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9. ABSTRACT

The purposes of this study are: a) to determine the pattern of diffusion from 1964 through 1973; b) to determine the influence of environmental factors on adoption as well as the influence of other factors such as farm size, cash crops, off-farm income, work experience, credit availability, formal education, and various types of extension contact; c) to characterize early, later, and non-adoptors of the new maize technology in terms of these socio-economic factors; d) to determine which portions of the "package" of recommended practices associated with hybrid maize are adopted and to what degree; e) to describe the maize industry in Kenya and to place the pattern of adoption in the context of Kenya's rural economic services; f) to consider the costs and benefits to Kenya of developing the new maize technology; and g) to draw conclusions as to why and how this development can be extended and improved. Among these conclusions are that a modest investment in the scientific breeding of maize has produced enormous returns to the government and people of Kenya. Even in those areas in which adoption levels are low, historical and survey data indicate that this has been a conscious process of non-adoption rather than "laggard" traditionalism.

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Abridged by CIMMYT

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FOREWORD: ON LAUNCHING THE STUDIES AND MOTIVATING HYPOTHESES

Launching the Studies

The study described in the following chapters is one of a series aimed at enlarging understanding of the factors impinging on the adoption of new maize and wheat technology. Better understanding of the elements shaping the diffusion of new cereals technology can help governments and development assistance agencies to increase farmer income, hence the interest in the topic. Interest increased as controversy about effects of introducing new technologies attracted widespread attention to the theme.

CIMMYT, with its mandate defining its role in the development and diffusion of maize and wheat technology, quickly assumed a participant's role in the discussions. The concern and the interest emanating from the critical importance of the theme stimulated CIMMYT to look for a modus operandi through which patterns of adoption and the forces shaping those patterns could be identified. Better understanding of these relationships would influence CIMMYT efforts to develop new technology, the orientation of its training program, and the approach taken in counseling governments about national programs.

In order to better comprehend what influences farmer response to new technology, CIMMYT set out to facilitate the research on which this and the other studies of the series are based. We decided to examine eight cases in which maize or wheat technology had been introduced to farmers. In identifying programs for study, we limited consideration to those in which the technology had been available to farmers for no less than five years and in which no less than 100,000 hectares of land might have been affected. Eight programs were selected for study. For maize the focus was on Colombia, El Salvador, Kenya west of Rift Valley, and Mexico's Plan Puebla. For wheat, programs in India, Iran, Tunisia and Turkey were considered. CIMMYT's maize and wheat staff participated in the selection of these programs. With their knowledge of programs around the world it was possible to choose a varied set of experiences—e.g. programs with and without irrigation, with and without effective price guarantees, with massive extension effort and with virtually none.

To the extent possible, each of the adoption studies was under the supervision of an indigenous economist. In only one case was it necessary to turn to an expatriate and there we had the good fortune to collaborate with a researcher with several years experience in the area. Each of the collaborators shared CIMMYT's concern for farmer response to new technology.

Beyond sharing this concern, each collaborator had an interest in farm level research done in close cooperation with agricultural scientists. The importance of this interest emerges from our conviction that agricultural scientists who are knowledgeable about a particular maize or wheat area can contribute substantively to research on the cereals economy of that area. Their special knowledge about the interaction between plants and their environments is important in identifying agro-climatic zones, critical periods for the crop, and activities which are essential to effective cultivation. Many agricultural scientists played a prominent role in these studies; each warrants our gratitude for his contribution.

As the studies were completed it became apparent that much could be said for publishing them in a standard format. With several serving as Ph.D. dissertations and others as less formal research pieces, a common format could only be achieved through reworking the original monographs. In every case but one, then, CIMMYT's publication is an abridgement of a longer piece. The Indian study, itself a review of the findings of several other research efforts, is being published in its entirely with no effort to recast it in the form of the others.

In making the abridgement we have followed certain norms. Mathematical proofs have been eliminated, literature reviews have been included only where they relate to points which are unique to a given study, and the discussion of the hypotheses motivating the studies have been dropped. This last decision arises from recognition of the substantial commonality of these hypotheses among the studies. This suggested that, rather than presenting essentially the same discussion in the text of each abridgement, the hypotheses could be treated once in an abbreviated form for all studies. That treatment follows below.

The Hypotheses

While each of the studies examines a somewhat different set of circumstances all depart from the same general assumption about farmer behavior. The assumption is that farmers are income-seeking risk averters who are sensitive to the nuances of the environment in which they farm and that they are generally effective in their decision making. For the six studies based on original survey data and to a more limited extent for the study of Plan Puebla, this common point of departure leads to a great deal of similarity in the motivating hypotheses.

Given a farmer oriented by the assumptions described above, we might expect to see relationship between the adoption of elements of the new technolocy and: 1) characteristics of the farmer—his age, education, family size, farming experience, off-farm work, percentage of land owned; 2) characteristics of the farm—its agro-climatic region, competition of industrial crops, relative importance of cereals, nearness to markets, farm size; 3) characteristics of government programs—access to credit, access to information (through extension agent visits or visits to demonstration plots).

Some of the relationships between these variables and the adoption of elements of the new technologh are more arguable, some less. Least arguable are hypotheses relating adoption to education, farming experiences, percentage of land owned, more favored climatic regions, relative importance of cereals, nearness to markets, farm size, access to credit, and access to information. With other things equal and accepting our assumptions that farmers are income-seeking, risk-averting, sensitive, and effective maximizers, virtually no one would argue that any one of these relationships should be negative.

Somewhat more arguable is the relation of age and family size to adoption. Even here it is likely that only a few would argue that these relationships might be positive.

Most arguable are the relationships linking adoption to off-farm work and competition of industrial crops. With respect to the former, some hold that the relationship is positive as more off-farm work implies more income, therefore a greater capacity to bear risk, hence a greater willingness to adopt new technologies. Others hold the converse, arguing that more off-farm work implies less interest in the farm, hence less willingness to put in the time and energy associated with taking on new technologies. So too for industrial commodities, where those who see the relationship as positive allude to greater experience with improved inputs and larger incomes while the contrary view rests on capital restrictions and the high opportunity cost of labor.

With knowledge of the relationships among these variables, researchers and policy makers can better develop and diffuse new technologies. Some of the variables considered, e.g. age and family size, are beyond the control of these decision makers. Nonetheless, by incorporating them in the analysis the effects of variables subject to their control are more clearly discerned. Knowledge of how these variables, e.g. agro-climatic zones and extension programs, relate to adoption can be of critical importance in affecting the development and diffusion of new technology.

With this rough sketch of the general argument, readers wanting more detail about the derivation of the hypothesized relationships can turn to the relevant original piece from which this series of abridgements was drawn. In all cases the studies feature the effects of agro-climatic region and farm size on adoption of elements of new technology. This emphasis is related to the earlier controversy about the effects of new technology where these two factors played prominent roles.

Before moving into the abridgement, some attention to the phrase "elements of the new technology" is warranted. Much has been made of the concept of a package of practices in the introduction of new technology. We've chosen to look at this a bit differently, taking the view that the differences in risk, expected income, and cost of each element of the technology are large enough to outweigh the effects of the interaction among these elements. That is to say, perceptive and prudent decision makers might well choose to take up only a part of the package rather than the entire package. For the programs studies, the two dominant elements in the package are improved seed and fertilizer. These two were analyzed as dependent variables for each of the studies. Of lesser importance are such elements as seed treatment, date of planting, method of planting, use of herbicides, use of pesticides, planting density, and seed bed preparation. Nevertheless, where one of these was recommended and where data are adequate, these are also treated as dependent variables.

What Follows

This report summarizes results of an extensive study of maize production in Kenya west of the Rift Valley. The study, which included a 1973 survey of 360 maize farmers, was a part of the dissertation research of John Gerhart at Princeton University. Gerhart's dissertation is entitled "The diffusion of hybrid maize in Western Kenya." His work was supported by the Ford Foundation.

Appendix II was prepared by Olaf Hesselmark. The Kenya Maize Board supported Hesselmark's work.

Don Winkelmann
El Batan

I. MAIZE IN KENYA

In this chapter we look at the importance of agriculture in the Kenyan economy and the role of maize as the basic staple in the Kenyan diet. Its central role, especially in diets, is immediately evident.

Agriculture in Kenya's Economy

Kenya's is basically an agricultural economy. In 1972, agricultural activities (both subsistence and monerary), excluding forests and fisheries accounted for some 34.6 percent of Gross Domestic Product, valued at £211.35 million making it by far the largest sector of the economy (Table 1).

Agriculture accounted for about 60 percent of all exports, either as raw or processed goods, provided about one-third of all wage employment, and supported about three-quarters of the total population.[1] Moreover, much of Kenya's growing manufacturing sector is based on the processing of agricultural commodities, including textiles, woolens, canned foods, pyrethrum, beef products, sugar refining, milling, coffee and tea. In addition, the production and distribution of agricultural inputs and services grew from £11 million to £26 million between 1965 and 1973.[2] Between 1964 and 1973, agriculture showed an average real growth rate of 6.0 percent in the monetary sector and 3.6 percent in the subsistence sector. In 1972 and 1973, however, agriculture grew considerably faster, with marketed production up 24 percent and 17 percent respectively. Although the share of agriculture in the total national product is expected to decline from 35 percent to 29 percent of GDP over the next Plan period, it is certain to remain the most important sector of the economy for the foreseeable future.

The continuing importance of the agricultural sector is reinforced by Kenya's rapid population growth, estimated at 3.5 percent or higher per year. According to the ILO employment study of 1972, the number of rural households in Kenya will increase from 1.7 million to 2.8 million between 1969 and 1985.[3] Given continued migration to the urban areas and increasing den and generated by rising incomes, food demand will grow by more than 5 percent per year in the rural sector and more than 10 percent per year in the urban sector. Using income elasticities calculated by the Food and Agricultural Organization of the United Nations and assuming growth rates of 3.5 percent for population and 6 percent for income, the ILO report projected average annual rates of growth of around 4 percent for maize, millet, sorghum, and other rough grains; between 4 and 7 percent for fruit, milk, pork, rice, vegetables, and wheat; and over 7 percent for beef, eggs, mutton, poultry, sugar, and edible oils. Because of already existing land shortages in the rainfed areas, these increases in production will have to come primarily through increased productivity per unit of land. Only about 7 percent of Kenya's total land area is classified as good agricultural land, with adequate, reliable rainfall and good soils and drainage. Irrigation potential is limited and extremely expensive, with development costs in the range of £700 to £1000 per hectare, rising to more than £2000 in more difficult areas.[4] Fortunately, however, a considerable potential for intensification of agriculture exists; in the case of almost every crop, average yields are less than half those obtained on the best small farms, husbandry is poor, planting material can be further improved, and use of commercial inputs is at extremely low levels.

Maize in Kenyan Diets

Maize is the most important crop in Kenya's agricultural economy, whether considered in terms of its value, its role as a basic dietary staple. Table 2 shows the gross marketed production of Kenya's major agricultural commodities from 1967 to 1972. In spite of fluctuations in prices and weather, substantial increases have been achieved in the production of temporary crops, most permanent crops (except sisal and wattle), and livestock products. The drought in 1970 and 1971 disguised the rapid increase in maize production deriving from the increase in hybrid maize usage, the results of which began to be apparent in 1972 and yielded large surpluses in 1973. Also disguised in these figures is the degree to which different commodities enter the market economy. It is estimated that only 5 to

Table 1. **Kenya's Gross Domestic Product, 1964 and 1972, value and sectoral shares (Kenya £ million in constant (1964) prices).**

Industry	1964 Value	1964 Share (%)	1972 Value	1972 Share (%)
A. Outside Monetary Economy				
Agriculture	73.36	22.3	98.55	17.8
Other	15.53	4.7	21.39	3.8
Total - Non-Monetary Segment	88.89	27.0	119.94	21.6
B. Monetary Economy				
Agriculture	51.97	15.8	85.80	15.4
Forestry	1.88	0.6	3.06	0.6
Fishing	0.85	0.3	1.13	0.2
Mining and Quarrying	1.46	0.5	2.45	0.4
Manufacturing and Repair	34.17	10.4	63.63	11.4
Building and Construction	6.82	2.0	14.14	2.5
Electricity and Water	4.84	1.5	8.85	1.6
Transport and Comminications	24.52	7.4	42.18	7.6
Wholesale and Retail Trade	32.54	9.9	52.49	9.4
Banking, Insurance	9.85	3.0	24.46	4.4
Ownership of Dwellings	13.34	4.0	15.02	2.7
Other services	11.90	3.6	26.45	4.7
Domestic services	2.94	0.9	3.80	0.7
General Government				
Public Administration	16.84	5.1	25.23	4.5
Defense	2.19	0.7	4.44	0.8
Education	11.20	3.4	28.68	5.1
Health	4.69	1.8	11.62	2.1
Agricultural Services	4.41	1.3	7.50	1.3
Other services	3.13	0.9	12.88	2.3
Total - Monetary Segment	239.55	72.9	433.81	78.3
Total Gross Domestic Product	328.44	100.0	553.75	100.0

Source: *Economic Survey, 1973,* Tables 1.1 and 1.4

15 percent of the maize crop, for example, is marketed through official channels, depending on yearly surpluses, leftover stocks on the farm, and local price differentials. In 1969, for example, if all the maize produced had been marketed at the then producer price (28 shillings per 200 pound bag), the maize crop would have been worth an estimated £21 million.[5] In 1972 it might have been worth £50 million. There are well-recognized problems in estimating the value of subsistence output.[6] Nevertheless, local prices often greatly exceed the official market price. Whether one uses world prices, f.o.b. Mombasa export prices, c.i.f. Nairobi import prices, local prices, or the official price for a given year, maize still ranks as the most important commodity in value terms.

Perhaps more important, however, is the role of maize as the basic staple in the Kenyan diet. Table 3 shows the proportionate areas in the small farm sector planted to major food crops in 1960 and 1970. In 1970, an estimated 1.1 million hectares were planted to maize, more than three times the area planted to the next largest food crop (beans), and about eight times as much as the next most important grain (sorghum). The dietary importance of maize is also indicated by what little nutritional data exist. A 1958 survey of 349 families in Nairobi showed maize accounting for 80 percent of starchy-staple calories, the second highest percentage (after Lusaka) of any African city.[7] A WHO-FAO-UNICEF survey in Kenya, although it was able to sample only seven of its intended 28 locations in the four years it had available, found maize to be the major cereal by far in all but one of the seven locations.[8] Bruce Jones, analyzing data from the 1969-70 Nairobi Urban Survey, found that maize was by far the cheapest source of calories and was second only to cow peas as a source of inexpensive protein:

Food	*Calories/Shilling*	*Grams Protein/Shilling*
Maize flour	6418	169
Cow peas	2850	192
Beans	2533	161
Wheat flour	2496	93
Rice	2200	42
Bread	1570	46

Although the average family spent only about 11 percent of its food budget on maize (and the lowest income bracket 14 percent), maize accounted for as much as half the calories consumed.[9]

The importance of maize established, we turn now to a discussion of several government programs focused on maize and on the diffusion of new maize technology.

Table 2. **Gross marketed production by commodity, 1968-1973 (Kenya £ thousands)**

	1968	1969	1970	1971	1972	1973*
Cereals						
Wheat	6,635	6,583	4,994	5,206	4,160	3,902
Maize	5,405	3,861	2,828	4,276	7,252	8,571
Barley	242	333	392	437	477	975
Rice	429	577	724	725	859	906
Other cereals	218	223	62	102	205	171
Total	12,940	11,577	9,000	10,746	12,953	14,525
Temporary Industrial Crops						
Castor and other oil seeds	569	503	556	400	272	227
Pineapples	140	210	242	295	326	412
Pyrethrum	2,622	1,317	1,477	2,523	3,662	3,038
Sugar cane	2,179	2,942	3,509	3,457	3,038	4,453
Tobacco	25	26	35	28	31	30
Cotton	700	834	695	878	980	983
Total	6,305	5,832	6,514	7,481	8,309	9,143
Other Temporary Crops						
Pulses	490	428	236	303	753	436
Potatoes	503	698	1,263	1,652	1,723	1,551
Other temporary crops	244	1,657	1,247	1,542	1,773	1,596
Total	1,237	2,783	2,746	3,497	4,249	3,583
Permanent Crops						
Coffee	12,266	16,163	21,814	18,922	24,165	32,396
Sisal	2,193	2,250	1,715	1,519	1,862	7,051
Tea	9,335	11,159	13,838	11,803	16,034	16,766
Coconut products	490	484	520	545	572	515
Wattle	433	464	420	423	530	468
Cashew nuts	422	423	1,186	944	638	862
Fruit and other permanent crops	670	702	745	1,025	1,080	972
Total	25,810	31,645	40,238	35,181	44,881	59,030
Total crops	46,291	51,837	58,498	56,905	70,244	86,281
Livestock and Products						
Cattle and calves	11,689	12,218	13,324	13,330	16,510	17,132
Sheep, goats and lambs	440	453	475	733	825	825
Pigs	890	614	750	593	631	651
Poultry and Eggs	358	320	998	1,032	1,207	1,207
Wool	533	560	346	220	205	503
Hides and skins	657	675	604	841	1,170	1,205
Dairy products	7,126	6,100	6,806	9,300	10,890	11,319
Total	21,673	20,940	23,303	26,049	31,438	32,842
Unrecorded Marketed Production	3,342	3,425	3,595	3,741	4,100	4,298
GROSS FARM REVENUE	71,306	76,202	85,396	86,695	105,931	123,421

*Provisional. Source: *Economic Survey, 1974*, p. 54.

Table 3. **Percentage of area planted to ten major food crops grown in the small farm sector, 1960 and 1970.**

Crop	1960 % of Total	1970 % of Total
Maize	44.0	51.4
Pulses	25.7	25.8
Sorghum	7.3	6.8
Millet	5.8	2.9
Cassava	4.4	4.2
Finger millet	4.2	1.8
Bananas	2.7	3.7
English potatoes	2.0	1.5
Sweet potatoes	2.5	1.3
Yams	1.1	0.3

Sources: *Kenya Statistical Digest, 1966* (1960 figures); *Economic Survey, 1973* (1970 figures). Note: Due to differences in sampling and classification, small differences (as among potatoes, etc.) may not be significant.

Notes

1. Republic of Kenya, *Development Plan, 1970-74*, p. 91.

2. Republic of Kenya, *Economic Survey, 1974*, p. 58.

3. International Labour Office, *Employment, Incomes, and Equality* (Geneva, 1972), p. 151.

4. International Labour Office, *Employment, Incomes and, Equality* (Geneva, 1972), p. 412. No maize is grown under irrigation in Kenya.

5. *Development Plan*, p. 237.

6. See, for example, Judith Heyer, "some Problems in the Valuation of Subsistence Output," Discussion Paper, University of Nairobi, August, 1965.

7. Marvin P. Miracle, *Maize in Tropical Africa* (Madison, 1966), p. 113.

8. M. Bohdal, N.E. Gibbs, W.K. Simmons, *Nutrition Survey and Campaign Against Malnutrition in Kenya, 1964-68, Nairobi* (no date), p. 128.

9. Bruce N. Jones, personal communication, Nairobi, August 1973.

II. GOVERNMENT PROGRAMS AND HYBRID MAIZE

In this chapter we consider government programs in research, extension, farmer training, credit, pricing, marketing, and input policies in the context of their contribution to the diffusion of hybrid maize. Along the way, some special efforts to reach small farmers with new maize technology are discussed and some conclusions drawn about their possible impact on the diffusion process.

Maize Breeding and Agronomic Research

Although some maize research trials took place as far back as the 1920s, these were carried on by isolated research workers and individual farmers in different locations and had little, if any, coordinated impact other than as selection work for yield improvement and disease resistance. "All a district agricultural officer seeking a sound solution to a problem had to do," Brown wrote of this period,[1] "was to go and look at what some good farmer was doing and there he had a practical demonstration of what could be done." Not until 1955, when the first research officer was appointed to work exclusively on maize at Kitale, did a systematic program for maize breeding get under way. In 1957 a program to develop early maturing maize types was started at Katumani, near Machakos in Eastern Province, and a program for developing medium maturity varieties was commenced at Embu in 1965. The details of these programs have been described by Harrison, Dowker, Eberhart, and Oagad, and have been briefly summarized by Smith.[2]

Using conventional breeding methods, inbred lines were developed from the well-adapted Kenya Flat White complex which had been selected by local farmers over the preceeding years. The inbred lines were formed into synthetic type varieties, the first of which, Kitale Synthetic II, was released in 1961. This became very popular and was grown on about half the large-scale farms in the Trans-Nzoia area by 1964, when the first conventional hybrids were commercially released. Because a synthetic is formed from a large number of inbred lines, it has considerable genetic variability and the farmer does not have to buy new seed every year. Hybrids, on the other hand, are developed from only three or four inbred lines, and, although they show hybrid vigor in the first generation cross, yields drop off by perhaps 20 percent in the second year. Farmers therefore have to buy seed fresh each season in order to get continuing high yields. For this reason, the original intention was to develop a joint program of synthetic and hybrid production in which the synthetics would be mainly intended for small-scale subsistence farmers and hybrids for large-scale commercial farmers. According to Harrison, "it was felt that small-scale farmers would not pay the high price needed each year for hybrid seed and too many would plant second-generation seed.... However, the impact of the higher-yielding hybrids was so great (about 30 percent higher than the synthetics) that soon after their release it became impossible to sell synthetics to either small-scale or large-scale farmers, and improved synthetics are now used only in [preparing hybrids]"[3]

The fact that the Kenya Flat White complex, because of its similarity of origin, had a rather narrow genetic base presented a complication. The possibility of extracting further inbred lines for continued hybrid production seemed to be limited. For this reason, a large collection of genotypes were imported in 1959 from Mexican and

Colombian germ-plasm banks to widen the genetic base of the Kenyan breeding program. Though nothing significant had come from earlier importations from temperate countries (U.S., Europe, South Africa, Australia), the Latin American material came from areas with similar ecological conditions to Kenya, close to the equator and with a wide range of altitudes. Moreover, material from the "original" or center-of-origin stock tends to have greater genetic diversity than varieties previously removed and adapted elsewhere. After careful pre-selection for late-maturing, high altitude, disease resistant types, 124 test crosses were grown in 1961 in a yield trial. Outstanding among the crosses was one between Kitale Synthetic II and Ecuador 573, a long-eared, high-altitude variety with tall stalks, and late maturity. This varietal hybrid was released as Hybrid 611 in 1964, the same year as the conventional hybrids, since no inbreeding had been required. Although the Ecuador 573 itself had yielded only 75 percent of the Kitale Synthetic II, the two varieties were sufficiently diverse to give excellent heterosis, and the first cross yielded 40 percent more than the Kitale Synthetic II. By improving both sides of the parent populations through recurrent selection while keeping the genetic variability within each, continuing improvements in yield have been made.[4] The breakthrough in yields, however, had already been made by 1964, at least for the high altitude areas, and within only a few years the reputation of "hybrid" was firmly established.

How did the new technology compare with the old technology on farmer's fields? Unfortunately, very few reliable data exist on actual on-farm yields in different localities, since measurement is costly and difficult, farmers generally don't know how large their fields are, some maize is picked green before harvest time, and husbandry practices differ considerably. Simply asking the farmer will give poor (generally high) results. Using research station results is often misleading since conditions are controlled. Even non-treated "control" experiments often given erroneous results due to residues of fertilizer left in the soil from previous years, insect control on neighboring plots, or merely from the advantageous location of most research stations. As we shall see below, even a deliberate attempt to approximate "poor" husbandry in the district husbandry trials yielded almost 50 percent more than the estimated average on-farm yield.

In the district variety trials, the effect of hybrid seed (assuming good husbandry in all cases) was found to be an increase of 30 to 80 percent depending mainly on altitude. (Chapter III, Figure 6) The effect of using the total package of recommended practices as compared with none of the recommended practices was an increase in yield of 307 percent and an estimated increase in profitability of 532/- shillings per acre at a price of 25/- per 200 pound bag. Most farmers, of course, would fall somewhere between these estimates, using some of the recommended practices and not others. A 1971 study of 153 farms in a high potential area, for example, found an average yield of 18.3 bags for 137 hybrid users and 12.6 bags for 16 non-hybrid users, although many of the hybrid users were specially selected participants in a government program and probably had higher levels of husbandry and input usage than the average farmer.[5] Nevertheless, a 50 percent increase is probably not an unreasonable average in that area. A follow-up on 36 farmers from the present study had too few non-hybrid users to give a comparative result, but found larger differences in yields due to different husbandry practices.[6] A comparison of hybrid yields on demonstration plots situated in farmer's fields (see Chapter III) showed substantial differences between hybrid yields in different agroclimatic zones, but again had no information on non-hybrid use. We can conclude that, although it is the combined package of practices that produces the most dramatic results, the use of hybrid seed alone will raise yields substantially, probably by as much as 50 percent under good conditions.

Plant breeding, of course, is only part of the research story. An active program of agronomic research has also been essential to determine proper fertilizer application, spacing, time of planting, and other recommendations. Although agronomic experiments go back as far as 1910, it is only since 1963 that A.Y. Allan, supported by funds from the Rockefeller Foundation and the British government, has developed a systematic program of agronomic research, closely tied to the breeding activities at Kitale. Prior to that time, the effects of husbandry, fertilizer application, and plant population had been examined singly or at best in pairs. Allan set up a series of district-maize-variety and district-cultural trials using a 3^3 factorial design with different levels of nitrogen, phosphate and plant population from which annual recommendations for farmers were prepared.[7] At that time, the average yield of maize in Kenya was estimated to be about five to six bags (1000 to 1200 pounds) per acre In the district variety trials, however, the unimproved local maize used in the control plots (with carefully supervised husbandry) yielded an average of 4000 pounds (20 bags) over the 1964-66 period. Clearly hybrids alone were not required to increase yields.

To test the effects of poor husbandry, Allan established a series of 2^6 factorial trials in which each of the six factors (time of planting plant population, type of seed, standard of weeding, and use of nitrogen and phosphate) were deliberately set at a "high" and a "low" level. The results of these experiments are shown in Table 4. Time of planting and type of seed were the most important factors in determining yield, followed by standard of weeding and plant population. Fertilizer application was not important, and, in the absence of good husbandry practices, was actually unprofitable. It is interesting that even the "low" level of the practices applied on the research plots yielded 1760 pounds per acre, considerably above the estimated national average of 1200 pounds. The results were illustrated clearly in a "maize diamond" (Figure 1) in which physical inputs (seed, nitrogen, phosphate)

Table 4. **Effects of husbandry and input use on maize yields.**

Factor	Treatment	Yields lbs/Acre	Added Return Shillings/Acre[1]	Added Cost Shillings/Acre[2]
Time of planting	Start of rains	5200	270	Very little
	4 weeks later	3040		
Plants per acre	16,000	4580	115	8
	8,000	3770		
Type of seed	Hybrid	4860	175	12
	Local	3380		
Amount of weeding	Three times, early	4640	130	20
	Once, late	3600		
Phosphate per acre	50 lb.	4160	10	32
	None	4080		
Nitrogen per acre	70 lb.	4380	65	72
	None	3860		

1/ At 1966 price of 25/- per 200 pound bag. 2/ Based on costs of inputs required and estimated labor costs. Source: A.Y. Allan, "District Husbandry Trials in Western Kenya, 1966 and 1967." Quoted in M.N. Harrison, "Maize Improvement in East Africa" in C.L.A. Leakey, Crop Improvement in East Africa, 1970. p. 45.

and poor husbandry are compared with good husbandry (early planting, weeding, proper spacing). The physical inputs alone produced a 66 percent increase over the original average of all practices taken at a low level, while the good husbandry practices produced a 148 percent increase. All six practices taken at a high level produced a 307 percent increase. The implication is clear that it is dangerous to recommend the use of expensive fertilizer in the absence of high levels of husbandry. A "second-best" formula is implied, in which improved seed genotype is combined with improved husbandry practices for a low-cost, high-return solution. This is what most farmers in western Kenya have, in fact, discovered for themselves (see Chapter III) although the extension service has continued to recommend the full package of practices.

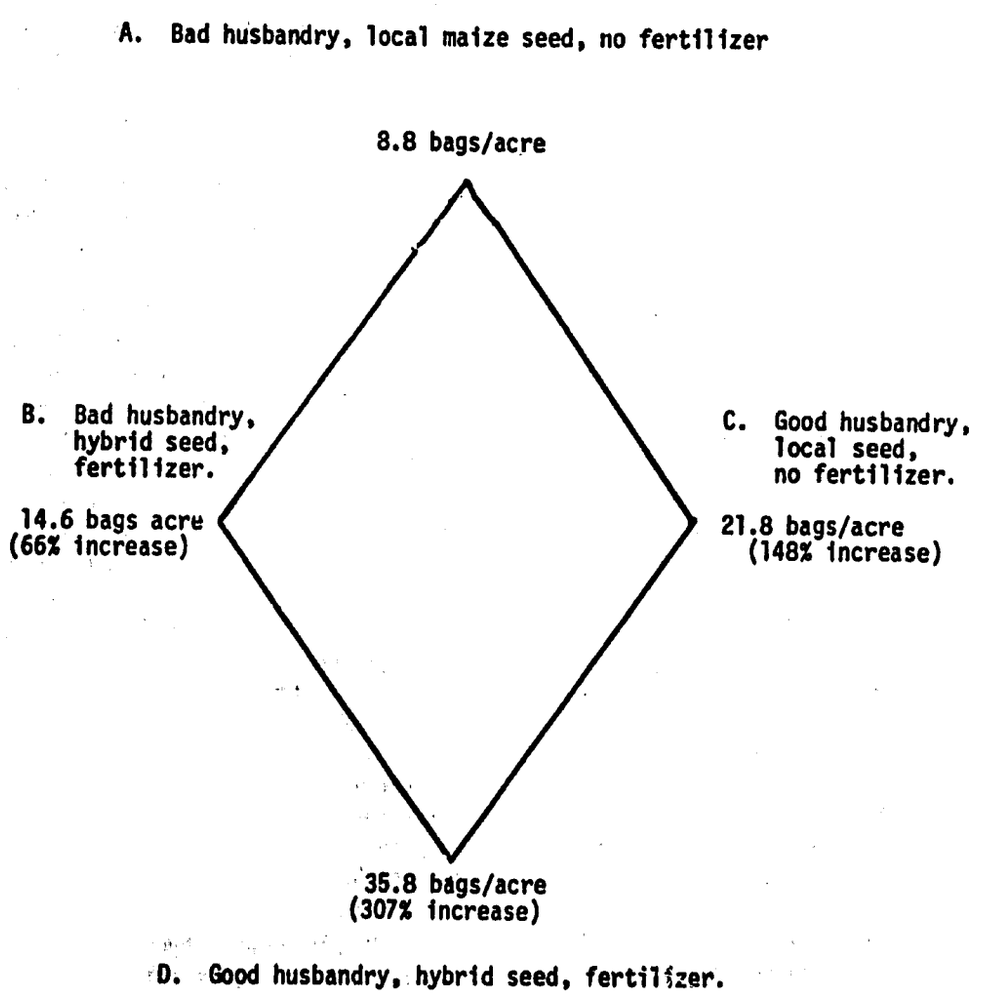
Probably the most important of the agronomic findings was the importance of early planting. Several explanations of this have been advanced, including the onset of fungal leaf infections, soil nitrogen fluctuations, and the moisture requirements of maize. Allan concluded that the effect of late planting was due primarily to poor root aeration in the early stages of growth. But simply, maize needs a small amount of moisture in its early stages of growth, when the growing point is still below the surface of the ground, and then considerable moisture in the later stages when it is tasselling and filling out the cob. Planting after the rains have started means that the plant starts off in very wet, cold, poorly aerated soil, and then may suffer later from water shortages when the rains are tailing off. The problem with this fact is that many, particularly small-scale, farmers have difficulty in planting early due to the hardness of the soil, delays in getting seed and fertilizer, and a fear that the rains will be late and the dry-planted seed will be wasted. As we see in Chapter III, planting before the rains had the lowest adoption level of any cultural practice in all three agroclimatic zones of the study. The costs of late planting, however, are enormous. In nine different experiments between 1966 and 1968, Allan found that each day's delay in planting after the rains started resulted in a loss in yield of an average of 75.9 pounds per acre per day (or 7.59 bags for a 20 day delay after the start of the rains). E.R. Watts found in Embu District of Eastern Province that the loss was as great as 6.2 bags per acre per week, yet only 58 percent of "progressive" farmers and 26 percent of a control group had planted before the rains due to the hardness of the soil and a lack of plows [8]

The possibilities for extended agronomic and breeding research are, of course, practically limitless. DeWilde, writing in 1966, complained that, although suitable recommendations existed for the highland mixed-farming areas, additional field traisl under "widely varying ecological conditions" were needed to determine a package of improvements for less favored areas.[9] Recognizing this need, the Kenya Maize Research Section recently began, with British assistance, an expanded agronomic research program in key maize growing districts. Belshaw and Hall, in an excellent discussion of research problems in Africa, recommended that more emphasis be placed on the economics of small-farm operations, including particularly analysis of labor constraints and of the reasons why small farmers persist in such practices as inter-cropping (planting mixed stands).[10]

Without implying that the initial success in breeding high yielding hybrids has solved all the research problems for hybrid maize, it is nevertheless useful to ask what in the Kenyan situation produced a breakthrough at all. What, if anything, can be generalized from the Kitale research experience? Several things are apparent. First, demand for the research product was immediately present. Kitale is centered in the middle of the biggest maize growing area in Africa and the maize industry pervades the town and the research station. This is in direct contrast to

many places in Africa where research stations are placed in cool hilltop conditions removed from the growers who are expected to benefit from the results. People in Kitale literally eat, drink, and talk maize. Secondly, the Kenyan case was patently not an attempt to transplant technology unalloyed from a developed, tropical environment. Fifty years of local adaptation and selection had taken place to produce Kenya Flat White, an appropriate parent stock. Thirdly, the importation of additional genetic material, when it came, was done systematically and carefully, taking advantage of a world-wide network of scientists who were able to preselect for Kenyan conditions from an analogous, but diverse, Latin American population and to use that imported material in a way that would produce results in the quickest and most productive way. In other words, a thorough knowledge of local conditions and extensive local research and breeding was a prerequisite to effective utilization of international research work. Fourth, the quality and continuity of the Kenyan maize program staff is probably unmatched in any national research program in Africa. From its inception in 1955 until 1973, the maize breeding program had only two directors, Michael Harrison and Festus Ogada, who themselves had three or four years of overlapping experience at Kitale. Their chief agronomist, A.Y. Allan, had more than a dozen years experience in Kenya. The program was supported by three American scientists coming out of the same (Iowa State) program over a period of nine years, each familiar with the others' methods and experience. In a governmental bureaucracy where two years is considered a long posting, this continuity in leadership (which has also largely been matched in supporting staff) is most remarkable. Finally, and perhaps most importantly, the Kenya Maize Research Program has never been isolated from the other components of a national maize program. It has worked closely with seed production staff, government extension personnel, and

Fig. 1. **"Maize Diamonds" in Kenya: Husbandry, physical inputs, and yield.** Source: 1966 District Husbandry Trials; A.Y. Allan, "Maize Diamonds", Kenya Farmer, January, 1968.



farmers themselves. As we look further at the other components of the system, we can see how important this constant communication and feedback have become.

Extension and Farmer Training

The literature and practice of agricultural extension efforts is, of course, enormous.[11] In Kenya, government interest in bringing new information to African farmers goes back at least to 1911, when, according to Fearn, "instruction was given in the use of the wheel-plough to sons of chiefs and others at Kibos, some four or five miles from Kisumu."[12] Unfortunately, the chiefly bias reflected in that early extension effort has persisted to the present day; extension contacts and farmer training are disproportionately distributed toward the larger and wealthier farmers. A study of farmers in one part of Central Province found that all of the most "progressive" 25 percent of the farmers had been visited by an extension agent during the previous year as opposed to 41 percent of "the least progressive" 18 percent of the farmers.[13] Leonard, in a detailed study of extension agents and clients in Western Province (part of the area covered in the present study), found that 57 percent of all extension visits were paid to "progressive" farmers (who constituted 10 percent of all farmers) and only 6 percent of visits were paid to "non-innovative" farmers (who constituted 47 percent of all farmers).[14] The present study found that 56.5 percent of the farmers over 50 acres in size had received extension visits in the past year, as opposed to 35 percent of all farms under 50 acres and only 27 percent of farms in the lakeside districts. Attendance at Farmers Training Center courses was even more highly skewed, with 48.6 percent of the largest farm owners having attended and only 8 percent of the farmers in the lakeside area. Although these percentages may be quite high by African standards, and one might even argue from the congruence of visits and progressiveness that the extension service is demonstrably effective, nevertheless the fact remains that the extension services favor the more progressive, and hence, in most cases, the wealthier farmers. This obviously has important implications for the pattern of diffusion of new technology.

Concentrating extension efforts on wealthier, more progressive farmers has been justified on the grounds that, since it is impossible to reach the majority of farmers with a limited extension network, a larger proportion of total farm area can be influenced by concentrating on larger farmers, who would also serve as models for the rest of the farm community to emulate. The argument has been supported to some extent by the attention paid by academic investigators to "innovators" or "progressive farmers" who tend, for a variety of reasons, to be better educated and to have larger farms.[15] Recently, however, a healthy corrective view has emerged, in Kenya at least, which puts emphasis on reaching those farmers who have been left behind by changes in agricultural development. In this view, attention should be devoted to those farmers who have not adopted new farm practices and more emphasis should be placed on group and mass media extension techniques.[16]

The case of hybrid maize provides an excellent test of the extension service at its best since, unlike many cases where the extension service has little or nothing to offer the farmers, in this case the service had a proven and profitable package of recommendations. As of 1972, the agricultural field services had some 2600 agricultural and animal health assistants (AAs and AHAs) with certificate level (post-secondary) training and some 5500 junior agricultural and animal health assistants (JAAs and JAHAs) with only on-the-job training of a limited nature. This represented about one trained extension agent per 700 farms (one to 138 on settlement schemes), although far from all the trained staff were available for actual extension work, many being occupied with administrative and statistical dueties. In addition, there were a total of 32 district farmer training centers, although, according to the ILO report, only 27 of these were operating even at modest levels and these suffered from "chaotic" financing, inexperienced staff and frequent changes in leadership (12 of 27 principals changing, for example, in 1971).[17] The quality of the field staff performance is also questionable. Leonard, for example, found that out of a possible high of 19 points on an index of knowledge of hybrid maize recommendations, the average score of 269 extension agents was only 13.7. Whereas 91 percent of the agents knew what fertilizers to recommend, only 59 percent knew how much to apply. Moreover, agents visited an average of only 7.2 farmers a week, which accounted for 35 percent of their work time, 13 percent devoted to demonstrations and 29 percent to administrative and statistical chores.[18] Although these figures are from only one in-depth study, they correspond rather closely to a Tanzanian study that found only 28 percent of extension agents' time was spent visiting farmers and 14 percent in demonstrations and group activities.[19] Although the staffing levels, by African standards, are not bad, the frequency, distribution, and content of extension contact with farmers leave much to be desired. Incidentally, there is in Kenya an Agricultural Information Centre, started in 1966, which produces posters, handouts, films, and radio programs for mass dissemination. At the time of a 1971 visits, however, the centre lacked adequate staff or funding to do its work well. By far the most useful of all mass media methods are the printed leaflets, in English and Swahili, enclosed in every package of seed sold by the Kenya Seed Company.

In spite of these deficiencies, however, one must conclude that the extension service did play an important part in putting across the basic message about hybrid maize. In 1965 over 5000 demonstration plots were organized in the country, mostly in the western portion. In recent years with FAO support, the extension service has conducted hundreds of fertilizer demonstrations each year in all the maize growing districts of western Kenya. In the present

survey, 25 percent of farmers claimed to have attended one personally, and such attendance was positively related to adoption and early adoption (especially in the high density districts where most of the demonstrations were held). Moreover, some 35.4 percent of 11 farmers said that they first heard of hybrid from extension agents (Table 5) and 64 percent said that they would go to an extension agent for advice if they had a question about their maize. (In two earlier surveys, 42 percent of farmers in Vihiga Division of Kakamega District reported an extension visit; 37 percent, demonstration attendance; and 7 percent, attendance at an FTC course. In Kisii, 89 percent reported an extension visit and 40 percent had seen demonstration plots.[20]) These findings indicate that, whatever its shortcomings, the extension service has played an important part in the diffusion of hybrid maize, with the result that by the time of the present survey, only 9 of 360 farmers (2.5 percent) could actually say they had never heard of hybrid maize.

Supply of Agricultural Inputs

Hybrid seed production in Kenya is carried out by the Kenya Seed Company, a locally-owned commercial enterprise in which the government, through the Agricultural Development Corporation, is a major share-holder. The commercial aggressiveness and efficiency of this enterprise is one of the major reasons for the Kenyan hybrid maize success story. The KSC was started in 1956 by a group of European farmers in the Kitale area to produce improved varieties of grass seed which had been selected from indigenous Kenyan grasses at the National Agricultural Research Station at Kitale. The founder of the company, Mr. W. Heilbuth, is still chairman of the company's board of directors. In the early 1960s, with Jomo Kenyatta's release from detention and the prospect of Independence on the horizon, European farmers stopped investing in improved pastures, and the company began to incur losses. Then, in 1962, a Dutchman, W.H. Verburght, was recruited as manager just at the time that the chief maize breeder at Kitale, Michael Harrison, was looking for someone to produce hybrid seed. Up to that time it was widely thought in Kenya that small farmers would not buy hybrid seed every year. Verburght, however, saw that with a declining number of European farmers, selling seed to small farmers was the company's best hope for success, and with Harrison's prodding and E.J.R. Hazelden, an aggresive former research officer, as sales manager, the KSC began pushing seed to anyone who would buy it.

Since the Kenya Farmers Association at that time was oriented almost exclusively toward European farmers, the KSC got the West Kenya Marketing Board and Dalgety, a trading company engaged in buying hides and skins in African areas, to handle the seed, as well as the Bungoma Farmer's Cooperative Society. The KSC then began appointing stockists, small-scale African storekeepers selected for their location, reputation, and interest, who alone would be allowed to buy seed at wholesale prices from the KFA or Dalgety's outlets. This network spread until, by 1972, the KSC had over a thousand registered stockists. Their distribution is shown in Map 1 in relation to population. The commercial maize-growing districts (Trans Nzoia, Bungoma, and Uasin Gishu) have less than 3000 persons per stockist, whereas the densely populated high potential districts (Kakamega, Kericho, and Kisii) together with Nandi, have between 3000 and 5000, and the lakeside districts (Busia, Siaya, Kisumu, and South Nyanza) have 10,000 or more persons per outlet. As the KFA and Dalgety gradually took over this promotion work on their own, the KSC reduced its staff to the present three salesmen (and the KFA increased to sixteen).

Seed is sold nationwide at a fixed price of 20 shillings for a 20 pound bag, enought to plant one acre. The wholesale price is 17.75 shillings and the total markup is divided so that each stage in the distribution chain, from factory to wholesaler to stockist, receives a larger share, and consequently, an incentive to push the product. This approach, modelled, according to Verburght, on the marketing of Wilkinson razor blades, has made "every stockist an extension agent." After an initial bad experience with credit, thw KFA now sells mainly for cash, although some stockists

Table 5. **"From whom did you first hear about hybrid maize? "(All answers in percentages)**

Source	Zone 1	Zone 2	Zone 3	Zone 4	Weighted Average
Extension agent	30.5	33.3	43.2	40.2	35.4
Dealer/stockist	15.8	6.7	4.5	4.1	9.9
Friend/neighbor	42.1	50.0	44.3	18.0	44.7
Employer	3.2	0	1.1	2.7	1.7
Agricultural show/field day	0	0	1.1	4.1	0.4
Newspaper	2.1	1.1	0	5.5	1.2
Can't recall, other	6.3	8.9	5.7	11.1	6.7
	100.0	100.0	100.0	100.0	100.0

pass on credit at their own responsibility to local customers.[21]

A recent parliamentary report, complained that stockists often ran short of inputs because they could not afford to carry inventories on a cash basis and recommended that a credit scheme for stockists and a subsidy incentive be introduced to encourage stockists to have inputs on hand in good time for planting.[22] The committee also recommended subsidizing the price of seed and fertilizers to lower their price to the farmer. Seed company officials generally are opposed to a subsidy on the grounds that farmers will use greater care in planting seed they have paid for and seed is a small cost relative to the value of output per acre. What seems more important, however, is guaranteeing that stockists and wholesalers have adequate profit incentives to insure that stocks are available in time for planting in the rural areas. For this reason, reducing the price of seed should be viewed with some caution.

Hybrid seed itself is produced by some 80 to 100 registered farmers in the Kitale area under close supervision (including weekly field visits to inspect weeding. detasseling, etc.) by the Kenya Seed Company and a government seed inspection unit. Farmers in 1973 received a price of 100/- for a 100 kg. bag of clean seed maize, which —at an average yield of 18 bags per acre— gives an adjusted gross margin of 320/- per acre for seed maize which compares with 213/- per acre for commercial maize at an equivalent yield and perhaps 190/- per acre for wheat, a competitive crop in some portions of the maize growing area.[23] Although seed growers complained that this was a lower profit margin than they had had in the past, given the trouble of growing seed maize,[24] a more serious long-term threat to seed maize growing is the continued break-up of large farms by land"companies" for squatter settlement. To ensure the isolation from other maize needed to grow seed correctly, a larger share of seed growing may have to be taken over by state farms in the area.

After harvesting, the seed is inspected, fumigated, and cleaned, graded and treated with a fungicide/insecticide dressing before being packed. The dressing includes a bright blue-green coloring which only the company is allowed to import, to prevent counterfeiting by stockists. Although the KSC has in some years run short of seed due to the rapid uptake of hybrids by small farmers, it now tries to carry over from one year to the next 20-50 percent of yearly sales to safeguard against sharply increased demand or a poor seed production season. In spite of these difficulties, however, the widespread sale of high quality seed at 20/- per bag is one of the strongest links in the hybrid maize chain in Kenya. The situation compares very favorably with most Latin American and Asian countries, where government-run seed agencies both grow and inspect their own seed.[25] Although the Kenyan government has a share in the ownership of the Kenya Seed Company, it has been wise enought to leave the production and distribution of inputs to commercial operations, while itself conducting a separate seed inspection unit. This production, distribution and inspection system may be the major reason why Kenya, almost alone among the poor countries of the world, has been successful with hybrids as opposed to synthetic maize varieties.

Table 6. **Imports of manufactured fertilizer into Kenya.**

Year	Amount (Metric Tons)	Value £000
1963	38,621	n.a.
1964	55,364	n.a.
1965	70,498	n.a.
1966	71,279	n.a.
1967	81,476	1601
1968	84,701	1875
1969	105,413	2272
1970	141,215	3041

Source: Annual Trade Report, E.A. Community, *Economic Survey, 1973.*

Fertilizer Distribution

No basic fertilizers are manufactured in Kenya, although several companies maintain storage, blending, and bagging factories designed to package a wide range of fertilizer mixes with a comparatively small tonnage of fertilizers each.[26] Some phosphates are imported from Uganda but most fertilizers are imported directly from overseas. Fertilizer imports for 1963-70 are shown in Table 6.

Fertilizers face the same distribution problems as hybrid maize seed, only more so. They are more expensive, bulkiers, more specialized in use, and are used more exclusively by the large farm sector. Demand for the products is limited to a relatively short period during the year, just before planting, and yet timely availability is all-important to sales. Stockists, however, have neither the capital, the storage space, or the transport to keep and move large quantities easily. The result of these problems is that fertilizer distribution has developed more slowly and less broadly than seed distribution, although essentially using the same channels, namely, wholesale firms such as the Kenya Farmers Association and Dalgety, cooperative societies in those districts (mostly in Central Kenya) where they are strong, and a broad system of selected and registered stockists.[27] In spite of the generally low level of fertilizer use in some areas (only 4 percent of farmers, for example, in Zone 3 of the survey area), overall usage is increasing rapidly as shown in Table 6. This increase has been helped by the FAO-supported fertilizer demonstrations which show average benefit/cost ratios for both phosphates and phosphates plus nitrogen of 2.4, 3.2, and 4.0 for 1969, 1970, and 1971 respectively as maize prices were increased from 25/- to 30/- to 35/- per bag while fertilizer costs held

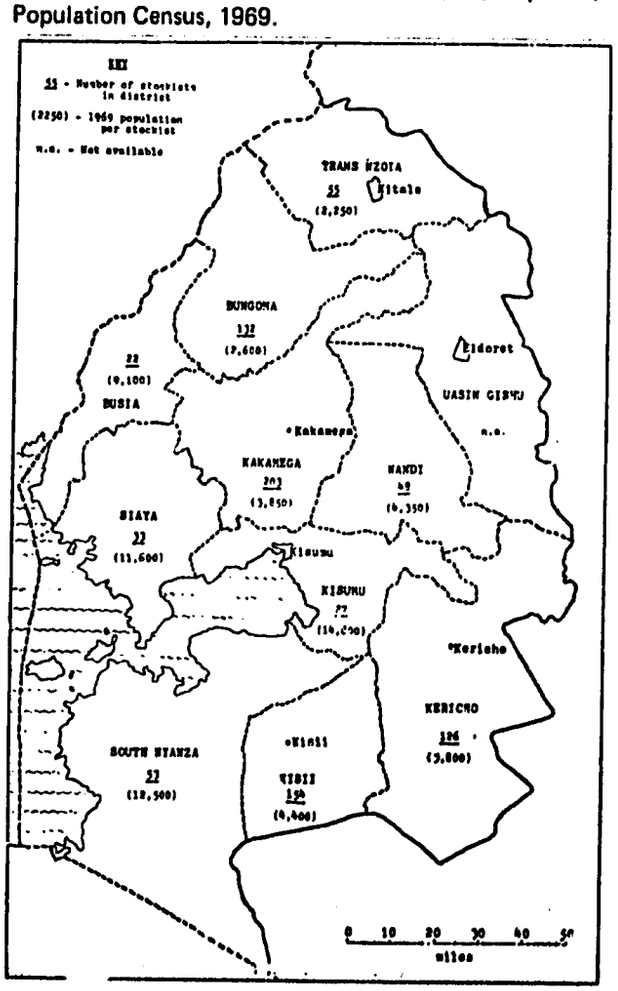
constant. The combined effect of the demonstrations and the increasing profitability of fertilizers obviously accounts for much of the increase in small farm use. (About 40 percent of total fertilizer imports are used on maize). Whether recent increases in fertilizer use will continue in the face of substantial increases in fertilizer costs remains to be seen. It should be remembered that these benefit/cost ratios were obtained on demonstration plots with relatively high levels of husbandry.

One reason why the fertilizer companies have not been as successful as the Kenya Seed Company in promoting their products in the small farm sector is that the bulkiness of fertilizer packages (sold in 50 kg. and 100 kg. units) makes them difficult to transport in areas where roads are poor and distances to a stockist are far. Some stockists have taken to breaking up packages and selling by the kilo, but this has aroused fears among some farmers that the fertilizer has been adulterated. Several papers and reports, therefore, have called for packaging in smaller and more manageable units.[28] Recent price increases in fertilizers have also coincided with a reduction in the government subsidy for fertilizers, making continued adoption by new users even more difficult. It is doubtful, anyway, that the subsidy was responsible for much of the increase in demand since 80 percent of the fertilizer imported is used on large-scale farms and estates, where use has been stagnant in recent years, whereas the increase in use is primarily on small-scale farms. The ILO Report recommended discontinuation of the subsidy on equity grounds, but a government working party and the parliamentary committee recommended it be continued and increased. The parliamentary committee also charged that "the fertilizer distributors in Kenya operate a cartel with strong links with parent companies in Europe" which prevented them from buying from cheaper Persian Gulf sources, and asked that this situation be investigated.[29] It also expressed convern that protection being granted to East African fertilizer producers "should not have the effect of increasing the cost of fertilizers to maize farmers," given the importance of increasing fertilizer use in the region. Similar problems also affect the distribution of insecticides. One representative pointed out that, although 60 percent of his total sales force was employed in servicing the smallholder areas, this effort accounted for only 20 percent of total turnover.[30] Most of the proposals to solve these problems have come in the form of stockist credit schemes, which are discussed in the following section.

Agricultural Credit

Seasonal credit for maize was initiated by KFA in the early 1930's as declining world prices and locust plagues created adverse circumstances for farmers. With pressure to increase production during World War II seasonal credit was expanded. Under the Guaranteed Minimum Return (GMR) system, a farmer applies to the Agricultural Finance Corporation (AFC) for a loan for a specific crop (either wheat or maize) and a specific acreage. After a cumbersome system of approvals, the AFC authorizes the Kenya Farmers Association (KFA) to make available inputs sufficient to cover that acreage. The farmer sells his crop through the KFA (acting as agent for thw Wheat or Maize and Produce Boards) and the outstanding loan is deducted from the payment. In case of a crop failure, the farmer is protected against loss, subject to an inspection of his fields by an agent of the AFC (hence, the title GMR). Unfortunately, like many other services, this system was designed to serve the interests of large-scale European farmers and has proved ill-adapted to current Kenyan farming conditions. As an excellent recent review of farm credit in Kenya points out,[31] there are some 1.2 million smallholdings and only 3500 large farms and ranches in Kenya. Although ownership of these large holdings has been shifted fairly successfully in recent years from European to African bands, some of the institutions designed to serve the large-farm sector have not as yet made the transition towards

Map 1. **Western Kenya, distribution of registed stockists, 1972.** Sources: Kenya Seed Company and Kenya Population Census, 1969.



serving the African farm sector as a whole. Most of the current credit institutions, including some experimental programs discussed below, are in the painful process of trying to make such a transition.

The first government loans to smallholders were made in 1948 by the Africa Land Utilization and Settlement Board, later the African Land Development Board (ALDEV).[32] In 1963, the lending activities of the two Boards of Agriculture (for African and European areas) were combined to form the Agricultural Finance Corporation, referred to above. Under the AFC, three basic types of loans are made:

—Long-term loans for land purchase, of dairy cattle and permanent improvements. These loans are made to farms with a minimum of ten acres and require land titles as security. These are estimated to account for 43 percent of all farm credit.

—Medium-term loans for farm development, machinery, and crops, available to all farmers but generally requiring title deeds for security. These are estimated to account for 31 percent of farm credit.

—Short-term loans, such as the GMR for planting maize and wheat, and other loans for the planting of pyrethrum and tea. These are estimated to account for about 26 percent of farm credit, although most of this comes from commercial banks and merchant suppliers, with the GMR itself accounting for only about 3 percent of total farm credit.

Excluding funds for land purchase provided under the Agricultural Settlement Fund, Donaldson and von Pischke's estimates show that about 23 percent of all farm credit from both public and private lending institutions went to some 200,000 small farmers whereas 77 percent went to about 3500 large farm borrowers.[33] GMR loans were divided about equally between large and small farmers, although the definition of small in this case is not clear, since GMR has a minimum acreage requirement of 15 acres. (Prior to 1964, in fact, the minimum acreage was 100 acres). In 1968, a survey in four districts of western Kenya showed that, in 1966, and 1967, the total of such loans was only 150 in Nandi District, 151 in Busia, 55 in South Nyanza, and 18 in Kisii.[34] Even at best, therefore, only 1.5 percent of official credit went for maize grown by small farmers as of 1972. From these data it is clear that the diffusion of hybrid maize among smallholders in Kenya could not have been dependent on credit, at least from official sources.

Credit from non-official sources is also extremely limited in Kenya particularly since maize trading is prohibited except through official marketing channels. It is probably safe to say that official credit in Kenya is largely restricted to wealthy farmers who are in a position to obtain credit from commercial sources. For this reason, numerous reports have recommended that commercial banks be encouraged (or required) to lend more to the agricultural sector and that the government concentrate its activities on aiding small farmers. A number of schemes to do this are being tried in Kenya, which offer some preliminary lessons about the problems involved in promoting smallholder development of hybrid maize.

Experimental Credit Programs

Three types of approaches have been tried in recent years to improve the provision of seasonal credit to small-scale farmers: cooperative credit, supervised individual credit, and stockist credit. All three are intended to address themselves to the administrative problems which make smallholder lending more difficult than lending to large, established enterprises. These problems may be grouped simply under the headings security, supervision and recovery. Small-scale farmers often lack title deeds to their land as security for a loan. A better security for the lender, in the view of many experts, is an assurance that the funds borrowed will be spent on a profitable activity but this requires farmer training and/or extension supervision to see that proper husbandry practices are used. Finally, the recovery of loans of small amounts from large numbers of poor farmers presents difficult and expensive administrative problems, especially where the crop for which the loan has been made is one which can be consumed on the farm or sold locally, as well as through official channels. The only substantial, successful smallholder lending in the past has been by the Kenya Tea Development Authority, which has a monopoly on purchasing the farmer's output and can easily effect recovery. Another problem is that using agricultural agents as loan collectors undercuts their subsequent effectiveness as advisors and motivators of the farmers they serve. Each of the methods recently tried in Kenya deals with some but not all of these problems.

Cooperative credit. The Cooperative Production Credit Scheme (CPCS) of the ministry of Cooperatives and Social Services was initiated in 1970 following a major report on cooperative credit by S. Lindquist in 1967 and the establishment of a Cooperative Bank in 1968. In 1969 some nine cooperative societies were participating in a pilot project which lent £25,000 to approximately 2000 members, and by March 1971, 52 societies had joined the project and had been allocated some £600,000 for lending to approximately 96,000 members.[35] This compares with a total of about 4500 smallholders receiving GMR seasonal credit through the Agricultural Finance Corporation. Most of loans, however, were used for coffee picking and husbandry improvements, which reflects the concentration of viable cooperatives in the coffee growing areas. Under the CPCS, loans are made largely in kind from the cooperative society's own store or from another supplier who bills the cooperative. Loans are secured by the crop proceeds of the farmer and two guarantors and are granted at an interest rate of from 8 to 12 percent. Loan money is obtained from the Cooperative Bank (at 8 percent) or from the societies' own funds (at a lower rate), allowing a blended cost of funds of about 6 percent to the society.[36]

The loans are then deducted from the payout of the cooperative to the farmer at the end of the crop season.

The CPCS has several distinct advantages over other methods. First, the security of a commercial cash crop (such as coffee or pyrethrum) can be used to cover food crops (such as maize) on which collection would be difficult. Second, the existing staff and accounts machinery of the cooperative can be used to handle the credit administration without involving extension staff in debt collection. Third, an excellent cooperative education program exists in Kenya to train society officials and employees in management of loan funds. Fourth, very large numbers of farmers can be reached through the cooperative system. The system, however, also has several drawbacks. First, it operates effectively only where cooperatives are strong, namely in the coffee and pyrethrum areas which are comparatively the wealthiest in the rural sector. Farmers in marginal areas or in districts where cooperatives are not functioning, who are most in need of seasonal credit to finance their input purchases, are generally excluded. Second, the program does not include close farmer supervision although some liaison with agricultural extension staff of course takes place. Third, only societies who have substantially cleared themselves of past debts are allowed to participate in the scheme. Since many societies have long-term unsecured loans outstanding (usually to their own officials), this has unavoidably restricted participation in the system. Nevertheless, for the areas where cooperative societies are strong due to the presence of high-value cash crops, this is the most promising credit system to date.

Supervised Credit. Two experiments in providing supervised credit to individual farmers have been tried under the Kenya Special Rural Development Program (SRDP) in Tetu Division of Nyeri District (Central Province) and Vihiga Division of Kakamega District (Western Province).[37] Both of these have been well-documented by academic researchers and project personnel, and there are some interesting differences between them. Both projects are in high-potential areas of extremely high population density where the intensification of farming through the adoption of hybrid maize would both improve family incomes and release land for growing of cash crops.

The Vihiga maize credit program began in 1971 when 63 selected farmers were given AFC credit vouchers redeemable for inputs through stockists in the area. Farmers were selected on the basis of "credit worthiness" from a random sample of some 600 farmers in the division, and hence, represented wealthier and better-than-average farmers, though of course on a lesser scale than the AFC's normal activities. Credit was given for two to four acres' worth of inputs. Farmers received intensive extension advice and obtained excellent yields (18-20 bags per acre). An 88 percent repayment rate was achieved, but only after considerable pressure from the chiefs, the AFC, and in some cases local extension staff. In 1972, 323 farmers received loans, but only a 58 percent repayment rate was achieved. In 1973, 920 loans at an average of 271/- each were made. The AFC estimated servicing costs (excluding repayment losses) at 2.2 percent. An analysis of loan repayments in 1972 showed that profitability of the inputs was similar between those who repaid and those who did not, but that repayers had more outside sources of income (50 percent vs. 26 percent for non-repayers).[38] Although the AFC has been able to streamline its loan-making and recovery operations considerably on the basis of the project's experience, it nevertheless seems clear that the administrative costs of supervising and recovering individual loans of such small magnitude makes the expansion of supervised credit programs extremely difficult.

The Tetu project differed from the Vihiga project not in the nature of the loan and the inputs used, but in the selection and training of farmers. After a careful baseline study, less progressive farmers were selected for participation in the program and were taken to the local Farmers Training Center for a three-day course in hybrid maize growing together with the extension staff from their immediate area. Participants were offered vouchers for inputs suitable for one acre of hybrid maize. After harvest, the AFC with the help of the government administration collected loan repayments, and farmers who repaid were eligible to receive another loan. Seventy-eight percent of farmers in the first FTC couse repaid the loan, although again only after intensive effort by the AFC and the local chiefs. The attractive part of this program is that poorer farmers are selected for participation and use is made of group extension methods, thereby reducing the costs of supervision. The costs of surveying and selecting the farmers were considerable, however, and the costs of collection raise the same problems as the Vihiga program. The widespread adoption of hybrid maize by other farmers on a purely cash basis in both the Vihiga and Tetu project areas raises questions as to how much of a constraint credit really is and indicates that the greatest benefits of supervised credit schemes to date may have been in the demonstration effect they had on surrounding farmers.

Stockist Credit. Faced with the limited (though substantial) regional coverage of a cooperative-based credit program on the one hand, and the problems of debt collection and loan security for giving supervised credit to individual farmers on the other, government and various aid agencies have looked to stockists credit as another means of improving the utilization of commercial inputs in maize farming. The most promising program along this line has arisen out of the FAO fertilizer demonstration plots and a pilot credit scheme in the Migori Special Rural Development Program in South Nyanza District of Nyanza Province.[39] In this experiment, credit was provided by the Kenya Commercial Bank to eight selected stockists chosen from a list of 15 prepared by the agricultural field staff. (One of the stockist was in fact a cooperative union). The loans varied in size from 3000/- to 5000/- at 9 percent interest and were paid by the bank to the KFA depot in the province from which inputs were delivered

to the stockists. The loans were secured by mortgages on the land and inventories of the various stockists. The stockists were therefore able to purchase adequate inputs and have them available in good time for planting and were encouraged to pass on part of the credit to their customers on their own. Because of adequate security, careful selection of stockists, and the small number of units involved, administrative costs were low and the bank experienced no bad debts. On the basis of this experiment, a proposal to extend the scheme to 400 stockist in 20 districts was accepted by the Danish aid agency to provide credit for seasonal purchases of inputs and construction of improved storage facilities totalling £500,000. This program should go a long way to improving the availability of inputs in the rural areas in adequate quantities, but does not provide supervisory services for the use of the inputs nor does it reach the farmers to whom credit is most likely to be a real constraint. Careful evaluation will be needed to see if greater availability of credit to stockists does result in improved private lending to their customers. In this connection, it should be remembered that the cost of seed (at 20 shillings per acre) is not a prohibitive investment for very many farmers and that fertilizer (at 100 shillings or more per acre) is not considered profitable unless used with good husbandry practices. It is likely, therefore, that improved credit systems are not a necessity for increased adoption of hybrid maize at present although they may become more important at a later stage when achieving still higher yields is required.

Pricing and Marketing Policies

Of all the institutions and policies affecting the Kenyan maize industry, none arouse as much interest, outrage, or concern as pricing and marketing policies. Since the first official maize report in 1922, periodic maize crises have provoked at least eleven commissions of inquiry, working parties or select committees to investigate and make recommendations on the pricing and marketing of maize.[40] Most of these investigations, moreover, have been competent undertakings which have conscientiously taken evidence, conducted expert analysis, and made responsible recommendations, only to see maize policy continue to be made on an ad hoc, emergency basis, with the authorities acting too late to meet the immediate crisis and then taking little remedial action until the next crisis occurs. The latest case is an excellent example. Following a maize shortage in 1971, a select parliamentary committee was appointed in July 1972, which prepared an excellent report that was unanimously adopted by Parliament in December 1973. Hardly a month later, the government rejected a relaxation of maize controls, the most important recommendation in the report, and proceeded instead to increase controls over the sale and movement of maize. As in previous crises, most of the blame was placed on traders who were "sabotaging the distribution system."[41] Road blocks were instituted by the police to "stamp out" movement of maize, rice, and beans, and new permits were introduced to control the movement of crops from farm to market and from millers to retail stores.[42]

The factors which cause this kind of periodic chaos are actually quite straightforward, but this unfortunately does not make thier solution any easier. The basic problem can be expressed in a very few statements:[43]

—Maize is the basic staple of about 90 percent of the population and the demand for it is highly price inelastic. It would be hard to find a more politically sensitive crop.

—There are regular but unpredictable changes in the weather in East Africa which affect the size of the maize crop, as well as the availability of other foods.

—Only 5 to 15 percent of total maize production is normally marketed through official marketing channels, depending on the size of the crop. In a good year, when maize is in surplus on farms and back market prices are low, the official marketing body will receive two or three times as much maize as in a bad year, when black market prices are high. Moreover, storage costs are reasonably high (about 5.60 shillings per bag per year in 1966) so it is costly to hold stocks from year to year.

—Because maize is bulky relative to its value, transport costs are high. There is a big gap between the price which Kenya receives for exports and the price it pays for imports and, until the recent increase in the world price of maize, Kenya could neither import maize more cheaply than it could produce it nor export at a profit.

In the face of these conditions, Kenya for years has sought to maintain a price level that would produce self-sufficiency in maize, but would not result in a large surplus which would have to be exported at a loss. The first guaranteed price emerged from farmer pressure in the 1930's when price declines accompanying the world wide depression led to a government guarantee. This required a guaranteed price, since swings in the market price due to variations in rainfall would be too great to assure adequate production if farmers could not be certain of covering their costs. Underlying this assumption, in the colonial period, was the belief that peasant farmers would not respond to price incentives, and European farmers had to be relied upon to produce adequate supplies to feed the African labor force. The Food Shortage Commission of Inquiry of 1943 made the point:[44]

> Since the Colony cannot safely depend on native grown maize to satisfy its internal requirements, it must look to the European farmer to produce a certain amount of maize. The European farmer cannot afford to produce maize for sale unless he obtains a return at least equal to that obtainable from other farming activities.

In fact, deliveries to the Maize Board from large farms have varied pretty consistently with variations in small farm deliveries, both depending primarily on the weather (Figure 2) The only difference may be that, whereas large-scale farmers may vary the size of their plantings according to the price level, small-scale farmers may vary the amount of surplus maize delivered to the official marketing channels rather than the amount actually planted.[45]

We have already noted how a guaranteed price was introduced temporarily during the Depression and again, permanently, in 1942. To keep the large-scale producer from being undercut by lower-cost producers in the African areas, however a controlled market had to be created as well. Since export losses were deducted from the payout to farmers the Europeans desired that this cost be shared across the crop as a whole. As a result, a system of tight controls was introduced which has persisted to the present. Without a special movement permit, it is illegal to move more than ten bags of maize within a district, or two bags of maize across district boundaries. Since the price differential between a maize-surplus and a maize-deficit district can be enormous (from 20/- to 100/- per bag), the possession of a movement permit enables the holder to make substantial profits. Otherwise, all sales must be made at the official price through the Maize and Produce Board. The recent Select Committee report stated that,

> There were many complaints both about pressure exerted on the Maize and Produce Board to issue permits to particular people, and about the illegal issue of maize movement permits by authorities other than the Board. Given their value, these movement permits provide potential sources of patronage and corruption on a large scale...the uncontrolled issue of movement permits obviously plays havoc with the controlled maize market; it is grossly inequitable, and it encourages production inefficiencies.[46]

To enforce the regulations requires frequent searches of trucks and bus traffic by police, which is also liable to corruption. Because the Maize and Produce Board sells most of its maize to millers and other large-scale users, the controlled market can create large price differentials even in the same town. In July 1973, we found maize selling in local markets for as much as 60/- a bag while maize and Produce Board depots not 300 yards away were overflowing with maize purchased at 35/-. Until 1967, in fact, the Board would only sell in quantities of 140 bags or

Fig. 2. **Sales to maize board by large and small farm sector, 1955-1965.** Source: Massell et a. "Maize Policy in Kenya." Institute for Development Studies, University of Nairobi, Discussion Paper, 1965, p. 8. (Data were not kept on this basis after 1965).

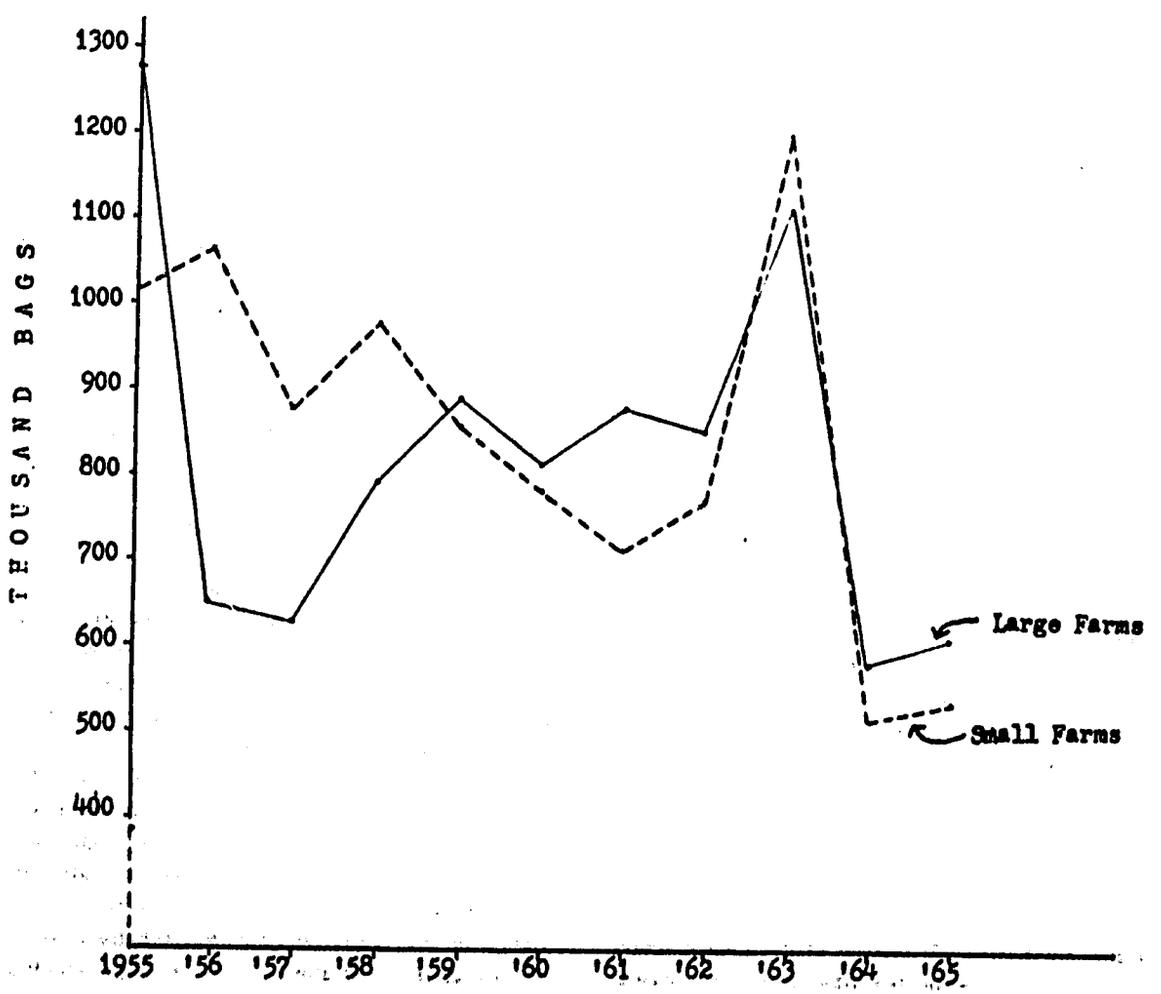


Fig. 3. **Producer price and acreage planted to maize on large farms, 1959-1972.**
Sources: Select Committee Report, pp. 13 and 15; Economic Survey, 1973, p. 58.

more, but since has sold in quantities of five and, recently, one bag.

There have been many proposals that the Maize and Produce Board should operates as a buyer of last resort, setting a floor price at which it would take all maize offered and offering to sell at a ceiling price to hold price fluctuations within a given range. Within that range farmers would be able to sell to anyone they pleased and traders could move maize easily and quickly between surplus and deficit areas, preventing the large differences in price which now prevail. Given the excellent system of highways and abundance of transport in Kenya, price differentials would vary only slightly, reflecting the costs of transport between producer and consumer. Trading in maize would itself be an asset in the development of entrepreneurial activity in the whole economy. There would also be a moderation in the sharp price variations over the course of the year which now prevail (Figure 4), since it would pay farmers to hold the maize on their farms longer after the harvest. At present, farmers have no incentive to hold back surplus maize since it may spoil and since the Board offers no differential in price according to time of delivery. In fact, farmers who deliver late may find, as many did in 1973, that the Maize and Produce Board stores are full.[47] Efficiency of production would also be improved by freeing the internal market, since at present the high price of maize in marginal (deficit) areas encourages farmers to grow maize there and surpluses in the optimal growing areas discourage maize production where it can be produced best. Under a free internal maize market, the Board would, of course, continue to maintain strategic storage reserves and would handle all exports and imports.

The main argument advanced against a free internal maize market has been that it would reduce the quantity of maize handled by the Board and that "overhead costs would be distributed over a much smaller turnover."[48] Given the profits Kenya can presently make on maize exports, however, this worry certainly should not continue to be a problem. Greater obstacles seem to be that those who now benefit from possessing movement permits would lose their monopoly positions, plus a general bureaucratic fear in government circles of any relaxation of controls. Because of the political outcry whenever imports have been required, civil servants are hypercautious about allowing any exports to take place. An analysis of Maize and Produce Board purchases and sales over the past 14 years (Figure 5) shows an average surplus of purchases over sales of 0.95 million bags (1.27 million over the past seven years) with the peaks getting successively higher. The greatest deficit in that period was only 600,000 bags. With present storage capacity of almost 3 million bags incuding a stra-

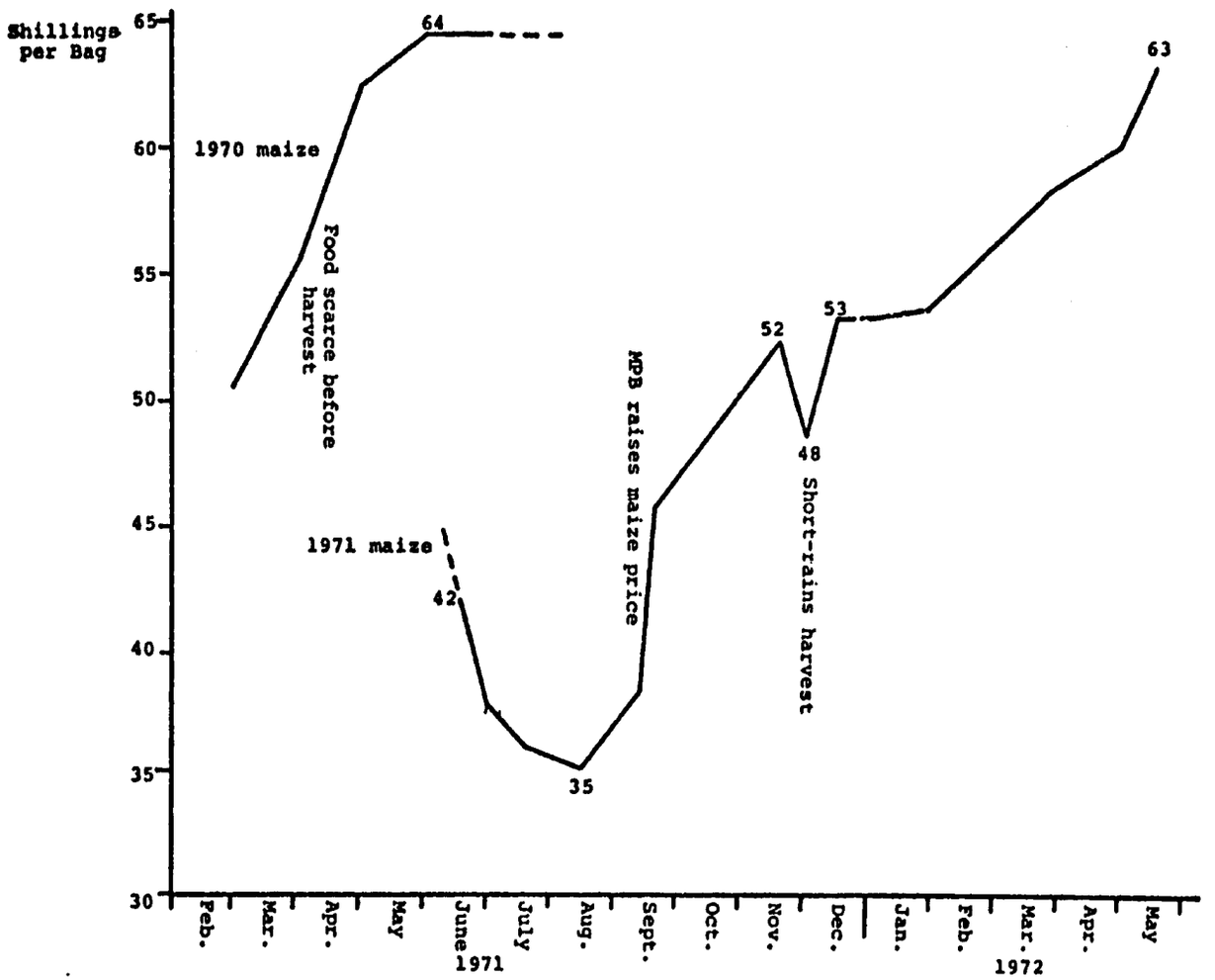


Fig. 4. **Maize price fluctuation in Vihiga, Kakamega district.** Source: Peter R. Moock, "The Vihiga SRDP Farm-Level Survey" Institute for Development Studies, University of Nairobi, Discussion Paper, 1971 p. 214.

tegic long-term reserve of more than a million, the country has ample capacity to avoid future domestic shortages. The increasing adoption of hybrid varieties means that Kenya has almost certainly entered a long-term surplus position. Moreover, the management of the Maize and Produce Board since the 1971 crisis has been greatly improved along with its capacity to plan imports and exports rationally. The deficits of the 1960s in fact were due more to mismanagement of stocks than to actual shortfalls of national production. In both 1965 and 1971 the decision to import maize came so late that the harvests were starting before the imports arrived. When they did come they were either reexported or sold for cattle feed.

Although it is clear that a guaranteed price has been an incentive to maize production in Kenya, the success of the maize industry has outgrown the rigidly restricted marketing system that continues. The recent increase in world prices has removed whatever rationale existed for an internally controlled market. Proposed bulk handling facilities would significantly reduce transport costs, increasing exports profitability margins still further. The widespread adoption of hybrid maize may yet bring about a freeing of the internal market. With maize in abundance in the country, the incentive to maintain monopolistic movement permits may itself be reduced to the point that a free internal market becomes a reality.

Bernd Schubert has suggested four criteria for evaluatting agricultural marketing systems: guaranteeing of urban food supplies; stabilization of prices, both seasonally and between localities; technical and allocative efficiency; and promotion of agricultural development.[49] Although Kenyan marketing policy has had a reasonable success in achieving the first and last of these objectives, it has performed poorly on the others. Given the increased adoption of

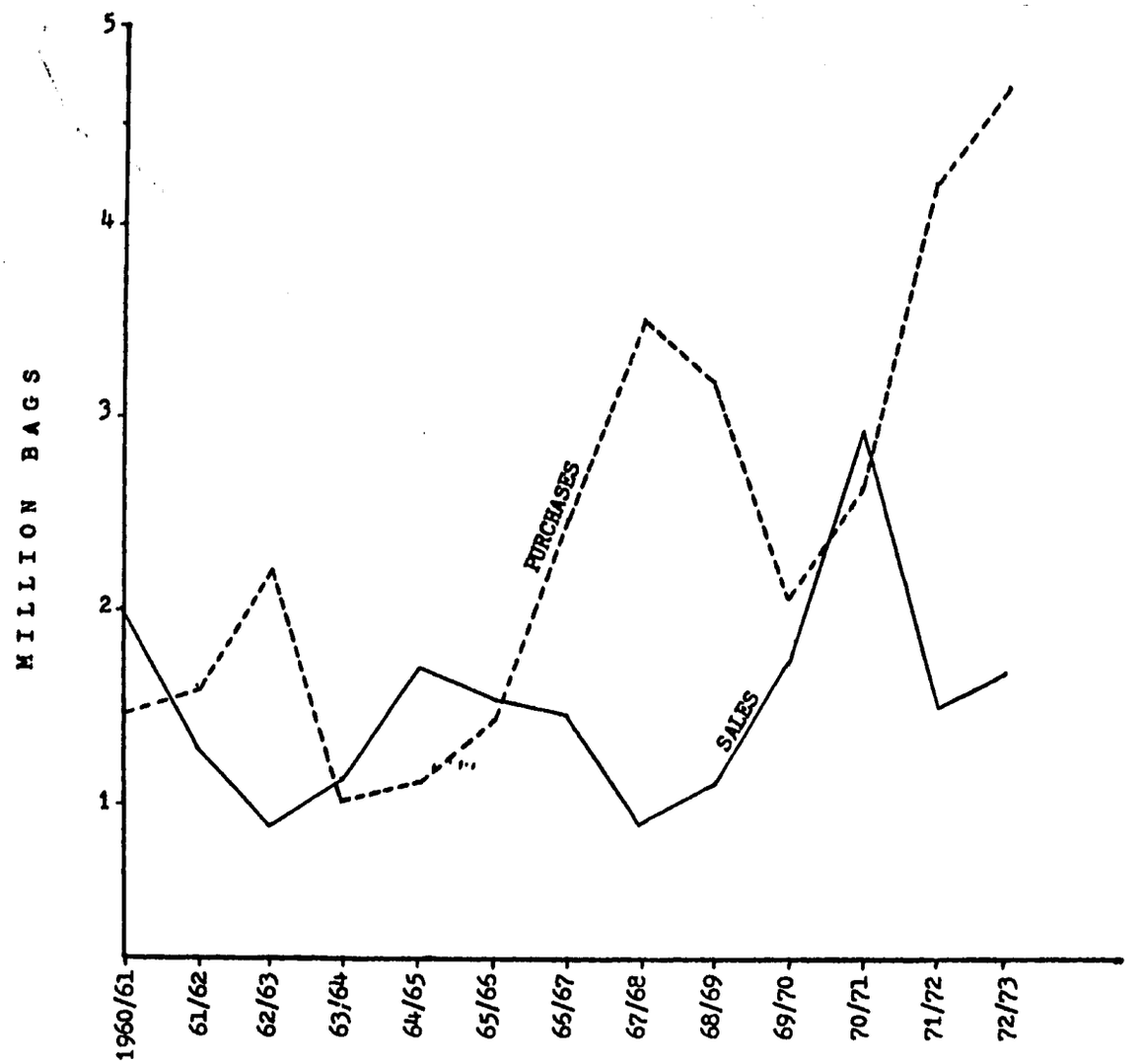


Fig. 5. **Kenya maize and produce board, purchases and sales of maize, 1961-1973.**

hybrid maize, the construction of improved handling facilities, higher world prices, new management in the Maize and Produce Board, and, hopefully, a relaxation of outmoded internal marketing restrictions, however, there is no reason why maize cannot continue its preeminent role as the most important crop in th Kenya economy.

Notes

1. L.H. Brown, *A National Cash Crops Policy for Kenya* (Nairobi, 1963) p. 79.

2. M.N. Harrison, "Maize Improvement in East Africa", in C.L.A. Leakey, Crop Improvement in East Africa, 1970. p. 21-59; Festus Ogada, "A Statement of the Status of the Maize Crop in Kenya," mimeo. (n.d.); S.A. Eberhart, M.N. Harrison, and F. Ogada, "A Comprehensive Breeding System," *Zuchter* (1967): 169-174; "Development and production of Hybrid Maize in Kenya," momeo, Maize Research Section (n.d.); B.D. Dowker, "Breeding of Maize for Low Rainfall Areas of Kenya," *Journal of Agricultural Science* (1971): 523-530; and L.D. Smith, "The Role of Maize Research in Kenya Agricultural Development," mimeo (n.d.).

3. M.N. Harrison, "Maize Improvement in East Africa", in C.L.A. Leakey, Crop Improvement in East Africa, 1970. p. 37.

4. The heterosis between these two groups has been so good, in fact, that the plants easily reach 17 to 18 feet in height and suffer damage from lodging (falling down) in storms. A special program has had to be introduced to lower the height of the plants by reducing the distance between leaves on the stalk.

5. Peter R. Moock, "Managerial Ability in Small-Farm Production: An Analysis of Maize Yields in the Vihiga Division of Kenya" (Ph.D. dissertation, Columbia University, 1973), p. 135.

6. Olaf Hesselmark, Kenya Maize and Produce Board, personal communication, February 20, 1974.

7. M.N. Harrison, "Maize Improvement in East Africa" in C.L.A. Leakey, Crop Improvement in East Africa, 1970. p. 45 "Maize Diamonds," *Kenya Farmer* (January 1968); A.Y. Allan, "Some Effects of Time of Planting on Maize in Western Kenya," mimeo (n.d.) and A.Y. Allan, "The Influence of Agronomic Factors on Maize Yields in Western Kenya," *op. cit.*

8. E.R. Watts, "The Adoption of Maize Growing Practices in Embu District, Kenya," East African Agricultural Economics Society Conference, 1969, pp. 2,5.

9. John C. de Wilde, *Experiences with Agricultural Development in Tropical Africa,* Vol. II (Baltimore, 1967), pp. 38-39.

10. D.G.R. Belshaw and Malcolm Hall, "The Analysis and Use of Agricultural Experimental Data in Tropical Africa, *"East African Journal of Rural Development* 5 (1972): 39-72.

11. For an excellent recent summary of knowledge, see George H. Axinn and Sudhakar Thorat, *Modernizing World Agriculture: A Comparative Study of Agricultural Extension Education Systems* (New York, 1973). On Kenya, see J.R. Weir, *Report of the Agricultural Education Commission* (Nairobi, 1967), and John C. De Wilde, *Experiences with Agricultural Development in Tropical Africa,* Vol. II (Baltimore, 1967) pp. 157-197.

12. Hugh Fearn, *An African Economy: A Study of the Economic Development of the Nyanza Province of Kenya, 1903-1953 (London 1961), p. 84.*

13. J.R. Ascroft et al., "The Tetu Extension Pilot Project. A Special Rural Development Report," paper read at the workshop on Strategies for Improving Rural Welfare, University of Nairobi, 1971, p. 27. "Progressiveness" was defined from an index of adoption of eight key cash crops.

14. David K. Leonard, "The Social Structure of the Agricultural Extension Services in the Western Province of Kenya," Institute for Development Studies, University of Nairobi, Discussion Paper, January, 1972, p. 4. "Progressiveness" was defined as growing hybrid maize and certain cash crops.

15. See Everett M. Rogers, *Communication of Innovations* (New York, 1968).

16. See J.R. Ascroft et al., The Tetu Extension Pilot Project. A Special Rural Development Report". Paper read at the Workshop on Strategies for Improving Rural Welfare, University of Nairobi, 1971: David K. Leonard, "The Social Structure of the Agricultural Extension Service in the Western Province of Kenya", Institute of Development Studies, University of Nairobi, Discussion Paper, January, 1972; and International Labour Office, *Employment, Incomes, and Equality* (Geneva, 1972), p. 153-154.

17. International Labour Office, *Employment, Incomes and Equality* (Geneva, 1972), p. 154-246.

18. David K. Leonard et al., "The Work Performance of Junior Agricultural Extension Staff in Western Province," Institute for Development Studies, University of Nairobi, Discussion Paper, June 1971, pp. 1, 3, 25.

19. "An Interim Report on the Evaluation of Agricultural Extension," Rural Development Research Committee, University of Dar es Salaam, 1968, p. 4.

20. Peter R. Moock, "The Vihiga SRDP Farm-Level Survey," Institute for Development Studies, University of Nairobi, Discussion Paper, 1971. Joseph Ascroft, Carolyn Barnes, Ronald Garst, "The Kissi SRDP Survey," IDS Discussion Paper, 1971.

21. Kenya Seed Company, mimeo, March, 1973. Also interviews with W.H. Verburght, A.Y. Allan, E.J.R. Hazelden, Festus Ogada, February. August 1973.

22. Republic of Kenya, *Report of the Seelct Committee on the Maize Industry* (Nairibo, 1973), p. 4.

23. Agricultural Extension Service, Kitale, "Economic Aspects of Seed Maize Production in Trans Nzoia District" (April 1973), pp. A1, A4.

24. Republic of Kenya, *Report of the Select Committee on the Maize Industry* (Nairobi, 1973), p. 5.

25. See for example M.N. Harrison, "Maize Improvement in East Africa". In C.L.A. Leakey, *Crop Improvement in East Africa,* 1970, pp. 52.

26. J.M. Colyer, "A Background to the Development of Fertilizer Utilization in East Africa," East African Agricultural Economics Society Conference Paper, 1969, p. 2.

27. K. Zschernitz, "Marketing of Fertilizers through Local Stockists in Kenya," FAO/DANIDA Regional Seminar on Fertilizer Use Development (Nairobi, 1972). Zschernitz concludes that the stockist system is the "most successful" method for a country at Kenya's level of development.

28. See for example, Fred E. Chege and Joseph Ascroft, "Marketing Farm Supplies in Rural Areas: A Study of Farm Inputs Availability in Tetu Division," IDS, University of Nairobi, 1972, and Republic of Kenya, *Report of the Select Committee on the Maize Industry* Nairobi, 1973, p. 4.

29. International Labour Office, *Employment, Incomes, and Equality* (Geneva, 1972), pp. 432-433; Republic of Kenya; *Report of the Select Committee on the Maize Industry* (Nairobi, 1973) p. 5; and Republic of Kenya, *Report of the Working Party on Agricultural Inputs* (Havelock Report) (Nairobi, 1971), pp. 19-20), pp. 19-20. The Havelock Report forecast a "conservative" increase of 100% in nitrogenous fertilizer demand by 1975 (over 1969) and a 47% increase in demand for phosphates.

30. D. Outram, Twiga Chemical Industries, "The Role of Private Industry for the Small Farmer Market," Conference on the Dissemination of Research Findings and Technology in Kenya, IDS University of Nairobi, 1973.

31. G.F. Donaldson and J.D. von Pischke, *A Survey on Farm Credit in Kenya* (Washington, D.C., 1973).

32. Josef Vasthoff, *Small Farm Credit and Development* (Munich, 1968), p. 23.

33. Donaldson and von Pischke, *Farm Credit,* pp. 4 and 7a.

34. Meyer et al., *Rural Development,* p. 55

35. Department of Cooperative Development, *Development Plan 1971-1974,* pp. 35-39.

36. Donaldson and von Pischke, *Farm Credit,* p. 120.

37. See Niels Roling, Fred Chege, and Joe Ascroft, "Rapid Development for Kenya's Small Farms," IDS, University of Nairobi, 1973: Peter Weisel, "The Vihiga Maize Credit Program," *AID Spring Review of Small Farmer Credit, 1973;* and "Minutes of Meeting to discuss Tetu and Vihiga SRDP Extension, credit, and Training Programmes, "Ministry of Agriculture, mimeo, July 1973.

38. Peter Weisel, "An Analysis of Maize Credit Loan Repayments, 1972," mimeo, July 1973.

39. Donaldson and von Pischke, *Farm Credit,* pp. 155-162. Also interviews with Ministry of Agriculture and Provincial Planning staff, August 1973.

40. See especially, in order of their appearance, V.G. Matthews, "Report on Kenya Maize Industry," Ministry of Agriculture

mimeo, 1963; Republic of Kenya, *Report of the Maize Commission of Inquiry* (Nairobi, 1966); W. David Hopper, "Marketing of Grains in Kenya, "Ministry of Agriculture, mimeo, 1968; "Final Report of the Working Party Studying the Maize and Produce Board in Relation to the Expected Crop Production in the 1970's, and in Particular with Regard to the Major Cereal Crops," mimeo, 1969; and Republic of Kenya, *Report of the Select Committee on the Maize Industry* (Nairobi, 1973). For a good discussion of some of the earlier reports and marketing in general, see William O. Jones, *Marketing Staple Food Crops in Tropical Africa* (Ithaca, 1972), pp. 198-232.

41. *East African Standard,* January 11, 1974, p. 1. A favorite activity for officials during the 1971 maize shortage was to visit traders' stores during the middle of the night to find the "missing" maize; no mention was ever made officially of the serious drought then occurring as a possible explanation of the shortage.

42. *East African Standard,* January 12, 1974, p. 1.

43. For a good discussion of underlying factors see Ian Livingstone "Production, Price and Marketing Policy for Staple Foodstuffs in Tanzania," in V.F. Amann (ed.), *Agricultural Policy Issues in East Africa* (Kampala, 1973), pp. 208-242, and B.F. Massell, J. Heyer, and H. Karani, "Maize Policy in Kenya," IDS, Discussion Paper, University of Nairobi, 1965. Both of these were written, however, when profitable exports from East Africa were not yet considered a realistic possibility because of lower world prices.

44. *Food Shortage Commission of Inquiry Report,* 1943, p. 46.

45. William O. Jones, *Marketing Staple Food Crops in Tropical Africa,* (Ithaca, 1972), p. 205, quoting Michael Harrison. It is even questionable how much large farm acreages follow price changes. Except for the large drop in acreage when farms were changing ownership in 1963-65, large farm acreages have remained fairly stable over the past 15 years (Figure 3). Moreover, price changes are often announced too late to affect planting, and sometimes even after harvests have been partially delivered.

46. Republic of Kenya, *Report of the Select Committee on the Maize Industry* (Nairobi, 1973), p. 21.

47. The drop in acreage of farmers applying for seasonal credit (GMR) in 1973 was apparently due entirely to the fact that many farmers were unable to deliver their maize to Maize and Produce Board stores and hence could not clear their 1972 accounts before planting time. As late as August 1973, when the 1973 crop was already beginning to come in, stacks of maize from the 1972 crop were piled under tarpaulins outside many MPB reception centers.

48. Republic of Kenya, *Report of the Maize Commission of Inquiry* (Nairobi, 1966), p. 23. The Report also claims that it would be impossible to control the price of maize meal to the consumer without permiting millers to make excessive profits. A distrust of millers and traders, many of whom are Asians, seems to have been a strong motivation for control among both Europeans and Africans from the earliest introduction of controls, even though Africans in the maize-deficit districts are the main victims of the present policy and African transporters would be major beneficiaries of the proposed changes.

49. Bernd Schubert, "Some Considerations on Methods for Evaluating Marketing Systems for Agricultural Products," *Eastern Africa Journal of Rural Development* 6 (1973): 39-54.

III. THE PATTERN OF ADOPTION IN 1973.

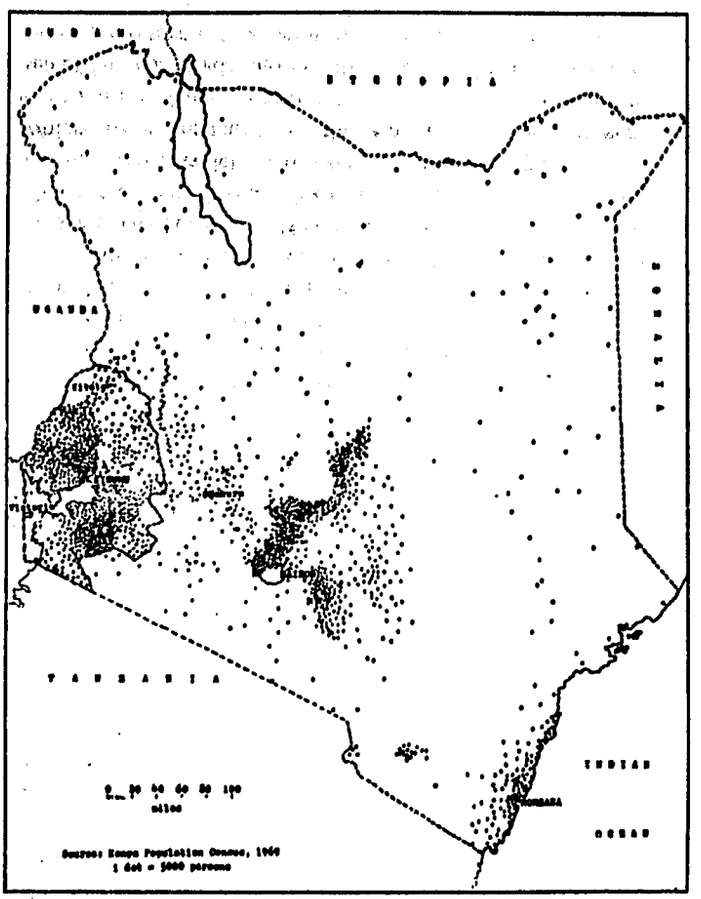
While other sources of data related to the adoption of maize technology exist in Kenya, it was decided that the larger purposes of this study could best be served by basing it on newly collected primary data. These data emerged from a sample survey of 360 maize farmers conducted in June and July of 1973.

Data from the survey have been analyzed using multivariate probit analysis, and method designed specifically to deal with a dichotomous dependent variable, which in this case is adoption and non-adoption of hybrid maize. Ordinary least squares regression has been used where the dependent variable is a continous one, and chi-square tests have been used with simple cross tabulations. In addition, the study makes use of extensive documentary evidence from such Kenyan sources as the Maize and Produce Board, the Kenya Seed Company, and the Maize Research Section, earlier farm level surveys in the region, interviews with persons involved in the Kenyan maize industry, and published sources.

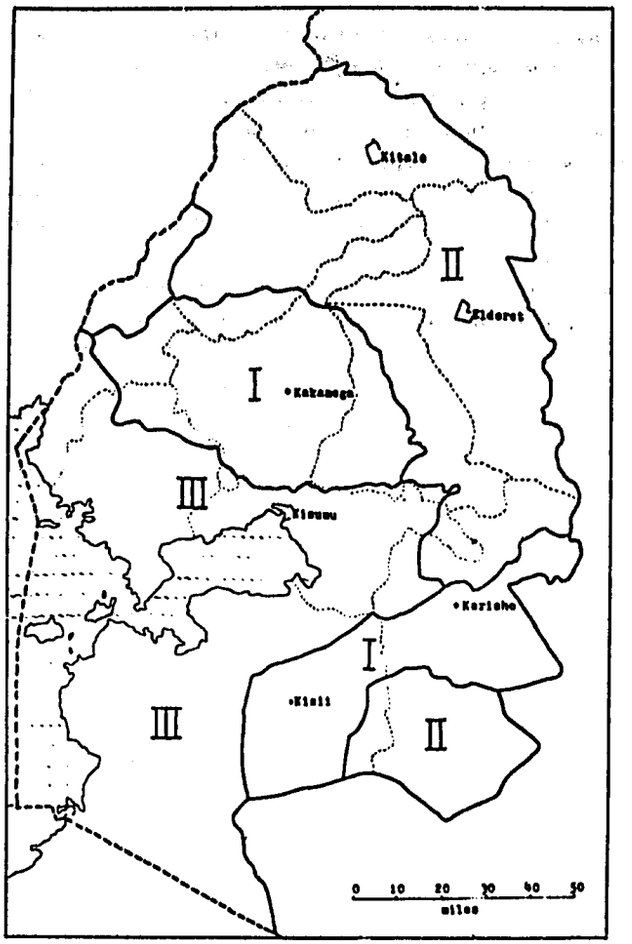
The farmers were drawn from the population of maize growers west of the Rift Valley. This area is one of the most densely populated in Kenya, produces the bulk of the country's maize and has had the longest history of support from the maize industry. Map 2 shows the distribution of Kenya's population and outlines the area of the study.

Delineating Agro-climatic Zones:

The general potential of the area west of Rift can perhaps best be summarized with the reference to the major agro-climatic zones used in this study, as shown on Map 3. These were determined with the advice of agricultural scientists at the National Agricultural Research Station and the criterion used for establishing these zones was that they should be internally homogenous with respect to the suitability of the new maize technology. Zone 1 is defined as that portion of the region receiving more than 60 inches of



Map 2. **Kenya, showing population distribution and area of study.**



Map 3. **Western Kenya, agroclimatic zones.**

rain per year. Ths includes virtually all of Kisii and Kakamega districts, about half of Nandi and Kericho districts, and the eastern third of Busia district. This is the zone with the highest agricultural potential, with generally good soils, and is consequently densely populated, especially in Kisii and parts of Kakamega. The major cash crops grown are tea, pyrethrum, potatoes, and dairy cattle in the higher elevations and coffee, sugarcane, and bananas at the lower levels. Maize is the dominant food crop everywhere. Zone 2 consists of that portion of the region found above 1500 meters which receives less than 60 inches of rain per year. This high-altitude, moderate rainfall zone includes half of Kericho and Nandi districts plus all of Uasin Gishu, and Trans Nzoia districts and almost all of Bungoma.[1] This zone includes most of the large-scale farms (in Uasin Gishu and Trans Nzoia) as well as settlement schemes. Farm sizes tend to be quite large by Kenyan standards (15 acres average) and there is considerable commercial farming, including especially maize (throughout), wheat (in Uasin Gishu), dairy cattle, and some tea. Zone 3 consists of that portion of land found below 1500 meters in altitude which receives less than 60 inches of rain per year. This zone includes part of Busia district, and all of Siaya, Kisumu, and South Nyanza districts. It is a moderate potential area with some cash farming of sugar, cotton and groundnuts, but mostly subsistence production of maize, millets, and sorghum. Farm sizes are relatively small and farming is hindered by special problems including flooding, impeded drainage, and tsetse fly infestation in some areas.

Stratification of the Sample.

In order to ensure a sample size adequate for making comparisons between agro-climatic zones, and farm size groups, the sample was stratified in four categories. Three of these are the zones described earlier.

Because it was believed that small-scale, primarily subsistence farmers would behave differently from large-scale commercial farmers, a special sample of some 50 large-scale, African-owned farms was taken in the Uasin Gishu and Trans Nzoia districts. These were formerly European-owned enterprises which have been or are being purchased by African owners and which have received extensive government attention and assistance in recent years. Although all of the farms in this category are located in zone

2, the large farm sample is referred to collectively and in the tables as Set 4. A few farms of over 50 acres from zones 1 and 3 were also included in Set 4.

Sampling Procedure

Within each of the three agro-climatic zones, a three stage sampling process was used to select approximately one hundred farms. First, grid squares of 100 square kilometers were numbered sequentially in each zone using 1 to 250,000 scale maps. Within each zone the populations of the various districts and parts thereof were summed and sampling segments were assigned to each district in proportion of its percentage of the total population in that zone. This step adjusted the sample for population density between districts though not within districts. Using a random number table, 34 sampling segments were selected in each zone.

Second, using 1 to 50,000 scale maps, each 100 square kilometer grid was further divided into 100 one square kilometer segments. A random number table was again used to select one square kilometer sampling segments within the larger grid. On this scale map, physical features including roads and even huts are identifiable and some adjustments were made, throwing out segments that fell in the middle of a lacke, game reserve, or town.

Third, within each segment, the interviewer made a list of all households by name before selecting any farms for interviews.[2] If there were not ten households in that segment, the inverviewer took additional households from neighboring segments to make a minimum total of ten. Interviewers took a maximum of twenty households within any one segment. After preparing the list of households, the interviewer used a random number card to select three names for interview. This procedure was followed to prevent the interviewer from being led to "better" or more prestigious farmers. Random field checks of the lists of names and the farmers interviewed indicated that interviewers kept closely to the sampling procedure. If the farmer grew no maize whatsoever, the interviewer was instructed to conduct the interview but also to take another farm which did grow maize in the same segment. Only four of the 361 farmers interviewed (about 1 percent) were growing no maize at the time of interview.

The large farm sample of some 60 interviews was taken from lists of some 700 large-scale commercial farms provided by the Ministry of Agriculture. With the help of the District Agricultural Officers in Trans Nzoia and Uasin Gishu and the German Extension Team Leader in Trans Nzoia, farms which had been effectively subdivided or which were managed by the Agricultural Development Corporation were removed from the list and a random selection was made among the others. These large-scale farms are referred to as set 4 in the tables and discussion.

The Interview

The chief instrument of the survey was a structured interview containing 81 primary questions, many with a number of different parts. The interview focused on the maize growing practices of the farm but included basic information on the farmer, his knowledge of recommended practices, communication channels used by the farmer, extension contacts, and other factors.

The questionnaire was prepared in consultation with scientists in the Maize Programme of the National Agricultural Research Station at Kitale. It draws on the experience of similar interviews both in Kenya and in other developing countries.

The findings of the survey show a high internal consistency. The only area of significant question involves acreage estimates which are notoriously difficult in areas where farms are not surveyed and fields are neither large nor necessarily rectangular. Whereas farmers whose land has been adjudicated are likely to know the total size of their farm. their estimates of field size vary widely.

Fortunately determining the nature of the maize technology being used on the farm did not depend (as a yield survey would) on accurate land measurements. However, wherever field size does enter into the analysis (as in fertilizer applications per acre), the limitations of the data should be kept in mind.

Farm interviews were carried out by ten trained and experienced interviewers of Research Bureau Limited of Nairobi, a market research firm with considerable experience in both urban and rural surveys in Kenya. Interviewers were given an intensive orientation seminar on the survey by the author and Dr. A.Y. Allan, Chief Agronomist in the Maize Research Section at Kitale. The interviews were carried out either in the vernacular or in Swahili.

The Pattern of Hybrid Seed Adoption in 1973.

Table 7 shows the pattern of hybrid seed adoption in western Kenya in June 1973 by agroclimatic zone.

The zones used and the survey methodology was described earlier in this chapter. For hybrids, "Adoption" was defined as use of hybrid seed for more than half of the farmer's acreage. However, only a handful of farmers were found growing both hybrid and local varieties on the same farm. Although farmers no doubt "tried out" hybrid on a portion of their maize acreage in earlier years, the innovation is now well enough known that farmers are apparently willing to adopt it on all their acreage or not at all depending on its reputation in their immediate area.

For other inputs examined, "adoption" was defined as use of the input on maize. Two additional modern inputs were examined, fertilizer and insecticide.

Farmers were asked two different questions relating to each of their maize fields, namely "What kind of maize

seed was planted in this field? " and "Was the seed planted this year new seed from a bag or did you use your own seed from last year's crop? " Table 8, gives the responses for specific types of maize seed. The distribution of these types is determined largely by availability since only recommended varieties for a given area are sold in that area. The second question was asked in order to ascertain whether farmers were planting second generation hybrid seed and still calling it "hybrid". Only three of 360 farmers explicitly said, when first asked, that they were using second generation seed and an additional six said they were using "hybrid" but also said it was "seed from last year's crop." The basic figures on hybrid use, therefore, are those responses to the second question (i.e. second generation seed is treated as a "local" variety). As discussed in Chapter II, some agricultural experts argue that hybrid seed is not practical for developing countries because farmers have to buy seed every year and if they do not, second generation hybrid seed gives a sharply reduced yield. The fact that only 2.5 percent of the farmers interviewed in the 1973 survey appeared to be planting second generation seed indicates that, in Kenya at least, the farmers' willingness to buy seed every year has been considerable.

The most striking feature of the adoption pattern is the wide disparity in adoption between Zones 1 and 2 and Zone 3. Much of the analysis of this thesis seeks to explain the discrepancy. According to Ogada,[3] a regression analysis of the 1971 Late Maturity Maize Variety Trials indicates that the yield performance of hybrid (in this case primarily Hybrid 632, which is recommended for Zone) indicates that the differential yield between hybrids and local varieties increases significantly with improvements in the environment. Using data from controlled experiments at a total of 20 different sites, Ogada compared the mean yield of each variety at each site on an environmental index. The index is simply "the difference between the mean yield of all varieties in an environment and the mean yield of all varieties at all environments or grand mean," and runs from roughly −30 to +30. Ogada went on to say, "In this particular case I can state without doubt that the Zone 3 environments would be represented by the range of −10 to −25 and the high altitude areas by +10 to +25." Figure 6 shows Ogada's findings and the declining advantage of Hybrid 632 over local varieties (in this case approximated by Kitale II Composite) as the environmental index declines.

The analysis of risk perception in the next chapter further supports this hypothesis as does certain additional evidence provided by the farmers themselves. After the examination of the farmer's maize fields, those farmers who did not plant hybrid maize were asked why they did not. Their responses are presented in Table 9. Responses total more than the number of farmers planting local maize since some farmers gave more than one answer. The interesting part of this question is that, whereas 100 percent of non-hybrid planters in Zones 1 and 2 gave "expense" as their reason, almost half the responses in Zone 3 gave other answers. I have grouped these answers under five main headings: cost, availability, information, performance, and "congruence" with traditional maize planting practices. In doing this, I also included the eight farmers in Zone 3 who said they had never heard of hybrid maize.

The coding of the questionnaire may have obscured a distinction between those farmers who said hybrid was "too expensive" (i.e. not worth the investment) which would have been a judgement of its performance and those who felt it was "to expensive" in that, although they would have liked to use it, they just did not have the money. The fact that a few farmers gave "has no money" as a separate answer may indicate that this was the case. The fact that several farmers said they did not plant hybrid because they "planted too late" may indicate that they are aware

Table 7. **Percent of farmers adopting hybrid maize in western Kenya by zone, 1973.**

Zone 1 (N= 96)	Zone 2 (N= 93)	Zone 3 (N= 95)	Set 4 (N= 76)
94.8	89.2	15.8	100

Table 8. **Types of maize seed used, 1973, by zone (All answers in percentage)**

Type	Zone 1	Zone 2	Zone 3	Set 4
511	0	0	3.2	0
512	0	1.1	0	0
611	0	4.3	0	17.4
612	12.5	12.9	0	4.3
613	53.1	54.8	0	71.8
622	5.2	4.3	7.4	2.2
632	12.5	2.2	2.1	0
Other	1.0	3.2	3.2	4.3
Local	3.1	7.5	78.9	0
Don't Know	12.5	9.7	5.3	0

Table 9. **Responses of farmers not planting hybrid maize to question, "why did you not plant hybrid maize? "**

	Answers in %		
	Zone 1	Zone 2	Zone 3
Number of Responses	9	14	102
1. *Cost:* Too expensive/Has no money	100	100	52
2. *Availability:* Not available/Distance to Stockist/Must buy every year	0	0	6
3. *Information:* Never heard of it/ doesn't know how to use it/ No experience of it	0	0	14
4. *Performance:* Yields less/Less certain Doesn't do well	0	0	20
5. *Congruence:* Too much work/ Planted late/Miscellaneous	0	0	7

Note: Includes 8 farmers in Zone 3 who had never heard of hybrid maize. Total responses exceed the number of non-adopters since some farmers gave more than one answer.

Table 10. **Adoption and farm size.**

	Zone 1	Zone 2	Zone 3
Smaller half	95.7%	83.7%	14.9%
Larger half	95.8%	95.1%	17.4%
Chi-square value	0.21	1.91	0.01
Significance level	NS	NS	NS

of the importance of early planting for hybrid yields and though that with late planting it would not be profitable.

In any case, we can conclude from the responses that, whereas hybrid is universally known and well regarded in Zones 1 and 2, a substantial number of farmers in Zone 3 have doubts about its efficacy or are still ignorant of its use. When asked "Have you ever planted hybrid maize?, 24 of the 90 farmers not planting hybrid in 1973 said yes, 18 of whom (75 percent) were in Zone 3. This indicates that hybrid has received some considerable trial in that area and, for various reasons, has been found undesirable.

Looking now at the impact of farm size on adoption of hybrids, the data of Table 10 shows that larger farmers consistently lead smaller farmers, even when zones are held constant. The difference between larger and smaller farmers shown in the table are not great. It must be remembered, however, that all farms over 50 acres —most of them in Zones 1 and 2— have been eliminated from the data on which the table was constructed. These farms had an adoption rate of 100 percent. Were they reintroduced, the percentages of adoption in all zones would increase slightly. The resulting comparison of farm sizes within zones would show virtually no difference between smaller and larger farms in Zone 1, a difference of some 14 percentage points in Zone 2, and a difference of roughly eight percentage points in Zone 3.

Looking now at fertilizer use by agro-climatic zone and farm size the impact of both factors are reflected in the data of Table 11 except in Zone 3, where rates of adoption are quite low. Even here, where differences between farm size groups within Zones 1 and 2 are large, the differences between agro-climatic zones are still more notable. For insecticides the relative impact of agro-climatic zones is even more evident.

Table 11. **Farm size and the use of other inputs.**

	Zone 1	Zone 2	Zone 3
Fertilizers			
Smaller half	47.8%	71.4%	2.1%
Larger half	75.0%	92.5%	6.4%
Chi-square value	6.23	5.03	0.25
Significance level	0.05	0.10	NS
Insecticides			
Smaller half	2.2%	21.3%	7.1%
Larger half	10.6%	43.9%	2.2%
Chi-square value	1.53	4.17	0.33
Significance level	NS	0.10	NS

The results of these two tables manifest clear support of the hypotheses that agro-climatic zone and farm size play a role in the adoption of new inputs. As differences among zones exceed differences within zones for each of the inputs, the tables tend to support the idea that agro-climatic factors play a dominant role in shaping adoption patterns.

With respect to hybrid seed especially, the influence of farm size is negligible as compared with that of the climate. However, because the use of commercial fertilizers and insecticides are significantly related to size, we cannot conclude that yields (and therefore profitability) of hybrids are neutral to scale. Moreover, since mechanized plowing is conducive to early planting and has genuine economies of scale, it is reasonable to assume that larger farms plant earlier and consequently get higher yields. Whether these advantages are offset by more intensive weeding or more timely harvesting on smaller plots is possible, but can only be determined by careful (and expensive) field sampling. In any case, we can conclude that small farmers in Kenya have not been excluded from enjoying the benefits of hybrid maize and have adopted it with alacrity where environmental circumstances warrant it.

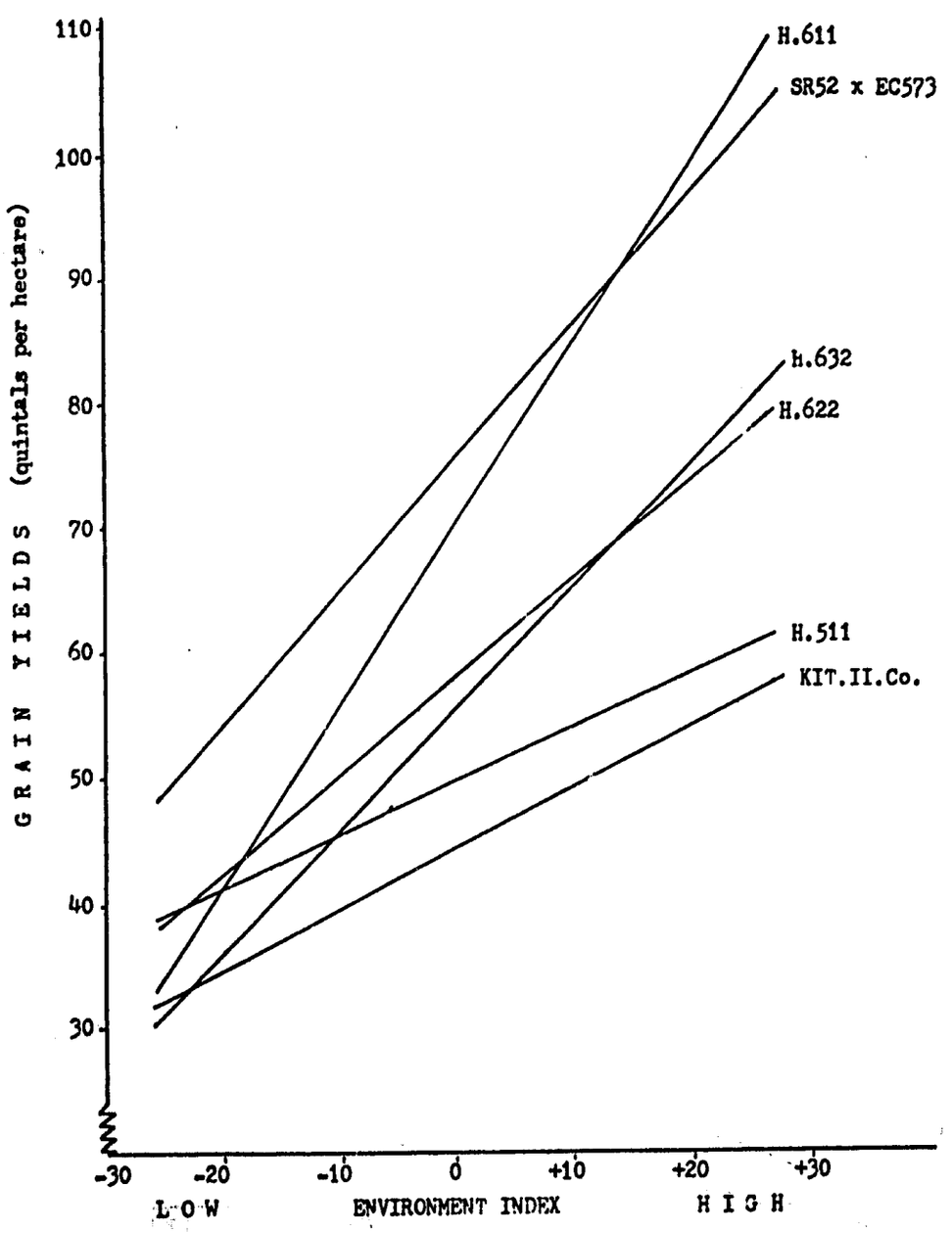
Table 12. **Farmers first hearing about and first using hybrid maize, by year and zone (All figures are percentages).**

	Zone 1		Zone 2		Zone 3		Set 4	
Year	Hearing	Using	Hearing	Using	Hearing	Using	Hearing	Using
1963 or earlier	2.4	0	3.5	1.1	4.5	0	19.5	8.7
1964	12.3	2.1	20.2	6.5	2.2	1.1	19.6	13.0
1965	11.1	6.3	17.8	16.1	1.1	0	26.1	23.9
1966	9.9	4.2	10.7	3.2	1.1	1.1	6.5	15.2
1967	12.3	10.4	7.1	9.7	2.2	1.1	8.7	8.7
1968	24.7	16.7	9.5	7.5	10.3	2.1	4.3	6.5
1969	7.4	11.5	9.5	6.5	13.7	5.3	6.5	8.7
1970	6.2	16.7	9.5	11.8	19.5	2.1	8.7	4.3
1971	8.6	7.3	4.7	9.7	19.5	11.6	0	10.9
1972	3.7	11.5	5.9	11.8	11.4	5.3	0	0
1973	1.2	1.0	0	3.2	4.5	3.2	0	0
None/Don't know	0	12.5	1.1	12.9	9.1	67.4	0	0

The Rate of Adoption Over Time.

Table 12 presents the percentage of farmers first hearing about hybrid maize and first planting it by year and by agroclimatic zone. Figure 7 presents the data on first planting in cumulative form. Both sets of information are based on the farmers' recollection of events as of June, 1973. For the reasons given in Chapter III, it is believed that this information is quite reliable in the case of first use of hybrid seed, although the farmers' ability to recall when they first heard about hybrid is probably less reliable. The mean time period between first hearing about and first planting hybrid was approximately 1.5 years for all zones, which compares with a mean time lag of five years for Iowa farmers.[4] The modal frequency of first hearing about hybrid varied considerably from 1964 (one year after hybrid was introduced) in Zone 2 to 1970 (seven years later) in Zone 3. In Zone 1 the modal frequency was in 1968. The mean year for hearing of hybrid varied in the same pattern as follows: Set 4 –1965, Zone 2–1966, Zone 1– 1967, and Zone 3–1969. These means vary directly with the distance of the respective zones from the National Agricultural Research Station at Kitale (in the large farm area of Trans Nzoia) but also reflect the relative

Fig. 6. **Response of varieties to environments.** Source: Late maturity maize variety trials, 1971; Festus Ogada, National Agricultural Research Station.



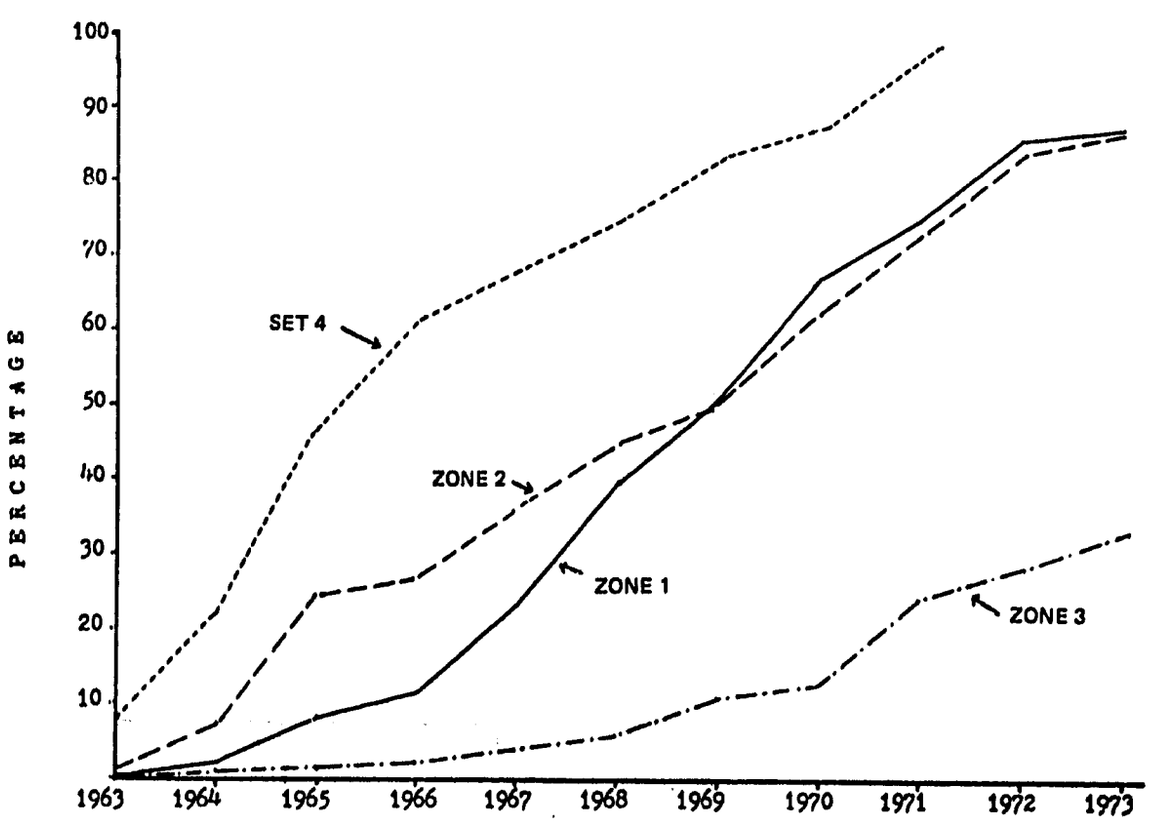
importance of maize as a cash crop among the different zones, and, hence, the general level of commercialized agriculture.

The modal frequency for first use of hybrid seed varied from two years after its introduction in Zones 2 and 4 to eight years in Zone 3. For Iowa corn farmers the modal frequency of adoption was ten years after its introduction and for Punjabi wheat farmers three years.[5] The mean frequency for first use varied from three years after first introduction for the large farm areas to five years in Zones 1 and 2 and seven years in Zone 3. It is apparent from these data that both large- and small-scale farmers in the high rainfall portions of western Kenya adopted hybrid maize at a rate faster than American farmers in Iowa in the 1920's and 30's. It should be remembered, however, that the relative yield advantage of Kenyan hybrids over local varieties was much greater at the time of its introduction in 1963 than was the comparable American case.[6] Nevertheless, it would be difficult to conclude from the rapid adoption rates and short time lags between first hearing and first use that African farmers are in any way inextricably bound by tradition or unopen to change.

A closer look at the adoption pattern in Figure 7 shows clearly the differences in adoption rates and ceilings between zones. The former European-owned farms (Set 4) reached almost 80 percent usage within five years. Hybrid use on the smaller, but still relatively large, commercial, maize-growing farms in the neighboring areas also spread quickly but was soon matched and even slightly overtaken by the smaller subsistence farmers in the high rainfall areas of Kakamega, Kisii, and Kericho. Hybrid use in the lakeside districts of Nyanza Province was much slower to develop and may actually be falling since the percentage of farmers who reported ever planting hybrid is now considerably higher (32.9 percent) than the percent who reported planting in 1973 (15.8 percent). These data are presented visually in Map 4.

Interestingly enough, the rate of adoption in the high rainfall zones has been so steady that they hardly show the traditional S-shaped curve characteristic of most innovations (in which potential adopters at first hesitate, then adopt quickly, and finally slow down again as "conservative" late adopters a lag behind).[7] Griliches reported that the S-shaped or "normal" curve typical of hybrid adoption in the U.S. was also found to exist for the adoption of combines, corn-pickers, and field forage harvesters, as well as new types of prescription drugs.[8] Griliches also pointed out that the equilibrium level of adoption in all parts of the U.S. never reached 100 percent. The western parts of Nebraska, South Dakota, and Kansas

Fig. 7. **Percentage of farmers first planting hybrid maize by year and by zone. (Figures are cumulative and therefore may exceed the total percentage of farmers planting hybrid in a given year).**



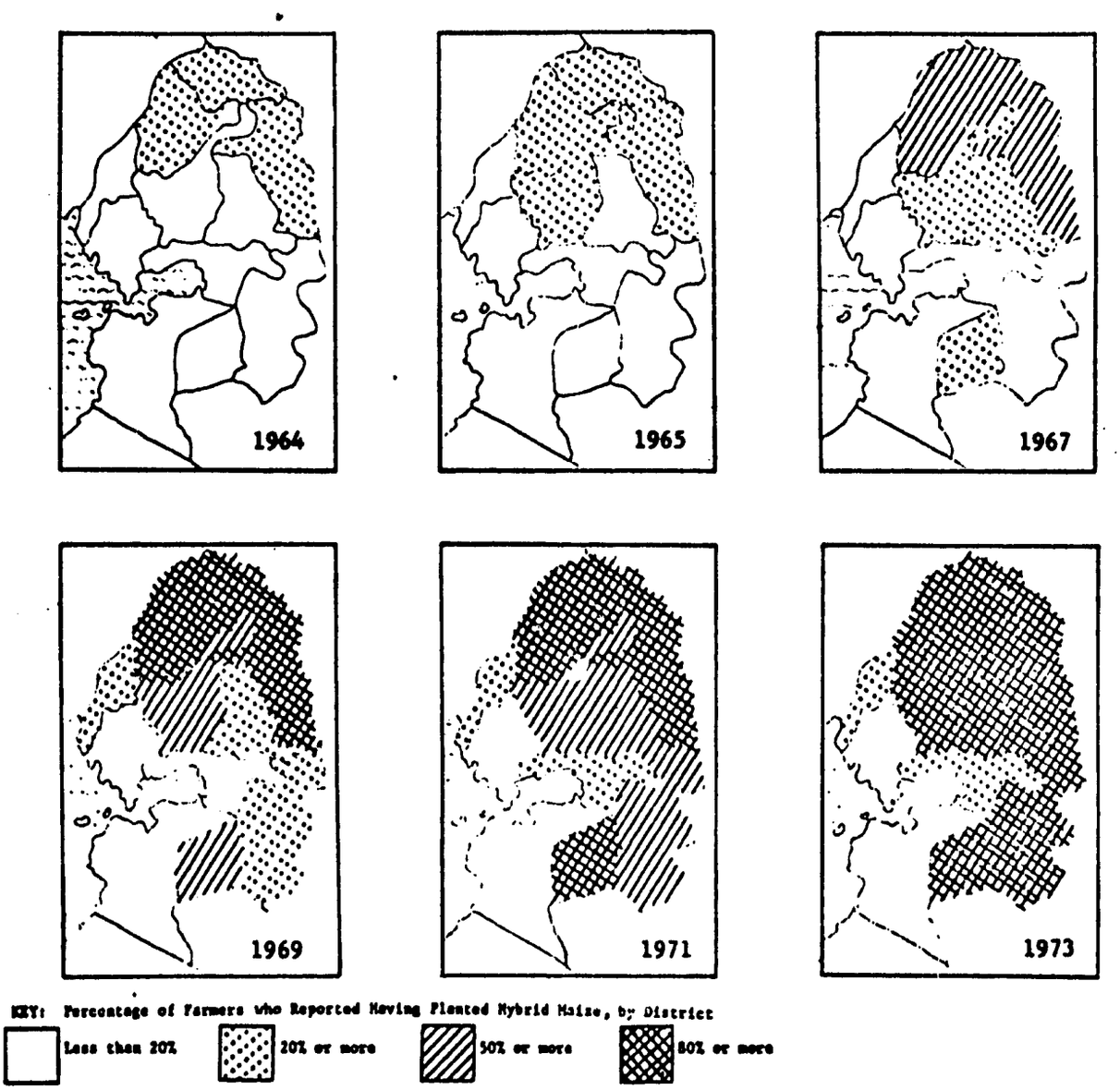
reached an equilibrium level after 30 years of 30 to 60 percent hybrid use. These are areas of highly variable rainfall where the use of hybrid was profitable only for those farmers on particularly good land or able to employ irrigation.[9] This may eventially prove to be the case in Zone 3. Unless new varieties specially suited to that environment are developed, hybrid use may stabilize only among farmers with certain, as yet unspecified, characteristics.

The Adoption of Associated Maize Technology.

Although the discussion so far has focussed primarily on the use of hybrid maize seed, this has never been considered in Kenya to be the sum total of hybrid maize technology. From the outset it has been recognized that a complete package of associated practices, including both physical inputs and improved husbandry, would produce the highest yields. Allan's definitive work on agronomic factors,[10] already discussed in Chapter II, and Moock's study of small farm maize yields in Vihiga[11] both indicate the importance of early planting, plant population, fertilizer use, and weeding for achieving higher yields.

According to Hazelden,[12] the conscious policy of the seed company and the extension service from the start was to use the new seed as a catalyst for achieving a general improvement in maize husbandry and yields. "Hybrid" was considered a completely new crop requiring

Map 4. **Diffusion of hybrid maize in Western Kenya, 1964-1973.** Source: 1973 Kitale/CIMMYT hybrid maize survey.



new techniques of production. The Kenya Seed Company painted "Hybrid" in large letters on its company Volkswagens and even today their publicity refers only to "hybrid" not "hybrid maize." Seed was never subsidized and farmers were taught that, if it was worth paying for, it was worth using properly. The early demonstration plots were few and well run and the farmers got high yields from the total hybrid package. The fact that some Europeans felt that African farmers were not "ready" for hybrid only served to heighten the demand for it. Farmers who laughed in 1963 at the idea of 20 bags an acre saw a farm manager get 47 bags in a yield contest in 1972. How well, though, did the strategy succeed in bringing about the desired changes in husbandry that accompany the use of hybrid seed? Have farmers accepted the new technology *in toto* or have they merely bought the seed while reverting to traditional methods of husbandry? And what has been the difference in acceptance between commercial, physical inputs and behavioral, cultural practices? The 1973 survey gives some interesting indications.

To begin with, Table 13 shows the percentage of farmers in 1973 using various recommended maize growing practices by zone. The use of manure (a beneficial but not actively recommended practice) is also included. Although the measurement of some of the practices may be fairly rough (e.g. the timing of weedings may be more important than the number of weedings and the meaning of planting "before the rains" instead of "with the rains" may vary from place to place), nevertheless, these figures give a reasonable picture of differential adoption of maize technology practices in western Kenya.

The pattern of associated technology use varies markedly both by practice and by zone. The use of commercial inputs varies from 100 percent (for hybrid seed in Set 4) to 4 percent (for insecticide and fertilizer in Zone 3). Cultural practices display a similar range, from a high of 100 percent planting in rows in Set 4 to allow of 10 percent planting "before the rains" in Zone 3. On the basis of the evidence no clear distinctions are noted between the adoption of "physical" and "cultural" practices. Each component of the recommended technology appears to have been adopted or rejected according to its own characteristics, including cost, profitability, risk, complexity, and congruence with traditional diets or labor patterns. Looking specifically at the commercial inputs, the weighted average of farmers using inputs falls from 67 percent (seed) to 49 percent (some fertilizer) to 46 percent (insecticide on stored maize) to 13 percent (insecticide in the field). This is in part a function of cost, since recommended levels of fertilizer cost about five times as much per acre as hybrid seed, and may also reflect availability. In the more commercialized maize-growing areas, of Zone 2 the use of commercial inputs of all types remains quite high whereas it drops off sharply in the smaller, more subsistence-oriented farms in Zone 1 and is uniformly low in Zone 3.

Among cultural practices, it appears that row planting has been overwhelmingly adopted by hybrid growers. Interplanting, however, continues in importance in all the subsistence areas. Moock found[13] in Vihiga that interplanting, controlling for plant population, was positively related to maize yield and speculated that legumes may release nitrates into the soil. He also noted that farmers claim the tall maize protects the interplanted crop from hail damage. Other reasons advanced for interplanting include improved soil cover to preserve moisture and reduce erosion, control of soil temperature, saving on weed control, and staggered growing periods which affect both labor demands and food requirements. As long ago as 1934, L.S.B. Leakey,[14] explaining the interplanting habits of the Kikuyu, wrote:

> The habit of regarding African methods of agriculture or of any other activities as inherently bad because they are different from our own is most unwise. I do not suggest that the methods used by different native tribes are all perfect. Doubtless the methods of agriculture employed by the Kikuyu could almost certainly be improved in many details, but this could only be done if European methods of research were employed in trying to develop the African method of cultivation, which is very different thing from trying to substitute European methods of planting for those which have been evolved out of reach by trial and error.

As a result of the durability of interplanting as a practice, the National Agricultural Research Station in 1973 began

Table 13. **Percent of farmers using recommended maize technology by zone.**

	Zone 1	Zone 2	Zone 3	Zone 4	Weighted Average
A. Physical Inputs					
1. Used Hybrid Seed in 1973	94.8	89.2	15.8	100	67.1
2. Used Some Commercial Fertilizer	61.5	80.6	4.2	97.8	49.0
3. Used Insecticide on Stored Maize	47.9	74.2	17.0	100	45.8
4. Used Insecticide in Field	6.3	30.1	4.2	50.0	13.2
5. Used Manure on Maize	25.0	20.4	15.8	10.9	22.8
B. Cultural Practices					
6. Planted in Rows	96.9	93.5	32.6	100	75.1
7. Planted a Pure Stand	64.6	61.3	41.1	91.3	57.4
8. Weeded More Than Once	83.3	51.6	46.3	69.9	63.3
9. Thinned Maize	31.3	44.1	64.2	43.5	45.2
10. Planted Early	31.3	26.9	10.5	47.8	23.0

Table 14. **Husbandry practices of hybrid and non-hybrid users, 1973.**

Practice	Hybrid Users (N= 189)	Non-Hybrid Users (N=93)	χ^2 Value
Planted in rows	97.2%	29.0%	**47.12
Used some commercial fertilizer	68.2	3.1	**32.73
Used some insecticide on crop	16.5	1.2	3.04
Thinned maize	35.7	66.6	**6.72
Weeded more than once	74.4	35.9	**12.37
Planted pure stands	67.0	36.4	** 6.57
Used manure	24.9	12.5	1.21
Planted before the rains	32.6	7.6	* 6.08
Used insecticide on stored maize	61.1	14.3	**17.03
Sold some maize	51.5	22.0	* 5.79

* = 5% level of significance.
** = 1% level of significance.

trial studies on interplanting to discover what physical interactions, if any, do exist.

Early planting, unfortunately, is difficult to measure since the beginning of the low rains varies considerably from place to place. For this reason, the question posed in the 1973 survey asked if planting began "before the rains started," "when the rains started," or "after the rains started." Even this phrasing presents problems, however, since there is not necessarily consensus on when the rains have actually "started" and since planting can be suspended if the rains appear to halt. Farmers, therefore, were also asked, "How many days passed between starting and finishing seeding in this field?" and the responses indicate some variance (from an average of 4.1 days in Zone 1 to 6.9 days in Zone 3). This appears to indicate greater caution among Zone 3 farmers. In any case, planting before the rains had the lowest acceptance of any cultural practice and was, once again, lowest in Zone 3. This is consistent with our risk hypothesis, namely, that farmers will forego the higher yields which result from early planting in favor of a greater certainty that the rains have actually started. Another factor affecting early planting, however, is that plowing (whether by oxen or by hand) is more difficult when the soil is hard (and coincidentally when the oxen are at their weakest due to the long dry period). It is not surprising, then, that early planting is highest (48 percent) in Set 4, where 100 percent of the farmers plowed by tractor, as opposed, for example, to 7 percent in Zone 3 and 25 percent in Zone 1.

Interestingly enough, the practice of thinning out weaker plants is highest in Zone 3 (65 percent) and lowest in Zone 1 (32 percent). This may be because farmers who have purchases hybrid seed are reluctant to pull up even a few stalks, even though it would improve their overall yield. Weeding, on the other hand, is highest in Zone 1 (where 84 percent of the farmers weeded more than once) although this is most likely a function of farm size rather than a newly adopted practice. The use of manure was also greatest in Zone 1.

Unfortunately, we do not really know the incidence of husbandry practices at earlier periods and are, hence, unable to assess precisely how much change is due to the introduction of the hybrid technology package. The evidence from earlier sample surveys, however, shows very low levels of fertilizer use in 1965, with increasing use in 1968 and again in 1970, but still lower than in 1973. Such information as does exist on row planting also shows a gradual increase and it is asserted that row planting was virtually unknown before the introduction of hybrid..

An indication of the "hybrid influence" can perhaps best be gained by comparing the husbandry practices of hybrid seed users with those of non-adopters. If we assume that husbandry improvements are a "secular" phenomenon, there should be no significant difference between hybrid and non-hybrid users. To measure the strength of whatever association does exist, we have used a simple chi-square test which measures the difference between the actual and the predicted observation. Any chi-square greater than 3.84 with one degree of freedom indicates a less than 5 percent chance that such a distribution would have occurred randomly; 6.63 or greater indicates a less than 1 percent probability.

Table 14 shows the practices of hybrid and non-hybrid adopters for the weighted average of the entire sample. In every case except two there was a greater than 95 percent probability that the distributions were not random. One of these was insecticide use which has a 90 percent probability and the other was manure use, which although not specifically recommended by the extension service, is nevertheless used by more than twice as large a percentage of hybrid than of non-hybrid growers.

Row planting and fertilizer use were especially strong-

ly related to hybrid use, while interplanting and thinning, as noted above, were positively related to non-hybrid use. Use of insecticide on stored maize and sales of maize off the farm are strongly associated with hybrid use.

From the evidence of the survey, we can conclude that the adoption of associated technology is strongly related to hybrid seed adoption regardless of the overall levels of adoption of each portion of the new technology. In other words the "package approach" seems to be justified even if it is not 100 percent adopted in each case. The one curious exception is the thinning of young plants, which is more prevalent among non-hybrid users. The general relationship is true both of physical inputs and of cultural practices, although the level of adoption of each practice varies with its cost, complexity, and congruence with traditional practice. Where the adoption of an innovation such as early planting may increase the riskiness of the food crop, however, its acceptance has been much more limited. In the following chapter we will look more closely at factors affecting differential adoption levels among farmers.

Notes

1. A small portion of western Bungoma and northern Busia districts which does not fall clearly in any of the three zones was excluded from the survey area, as were the forest areas on Mt. Elgon and in Kakamega and Nandi districts. The zones used here correspond roughly to the Star Grass, Kikuyu Grass, and Savannah zones mentioned in the literature.

2. "Households" were used in making this list to avoid a possible bias of being directed to only the better "farmers," a frequent survey problem.

3. Letter from Festus Ogada, Director, Kenya National Maize Breeding Programme, February 12, 1974.

4. Bryce Ryan and Neal C. Gross, "The Diffusion of Hybrid Seed Corn in Two Iowa Communities," *Rural Sociology 8* (March 1943); 17.

5. Zvi Griliches "Hybrid Corn and the Economics of Innovation." *Science* 132 (July, 1960): 277-279, and Max K. Lowdermilk, "Diffusion of Dwarf Wheat Production Technology in Pakistan's Punjab. A Summary Report Condensed from a Doctoral Thesis", Cornell University, 1972, p. 17.

6. Zvi Griliches, "Hybrid Corn and the Economic of Innovation," *Science,* 132 (July 1960): 278. Griliches estimated that hybrid outyielded open-pollinated varieties by 15-20 percent at that time.

7. Everett M. Rogers, *Communication of Innovations* (New York, 1971), pp. 176-179.

8. Griliches, "Hybrid Corn," p. 275

9. Ibid., p. 279.

10. A.Y. Allan, "The Influence of Agronomic Factors on Maize Yields in Western Kenya with Special Reference to Time of Planting" (Ph.D. Dissertation, University of East Africa, 1971).

11. Peter Moock, "Managerial Ability in Small-Farm Production" (Ph.D. dissertation, Columbia University, 1973).

12. Interview with E.J.R. Hazelden, Kenya Seed Company, February, 1973.

13. Moock, "Managerial Ability in Small-Farm Production," p. 259.

14. L.S.B. Leakey, "Science and the African," 1934. Given the author by T.M. Wormer.

IV. ANALYSIS OF ADOPTION AND EARLY ADOPTION

In this chapter we look more closely at the characteristics of adopters and non-adopters of the new maize technology and at the characteristics of "early" adopters. In particular, we consider the relationships between the adoption of hybrid seed in 1973 and such factors as agroclimatic zone, perceived risk, ability to "tolerate" or withstand risk, and knowledge, as well as availability, of the new technology.

The purpose of this analysis is twofold. First, it is important to see what, if anything, characterizes non-adopters in order to be able to modify research, extension, or input supply systems in ways that will better reach this segment of the population. Secondly, it is important to distinguish differences between early and later adopters so as to judge what effects the introduction of the new varieties has had on income distribution and employment. After comparing the factors related to early and later adoption we will consider whether time lags in adoption have caused serious problems for income distribution in Kenya.

Both bivariate and multivariate methods have been used in the analysis of adoption, including difference of means tests, chi-square tests, Pearson correlations, probit analysis, and multiple regression analysis. Of these, probit analysis merits special mention since it is as yet infrequently used in social science applications. The most readable explication of multivariate probit analysis is still probably James Tobin's

1955 paper the "Application of Multivariate Probit Analysis to Economic Survey Data."[1]

The Multivariate Model for Hybrid Adoption

Based on the established procedures for multivariate probit analysis the equations for examining the factors influencing adoption are

$$I = a + bX_1 + cX_2 + dX_3 \ldots + nX_n$$

and

$$Y = g(I)$$

where I is an index reflecting the combined effect of the X factors which prevent and promote adoption. $Y = 1$ (adoption) if I exceeds a threshold value; $Y = 0$ (non-adoption) if I falls below a threshold value.

The following independent variables are used:

Interval-Scale Variables

X_1 = *Age* (in years)
X_2 = *Education* (formal education in years)
X_3 = *Size* (size of farm in acres)
X_4 = *Distance* (distance to nearest source of inputs in miles).
X_5 = *Cash* (imputed value of cash crops in thousand shillings per annum)

Dummy Variables

X_6 = *Zone* (0 = Zone 3)
(1 = Zones 1 and 2)
X_7 = *Risk* (0 = "risky" —famine crops present)
(1 = "not risky" —famine crops not present)
X_8 = *Job* (0 = no job off farm)
(1 = job off farm)
X_9 = *Experience* (0 = Farmer has never worked off farm)
(1 = Farmer has worked off farm)
X_{10} = *Large farm* (0 = Farmer has never worked on a large commercial farm)
(1 = Farmer has worked on a large commercial farm)
X_{11} = *Credit* (0 = Farmer believes farmers in his area cannot get credit)
(1 = Farmer believes farmers in his area can get credit)
X_{12} = *Extension* (0 = No extension visit in past year)
(1 = Extension visit in past year)
X_{13} = *Demonstration* (0 = Farmer has never attended maize demonstration)
(1 = Farmer has attended maize demonstration)
X_{14} = *Training* (0 = Farmer has never been to farmers Training Center)
(1 = Farmer has been to Farmers Training Center)

The variable X_7 warrants additional explanation. Interplanting maize with other crops is a common practice among Kenyan farmers (see Table 13). Oftimes, especially in Zone III, maize is found intercropped with millets and sorghums, both drought resistant crops. While there may be explanations for this practice, given the physical properties of the drought-resistant crops and the taste preference for maize evidenced by its rapid spread, it seems reasonable to assume the presence of drought-resistant crops in the farmers' crop mix represents a risk averting action. In the analysis which follows, the variable X_7 serves as a proxy variable for risk aversion.

A computer program, "N-chotomous Multivariate Probit Program" was used to make the necessary computations.[2] This program produces sample means and variances for each independent variable, maximum likelihood estimates for the coefficient of each variable, standard errors, and a t-test (MLE/SE). The log of the likelihood function and −2 times the log of the likelihood ratio are given, the latter of which is distributed like chi-square with m degrees of freedom for large samples and can be used as a measure of the explanatory power of the independent variables taken in groups.[3] Using the coefficients obtained by the maximum likelihood method and substituting the values of the independent variables in the equation, the equation is solved and the resulting solution is converted to a probability of adoption from the normal distribution table. By substituting the average values of the sample for all but one variable at a time, an idea of the relative importance of each variable for an "average" case (if such exists) can be obtained.

Tables 15 and 16 give the "probits" or probit runs which are used in the analysis. The following sections discuss each of the key independent variables roughly in order of their importance. Arithmetic means (for continous variables) and frequency distributions (for dummy variables) are presented for adopters and non-adopters. Where these statistics differ between zones, the reasons for those differences and their possible implications for adoption are discussed.

To recapitulate briefly, it is hypothesized that adoption will be positively correlated with education, farm size, presence of cash crops, presence of an off farm income, availability of credit, relevant work experience off the farm, attendance at maize demonstrations, an extension visit in the past year, and location of the farm in a high rainfall zone. It is anticipated that adoption will be negatively correlated with age, distance to a source of inputs, presence of "famine crops" in the crop mixture, and location of the farm in a moderate or variable rainfall zone (Zone 3). Special importance is ascribed to those factors (agroclimatic zone and the presence of "famine crops") associated with risk and, where these factors are themselves important, it is anticipated that "risk tolerance" or ability to absorb risk (as measured by outside income, access to credit, farm size, and presence of cash crops) will be positively related to adoption. Chi-square and difference of means tests are applied, where applicable, to the bivariate analysis, and simple correlations between variables are given with appendix.

Factors Affecting the Adotpion of Hybrid Maize.

Using the model presented previously, probit analysis was carried out separately on the sample population as a whole and on the sample in each of the three agroclimatic zones. Analysis of Set 4 was not undertaken since 100 percent of farmers were adopters. The results of the analysis are given in Tables 15 and 16. Because of the very small number of non-adopters in Zones 1 and 2, no statistically significant coefficients were found in Zone 1 and only imputed value of cash crops was significantly related to adoption in Zone 2 (at the 0.5 level). Most of the multivariate analysis, therefore, concentrates on the sample taken as a whole (including agroclimatic zone as an independent variable) and on adoption and non-adoption in Zone 3 (excluding agroclimatic zone as an explanatory variable).

As Table 15 shows, the following factors significantly influenced the adoption of hybrid maize in western Kenya: agroclimatic zone, perception of risk (as measured by the planting of famine crops), level of formal education, knowledge of credit availability, and imputed value of cash crops. As hypothesized in Chapter IV, zone, education, credit, and cash were positively related to adoption and risk was negatively related. Although the significance of formal education as an independent variable declined with the introduction of partially collinear variables such as credit and cash crops, it remained significant at the 0.10 level in the presence of all the major variables (equation one). Among the other variables, age was negatively related to adoption and size of farm was positively related, as hypothesized, although neither had large coefficients or *t*-values. Measures of extension contact (extension visits and attendance at maize demonstrations or Farmers Training Centers) were positively related to adoption, though only one was significant at more than a 0.05 level (equation three). Previous off-farm work experience, whether in general or on a large, commercial farm, was, surprisingly, negatively related to adoption, and having a job off the farm at the timesof the interview, though positive in sign, was not significantly related. Distance to a source of inputs did not prove a useful indicator, since non-adopters were generally unable to answer the question correctly, and it therefore was dropped from the analysis. In fact, distance from a source of inputs, when included in the equations, turned out to be positively (but not significantly) related to adoption, perhaps because the few non-adopters who knew the distance to a source of inputs were those who lived closest to such a source. Finally, the chi-square values for all of the equations indicate that the expalantory power of the independent variables taken together was significantly different from zero at the 0.001 level. The R^2 or pseudo-R^2 values for the two main equations were encouraging (0.76 and 0.75), and the coefficients obtained predicted almost 92 percent of the cases correctly.

As Table 16 shows, the following variables were significantly related to adoption in Zone 3: risk, education, and credit availability (at the 0.05 level) and imputed cash income

Table 15. **Multivariate probit analysis of hybrid maize adoption in western Kenya—all zones.**

Independent Variables	Equation 1[1,2]	Equation 2	Equation 3
CONSTANT	- 0.60	-1.22	
Agroclimatic zone	2.07 (8.06)+++	2.09 (8.55)+++	3
Age in years	- 0.01 (1.61)+	– –	
Education in years	0.06 (1.30)+	0.07 (1.74)++	
Farm size in acres	0.01 (0.05)	– –	
Risk (famine crops)	- 1.42 (3.89)+++	-1.41 (3.90)+++	
Credit availability	0.98 (3.08)+++	0.88 (2.94)+++	
Cash (000 shillings)	0.21 (2.15)++	0.21 (2.11)++	
Job off farm			0.28 (0.92)
Ever worked off farm			-0.69 (2.66)+++
Worked on large, commercial farm			-0.75 (2.34)++
Extension visit in past year			0.29 (1.32)+
Attended maize demonstration			0.13 (0.69)
Attended Farmers Training Center			1.33 (2.60)+++
-2 times log likelihood ratio	221+++	218+++	
χ^2 distribution-degrees of freedom	7	5	
Estimated R squared (R^2)	.76	.75	
Percent of cases predicted correctly	91.9%	91.5%	

1. The maximum likelihood estimate of the coefficient is given first, followed by t statistics in parenthesis. 2. One, two, and three plus signs (+) indicate significance levels of 0.10, 0.05, and 0.01 respectively for a one-tailed test. 3. Equation three included the same variables as equation two with each of the work experience and information variables added in turn. The coefficients of the independent variables in equation two changed only very slightly with the addition of an additional variable, as did the constant and the chi-square value.

(at the 0.10 level). Attendance at Farmers Training Centers was positively and significantly related to adoption, and previous work experience off the farm was significantly and negatively related to adoption (equation three). Age and size of farm were not significantly related to adoption, had very small coefficients, and negative signs. Again, the chi-square values of the equations indicate that the explanatory power of the independent variables was significantly different from zero at the 0.001 level. The R^2 values were 0.72 and 0.69 and 91.6 percent of the cases were predicted correctly. In the following sections, each of the independent variables is discussed in greater detail.

Adoption and Agroclimatic Zone

The percentage of farmers in each zone using hybrid maize seed on more than half their maize acreage in 1973 has already been reported as follows:

HYBRID SEED ADOPTION BY ZONE

Zone 1	*Zone 2*	*Zone 3*	*Set 4*
(N = 96)	(N = 93)	(N = 95)	(N = 74)
94.8%	89.2%	15.8%	100%

The importance of agroclimatic zone is indicated in equation (1), Table 15. By substituting the mean values for the other variables and solving the equation, we find that location of the farm in Zones 1 or 2 increases the probability of adoption from 17.7 percent to 87 percent. The importance of zone is also indicated when adoption and zone are cross-tabulated, giving a chi-square value of 53.64, which is significant at the 0.001 level. The simple correlation between zone and adoption is 0.78 which is also significant at the 0.001 level.

The basic puzzle in the study of hybrid maize adoption in western Kenya is to explain this substantial difference between the higher altitude, high rainfall zones (1 and 2) and the medium altitude, moderate rainfall zone (3). In the absence of reliable yield data for farms in both areas, we must regard agroclimatic zone as a measure of the general environment conditions in which the farmer makes his decisions. This includes not only the relative profitability of the new technology in each zone (se Chapter II) but also the variability of rainfall among zones. It seems to be a well-established principle of meteorology that areas with lower average rainfall tend also to have higher variability from year to year. Evidently this is the case in western Kenya, as is indicated by the persistence of famine crops in the moderate rainfall area (see the discussion of "risk" below).

The best data on relative yields in western Kenya are from the F.A.O. Fertilizer Program demonstration plots.[4] These plots, laid out by the extension staff on farmers' fields in highly visible locations, have three portions: a control plot with hybrid seed and no fertilizer, a plot treated with 60 kg. phosphates (P_2O_5) at planting, and a plot with phosphates and 60 kg. of nitrogen topdressing. Since no

Table 16. **Multivariate probit analysis of hybrid maize adoption in western Kenya—zone three only.**

Independant Variables	Equation 1[1,2]	Equation 2	Equation 3
CONSTANT	-0.96	-1.67	
Age in years	-0.01 (0.82)	.	3
Education in years	0.13 (1.57)+	0.14 (1.81)++	
Farm size in acres	-0.02 (-0.53)	.	
Risk (famine crops)	-2.33 (3.06)+++	-2.23 (3.07)+++	
Credit availability	2.04 (3.56)+++	1.86 (3.56)+++	
Cash (000 shillings)	0.28 (1.46)+	0.27 (1.39)+	
Job off farm			0.46 (0.77)
Ever worked off farm			-0.95 (1.76)++
Worked on large, commercial farm			-3.41 (0.10)
Extension visit in past year			0.60 (1.22)
Attended maize demonstration			0.47 (1.21)
Attended Farmers Training Center			1.28 (1.76)++
-2 times log likelihood ratio	41+++	39+++	
χ^2 distribution-degrees of freedom	6	4	
Estimated R squared (R^2)	0.72	0.69	
Percent of cases predicted correctly	91.6%	91.6%	

1. The maximum likelihood estimate of the coefficient is given first, followed by the t statistic in parenthesis. 2. One, two, and three plus signs (+) indicate significance levels of 0.10, 0.05, and 0.01 respectively for a one-tailed test. 3. Equation three included all the variables in equation one plus each of the work experience and information variables added in turn. The coefficients of the independent variables in equation one changed very slightly with the addition of the other additional variable and have not been reproduced.

local seed varieties are used, the results of these trials only show the relative performance of hybrids in the three zones and not of the relative performance of hybrids *vis-à-vis* local varieties. We should note also that the level of husbandry on these demonstration plots is certainly well above that of the average farm. Nevertheless, the results give at least some indication of the differing performance of hybrids in the three zones.

By averaging the yields obtained in Busia, Siaya, Kisumu, and South Nyanza districts (all basically in Zone 3) in 1969, 1970, 1971 and 1972, and comparing them with the other higher rainfall districts in western Kenya (all of which would be in either Zone 1 or 2) we get the results shown in Table 17.

Using this measure, hybrid yields averaged 22 percent higher over a four-year period in the districts of Zones 1 and 2 than in the districts of Zone 3. Because of the hybrids' greater genetic potential, moreover, we know (Chapter III) that their advantage over local varieties will be greater under good conditions than under poor conditions. Therefore, the differences in yields between hybrids and local varieties should be even greater than the differences found between hybrids taken alone. In sum, there are good reasons to believe that differential profitabilities play an important part in explaining the substantial differences in adoption between the high and moderate rainfall zones and, consequently, in the overwhelming importance of agroclimatic zones as an explanatory variable in the sample taken as a whole.

Unfortunately, the problem is not this simple because the three zones are not homogenous with respect to their history or their existing infrastructure. Hybrid maize was quite understandably promoted first in those areas where it was thought to do best. Similarly, inputs were supplied first to those areas where demand was greatest. Knowledge of the new technology, in spite of extension efforts, varies more or less inversely to the distance from the National Agricultural Research Station at Kitale. The lakeshore areas of Zone 3, therefore, combine a number of features disadvantageous to the adoption of the new technology: lower altitude and rainfall, greater variability in rainfall, poorer soils and drainage, poorer roads and input availability, lower levels of extension and farmer training, greater distance from the key research center and from input outlets, and a later introduction of hybrid varieties in the first place.[5]

Table 17. **Yields of hybrids in 1074 F.A.O. fertilizer demonstration control plots, 1969-1972.**

Zone	Number of Plots	Yield, kg/ha
1 and 2	655	3417
3	419	2796

Agroclimatic conditions, then, are confounded by differing levels of general development and services. Moreover, the cash crop opportunities in Zone 3 (cotton, groundnuts, sugar) are generally not as lucrative as those in Zones 1 and 2 (tea, coffee, pyrethrum, dairy, bananas). Cash incomes from the farm are therefore much lower, and the corresponding interest in farming as a way of earning a living can be logically expected to be less. Another problem is the fact that the cash crops in Zone 3 are more seasonal than those (except coffee) in Zones 1 and 2, which means that they provide a less steady source of cash income with which commercial inputs can be bought. Because of the lag between harvesting (from August to October) and planting (in February-March) of the long-rains maize crop, ready cash is not easily available for purchasing inputs for those farmers without access to credit.

Another factor closely related to agroclimatic zone is ethnic composition or tribe. Tribal boundaries in Kenya, with few exceptions, are well delineated and often conform closely to geographical features. This is especially true in the region around Lake Victoria in Kenya, where the Kisii hills and Nandi escarpment mark a sharp boundary between the Luo-speaking people of the lakeshore and the Bantu and Kalenjin-speaking peoples of the highest elevations. Only on the boundary between the Luo and Luyia tribes north of the lake is there anything like a gradual transition. And only in the formerly European-occupied districts of Uasin Gishu and Trans Nzoia, where hybrid adoption is virtually 100 percent, are these substantial numbers of farmers from a variety of tribal backgrounds. The result of this situation is that tribe and agroclimatic zone are inextricably confounded. For example, there were only three Luo farmers in the sample outside Zone 3 and ten non-Luo farmers in Zone 3. These 13 farmers behaved as the majority of farmers in their zone rather than as farmers from their tribe in other zones. I have not, therefore, found it possible to distinguish tribe as a separate explanatory variable. While not in any sense ignoring the importance of cultural and ethnic factors in determining responses to change, I would defend this conclusion in this particular case on the grounds that, whereas the Luo tribe make up the overwhelming proportion of farmers in Zone 3, a wide variety of tribes in Zones 1 and 2, including those more closely related to the Nilotic Luo than to the Bantu-speaking peoples, have responded to the favorable conditions for adoption hybrid maize. Within Zones 1 and 2, there were no significant differences in adoption by tribe.

In the colonial period, the lower level of agricultural development in the lakeshore region was attributed primarily to "people problems." Typical of the colonial view were the writings of Elseth Huxley, the historian of and apologist for the white settlers in Kenya. In her book, *The New Earth,* published in 1960, Huxley entitled a chapter "The Reluctant Luo."[6] "Their obstinacy is legendary," she reported, "they are inclined to be sullen and suspicious.... Faintly Teutonic in an African fashion

...[1]. It is not surprising that of all the major Kenya peoples, leaving aside the Masai, the Luo have put up the stiffest resistance to the forward march of Progress in the agricultural field." Similar, though less extreme, views were expressed by Fearn, de Wilde, Ruthenberg, and a variety of government reports, most of which complained of the reluctance of the Luo to adopt practices recommended by the agricultural services.[7]

These opinions have recently been soundly rebutted by Margaret Jean Hay in an excellent study of the economic history of Kowe, a sub-location in Central Nyanza (now in Kisumu District), from 1890 to 1945.[8] In looking at the Luo responses to a wide variety of innovations (white maize, cotton, cassava, farm implements, education, trading) she concludes that "far-reaching changes" took place in the Luo economy during this period and that programs which were rejected "did not represent the optimal allocation of land and labor resources."[9] In general, she says, "the agricultural potential of the area has been exaggerated byoutsiders who hoped to develop it." A survey of Annual Reports of the Department of Agriculture from 1906 to 1959 showed only 12 years in which droughts, floods, or poorly distributed rains were not cited by agricultural officers.[10]

Although colonial officials were important in introducing crops to the area, they were less significant in winning acceptance of them. Introduction often involved coercion, forced labor on demonstration plots, low prices, and conflicting recommendations. The poor acceptance of cotton, for example, introduced by John Ainsworth near Kisumu in 1906-07, has been often cited as evidence of Luo backwardness. As Hay points out, however, cotton faced a 50 percent price drop between 1910 and 1914 and again after it was reintroduced in the 1920s and 1930s. Moreover, the heavy labor demands of cotton conflicted sharply with the Luo food crop cycle. In spite of these problems, the Director of Agriculture noted in 1930 that "the failure of the natives to accustom themselves to market fluctuations" had retarded production.[11]

Hay contrasts the response to cotton with that to maize, which spread steadily after its introduction in 1917, probably by one H.H. Holden, a Luo-speaking West Indian employed by the Department of Agriculture. The new maize was called *Orobi* (after Nairobi) or *ababavu* ("a great thing") because it was larger than existing varieties. It required little adjustment in techniques of planting or preparation, although it did not really become widespread until after the introduction of a complementary innovation, the hand gristmill, about 1929—when it could readily replace the easier to grind sorghum as a flour staple. White maize was also reputed to give higher yields and made a preferred white flour.[12] Also readily accepted were cassava, especially after the famines of 1918-19 and the locust invasion of 1931-32, and groundnuts, introduced in 1913-14 and again in the 1920s.

After 1930, Hay found, famines in 1931-32 and 1943-44, the collapse of cotton prices during the depression, the discovery of gold nearby, and eventually the labor demands of World War II drew men off the land. Labor migration and local trade became important as sources of cash income. These plus increasing population pressure, shorter fallow periods, and soil exhaustion led to a "gradual de-emphasis of the agricultural sphere within the economy as a whole."[13] By 1945 labor migration was an accepted pattern. Although the colonial administrators took the failure of cotton compaigns and soil conservation measures as proof of a retrograde traditionalism among the Luo, Hay concludes that the de-emphasis of agriculture in favor of out-migration to work and engagement in trading opportunities was a rational response to their conditions. Moreover, the colonial view ignored the successful adoption of other agricultural innovations, ones which either increased economic security (such as groundnuts and cassava) or reduced labor expenditure (such as gristmills and plows).

From the evidence of the 1973 survey we can conclude that agroclimatic zone is the most important factor in determining the adoption or non-adoption of hybrid maize seed in western Kenya. Although hybrid maize has done well on some farms in the lakeshore zone, evidence from fertilizer control plots indicates that hybrid varieties yield substantially less in the lakeshore districts than in the higher rainfall zones. This conforms with other data from variety trials which indicate that the relative advantage of hybrids over local varieties also declines with an index of environmental conditions (Chapter III).

Further suspicion about the relative performance of hybrid versus local maize is aroused by the responses of farmers in Zone 3 when asked why they did not plant hybrids (Table 9) and by the large difference between farmers in Zone 3 who had ever planted hybrid (33 percent) and those who were planting it in 1973 (16 percent) (Figure 6). Farmers in Zone 3 have also suffered from lower levels of extension services and farmer training, more difficult access to inputs, poorer communications, less well-organized marketing facilities, and a later introduction of the new varieties.[14] Moreover, Hay's historial study shows that the Luos, the major ethnic group in Zone 3, have readily adopted other agricultural innovations which either increased economic security or reduced labor expenditures. The record she presents of periodic famines and irregular rainfall in Luoland indicates that risk-aversion may be important in the way the Luos observe the new maize. Just how important we will see in the following section.

Adoption and Risk

The theoretical basis for including risk as an independent variables has been presented. A dummy variable—whether or not the farmer planted drought-resistant but otherwise less desirable "famine" crops— was created as a proxy for the farmer's perception of the risk of not getting a maize

crop. The "famine" crops used in the dummy variable were sorghum, bulrush millet, cassava, and groundnuts. The hypothesis was that farmers who include "famine" crops in their crop mix will be less willing to invest cash resources in the purchase of hybrid seed and complementary inputs. The dummy variable "risk" was negatively correlated with adoption (−0.54) which was significant at the 0.001 level. Crosstabulated with adoption, the risk proxy gave a chi-square value of 24.82 which is also significant at the 0.001 level.[15]

ADOPTION AND "RISK"

	Adopters	*Non-adopters*
Famine crops present	6	45
Not present	183	48

"Risk" was also negatively correlated with adoption in each of the three zones taken separately:

	Zone 1	*Zone 2*	*Zone 3*
Simple r	−0.18	−0.42	−0.33
Level of significance	0.05	0.001	0.001

Chi-square values for the crosstabulation of risk and adoption were also significant (at the 0.01 level) for Zones 2 and 3, though not for Zone 1.

Because risk was also correlated with zone ($r = -0.50$), however, it was included both with and without zone in the probit analysis. When included with zone (equation 1), risk had a coefficient of −1.41 and zone, 2.09. Without risk in the equation, the coefficient of zone was 2.32. In spite of this multicollinearity, risk added significantly to the equation (the chi-square value increased from 185 to 203) and risk was therefore retained as a variable in most of the equations. Because zone is so important as an explanatory variable, the alternative of running risk without zone in the equations was discarded. (When this was tried, the chi-square value dropped to 119).

To get a better idea of the importance of risk perception as an influence on adoption, we can substitute representative values for the independent variables in equation 1. Setting the independent variables at their mean, we find that, if a farmer in Zones 1 or 2 grows famine crops, his probability of adoption is reduced from 97 percent to 71 percent. If a farmer in Zone 3 (Table 16) grows famine crops, his probability of adoption falls from 25.2 percent to 0.2 percent.

From the analysis we can conclude that the farmer's perception of risk, as measured by the planting of "famine" crops, is an important negative influence on adoption. What we do not know is whether this reluctance is due to the fact that hybrids per se are less reliable than local varieties, or whether, in the presence of considerable doubt about whether he will get a maize crop, the farmer is unwilling to pay cash for commercial inputs. A possible genetic explanation for the former case might be that the local varieties of maize stem originally from lowland tropical varieties imported at an early stage by the Portuguese from the Caribbean and Brazilian coasts whereas the hybrids developed at Kitale stem primarily from a cross of a settler-selected plateau variety with an imported Latin American highland variety. The theory here would be that local varieties are more tolerant of heat and humidity than the cooler highland cross. It is certainly true that the higher the altitude, the longer growing season a variety requires.

My own opinion, however, is that given a basic doubt about getting a maize crop at all, farmers are reluctant to pay cash for commercial inputs. Because of better selection, production, storage, dressing, and handling, hybrid seed is, if anything, probably more reliable in its germination than local seed. The distinction is an important one. In either case, the development of varieties specifically suited to the lakeshore zone is probably essential if widespread hybrid use is to be achieved. But if a reluctance to purchase commercial inputs is the problem the development of a synthetic or compositive variety (in which the seeds can be used for planting year after year) may in fact be necessary. And, finally, until and unless a reliable lakeshore maize variety is developed, farmers should certainly not be discouraged from planting drought-resistant crops. Much greater research emphasis should be devoted to improving the yields and the nutritional value of such crops as sorghum, millet, and cassava.

Adoption and Farm Size

Most of the studies of the Green Revolution in Asia and elsewhere have paid particular attention to the importance of farm size in determining the adoption of new technologies. Gotsch, Falcon, and others have argued that the new agricultural technologies have increased income inequalities because larger, wealthier farmers have enjoyed economies of scale in production and have had easier access to seeds, fertilizers, and, particularly, complementary inputs of tractors and irrigation.[16] More recently, Harrison and others have argued that economies of scale are not significant in LDC agriculture and are often offset by more intensive input use on smaller farms.[17] Lowdermilk, in his Pakistan study, claims that there is "no conclusive evidence that farm size itself is of major importance" in the adoption of high yielding varieties, and quotes several studies from India which found size of little importance in determining adoption.[18]. He quotes Dr. S.R. Sen on the subject as follows:

> The new technology is basically biological and chemical rather than mechanical in nature. Therefore, the new [High Yielding Varieties] did not give rise to such an economy of scale as to place the small farmer in a substantially disadvantageous position as compared to big farmers.[19]

and contrasts this with the conventional wisdom:

No theory of farm practice adoption can ignore the farm operator and the scale of his operation.... The importance of economic status in adoption, size of unit, gross returns from the unit are more highly correlated with adoption than other variables.[20]

In the present study, farm size was not found to be significantly related to adoption in any of the probit equations, either in individual zones or in the sample taken as a whole. In equation 1, even a ten acre increase in farm size (almost 100 percent of the average farm size) would have increased the "average" farmer's probability of adoption by only 3 percent. Although the mean farm size of adopters was larger than that of non-adopters in each zone, these differences were not statistically significant except in the entire weighted sample where the generally smaller farm sizes in Zone 3 made the size difference significant at the 0.001 level.[21]

Adoption and Cash Crops

It was hypothesized that adoption of hybrid maize seed would be positively associated with the presence of cash crops on the farm. The theoretical basis for this hypothesis is twofold: first, that the presence of a cash income would offset the risk of experimenting with a new food crop, and, second, that the availability of cash from the sale of cash crops would facilitate the purchase of the necessary inputs. In the analysis, a variable "cash" was created by multiplying the acreage of each major cash crop (coffee, tea, pyrenthrum, bananas, sugar, wheat, and cotton) by an "average" estimated gross margin for that crop.[22] To this was added a figure for dairy production (the number of grade cattle times an average estimated net return per cow) and for marketed maize (the number of bags sold times an estimated net of 25 shillings a bag), since maize itself is the most important cash crop in Zone 2. Although there are obvious difficulties in using an "average" return since variations in yield are substantial between farms (the best farmers often getting double the average yield), nevertheless, this variable gives a rough measure of the cash income accruing to each farm from sales of farm produce. Sales of minor cash crops (groundnuts, passion fruit, wattle) would constitute a small fraction of total farm income. The values of the "cash" variable for the different zones are shown in Table 18. Although these are only imputed cash incomes and are not based on actual marketed farm produce, they do reveal the substantial difference between cash incomes in Zones 1 and 2 and those in Zone 3, where both the number and value of cash crops present are more limited.

The sharp difference in the "cash" variable between adopters and non-adopters of hybrid seed lends strong support to the hypothesis that income from cash crops is associated with adoption (Table 29). In each case, the imputed income from cash crops was very much higher for adopters than for non-adopters and these differences were significant except in Zone 1.

Table 18. **Mean value of "cash" variable by zone.**

	Zone 1	Zone 2	Zone 3	Weighted Average
Mean	2001	2178	639	1588
Standard deviation	3228	3289	2255	3037
Number	96	93	95	

In the probit analysis, "cash" was significantly and positively related to adoption in the sample taken as a whole. For the hypothetical "average" farmer, an additional thousand shillings of imputed cash income would increase the probability of adoption from 76 percent to 82 percent (equation 1). In Zone 3, "cash" was significantly related to adoption at a 0.10 level for a one-tailed test. A thousand shillings of "cash" would increase the probability of adoption of an "average" farmer in Zone 3 not growing famine crops from 21 percent to 31 percent. We may conclude from the analysis that the presence of cash crops on the farm, itself a measure of the farmer's involvement in the monetary economy, greatly facilitates the adoption of the new technology. Marvin Miracle has argued persuasively that the term "subsistence agriculture," defined by some given percentage of farm production which is marketed, is not a particularly useful way of classifying small-scale farmers.[23] More appropriate measures, he feels, relate to the decision-making environment of the small farmer, including degree of isolation, level of living, commitment to agriculture, security of tenure, labor availability, and other factors. While we may agree that "subsistence" as a term has been used so broadly as to be virtually meaningless, nevertheless, at the bottom end of the market-subsistence continuum, the presence of crops grown specifically for sale is an important influence on farm behavior.

Adoption and Credit Availability

Like cash crops, availability of credit was hypothesized to be positively related to adoption of the new technology. The reasons for this are obvious. As Ronald McKinnon has written,[24]

Table 19. **Mean value of "cash" variables by adoption.**

	Zone 1	Zone 2	Zone 3	Weighted Average
Adopters	2056	2424	2163	2180
Non-adopters	1244	135	355	386
T-Value	0.49	5.95	2.93	2.79
Level of significance	NS	0.001	0.01	0.01

Table 20. **Availability and sources of credit (All answers in percentages).**

	Zone 1	Zone 2	Zone 3	Set 4
Farmers reporting credit available	27.7	40.9	17.9	63.5
Sources of credit cited:				
Kenya Farmers Association	9	25	0	24
Friends and relatives	9	0	25	0
Agricultural Finance Corporation	63	63	50	63
Cooperatives	18	12	25	12

Table 21. **Availability of credit and adoption (Farmers reporting credit available (percent)).**

	Zone 1	Zone 2	Zone 3	Weighted Average
Adopters	27.0	45.1	60.0	35.5
Non-adopters	50.0	10.0	10.3	12.4
Chi-square values	0.18	3.20	17.64	4.40
Level of significance	NS	0.10	0.001	0.05

Poverty and the inability to borrow to finance *discrete* increases in expenditures can be formidable barriers to the adoption of even the simplest and most productive innovations.

In spite of the high "divisibility" of hybrid seed itself, the recommended package of seed, fertilizer, and insecticides can represent a substantial cash outlay for a farmer with a small net income. This is no doubt part of the reason why the use of fertilizer (49 percent) and insecticide (13 percent) lagged substantially behind the use of hybrid seed (67 percent) in the sample as a whole and particularly in the small farm areas (Zones 1 and 3). The fact that fertilizer is less profitable than hybrid seed is obviously also important.

In the 1973 survey, a farmers were asked whether or not credit was available in their area, but for fear of biasing the responses were not asked directly whether or not they used outside credit sources themselves. The percentages of farmers reporting that credit was available, and the sources of credit reported are shown in Table 20. Interestingly, no farmer cited either stockists or commercial banks as sources of credit, testimony to the poorly developed nature of private lending institutions in the rural areas.

Although we can safely assume that farmers who were not aware of credit did not avail themselves of it, we cannot be certain that farmers who felt it was available either used it or required it. Nevertheless, knowledge of credit availability was highly significant (at greater than the 0.01 level) in the probit analysis, even when included with variables such as education, cash, and farm size, with which it might be expected to be correlated. For the hypothetical "average" farmer in the sample taken as a whole, for example, knowledge of credit availability increased the probability of adoption from 77 percent to 96 percent. When crosstabulated with adoption, knowledge of credit availability was significantly related to adoption in all zones except Zone 1 (Table 21).

The peculiar response in Zone 1 is due to the presence of only four non-adopters and is not significant. Although it is tempting to draw grandiose conclusions from the high level of significance in Zone 3, namely, that lack of credit is a major barrier to adoption, my view is that what is being measured here is something less. Since private sources of credit are virtually non-existent and since government loans for maize were limited (prior to 1974) to farms over 15 acres, lack of credit cannot have been a formidable barrier to the many small-scale adopters in Zones 1 and 2. What I suspect is actually being measured here is the farmer's knowledge of and interest in commercial maize growing per se. In this case we would certainly expect adopters to be aware of the available sources of credit to a degree unmatched by non-adopters. In fact, GMR credit is given only to those maize farmers who grow hybrid maize. Some support for this explanation may be found in Moock's study of maize yields in Vihiga.[25] He found that farmers receiving credit were invariably richer and better farmers than average and that credit per se was not essential to the operations of those who received it, nor was it significantly related in a multivariate analysis to obtaining higher yields. This, of course, does not say anything about the possibility that *lack* of credit is in fact a very real constraint to farmers at the bottom end of the scale. It is merely evidence of the fact that farmers who can get credit generally do not need it.

Adoption and Off-Farm Work

The influence of labor migration on the adoption of farm practices has long interested social scientists. Rogers reports that innovators are more "cosmopolite" in that they travel widely beyond the boundaries of their local system. He records 132 studies (including the classic Ryan and Gross sutdy of Iowa farmers) which support a relationship between "cosmopoliteness" and innovativeness and only 42 which do not support such a relationship.[26] Miracle points out that the nature of off-farm activities is important:

Farmers who work elsewhere in agriculture—especially those working on farms much like their own except that a higher level of productivity has been achieved—are more likely to adopt innovations than are those whose wage experience is in mining or manufacturing. The spread of plows and improved varieties of maize among small-scale African farmers in Rhodesia, Zambia, Kenya and the Malagasy Republic seems clearly to have been encouraged by the work experiences on farms operated by white settlers.[27]

Table 22. **Off-farm employment experience.**

	Zone 1	Zone 2	Zone 3	Zone 4
Presently has job off-farm ("job")	33%	22%	15%	22%
Ever worked off-farm ("work")	54	48	58	38
Worked on large commercial farm ("large farm")	12	23	9	15

De Wilde points out that the Luos, unlike the Kikuyu, did not find European farming areas in which they could work nearby and that, although many Luos have worked on tea plantations in Kericho, this employment had little relevance to the agriculture of Central Nyanza. While reporting the conventional view that "progressive farmers are often those whose receptivity to change has been enhanced by their work experience," he also points out wisely that "the extent to which people return to their farms for the purpose of earning a living, rather than of simply retiring, tends to depend on the relative attractiveness of agricultural opportunities in the district, on the one hand, and of job opportunities outside the district, on the other."[28]

Off-farm work experience is generally thought to be positively related to technological change because (1) it provides an outside source of capital to finance necessary inputs, (2) it widens the horizons of the farmer and increases his desire for a better standard of living, and/or (3) it provides the farmer with work experience directly relevant to his own farming situation. The percentages of farmers with present or former off-farm employment is seen in Table 22. When crosstabulated with adoption, however, neither "job" or "work" had significant chi-square values for any zone. In the probit analysis, "job" was positively but not significantly related to adoption. Having previous off-farm work experience, however, was negatively (and significantly) associated with adoption in both Zone 3 and the sample as a whole. Even more surprising, having worked on a large, commercial farm was negatively associated with adoption (also at significant levels in the sample taken as a whole.) This is partly explained in the case of Zone 3 by the fact that 61 percent of these farmers had worked on plantations where sisal, sugar cane, or tea rather than maize was the major crop. In Zones 1 and 2, however, almost half had worked on farms where maize itself was the most important crop.

In spite of the intuitive reasoning (and in some cases historical evidence) for the importance of work experience, the 1973 hybrid maize study found no statistical evidence to support a positive relationship between previous work experience and adoption per se. The reasons for this are probably twofold. First, farm owners presently away from their farms have neither the time nor the interest to devote to farming because farming in general does not pay better than modern sector employment. Moreover, in these cases the farm decision-making is often not clearly allocated between husband and wife; the husband usually retains the "spending" authority while the wife actually does the work. In these circumstances it is difficult to make timely purchases and application of inputs.[29] Secondly, long-term residence outside the area (such as is typical of many farmers in Zones 1 and 3 who have worked in the police, railways, and the like) is often in Moock's terms, "a liability in the acquisition of relevant agricultural knowledge." Joyce Moock found in Maragoli that farm heads employed off the farm are *less* likely to make investments at home in spite of their higher incomes. She concluded that "the individual most likely to respond to local opportunities...is one [like a teacher] who is employed and who, at the same time, can live at home."[30] We can conclude that the farmer's attitude toward farming and the profitability of farming in a given area are probably better indicators of progressiveness than work experience per se. That this is not always the case, however, will be seen in our analysis of early adoption.

Adoption and Information Variables

In this section we discuss the relationship of such "information" variables as formal education, extension visits, attendance at maize demonstrations, and attendance at Farmers Training Center courses to adoption. It is hypothesized that all of these will be positively associated with it. Here we can also conveniently discuss age, which we hypothesized will be negatively associated with adoption, most likely because of its negative correlation with education ($r = -0.34$) as well as because of greater conservatism in older, more traditional farmers. In his summary of studies of early adopters, Rogers found that education (74 percent of the studies), change agent contact (87 percent of the studies), and exposure to mass media (69 percent) were positively related to early adoption, while age had no clear relationship.[31] In his Vihiga study Moock found formal education, extension visits, and attendance at demonstrations to be positively related to maize yields although only schooling was significant in all the equations at the 0.05 level. Differences among different types of extension contact, however, are of interest as a measure of extension effectiveness. Since one-to-one visits are of necessity more time consuming and more expensive than group techniques, it is more than of academic interest whether they show more concrete results.

The mean values of the "information" variables in the survey are shown in Table 23. Farmers in Zone 3 on average are older, have less formal education, and receive markedly lower levels of extension contact than farmers in the other zones. Farmers in the large-farm sample, on the other hand, have considerably more formal education and much higher levels of extension contact.

Table 23. **Age, education, and extension contacts by zone.**

	Zone 1	Zone 2	Zone 3	Zone 4	Weighted Average
Age (years)	39.3	37.2	44.5	39.8	40.6
Formal education (years)	4.1	3.5	2.9	6.1	3.6
Extension visit in past year (%)	39.6	38.7	26.9	56.5	35.0
Ever attended maize demonstration (%)	26.0	30.1	20.0	64.0	24.9
Ever attended Farmers Training Center course (%)	24.2	26.4	8.1	48.6	19.3

A difference of means test for age and education averages of adopters produced the results given in Table 24. Non-adopters were significantly older in Zones 1 and 2 and in the sample as a whole, but not in Zone 3, whereas adopters had significantly more formal education in Zone 3 and the sample as a whole but not in Zones 1 and 2. In all cases, however, the direction of the relationship was as hypothesized.[32]

In the probit analysis, age was not significant in any equation, either in Zone 3 or in the sample as a whole, although it always had a negative sign. Its coefficients were uniformly low (an additional ten years of age decreasing the "average" farmer's probability of adoption by only about 2 percent) and it was left out of subsequent equations. Formal education was significantly and positively related to adoption in most equations, though generally not in the presence of "credit." Its coefficient, however, was generally low. For an "average" farmer in Zone 3, for example, ten years of education (a very large amount in Kenya) would increase the probability of adoption from roughly 2 percent to only 22 percent. We may conclude then that age and education, although related to adoption in ways consistent with the hypotheses, are not decisive influences in their own right in the presence of other, more specifically relevant variables.

Turning to the extension variables, Table 25 shows the percentage of adopters and non-adopters in each zone receiving different types of extension contact. All three forms of extension contact were significantly different for adopters in Zone 3 but were not in Zones 1 and 2 because of the small numbers of non-adopters. Nevertheless, the direction of the relationships was as hypothesized in all cases.

Again, however, a word of caution must be advanced about these findings and the cause and effect relationship implied. Other studies (Chapter II) have found that extension workers are predisposed toward visiting the better farmers and that actual farm visits are more often related to veterinary problems or cash crops than to food crops. Likewise, farmers selected for F.T.C courses tend to be better, richer farmers. Since participation fees are usually charged, in fact, only the wealthier farmers are sometimes able to attend. Maize demonstrations, on the other hand, are open to all farmers in a given area and the farmer decides whether or not he will attend. Since the demonstration is aimed at imparting a particular message, it is logical to expect it to have a more direct impact on adoption. The fact that demonstration attendance was the only one of the three variables that was significant in more than one zone may give some support to this thesis. In the probit analysis, all three extension variables were positively related to adoption in all equations and at significant levels in some (Tables 15 and 16). Again, however, it is unclear whether the extension contacts are successful in promoting hybrid adoption or whether extension agents are merely visiting the more progressive farmers. Since the better farmers obviously make more demands on the extension staff and are probably more responsive to advice, it is not surprising that they receive the most extension contact.

Adoption of Fertilizers

Efforts to relate fertilizer use per acre of maize to independent variables were singularly unsuccessful. In models containing all three zones only the dummy variable for Zone 3 showed appreciable levels of statistical significance, reflecting the differences between Zones 1 and 2 and Zone 3 manifested in Table 11. Again as in Table 11 farm size showed appreciable levels of significance.

In general these models explain so small a part of the variation in fertilizer use that they offer little information over that contained in Table 11. Because of this they are

Table 24. **Age and education variables by adoption (years).**

	Zone 1	Zone 2	Zone 3	Weighted Average
Age				
Adopters	40.27 ++	37.50 +++	43.14	39.62++
Non-adopters	50.25	46.66	45.59	45.93
Education				
Adopters	4.20	3.53	4.40 +++	4.01++
Non-adopters	2.75	2.90	2.67	2.69

++ = significant at 0.05 level for a one-tailed test.
+++ = significant at 0.01 level for a one-tailed test.

Table 25. **Adoption and extension contacts.**

	Zone 1	Zone 2	Zone 3	Weighted Average
Extension visit in past year (%)				
Adopters	40.7	39.8	40.0+++	40.3
Non-adopters	25.0	30.0	23.7	24.3
Attended maize demonstration (%)				
Adopters	26.7	35.0+	40.0++	30.4
Non-adopters	25.0	0.0	15.6	15.0
Attended farmers Training Center courses (%)				
Adopters	25.3	29.5	26.7+++	26.7++
Non-adopters	0.0	0.0	2.9	2.5

+ = chi-square value significant at 0.10 level. ++ = chi-square value significant at 0.05 level. +++ = chi-square value significant at 0 01 level.

not reported here. It should be emphasized that the absence of explanatory power might be a consequence of inaccurate estimation of the dependent variable pounds of nutrient per acre. Recall that this point was made earlier when it was acknowledged that the area of fields is only loosely known by most of the farmers of the sample. This reduces the reliability of any figure purporting to describe on a per acre basis.

Analysis of Early Adoption

In this section we look at the characteristics of "early" adopters as opposed to those of adopters and non-adopters ten years after the innovation was first introduced. Concentrating on early adopters has been a popular focus in the diffusion study literature. Such a focus is, in fact, much more common than studies of "mature" adoption levels or ceilings for a variety of reasons. First, social scientists are often interested in deviant behavior, whether progressive or regressive, precisely because it is different. Second, the growing realization of the importance of entrepreneurial behavior in the development process has led us to seek to identify the innovating or achievement-oriented individual. Third, it has often been asserted that by working through early adopters of innovations we can influence and even accelerate the adoption process among the general population. And, fourth, because the year of adoption gives us a continous dependent variable, social scientists can avoid the methodological problems hitherto encountered with a simple dichotomous or binary dependent variable such as adoption and non-adoption. (For the same reason, the percentage of acreage planted to new varieties and an index of dissimilar innovations are also frequently encountered as dependent variables). As we shall discuss later, this preoccupation with early adoption per se has some limitations, not the least of which is the emphasis it puts on the characteristics of the innovator rather than the innovation. It is useful first, however, to characterize early (or earlier) adopters and to see whether this characterization corresponds to that of the adopter vis à vis the non-adopter.

Rogers[33] has characterized early adopters of innovations as having more education, higher social status, larger units of operation, a commercial rather than a subsistence orientation, more specialized farm operations, and a favorable attitude towards credit. "Laggards," on the other hand, have been characterized as being "localite" in their outlook, past-oriented, suspicious, and "alineated." In the bivariate analysis which follows, we have defined "early" adopters arbitrarily as those who first used hybrid seed more than one standard deviation in time before the mean year of adoption. In a normal distribution, this would be approximately the first 16 percent of adopters. The mean year of adoption and standard deviation by zones are reported in Table 26.

In the multivariate analysis, the same variables used for the analysis of adoption in 1973 have been included, except that the dependent variable is the year of adoption subtracted from 1974 (so that 1973 equals 1, 1972 equals 2, and so forth up to 1963, which equals 11). One qualifying point needs to be made here. Because we asked the farmer in what year did he *first* plant hybrid seed, we may be violating our definition of adoption as "use of hybrid on

Table 26. **Mean year of adoption by zone.**

	Zone 1	Zone 2	Zone 3	Weighted Average
Mean year of adoption	1968.8	1968.3	1970.3	1968.9
Standard deviation	2.2	2.9	2.2	2.5
"Early" adoption (before)	1967	1966	1968	1967

at least 50 percent of maize acreage." It is logical to think that farmers first tried hybrid seed on less than their total maize acreage, although in 1973 only a tiny proportion of farmers were planting both hybrid and local varieties on the same farm. We also know that some farmers in Zone 3 tried hybrid seed in the past but were not using it in 1973. Since we do not have any way of knowing what percentage of maize acreage was planted to hybrids in the various first years of use, our definition of "adoption" in this section is not strictly comparable to that used when discussing adoption and non-adoption as of 1973. We have no a priori reason to believe, however, that farmers who first used hybrid seed are significantly different from those who first used hybrid seed on 50 percent or more of their maize acreage.

Table 27 gives the characteristics of "early" adopters (those adopting one standard deviation or more before the mean year of adoption), as compared with later adopters in the survey. Non-adopters have not been included in the analysis because of our belief that the difference between non-adoption and adoption is of a different magnitude, if not generically different, from the numerical difference which would separate a non-adopter from a 1973 adopter in the dependent variable. Although these simple crosstabulations are almost all consistent with the hypothesized relationships, only farm size had a chi-square value significant at the 0.05 level. This is due primarily to the limited sample size of early adopters in each zone. In the sample taken as a whole, all the relationships without exception are in the direction anticipated. "Early" adopters had larger farms, more cash crop income, more extension contact, more work experience, were less likely to grow famine crops, and were more likely to have a primary education than later adopters. Interestingly, although work experience on a large farm was negatively associated with final levels of adoption, it was positively associated with early adoption (especially in Zone 2, where hybrids were first introduced). This is consistent with the view that hybrids were *first* used by many of those African farmers who had seen them being used on European mixed farms. The negative relation of large-farm work experience to early adoption in Zone 3 may in turn be due to the irrelevance of the plantation-type off-farm work experience (on sugar, tea, and sisal estates) of most of the farmers from that region to their own farming situation.

Table 27. **Crosstabulation of early adoption and selected factors.**

	Zone 1	Zone 2	Zone 3
Completed 4 years of primary education (%)			
Early adopters	36.4	40.0	80.0
Later adopters	45.2	39.3	34.6
Grows famine crops (%)			
Early adopters	4.5	0	15.4
Later adopters	6.5	1.8	40.0
Job off-farm (%)			
Early adopters	38.1	26.1	25.0
Later adopters	31.7	24.1	20.0
Previous work experience (%)			
Early adopters	57.1	50.0	100
Later adopters	48.4	48.1	69.2
Worked on large farm (%)			
Early adopters	26.7	58.3	0
Later adopters	20.0	42.3	21.1
Extension visit (%)			
Early adopters	54.5	44.0	50.0
Later adopters	41.9	41.1	50.0
Attended maize demonstration (%)			
Early adopters	40.9	30.4	20.0
Later adopters	25.8	32.7	20.8
Attended farmers training center (%)			
Early adopters	36.4	30.4	40.0
Later adopters	24.1	30.8	16.7
Farm greater than 10 acres (%)			
Early adopters	54.5+	70.8	20.0
Later adopters	29.5	49.1	15.4
"Cash" variable greater than 500 shillings (%)			
Early adopters	68.2	64.0	40.0
Later adopters	54.8	64.3	23.1

+ = chi-square value significant at 0.10 level. ++ = chi-square value significant at 0.05 level.

In addition to the bivariate analysis of early adoption and other factors, multiple regression analysis of early adoption was carried out with year of adoption as the dependent variable. Table 28 shows the results.

Farm size, agroclimatic zone, and imputed cash income were significantly related to adoption at the 0.10 level. In the absence of zone, farm size was significantly related to adoption at the 0.01 level. None of the other variables (extension contacts, work experience, etc.) were significant when included with zone and/or farm size. When the regression was limited to the three variables farm size, zone, and cash, the coefficients were essentially unchanged and all three were significant at the 0.05 level.

Regression analysis was also carried out separately on each of the zones with interesting results. Table 29 shows the results for Zone 1.

Once again, farm size is the most significant variable, risk in negatively associated with early adoption, and age and education, while positive, have very small coefficients (ten years of education increasing the time of adoption by less than a year). Cash, interestingly, was not significant in the presence of farm size in this Zone. The only other independent variable which proved significant (at a 0.05 level) was attendance at a maize demonstration, which increased the earliness of adoption by more than a year (coefficient 1.064). Extension visits and attendance at Farmers Training Centers, while positive in sign, were not significant and had much smaller coefficients.

In Zone 2 only two independent variables were significantly related to adoption, both at the 0.10 level. These were farm size (coefficient 0.04) and work experience on a large, commercial farm (1.30). The latter is especially interesting since it supports the view, discussed earlier, that hybrids were first used by those who had seen them

on European farms. This is especially likely to be the case in Zone 2, where the former European farms are located and where both the mix of crops and general ecological conditions would be similar between European and African farms. The seemingly contradictory fact that large-farm work experience was negatively related to final levels of adoption in the probit analysis is due perhaps to the fact that (a) the large-farm work experience of farmers in Zone 3 was not closely related to their home farm conditions and (b) large-farm work experience may have, in many cases, actually preceeded the introduction of hybrid maize. When the sample was restricted, then, to adopters and to farmers in Zone 2, it makes more sense that such experience would be positively related to early adoption. (When a regression on early adoption was run on the very large-scale farmers themselves [Set 4], work experience on a large commercial farm was the only variable that proved significant).

In the analysis of early adoption in Zone 3, the only variable which proved significant at .. 0.01 level was imputed cash income (coefficient 0.44, that is to say, a thousand shillings of cash crop income would increase the earliness of adoption by almost a half year). Farm sizes were fairly uniform in this zone and were not, therefore, a particularly good measure of variations in income or ability to absorb risk. Moreover, since this sample included adopters only, farmers growing famine crops were virtually entirely excluded and "risk" as such was not as important a factor in the earliness of adoption as it had been in determining adoption per se. The importance of cash crops, whether as a protection against risk or simply as a source of money with which to buy the necessary inputs, is strongly reinforced by this result.

The only other variable besides imputed cash income which proved significant in Zone 3 (though at only a 0.10 level) was large-farm work experience, which had a coefficient of–1.61, that is such experience on average delayed adoption by more than a year and a half. Again, this may be due to the irrelevance of the plantation-type experience of most of the Zone 3 farmers to their own farming conditions or to the fact that this experience took place before hybrids were introduced.

In sum then, there are at least two noticeable differences between factors affecting early adoption and factors affecting adoption per se. One of these–work experience on a large commercial farm–has already been discussed and, on closer examination, has been found to relate to the particular relevance of the work experience to the farmer's own farm situation (strongly positive in Zone 2 and strongly negative in Zone 3). The other interesting difference is the role of farm size, which was not significant in the analysis of adoption per se, but proved to be the most significant single variable influencing early adoption, even controlling for differences in farm size between zones. In one or more equations, farm size was significant at the 0.01 level in both Zones 1 and 2 and in the sample as a whole. Only in Zone 3, where farm sizes are quite uniform, was it not the most important explanatory variable and there another possible proxy for general wealth (cash income) was the most important variable.[34]

Table 28. **Regression coefficients, standard errors, F-values, and levels of significance of variables related to early adoption of hybrid maize in western Kenya.**

Independent Variables	Regression Coefficients	Standard Error	F-Value (T^2)	Level of Significance
Farm size (acres)	0.038	0.024	2.39	0.10
Agroclimatic zone	0.849	0.601	1.99	0.10
Cash (000 shillings)	0.120	0.080	2.00	0.10
Age (years)	0.019	0.019	1.02	NS
Education (years)	0.062	0.083	0.55	NS
Risk	-0.204	0.709	0.08	NS
Constant	2.970			

Without stretching the analysis more than it will bear, this differing significance of farm size may have an important (and, I think, hopeful) implication about the adoption process. For if genuine economies of scale were involved in determining which farmers adopt the new technology, one would expect that farm size, as an independent variable, would retain its importance with the passage of time. Instead, we find that, although farm size was significant in determining which farmers adopt *first*, it was not significant in determining "mature" levels of adoption. This supports the hypothesis that the ability to absorb or tolerate risk is important in the adoption process. Because they are risking a smaller portion of their total assets on a given investment, the larger farmers (or those with significant cash incomes) are able to try out the new technology without endangering their overall security. Where, as in Zones 1 and 2, the new technology proves not to involve significant risks, it is then rapidly adopted by farmers of all categories. Where, as in Zone 3, significant doubts about the efficacy of the new technology remain, risk perception and ability to absorb risk (as measured by

Table 29. **Regression coefficients, standard errors, F-values, and levels of significance of variables related to early adoption of hybrid maize in Zone 1.**

Independent variables	Regression Coefficients	Standard Error	F-Value (T^2)	Level of Significance
Farm size (acres)	0.068	0.027	6.40	0.01
Risk	-2.050	1.295	2.50	0.10
Age (years)	0.037	0.025	2.17	0.10
Education (years)	0.096	0.092	1.08	NS
Constant	2.589			

imputed cash income) continue to be important in determining who adopts. Although work experience (in Zone 2) and attendance at maize demonstrations (in Zone 1) were both important, as we might expect in influencing early adoption, their importance declined as the new technology became widely known. Other "informational" variables (knowledge of credit availability, extension visits, and attendance at Farmers Training Centers), although positively related to adoption, may not be entirely causally related for institutional reasons we have already mentioned.

These conclusions are consistent with the historical process of hybrid maize diffusion as we know it. The new technology as introduced first on European farms in Zone 2 and spread first to African farms in the same area, presumably because many of their owners worked on the European farms. Intensive maize demonstration campaigns by the Ministry of Agriculture, especially in such Zone 1 districts as Kakamega, Kericho; and Kisii, quickly spread the new varieties to these areas. Adoption in the lakeshore districts of Zone 3 lagged behind because the new technology was riskier, appeared to have a smaller relative advantage over local varieties, because employment experience on large mixed farms (as opposed to plantations) was less, and because levels of all types of extension contact were lower. In the face of greater climatic insecurity, drought-resistant famine crops continued to hold an important place in the farmers' mix of staple food crops.

The Importance of Early Adoption

Having looked both at early adoption and at "mature" levels of adoption ten years after hybrid maize technology was first introduced, we can now ask what important effects early (as opposed to later) adoption may have had. Although we are inevitably interested in the nature of the innovators who adopted the new technology first, it can be argued in this case at least, that early adoption patterns are ultimately less important than "mature" adoption patterns for those concerned about economic progress and income distribution.[35]

Every society may be presumed to have some proportion of relatively more innovative individuals, who, for reasons of achievement motivation, intellectual satisfaction, scientific predilection, or simply better access to new information are willing to try out new ideas and technologies. The absolute number (or proportion) of these individuals may be of some importance depending on externalities involved in the particular innovation, but in most cases an adequate number will exist. It may even be fortunate that a majority of society's members are not in this category since innovations often prove unprofitable. By bearing the risks of experimentation for a larger society, the innovator may prevent widespread losses or may direct attention to improvements in the innovation necessary for its wider acceptance. Because we too often tend to think of innovations as being uniformly advantageous, this positive aspect of differential innovation is often ignored.

What is much more important than who adopts an innovation first is who is ultimately unable to adopt it and why. Unless early adoption of an innovation by a minority precludes subsequent adoption by others, final or mature ceilings of adoption will affect levels of welfare and income distribution more profoundly than relatively modest differences in the time of adoption. There are obviously cases in which early adoption of an innovation by one segment of the population results in long-term differentials in income distribution or political power. Those areas of Kenya which had planted coffee before the introduction of coffee quotas, for example, have achieved a significant long-term income advantage over the other areas. We have already mentioned an Ethiopian case in which adoption of high yielding wheat varieties has greatly increased land values resulting in the expulsion of an estimated 5,000 tenant farmer families from the land by landlords.[36] There is also evidence from parts of Asia that, where economies of scale in wheat production are joined with an active land market, early adopters of new grain varieties have used their profits to buy out smaller landowners, thereby worsening income distribution.

Fortunately, however, for a variety of reasons, this does not appear to be the case with hybrid maize in Kenya. First, it is questionable whether there are significant economies of scale at work in Kenyan maize production. Although mechanized plowing permits earlier planting and consequently higher yields, this advantage is at least partly offset by more intensive weeding and more careful harvesting and drying on smaller holdings. Secondly, the technology itself is highly divisible and not particularly complex. Thirdly, sharecropping and tenant farming are virtually unknown in Kenya and tenure is overwhelmingly (*de facto* if not *de jure*) under individual title. Fourthly, the government has maintained a guaranteed minimum price for maize for any given year, which has generally (though not always) protected the p oducer from sudden drops in the market which would undercut continued expansion of the new varieties. Fifthly, although the buying and selling of land is increasing in frequency in Kenya, this is primarily in the formerly Scheduled (European-owned) areas. Land in the traditional African areas does not change hands easily and it is unlikely that those land purchases which are taking place today are being made by early hybrid adopters from their profits on hybrid maize. Adoption in the high rainfall maize growing areas has been exceedingly rapid (faster than among American farmers in the 1930s) with the result that the advantages of early adoption per se have been relatively short lived. In fact, early adoption by some farmers has facilitated rather than hindered subsequent adoption by others, both by reducing the perceived risks of the new technology in the high rainfall areas and by stimulating improved availability

of seeds and fertilizers. Although there were local problems of oversupply in 1972 and 1973, this is likely to be a temporary problem until export handling and storage facilities are improved. Given periodic droughts in Africa and elsewhere and rapid population growth, overproduction of maize is not a serious threat to continued hybrid expansion.

We can conclude from this discussion that differences in time of adoption per se have not significantly worsened income distribution in the hybrid growing areas of western Kenya. If one wants to generalize about the effects of the diffusion of innovations on income distribution, a useful distinction can be made between those innovations which we might call "preclusive" whose adoption by some individuals precludes either directly (through monopolies or quotas) or indirectly (through market effects) subsequent adoption by others and those innovations which we might call "facilitative" whose adoption by some individuals facilitates adoption by others. If coffee planting under quota conditions is an example of the former, hybrid maize is fortunately an example of the latter. The very rapidity of the adoption process in the high rainfall of western Kenya is testimony to the fact that early adoption by some has not prevented the benefits of hybrid maize from being shared by many.

Far more serious problems are presented by those who have not adopted hybrid technology ten years after its introduction. Without implying that further increases in hybrid use will not still take place, real doubts must nevertheless be raised about the suitability of present hybrid technology for the lakeshore areas. Whether for reasons of lower relative yield advantage, lower reliability, inability to finance cash purchases, lower levels of services, or more likely, a combination of all these, a substantial number of farmers in Zone 3 have tried but later discarded hybrid seed. Given this fact and the generally low level of hybrid use (15 percent) in that zone, this must be regarded as a problem of conscious non-adoption rather than mere "laggardness." As discussed earlier, further research and adaptation and possible introduction of composite or synthetic varieties may be required to overcome this problem. Special action may also be needed to reach the remaining non-adopters in the high rainfall areas, though as we have seen in Chapter II, achieving this through government programs is not always easy.

In the end, the "non-adoption" problem is serious because it is essentially ecological and regional. As Griliches found in the U.S., hybrid corn was never fully adopted in those western fringes of the high plains where corn could only reliably be grown under irrigation. This might also prove the case in the more marginal rainfall areas of Kenya where intrinsically drought-resistant grains will continue to dominate. If high-yielding maize varieties are ultimately restricted to the high rainfall zones, this will obviously worsen relative income distribution on a regional basis. Even so, absolute levels of welfare will not be worsened by hybrids since the non-maize growers would still benefit as consumers from a lower maize price than would obtain in the absence of hybrid expansion. But because ethnic and ecological boundaries are closely related in Kenya, a worsening income distribution on a regional basis is a dangerous prospect. Among the dualities of developed and developing nations, urban and rural sectors, and the like, the duality between high rainfall and low rainfall areas may yet prove the most difficult to solve.

Notes

1. James Tobin, "The Application of Multivariate Probit Analysis to Economic Survey Data," Cowles Foundation Discussion, No. 1 1955. See also, D.J. Finney, *Probit Analysis* (Cambridge, 1971); D.R. Cox, *The Analysis of Binary Data* (London, 1970); Arthur S. Goldberger, *Econometric Theory* (New York, 1964), pp. 248-251, and especially an excellent recent paper on probit analysis by Richard D. McKelvey and Willian Zavonia, "A Statistical Model for the Analysis of Ordinal Level Dependent Variables," University of Rochester, May 1973.

2. Richard McKelvey, "N-chotomous Multivariate Probit Program," Rochester University, as modified by Jan Juran, Princeton University Computer Center, 1974.

3. McKelvey and Zavonia, "Analysis of Ordinal Level Dependent Variables," pp. 29-31. The authors have also developed a pseudo-R^2 or R^2 to measure goodness of fit. R^2 can be interpreted much the same as the corresponding R^2 for regression analysis, but should be used with some caution because its sampling distribution is not known (p. 34). The N-chotomous Multivariate Probit Program also calculates the percentage of cases predicted correctly by substituting the coefficients obtained back into the equations with the actual values for each case and then solving each case and comparing the predicted with the actual value.

4. F.A.O. Fertilizer Programme, "Summary of West Kenya Results," 1969, 1970, 1971, and K. Zschernitz and A.J. Ikalo, "F.A.O. Fertilizer Programme, Report No. 4. Planting season 1972. Average Yield Data," 1972. [I am grateful to Mr. A.J. Okalo of the Ministry of Agriculture Nairobi, and Dr. A.Y. Allan of the National Agricultural Research Station, Kitale, for these data.]

5. Indicative of the problems in Zone 3 is the fact that the low incidence of hybrid usage was not fully appreciated before the 1973 survey. Following the preliminary results of the survey, the extension service and the Kenya Seed Company discussed revising their promotion strategies, the latter reportedly assigning a key sales agent to work in the lakeside area. A.Y. Allan, personal communication, February 11, 1974.

6. Elspeth Huxley, *A New Earth* (New York, 1960).

7. Hugh Fearn, *An African Economy* (London, 1961), pp. 116-117. John C. DeWilde, *Experiences with Agricultural Development in Tropical Africa*, Vol. II (Baltimore, 1967), p. 121. Hans Ruthenberg, *African Agricultural Production Development Policy in Kenya 1952-1963* (Berlin, 1966), pp. 30-31.

8. Margaret Jean Hay, "Economic Change in Luoland: Kowe,

1890-1945" (Ph.D. thesis, University of Wisconsin, 1972).

9. Ibid., p. 3.

10. Ibid., p. 21.

11. Margaret Jean Hay, "Economic Change in Luoland: Kowe 1890-1945" (Ph.D. thesis, University of Wisconsin, 1972) pp. 134-139.

12. Marvin P. Miracle, Maize in Tropical Africa (Madison, 1966). p. 140 cited by Margaret Jean Hay, "Economic Change in Luoland: Kowe, 1890-1945" Ph.D. Dissertation, University of Wisconsin, 1972.

13. Margaret Jean Hay, "Economic Change in Luoland: Kowe, 1890-1945" Ph.D. Dissertation, University of Wisconsin, 1972, p. 242.

14. John Harris, "Some Theory of Agricultural Innovation," East African Agricultural Economics Society Conference Paper, June 1969, p. 8, talking of Nyanza (Zone 3), says that "hybrid" maize is more sensitive to rainfall variation than are traditional maize varieties" and also that early planting, which is important for hybrid maize, "involves not only greater physical effort but also requires abandonment of fishing in a period when catches are highest." I have not been able to confirm this point. Hay reported (personal communication, July 1974), that "when there were problems of the amount or the distribution of rainfall, local maize fared much better than the hybrid, and people were very quick to point that out. The hybrid maize was also much more susceptible to bird damage."

15. Another proxy variable for risk was tried and discarded in the analysis, namely the actual acreage of famine crops planted. In addition to the problem of measuring acreages (especially when many of the same crops are interplanted with each other) it was felt that farmers do not in fact plant proportionately more "famine" crops the more worried they may be about getting a maize crop but, if they are worried, plant a fixed amount as a precaution. This in fact proved to be the case, e.g., farmers planting cassava planted a mean of 0.68 acres with a standard deviation of 0.47.

16. Walter P. Falcon, "The Green Revolution: Generations of problems," *American Journal of Agricultural Economics* (December 1970: 598-712. Carl Gotsch, "Technology, Prices, and Incomes in West Pakistan Agriculture: Some Observations of the Green Revolution," mimeo (January 1972).

17. James Q. Harrison, "Agricultural Modernization and Income Distribution: An Economic Analysis of the Impact of New Seed Varieties on the Crop Production of Large and Small Farms in India" (Ph.D. thesis, Princeton University, 1972).

18. Max K. Lowdermilk, "Diffusion of Dwarf Wheat Production Technology in Pakistan's Punjab (Ph.D. thesis, Cornell University 1972),p. 185.

19. S.R. Sen, "Agricultural Development and Poverty," in *Some Issues Emerging from Recent Breakthroughs in Food Production*, edited, by Kenneth L. Turk (Binghornton, 1971), p. 480. Quoted by Max K. Lowdermilk, "Diffusion of Dwarf Wheat Production Technology in Pakistan's Punjab" (Ph.D. Thesis, Cornel University, 1972) p. 188.

20. James Copp, "Towards Generalization in Farm Practice Research," *Rural Sociology* 23 (June 1958): 107. Quoted by Max K. Lowdermilk, "Diffusion of Dwarf Wheat Production Technology in Pakistan's Punjab" (Ph.D. thesis, Cornell University, 1972), p. 187.

21. Moock found for the range of farm sizes in his Vihiga Study that size was not significantly related to yields. These were all very small farms, however, the largest having only six acres of maize. Peter R. Moock, "Managerial Ability in Small-Farm Production: An Analysis of Maize Yields in the Vihiga Division of Kenya," (Ph.D. dissertation, Columbia University, 1973), p. 194.

22. I am grateful to the Farm Planning Unit of the Kenya Ministry of Agriculture for these figures. They are, of course, only rough estimates; they assume average yields, and crops such as tea and coffee are taken at maturity levels of output, whereas in fact much of the acreage would not yet be in full production. The gross margin figures used were (in shillings per hectare): Bananas, 89/-; Sugar, 225/-; Wheat, 269/-; Tea, 1330/-; Coffee, 910/-; Cotton, 210/-; Pyrethrum, 907/-.

23. Marvin P. Miracle, "Subsistence Agriculture: Analytical Problems and Alternative Concepts." *American Journal of Agricultural Economics* 50 (May 1968), pp. 292-310.

24. Ronald I. McKinnon, *Money and Capital in Economic Development* (Washington, 1973), p. 12.

25. Peter R. Moock, "Managerial Ability in Small-Farm Production: An Analysis of Maize Yields in the Vihiga Division of Kenya," (Ph.D. dissertation, Columbia University, 1973), p. 199.

26. Everett M. Rogers, *Communication of Innovations* (New York, 1971), p. 369.

27. Miracle, "Subsistence Agriculture", p. 304.

28. John C. deWilde, Experiences with Agricultural Development in Tropical Africa, Vol. II (Baltimore, 1967), pp. 128-129.

29. This should not be taken to mean that female farm managers are less able than their husbands, only that they are often not given adequate authority to make the spending decisions necessary to their work. Sex of farm manager was crosstabulated with adoption and no significant differences in adoption were discovered. Extension agencies would do well to recognize the importance of female farm managers in their efforts to bring about agricultural change.

30. Joyce Moock, quoted by Peter R. Moock, "Managerial Ability in Small-Farm Production: An Analysis of Maize Yields in the Vihiga Division of Kenya" (Ph.D. Dissertation, Columbia University 1973) p. 121.

31. Everett M. Rogers, *Communication of Innovations* (New York, 1968) p. 352.

32. To test the proposition that what is important in education as it relates to farming is not the total number of years but the acquisition of basic functional literacy, the education variable was recoded as a dummy variable, whether or not the farmer had four years of formal schooling, the level used by UNESCO and some other agencies as a basic equivalent of literacy. When crosstabulated with adoption, this dummy variable gave the same results as education treated as a continous variable.

33. Everett M. Rogers, *Communication of Innovations*, (New York, 1968) p. 195.

34. "Cash" is in some senses a measure of the quality rather than the quantity of farm land since high value cash crops cannot be grown in all locations.

35. I am grateful to Professor Don Kanel of the University of Wisconsin for suggesting some of the ideas which follow.

36. For a recent discussion of the CADU case, see John M. Cohen "Rural Change in Ethiopia: The Chilalo Agricultural Development Unit," *Economic Development and Cultural Change 22* (July 1974): 580-614.

V. CONCLUSIONS AND RECOMMENDATIONS

This thesis has sought to look closely at the diffusion of hybrid maize technology in western Kenya as a case study of the spread of new agricultural technology among small-scale African farmers. Its purposes have been (a) to determine the pattern of that diffusion over the period 1964-1973 and, particularly, as of June 1973; (b) to determine the influence of environmental factors (such as agroclimatic zone and risk perception) on adoption as well as the influence of such other factors as farm size, cash crops, off-farm income, work experience, credit availability, formal education, and various types of extension contact; (c) to characterize early, later, and non-adopters of the new maize technology in terms of these socio-economic factors; (d) to determine which portions of the "package" of recommended practices associated with hybrid maize are adopted and to what degree; (e) to describe the maize industry in Kenya and to place the pattern of adoption in the context of Kenya's rural economic services; (f) to consider the costs and benefits to Kenya of developing the new maize technology; and (g) to draw conclusions as to why hybrid maize has been relatively successful in Kenya, and how this development can be extended and improved. In this chapter we will review our findings, first, in the light of the 1973 Kitale/CIMMYT Maize Survey results, and secondly, through our analysis of the Kenya maize industry. Finally, we will comment briefly on the implications of this study for an overall view of small-scale farmers and their responsiveness to change.

Summary of Main Survey Findings

In a period of only ten years, the use of hybrid maize varieties in Kenya has increased from an initial 400 acres to at least 800,000 acres, accounting for perhaps half the country's total production. In the high and medium potential areas west of the Rift Valley about two-thirds of small-scale African farmers had adopted hybrid seed by 1973, including up to 90 percent of the farmers in the higher altitude and rainfall zones. In the lower altitude, lower rainfall areas around Lake Victoria, however, adoption levels have been much lower, with twice as many farmers sampled (32.5 percent) reporting ever having planted hybrid maize as were planting it in 1973 (15.8 percent). Agroclimatic zone, as described in Chapter I, was found to be by far the most important variable in explaining adoption within the farmer sample taken as a whole. Location of the farm in a high rather than lower rainfall/altitude zones increased the likelihood of adoption of an otherwise "average" farmer from 18 to 87 percent.

The pattern of adoption over time, shown in Map 4 and Figure 7, indicates that adoption began first in the large-scale farming areas closest to the National Agricultural Research Station at Kitale, but spread rapidly to the densely populated high rainfall districts of Kakamega and Kisii and then to the somewhat less densely populated but also high rainfall districts of Kericho and Nandi. Evidence from records of seed sales and from other, earlier farm-level surveys in the region support the picture obtained through farmers' recollections that the difffusion process proceeded quite steadily, at a rate somewhat more rapid than hybrid corn was adopted by American farmers thirty years earlier. Within agroclimatic zones, farmers of all ethnic groups and both sexes had adopted the new varieties to a comparable degree.

The effect of farm size on adoption has changed markedly over time. In the multivariate analysis, farm size was not significantly related to adoption in 1973 in any of the agroclimatic zones or in the sample considered as a whole. In the bivariate analysis, farm size was also not significantly related to adoption in any of the agroclimatic zones, although—because of the larger farm sizes in Zone 2—it was related in the sample taken as a whole. Size of farm, however, was significantly related to the earliness of adoption in Zones 1 and 2 and in the entire sample, although the size of the coefficients was not extremely large (ten acres increasing the earliness of adoption by between 0.4 and 0.7 years). This relationship was though to be a function either of greater capacity on the part of larger farmers to take risks, and/or on the preferential treatment that large-scale

farmers receive from the extension services. Because of the nature of the technology and the security of individual land tenure in Kenya, however, early adoption by larger farmers was probably more facilitative than preclusive of subsequent adoption by smaller farmers.

Two other variables closely related to environmental conditions were found to be significantly related to hybrid maize adoption. The presence of drought-resistant crops in the farmer's crop mix, used as a proxy variable for risk perception, was strongly and negatively related to hybrid maize adoption in both the multivariate and bivariate analyses. Imputed income from cash crops, a rough measure of the quality as well as quantity of the farmer's land, was positively related to both earliness of adoption and to adoption per se in 1973. The imputed value of cash crops was particularly significant in the zone with the highest risk perception, indicating perhaps that ability to withstand risk is an important determinant of adoption where risk itself is perceived to be great. The presence of an off-farm source of income, another possible measure of ability to absorb risk, was positively but not significantly related to adoption.

Other characteristics of the farmer and his farm environment which were found to be positively and significantly related to adoption included formal education, knowledge of credit, availability, and (in most cases) extension visits, attendance at Farmers Training Center courses, and attendance at maize demonstrations. The latter variable was significantly related to early adoption in Zone 1, where the greatest number of maize demonstrations took place in the mid-1960s. Distance to a source of inputs had to be rejected as an explanatory variable because very few non-adopters were able to give the distance correctly. However, average distance to a source of inputs were significantly greater in the zone with the lowest overall level of adoption. Previous work experience off the farm proved to be negatively and significantly related to adoption per se in most zones and in the sample taken as a whole. However, work experience on a large farm was positively and significantly related to early adoption in Zone 2, the large-scale farming area. Those with such experience adopted on average 1.3 years earlier than others in their area, other factors being equal. Farmers with large farm work experience in Zone 3, who had worked mainly on sisal, sugar, and tea plantations, were, *ceteris paribus,* 1.6 years *later* in adopting hybrid maize.

In addition to looking at the adoption of hybrid maize seed, other components of the new technology were also investigated. Adoption of related practices ranged from 4 percent to 100 percent depending on the practice and zone involved. No clear differences were perceived between adoption of cultural practices and the use of physical inputs. In order of acceptance (in the weighted average of all three zones) the most widely accepted recommended practices were: planting in rows (75 percent), use of hybrid seed (67 percent), weeding more than once (63 percent), planting pure stands (57 percent), use of commercial fertilizer (49 percent), use of insecticide on stored maize (46 percent), thinning of plants (45 percent), planting "before the rains" (23 percent), using manure (23 percent), and using insecticide in the field (13 percent). Percentages varied considerably, however, by agroclimatic zone, and the definitions of what constituted "acceptance" of a recommendation of course varied, as did the probable importance of such inputs as insecticide and fertilizer in a given area. In spite of the wide variation in levels of adoption of individual recommendations, hybrid seed adopters had significantly much higher levels of adoption of related practices than non-adopters had. The only exception to this principle was the thinning of young maize plants, which was more common among non-adopters. The strength of the relationships between hybrid seed adoption and the adoption of other practices, indicates that the "package" approach of presenting hybrid as a new crop requiring new practices has been relatively successful. The persistence of such practices as interplanting and later planting, however, indicates that closer study of farmers' labor patterns, food preferences, and risk aversion behavior is required. Because of the importance of early planting to obtaining higher yields, and the farmers' strong aversion to planting in advance of the rains, more work on early maturing varieties and on small farm mechanization is needed.

Why Have Hybrids Been Successful in Kenya?

In describing the Kenyan maize industry and its history, we have tried to discover what factors have accounted for its relative success. It is of course difficult to say, on the basis of one case, which of these factors are peculiar to Kenya and which are generalizable to situations elsewhere. It is hoped that readers familiar with circumstances elsewhere will be able to discern for themselves which factors are likely to be relevant to a particular situation. If anything, this study shows how very site-specific agricultural technology is, even within one region of one (admittedly very diverse) country. For this reason, I have refrained from making broad generalizations about agricultural technology in developing countries. In this section, however, it may be appropriate to speculate on some of the generalizable features of the Kenyan experience with hybrid maize.

To begin with, Kenya is fortunate in possessing certain highland areas with good soils and reasonably reliable rainfall. Although these high potential areas occupy a very small part of the country's total area (7 percent in one estimate), they are nevertheless large enough to support a thriving agricultural industry (Chapter I). Similar, if not directly comparable, areas exist in most of the countries of the Eastern African plateau, including Ethiopia, Ugada, Tanzania, Zambia, and Malawi, most of which, incidentally, import hybrid maize seed from Kenya. These high potential areas were largely responsible for the colonial

interest in Kenya, if not initially, at least once the Uganda Railway was completed in the early 1900s. That interest, in turn, was responsible for the construction of the rudiments of an agricultural industry—including a transport network, crop research, marketing boards, guaranteed prices, and an extension service—which have been greatly increased and improved since Kenya's Independence in 1963. The development of Kenya Flat White maize, improved Pokot Rhodes grass, selected Kenya Boran Cattle, and other indigenous products represents the kind of basic agricultural research and development which can only take place over time. Perhaps more important, the agricultural success of the European farmers made farming appear profitable as an occupation worthy of investment and research. Having based its independence movement on the rights of the Kenyan people to the country's high potential land, it would have been surprising if the Kenya government had not made the continued development of its farming resources a major priority. The political power of African farmers, both large-scale and small-scale, ensures that agriculture continues to receive priority attention at the highest levels of government. This historical, phychological, and political experience is perhaps the most difficult part of the Kenyan case to duplicate elsewhere.

Secondly, Kenya possesses all or most of the components deemed necessary to the successful development of new cereal varieties. As Hill and Hardin have written, "the principal barrier to increased agricultural production in less developed countries is not the necessity of changing farmers' traditions, attitudes and customs but a problem of developing production technology capable of substantially increasing yields and making it possible and profitable for farmers to adopt it.... Adapted, high-yielding production technology; ready access to critical off-farm inputs; and product/factor price relationships at the farm...are critical ingredients in triggering an agricultural revolution."[1] That Kenya possesses the basic production technology for the high potential areas is beyond doubt. We have reviewed the reasons for its development in Chapter II: an already existing commercial maize sector that created the demand for the product; a systematic breeding and agronomic research program with close ties to the users of its product and to the extension services; quality staff and remarkable staff continuity; a locally based commercial production company ready to put the product into widespread use; foreign, governmental, and producer-supplied financial support; and contacts with international research institutions. The Kenyan case is an excellent example of what Robert Evenson calls "knowledge transfer" rather than direct technology transfer: "the higher the level of indigenous research activity the more productive is the regional research...new varieties better suited to local regional conditions [are] developed by crossing local varieties with international genetic material."[2] It is not accidental that the Kenya maize research program came up with a very high-yielding hybrid variety. Rather, the existence of a well-adapted local variety, a sound breeding program, and preselected analogous varieties from an international collection of genetic material made the discovery of the Kenyan hybrid varieties only a matter of time. There are few, if any, shortcuts for developing countries seeking to "import" the green revolution. As Griliches pointed out in the case of American hybrids, hybrid maize is not a single invention but a *method* for inventing corn varieties for specific localities. There is no alternative to investing in local research capacity in individual countries *in order to* maximize the returns on the investments that have been made in international research institutions. In Kenya's own case, the need now is to move toward still more localized research activity, especially in agronomic work. More off-station research trials are needed to determine the constraints to adoption under smallholder farming conditions, including particularly trials conducted with inter-planting of other crops. Kenya has the core staff to direct such programs, but needs many more well-trained subsidiary staff to carry them out. The training and retention of well-qualified scientific staff continues to be a matter of high priority.

The results of the present survey indicate the strong influence of risk and of agroicimatic zone on adoption. More research on early-maturity, drought resistant varieties is needed if the expansion of acreage under improved varieties is to continue. Improved varieties of sorghum and millet are also needed for the drier areas and work on high-lysine maize needs to be accelerated. Because of its great ecological diversity, Kenya cannot assume that the breakthrough in high-yielding late-maturing varieties has solved its food problems. Most Kenyans continue to grow all or almost all of their own food. If productivity is not improved in all farming areas, income inequalities between high and low potential areas will worsen, thereby exacerbating ethnic differences.

After the production technology itself, the most important ingredient in the Kenyan hybrid success story has probably been the commercial system of seed production and distribution. As Guy Hunter and others have written, different types of development institutions are necessary to different stages and levels of development. It is unwise to prescribe one type of institution for any and all development situations. Although many persons have advocated either state-run or cooperative-based input distribution systems for Kenya, the available evidence indicates that Kenya, at its present level of development, has been reasonably well served by the commercial sector both in seed multiplication and in distribution. In the former case, the most important factor has been the maintenance of quality in the product, without which hybrid utilization would not have continued to expand. Although the Kenya Seed Company enjoys a monopoly on seed sales in Kenya, its vested interest in maintaining the reputation of hybrid maize and expanding its usage, plus government control of seed prices and the government inspection service for seeds have combined to prevent the kind of deterioration in

product which has taken place in many countries under government run seed monopolies.

The maintenance of a system based on hybrid, rather than synthetic, varieties, however, would not have been possible without a distribution system that could deliver new seed to the farmer each year. It is unlikely that a public sector distribution system could do this as effectively. By using established wholesalers and selected private traders or stockists in the rural areas, the seed company is sharing overheads of distribution with literally hundreds of other inputs and consumer products. It has been estimated that while there is a health center for every 50,000 people in Kenya, there is a small store or *duka* for every 500. As we have seen, the population per registered stockist falls somewhere in between, ranging from 2,200 to 14,000 according to districts in western Kenya. Without establishing an enormous distribution network of its own, the government could not hope to distribute inputs except through the private sector. Of course, cooperative societies are often used for distribution where they are active, but functioning cooperatives are unevenly distributed around the country. It is the view of some authorities, moreover, that the slower uptake of improved maize varieties in central Kenya is due in part to the fact that cooperative societies play a larger role in input distribution in that area.

The rapid expansion in hybrid seed sales over the past ten years would argue that the commercial distribution system has been demonstrably successful. It may be, however that the cost of hybrids makes them too expensive for farmers in the marginal areas to buy every year. For this reason, the early maturing Katumani varieties used in eastern Kenya have been produced as synthetics. Unless improved hybrids can be developed for the lakeshore districts of western Kenya, the development of a cheaper synthetic for that area may also prove necessary. Belshaw and Hall went so far as to recommend that a completely revised package of free synthetic-type seed plus recommended interplanting with (supposedly) nitrogen-fixing legumes be developed to avoid the necessity of purchasing any inputs at all.[3] With Kenya's reasonably good transport system and a relatively well-developed retail system, however, it is not clear that the benefits of hybrid's higher yields need be sacrified. Even if hybrids yield only 10 percent more than the best composites and synthetics, a farmer (at the new price of 40/- a bag) need only get yields over 5 bags an acre to make the 20/- price of seed worthwhile. It has also been proposed that the governmnet eliminate the KFA and other wholesalers as middlemen in order to reduce the cost of seed to the farmer. It is questionable whether the savings in seed cost would not be more than offset by delays in distribution under such a system. An incentive scheme giving discounts to stockists who order and take delivery of inputs before a certain date would probably be a better way of improving timely distribution, allowing earlier planting, and thereby increasing farmers' profits. A thorough study of fertilizer pricing, subsides, and distribution is beyond the scope of this thesis. We can only say that fertilizer usage is likely to increase in importance over time as soil fertility is depleted. The favorable increases of the late 1960s in product/factor price relations have almost certainly been reversed in the last two years by world fertilizer inflation. The deleterious effects of this change on fertilizer utilization cannot yet be determined.

A third important ingredient after technology development and input distribution has been the extension and training services of the Kenya Ministry of Agriculture. As much maligned as it has been in recent years for its fairly consistent bias toward large-scale farmers, the extension service has nevertheless conducted literally thousands of maize demonstrations, initially focusing on hybrid seed and more recently on fertilizer utilization with hybrid varieties. An agricultural journalist, visiting Kenya on behalf of the Rockefeller Foundation in 1972, reported that "Kenya has the most effective extension service for reaching small farmers I have ever seen, and over the years I have seen a good many."[4] Although this view might surprise some observers in Kenya, it may not be far from the truth. In western Kenya, 35 percent of the farmers surveyed reported an extension visit in the past year, 25 percent had personally attended a maize demonstration, and almost as many reported first hearing of hybrid from an extension agent as had heard about it through the usually far more important interpersonal channels. In spite of these achievements, however, there is still much room for improvement in the extension services. Too many field staff are largely untrained (in spite of serious efforts at in-service training courses). Administrative back-up to field staff is almost non-existent; promotion policies are poor; and employee morale is generally low. More use needs to be made of group extension techniques and more contact is needed between extension workers and research stations. More extension effort needs to be directed toward women farmers and toward farmers in the lakeshore districts which receive considerably lower levels of agricultural services.

Contacts between research and extension staff need to be further improved. In spite of the relatively short distance across western Kenya, very few agricultural staff interviewed below the district level had ever visited the National Agricultural Research Station at Kitale. Farmers Training Centers are generally poorly staffed, run at low levels of capacity utilization, and are much too academic in their approach to farmers. In one case a visitor found farmers in a classroom being lectured on the dignity of farming while prisoners from a nearby jail tended the demonstration fields outside the classroom window. It is probably safe to say that the extension service, no matter how great its achievements, will always have considerable room for improvement.

As for official sources of farm credit, because of minimum acreage restrictions, they have played little or no part in the diffusion of hybrid maize among small-scale farmers except

possibly through a demonstration effect in some key areas. Kenya, however, has had the good sense to experiment with various credit programs under its Special Rural Development Program, and it is likely that improved smallholder credit schemes will be developed drawing on the lessons from that experience. At the very least, the stockist credit scheme should help to improve input availabilities in many areas and may result in the extension of some private credit for maize inputs to local customers. The problems of recovery of loans on a crop which can be sold anywhere or consumed on the farm, however, make individual credit for seasonal inputs difficult to extend on a broader basis. Although credit has not played a major role in the adoption of hybrid seed to date, it will become increasingly important as fertilizer use increases over time. The importance of cash crop income as an explanatory variable in the analysis of adoption indicates that liquidity can be a problem for small-scale farmers entering the market economy for the first time.

Finally, the role of the marketing system in promoting maize development must be recognized. Although it was founded to serve the interests of large-scale European commercial farmers, the guaranteed price system has been important in setting a floor to protect all farmers against wide price fluctuations. The gradual improvement of storage facilities, moreover, has given the country a strategic storage capacity great enough to protect it against the shortages which have periodically plagued the market in the past. The recent increase in world prices to a level comfortably above export parity has removed the problem of exporting at a loss just at the time when hybrid production has placed Kenya in a long-term surplus position. This is a prospect that few African countries can envisage in the near future and it should make maize an important export product for Kenya over the next decade. Only the introduction of bulk handling facilities to cut export costs and the relaxation of controls on domestic marketing remain to be enacted for maize to realize its full potential as Kenya's most important agricultural product.

In conclusion, we have found that a modest investment in the scientific breeding of maize has produced enormous returns to the government and people of Kenya. Small-scale as well as large-scale farmers in the high potential areas of western Kenya and more recently in central Kenya as well, have adopted hybrid maize technology at rates at fast or faster than American farmers did in the 1930s and 1940s. No evidence has been found that "traditionalism," "custom," or "conservatism" has hindered the adoption of a profitable innovation. Even in those areas where adoption levels are low, historical and survey data indicate that this has been a conscious process of non-adoption rather than "laggard" traditionalism. Although farmers in the drier areas suffer from lower levels of profitability, greater risk, lower levels of agricultural services, and less income from other cash crops, many of them have tried the new technology but later given it up. As Griliches concluded about American farmers, "taking account of uncertainty... farmers have behaved in a fashion consistent with the idea of profit maximization. Where the evidence appears to indicate the contrary...a closer examination of the relevant economic variables will show that the change was not as profitable as it appeared to be." This appears to be the case in western Kenya. It is hoped that a case study of the willingness of African farmers to adopt profitable agricultural innovations and the factors affecting adoption and non-adoption will encourage those seeking to develop improved technology for food production in tropical Africa.

Notes

1. F.F. Hill and Lowell S. Hardin, "Crop Production Successes and Emerging Problems in Developing Countries," paper presented at a Workshop on Emerging Issues Accompanying Recent Breakthroughs in Food Production, Cornell University, 1970, pp. 9, 11.

2. Robert Evenson, "Science and the World Food Problem," mimeo, 1974, pp. 16, 19. Kindly made available by Mr. R. Mohan.

3. D.G.R. Belshaw and Malcolm Hall, "The Analysis and Use of Agricultural and Experimental Data in Tropical Africa," *East African Journal of Rural Development* 5, 1-1, (1972): 70.

4. Carrol P. Streeter, Untitled paper, mimeo, 1972, p. 3.

Appendix I. Correlation coefficients—adoption of hybrid maize and selected factors.

	Hybrid	Zone	Age	Education	Farm size	Risk	Job	Work	Large farm	Credit	Extension	Demonstration	FTC	Cash
Hybrid														
Zone	0.76													
Age	– .24	–0.21												
Education	.19	.13	–0.34											
Farm size	.28	.30	– .05	0.18										
Risk	– .54	– .50	.10	– .06	–0.13									
Job	.16	.13	– .15	.28	– .07	–0.09								
Work	– .08	– .06	.08	.05	.09	– .04	0.25							
Large farm	– .05	– .18	– .18	– .00	– .12	.03	.07	–0.12						
Credit	.26	.17	– .03	.13	.24	– .10	– .00	.00	–0.05					
Extension	.15	.11	.02	.15	.10	– .07	.07	– .00	.05	0.17				
Demonstration	.18	.09	.05	.14	.10	– 07	.03	.02	– .15	.18	0.28			
FTC	.29	.20	.08	.13	.16	– .13	.05	– .01	– .09	.15	.22	0.41		
Cash	.28	.22	– .07	.19	.40	– .17	.12	.09	– .05	.18	.17	.21	0.22	

Appendix II. The 1974 Kenya Maize Farmers Survey

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Introduction

In 1974 the Kenyan Maize and Produce Board did a follow-up study on the 1973 Kitale–CIMMYT survey including the higher rainfall areas of Central as well as Western Kenya. This survey was jointly financed by the Maize and Produce Board and the Kenya Seed Company in Kitale. The suggestion to repeat the exercise came from the KSC, which had a particular interest in adoption rate in Central Province, where an almost explosive adoption–with annual increases of 50 percent in seed sales–has taken place over the last few years. It was therefore decided to extend the survey into Central and parts of Eastern Province, i.e. into the Central Highlands. Thus the KSC and the MPB had joint interests in the survey–the MPB could use the results for better predictions of the total maize production and hence for better marketing and storage decisions; the KSC would get a more solid basis for decisions on seed production and marketing.

The planning of the survey was made together with two statisticians at the Agricultural Statistics Section at the East African Community, Messrs. Macandu and Dunbar. Much valuable advice also came from Mr. Verburght of KSC and Dr. A.I. Allan of the Maize Research Center at Kitale. The interviews were carried out by Research Bureau Limited as in the 1973 survey. In Western Province the majority of the interviewers were the same as in the earlier survey, and whenever possible the same interviewer went back to the farmer. The RBL again performed very well under sometimes difficult conditions.

Sampling Procedure

The sampling procedure was essentially that employed by Dr. Gerhart in the 1973 survey. In Western Kenya it was identical, insofar as the same farmers were visited. In Central Kenya the same technique was used. The area was divided into two zones, one at higher (above 1500 m) altitudes. In each zone the total area comprised of a number of 100 square kilometers segments of which a random sample was drawn.

The Central Province

The area that constitutes zone 4 and 5, in the 1974 survey is located in Kenya's Central and Eastern Provinces, and includes the following districts: Kiambu, Murang'a, Nyeri, Kirinyaga in Central Province, and Meru and Embu in Eastern Province. This is a densely populated area with almost exclusively small scale farms, inhabited by the Kikuyu, Meru and Embu tribes. In the southern part, the country slopes eastwards from the Aberdare Mountains from the forest zone at 2000 - 2500 m altitude down towards the plains at 1100-1300 m in the eastern part of Murang'a and Kiambu Districts. This land is intersected by deep valleys, and the dominant landscape features are the long almost parallel rivers and ridges running from north-west to south-east. Further north there is a great valley between the Aberdares and Mount Kenya, whose peaks are about 80 km apart. This is the location of Nyeri District. Around Mount Kenya on the sourthern and eastern side are Kirinyaga, Embu and Meru Districts.

The rainfall pattern is fairly contrasting, with rainfall generally increasing with altitude. The eastern slope of Mount Kenya receives considerably more rainfall than the western side; thus Meru receives 1800-2000 m compared with 900 mm per year in Nyeri. The natural forest boundary is at about 1500 to 1700 m altitude, but population pressure has led to considerable cutting down of forests, and cultivation sometimes takes place as high as 2500 m (in Limuru north of Nairobi).

In our sample, zone 4 consists of the land which is below 1500 m and zone 5 is that land which is above 1500 m. Zone 5 then is between 20 and 30 km wide, and follows the forest boundary along the two mountains. Zone 4 is the valleys and plains below down to 1100-1300 altitude. Below 1100 m the rainfall is usually not thought sufficient for hybrid maize.

The Interviews

A main objective of the survey was to find out how hybrid seed is actually being utilized by small farmers. This is particularly important in those areas in Western Kenya where we already knew that a vast majority uses hybrid seed. The relative intensity of cultivation i.e. plant populations together with selected husbandry practices, would indicate what potential increases in seed sales, land utilization and maize production exist in that area. In the non-adopting zone 3, the survey perhaps could give more information on the reasons for non-adoption in those areas. Since 1972, in Central Kenya, the KSC has witnessed a spectacular increase in seed sales, and it was therefore interesting to

establish the general level of adoption, in order to estimate the level and the point in time at which seed sales would be expected to level off. Compared with the 1973 questionnaire, the 1974 survey focussed more on the question "how many" of the farmers use hybrid rather than "why" or "why not". Some of the questions used to find out the reasons for adoption or non-adoption were therefore discarded. This is perhaps unfortunate, since it is not possible to treat the material in the same way as in the earlier study. For Central and Eastern Provinces, however, the willingness to adopt hybrid seed once it is available has been demonstrated already, and the recent phenomenal adoption rate indicates that full adoption will be reached in two or at most three years.

The most important change in the questionnaire and in the interviews was a precise plant count, from which the number of plants per hectare and number of ears per hectare was computed. The reason to include this was twofold. First, a prceise measurement of plant populations would be of value for KSC's marketing decisions. Secondly, this information can be used to estimate the total production from hybrid seed in the country. Given the amount of seed sold in various areas, the total number of maize plants and ears can be computed. When the count is complemented by a sample of mature, maize cobs, whose grain weights are measured, the total hybrid maize production in each area can be estimated—from the number of cobs and their weight. The second sample has now been carried out, and it is hoped that this will provide the first estimate of Kenya's maize production that is not based entirely on guesses.

Results

The sample. For zones 1, 2 and 3, a sample was drawn from the 300 or so earlier questionnaires because financial reasons made it impossible to visit all the farmers from the 1973 survey. The target was to have about 150 interviews and by tossing a coin one half of the segments were selected. All in all, 117 successful respondents were about 22 percent of the total sample. The discarded interviews seem to be randomly distributed over the sample.

Zones 4 and 5 (in Central Kenya) had not been visited in the 1973 survey, and a completely new sample was drawn. After studying population maps it was concluded that the population density was roughly equal in the two zones, and it was decided that the number of segments, i.e. the area of each zone would determine the sample size for each of them. A total sample size of 120 was set as the target, which would mean the selection of every second segment in each area. The selection was randomized by tossing a coin. The actual number of successful farm interviews was 104, the remainder being non-maize farmers, non-accessible segments and other field problems.

Adoption Rates. It appears that about two farmers out of three have adopted hybrid maize in those areas of Kenya where hybrids can be grown. If zone 3 is excluded, one is left with practically all high-potential small-scale farming areas in the country. The results in these areas only, indicate an overall adoption rate of 74 percent. The Central Province had about 55 percent adoption, with no significant difference between zones 4 and 5.

ADOPTION RATE BY ZONE, 1974

	Hybrid Users		*Non-Users*		*Total*
Zone	*No.*	*%*	*No.*	*%*	*No.*
1	39	100	0	0	39
2	43	89	5	11	48
3	4	13	26	87	30
4	25	59	17	41	62
5	33	53	29	47	62
Total	144	65	77	35	221

Kenya's Hybrid Acreage. According to KSC and Ministry of Agriculture recommendations, plant populations for pure hybrid stands are between 45,000 and 53,000 plants per hectare depending on variety. The achieved plant populations were measured by counting the number of maize stalks in the field, and by measuring the distance between rows.

PLANT POPULATIONS
(Weighted averages. Farms not practicing row planting excluded).

	1000 plants/ha	
Zone	*Hybrid Users*	*Non-users*
1	33.4	–
2	37.5	32.5
3	22.5	20.0
4	36.6	35.8
5	32.2	28.9
Total	34.4	28.8

KSC area estimates based on seed sales and an assumption of 9 kgs. of seeds per acre should be increased by 1.24 (from 336,000 ha to 416,000) to give the true number of hectares under hybrid maize in the country.

An important factor influencing plant population is of course interplanting, a practice which is widely spread throughout the small scale Kenyan Agriculture. The merits of interplanting have never been studied or demonstrated conclusively, although most authorities seem to agree that the practice has a lot of advantages in the African small-scale environment.

INTERPLANTING OF MAIZE AND OTHER CROPS

	Yes		*No*		*Total*
Zone	*Nr*	*%*	*Nr*	*%*	*Nr*
1	17	43	23	57	40
2	12	25	36	75	48
3	24	71	10	29	34
4	26	62	16	38	42
5	42	68	20	32	62
Total	121	54	105	46	226

INTERPLANTING, ZONE AND ADOPTION

	Interplanting, %		Pure Stands, %		
Zone	Hybrid	Non-Hybrid	Hybrid	Non-Hybrid	Total
1	43	–	57	–	100
2	25	–	67	8	100
3	23	67	9	21	100
4	36	26	24	14	100
5	23	45	29	3	100
Total	26	27	38	8	100

Apart from the repeated pattern from the 1973 survey for zones 1, 2 and 3, zones 4 and 5 show a remarkably different picture from Western Kenya. First, interplanting is one the whole more common than in Zones 1 and 2. Second, interplanting does not seem to vary with hybrid use as much as in zone 1, 2 and 3. In zone 1 and 2, only 35 percent of hybrid users interplanted, whereas 51 percent of hybrid users in Central Province did. It is difficult to explain this behaviour. In the 1973 survey it was concluded that adoption of hybrid maize went along with a whole series of agricultural practices, including planting in pure stands. This problem will be examined later in greater detail, but it seems as interplanting may be a more deeply rooted habit in Central Province.

The low plant populations per hectare mean that hybrid maize is actually planted over a much larger area than has previously been thought. Obviously, here lies the key to increased maize production. If it is the case that low plant populations are realized in pure stands as well as in interplanted fields, considerable increases in the number of plants can be made.

Adoption and Husbandry Practices. In the 1973 survey it was demonstrated that adoption of hybrid seeds tends to go together with the adoption of a whole packet of improved husbandry practices, such as use of fertilizers, planting in rows and in pure stands, early planting, etc. Through careful analysis of his material, Dr. Gerhart showed that there actually was a relationship between seed adoption and changed husbandry practices. It is not a coincidence of two independent trends. Hybrid seed is considered by the farmers as a new crop whose growing is inherently different from the cultivation of the old type of maize.

In the 1974 survey, the data for zones 1, 2 and 3 again show the same pattern as in 1973. Zones 1 and 2 have very high numbers using hybrid-related practices, significantly higher than in zone 3. e.g. 93 and 94 percent of the farmers in zone 1 and 2 planted in rows, vs. 47 percent in zone 3. The use of different practices is shown below:

USE OF RECOMMENDED PRACTICES, BY ZONES

	Zone				
	1	2	3	4	5
Physical inputs					
Hybrid seed	100%	90%	12%	60%	53%
Fertilizer	55	90	0	52	50
Insecticide in store	58	88	15	41	39
Insecticide in field	8	44	0	26	26
Manure	33	21	27	36	48
Cultural Practices					
Row planting	93	94	47	83	90
Pure stand	58	75	29	38	32
Weeded more than once	95	52	59	52	67
Thinned	33	15	53	50	45
Planted early	28	23	21	21	50
Nr farms	39	48	34	42	62

Central Province (Zone 4 and 5) showed a slightly different pattern. The high scores for row planting and for fertilizer use should be noted, as well as the high percentage of farmers interplanting maize with other crops (62 and 68 percent). Farming Methods in the often very high and hilly zones 4 and 5 are definitely different from those in Western Kenya. This is of course a well known fact. Particularly interesting to note is the use of manure, and the fact that many farmers thinned their maize. In the 1973 survey thinning was shown to be negatively related with adoption in zones 1, 2 and 3, in accord with the hypothesis that planting a large number of seeds in each hole was related with broadcasting and other husbandry practices employed before hybrid was introduced. In Central Province, however, it is common to pull out maize plants during the growing season and feed them to cattle. Also, planting many seeds in a hole reduces the number of planting stations and thereby labour requirements at planting time. There is evidence that labour supply at planting time is an important constraint on the area that can be planted at the right time. In Central Province, where rainfall is less abundant and its variations are greater, than in the West, late planting is related with severe yield reductions. Therefore farmers should be expected to employ various techniques to enable them to plant a large area within a short time. In the absence of mechanical implements, planting many seeds in a hole constitutes one such technique. Thus many seeds in a hole may be done for other reasons than to ensure germination from poor seed.

In the 1973 survey it was investigated whether there was any difference between hybrid and non-hybrid users with regard to other husbandry practices. The hypothesis was that since hybrid has been introduced as a package of husbandry practices rather than by simply encouraging farmers to buy the new seed, it would be expected that hybrid adopters are more likely to use for example fertilizers, row planting, pure stands etc. This hypothesis was confirmed in the 1973 survey, and it has been repeated with 1974 data. The method employed was a simple chi-square test where samples of non-adopters for one practice at a time. For this analysis, a chi-square value of 2.71 or higher makes the hypothesis accepted at a 90 percent confidence level. The results are given in the table below. The sample has been divided into two parts, Western Kenya (Zones 1, 2 and 3) and Central and Eastern Provinces (Zone 4 and 5).

HUSBANDRY PRACTICES IN ZONE 1, 2 and 3, 1974.
(Proportion of each group of respondents users and non-users—that employed the practice in question).

Practice	Hybrid users n = 88	Non-users n = 34	chi-square
Row planting	96%	47%	36.2**
Fertilizer	73	3	44.9**
Insecticide on crop	26	3	6.8**
Thinned	24	50	6.6**
Weeded more than once	71	53	2.5 ns
Pure stands	67	32	10.4**
Manure	25	29	0.2 ns
Early planting	25	18	0.4 ns

HUSBANDRY PRACTICES CENTRAL PROVINCE, 1974

Practice	Hybrid users n = 57	Non-users n = 47	chi-square
Row planting	96%	79%	6.4**
Fertilizer	72	17	29.1**
Insecticide on crop	39	11	11.7**
Thinned	46	49	0.1 ns
Weeded more than once	46	49	0.1 ns
Pure stands	47	17	9.2**
Used manure	46	40	0.1 ns
Early planting	53	21	9.5**

In both areas, row planting, fertilizer, insecticide on crop, and pure planting were all highly significant, i.e. adopters are more likely to use these practices than non-adopters. Thinning the maize plants was significant in Western Kenya but not in Central. The probable reasons for this has been indicated above. Early planting was significant in Central but not in Western, and likewise, this has been discussed above. For weeding and use of manure there were no significant differences between adopters and non-adopters.

The conclusions from this exercise as from the 1973 survey are that there are indeed significant differences between adopters and non-adopters. When farmers start using hybrid maize, they simultaneously take up a whole series of husbandry practices. Hybrid maize is then regarded as a "new" crop, different from local not only in seed, but also in farming methods. Increased production can therefore not be attributed to the seed alone, but on the other hand the seed was the vector that started the development. Without the seed, it might have been much more difficult to change the methods.

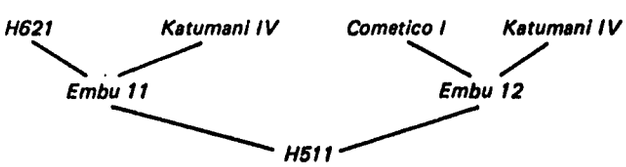
The Embu Medium Maturity Breeding Programme

What was responsible for the rapid increase in hybrid use in Central Kenya after 1970? The following description is a concentrate of Annual Reports from the Maize Research Institute of Embu 1966 to 1973.

The maize breeding programme at Embu focussed on the production of medium maturity varieties for Central and Eastern Provinces. The climate there is characterized by two distinct rainy seasons of limited duration, and by moderate altitudes (3500 to 7000 feet). The requirements of the climate were important all the way from the beginning of the programme, which started in 1965 with a large number of crosses from a widely based genetic material.

In 1967, the first results were Embu Composite I and Embu Composite 2, both formed from coloured exotic material. A systematic selection for whiteness was performed on these varieties. At the same time, crosses of late maturing Kitale hybrids and Katumani was performed to get a variety with the same maturity time as the most common local maize. The local is called the Muratha Maize, and has been used as a common denominator in most comparisons throughout the programme.

In 1967, the first hybrid (H511) was produced. It had the same maturity as Muratha, but this first version outyielded the local variety by 24 percent. The genetic material was the following:



The variety was regarded as so successful, that it went on sale commercially in 1968. It was also improved in the next year, when it outyielded the local Muratha by 44 percent.

During the first years of the breeding programme, agronomic trials were also conducted at Embu, and the findings were similar to those at Kitale. It was concluded, that early planting, a high plant population (53,000 plants/ha) and good weeding increase yields significantly. Recommendations for planting were issued in 1970, (then for H511).

In 1969, the next breakthrough in breeding was made with the production of H512, being a cross of H511 with another variety (SR52). H512 had very desirable characteristics, and in 1970 it outyielded the local by 61 percent. It was also released in that year.

By 1970, the immediate needs to produce an acceptable hybrid had thus been covered. In the years since its introduction, H512 has gained great popularity in Central and Eastern Provinces, and well over half the maize acreage in that area is expected to be planted with H512 in 1975. The breeding programme has therefore focussed more on the long term aspects of high protein and high lyseine maize, and some progress has been made over the last years. Another aspect that has been of some interest is that H512 outyields all other varieties under normal rainfall, but in dry years the hybrids is outyielded by local maize with the same maturity, and both are outyielded by Katumani. Efforts are therefore made to improve the overall performance of H512 under dry conditions.

Like the maize research at Kitale, the Embu programme must be judged as highly successful. In a very short time, very tangible results have been achieved in terms of high-

yielding hybrids. The actual production of commercial seed has been made by the Kenya Seed Company at Kitale, and KSC has also been responsible for the distribution of seed. The characteristics of H512 are very desirable in all of Central Province, and farmers have been very quick to see the benefits. There are indications that the rate of increase in acceptance has been even faster than in Western Province, and again the KSC has succeeded in distributing the seed. A comparison between seed sales in Central and Western Provinces is given below:

SEED SALES IN WESTERN AND CENTRAL PROVINCES

	Central		*Western*	
Year	*10-kg bags*	*Increase, %*	*10-kg bags*	*Increase, %*
67/68	10,500		36,000	
68/69	13,200	26	64,000	78
69/70	27,700	110	80,000	25
70/71	45,800	65	127,000	59
71/72	68,100	49	135,000	6
72/73	82,700	22	185,000	37
73/74	120,000	45	205,000	11
74/75	150,000*	25	218,000*	6
Compound interest growth rate, 67/68-74/75		46		29

*Projected

The growth rate in Central Province is a stunning 46 percent a year since 1967/68, when H511 was first introduced, and the projected 1974/75 sales are 14 times as large as in the first year, and over 3 times as large as in 1970/71. Without pressing the data too much, it appears that the growth is even faster than in Western Province, where sales now are levelling off because of saturation of the market, as we have seen earlier. In Central Province, it should still be possible to double the seed sales over the 1973/74 level, since only about 50 percent of the farmers indicate that they are using hybrid seed. This suggests a saturation level for Central Province of 220,000 to 240,000 packets, or about the same as Western. As with Western Kenya, it is the small farmers that have adopted hybrid seed. (In Central Province, this can be asserted even without any analysis, since there are hardly any large farmers in the Province). The story of hybrid diffusion throughout Kenya is thus a success story, where rapid adoption has been achieved within the small-holder sector.

Conclusions

The 1974 survey has at least demonstrated two things. One is that the results for 1974 in Western Kenya are consistent with those of 1973. The other is that a similar development of hybrid maize has taken place in Central Kenya a few years later. The reason for the lateness in Central Kenya is simply that a suitable hybrid variety became available later there.

Perhaps the most valuable part of the whole survey and the analysis has been to point out in what areas we need further investigations. After the survey was completed, work started immediately on the planning of a system for objective yield surveys of maize in Kenya, which is being conducted in 1975. The work is going to be carried out by the Maize and Procedure Board together with the Central Bureau of Statistics. The earlier surveys have been invaluable in the planning, because they provided information necessary to determine sample sizes and error levels in the yield surveys. For the objective yield survey, they have acted as pilot studies, and we have been able to avoid a large number of pitfalls and problems through what has been learnt from them. It is through its indirect influence on the more comprehensive study that the survey has been of some value, not through its actual findings.