruiting a plant breeder in 1955. The first maize hybrid was released ten years after initiation of the hybrid breeding research program.

Several lessons about agricultural research can be learned from this. First, the basic requirement for improvement is a profitable technology package, providing significantly higher yields and profits than the traditional technology. Kenya was fortunate to have people and organizations that could be mobilized, adapted, and coordinated to provide the services needed to make the new techniques available to farmers. Second, the issue of research financing is critical. The program funding level rose until the 1970s and beyond that declined (in real terms). Agricultural research

is an expensive venture, often with long gestation periods. One cannot expect better technique and farmer recommendations to be generated on declining funding. If research is to meet the herculean challenge ahead, then funding must be increased, sustained, and commensurate with the importance of maize in the Kenyan economy. Third, establishment of a research focus is critical especially when faced with limited resources. For this reason, the government needs to determine research priorities and allocate scarce resources accordingly.

In 1990-1991, **KARI** set institute-wide research program priorities that established maize research as the first priority crop research agenda (KARI, 1991). The institution also went on to formulate a strategic plan and within-program priorities for maize research in an effort to map out the future direction of research (KARI, 1993; Mills et al, 1995). These exercises established that proportionately more research resources be spent on agronomic rather than breeding research and smallholder rather than large-scale farmer issues. Should more research be used in the increasingly important low-rainfall regions of the country or in the traditional maize growing regions in the highlands?

Future research will require increased funding levels and a strong domestic financial commitment. Faced with declining domestic public finance, alternative funding for agricultural research must be sought. This may include encouraging private sector participation in research and re-established produce-cess deductions that worked well in the 1970s. This may become more complicated than before, now that maize marketing has been liberalized. The former option has not been exploited fully. However, there is hope in the near future that the seed industry will be liberalized and attract other private companies.

The challenge ahead is great. Maize will continue to be a major staple and will have to feed a rapidly growing population on declining per-capita land area and limited research resources. Since future productivity growth in maize is expected to come more from yield increases than from area expansion, maize research faces an uphill task of generating the innovations required dramatically to increase maize production.

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