Adoption of Maize Production Technologies in the Coastal Lowlands of **Kenya**

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KARI

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International Maize and Wheat Improvement Center

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Abstract: Maize is the major food crop grown in the coastal region of Kenya and constitutes a major component of the diet of the population in the region. However, average yields are far below the potential for the region and low production levels create serious food deficits. Over the years, new technologies have been introduced but adoption has remained low, especially for fertilizer. This paper examined current maize-farming practices and technological and socioeconomic factors that influenced adoption in the Kilifi and Kwale Districts of the Coast Province, that together account for half of maize production in the region. The study found low adoption levels for improved maize varieties and technology, especially fertilizer, among farmers in the area. Farmers cited poor availability of improved varieties, high cost, lack of knowledge, and unfavourable characteristics of improved varieties as reasons for non-adoption. The high price and poor availability of fertilizers, farmers' inexperience with them, and their perception that soils were already fertile were among reasons given for low fertilizer use. The low levels of adoption of improved varieties indicate that they are not meeting farmers' needs. The authors recommend that researchers communicate with and include farmers' criteria when breeding varieties. In addition, alternative options should be extended to farmers who are not able to use inorganic fertilizers. Finally, given the major influence of the institutional environment found in the study, it is recommended that extension services be strengthened, especially where lack of knowledge was cited as a hindrance to adoption.

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Acronyms and Abbreviations

AFC	Agricultural Finance Cooperation
CAN	Calcium ammonium nitrate
CIMMYT	International Maize and Wheat Improvement Center
CL2	Coastal lowlands 2
CL3	Coastal lowlands 3
CL4	Coastal lowlands 4
CL5	Coastal lowlands 5
CL6	Coastal lowlands 6
DAP	Di-ammonium phosphate
EU	European Union
KARI	Kenya Agricultural Research Institute
PH1	Pwani hybrid 1
PH4	Pwani hybrid 4
RRC	Regional Research Center

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Executive Summary

Maize is the most important food crop in Kenya and in coastal Kenya is a primary staple for the majority of the population. It is grown in all agroecological zones of the Coast Province, including arid and semi-arid lowland areas suitable for sorghum and millet. However, average yields are far below the potential for the region and low production levels create serious food deficits.

Maize improvement work at the coast began in 1952 and a number of varieties have been developed for the region since then. While some were discontinued, three improved varieties were developed and released: the open-pollinated Coast Composite and the hybrids Pwani 1 (PH1) and Pwani 4 (PH4). Despite the release of these improved varieties, adoption has remained low, especially for fertilizers. As improved maize technologies are key to improving production levels and helping ease food deficits, this study examines current maize-farming practices and technical and socioeconomic factors that influence adoption in the region.

The study was carried out in 1998 in the Kilifi and Kwale Districts of the Coast Province, that together account for half of all maize production in the region. In total 200 households were surveyed using a structured questionnaire. Adopters of new maize varieities were defined as farm households that planted certified seed on at least 1 acre[1] of land. Eighty households were thus classified as adopters.

The results showed that adoption rates for improved maize technologies were generally low. Adoption was lowest for fertilizer—only 6% of respondents used inorganic fertilizers. The main constraints farmers mention regarding the adoption of fertilizer were high cost (36.5%), a perception of sufficient soil fertility (20%), lack of knowledge (14.5%), poor availability (9.5%), and lack of cash or credit.

Improved maize seed was not as popular as local seeds; only 40% of respondents used improved seed. Moreover, seed recycling was common. Coast Composite was the most popular improved variety among farmers (22%), followed by Pwani Hybrid 1 (21%), and Pwani hybrid 4 (5%). Only 32.8% bought maize seed during the study year; of this, two-thirds were certified seed (65.2 %) and one-third were local seed (34.8%).

Farmers gave several reasons for the low adoption of improved maize. Generally, they prefer to use their own seed because it is cheaper and more readily available. Non-availability of improved maize seed was reported by 29% of farmers as a constraint to adoption. The high cost of certified seed (100 Kenya shilling (Ksh)/kg against 10 Ksh/kg for local seed)[2] also discouraged farmers. Other factors were lack of knowledge of technological packages and their use (13%), unfavourable characteristics of improved varieties (6%), unfavourable climatic conditions, lack of money and credit, and limited availability of labor. Farmers who adopted improved varieties preferred them because they had significantly higher yields, larger cob sizes, more cobs per maize plant, and good grain filling.

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1 1 acre = 0.405 ha.

2 US$ 1 = 60.26 Ksh (1998).

Row planting was the most adopted technological package among farmers (72%). Only 15% of farmers applied pesticides. While research recommendations were for pure stand maize crops, 73% of farmers planted maize with other crops. Also, even though most respondents relied on saved seed for maize, the seed selection process was not developed. Fifty-five percent of farmers selected seed just before planting, 26.7% selected seed after harvest, and 17% during harvest. Only 1% selected seed during the growing period.

Adopters of improved maize varieties were compared with non-adopters using *t*-test for independent samples for quantitative variables and Pearson's c^2 test for qualitative variables. Two household head characteristics were found to be different between the two groups literacy (75% for adopters and 61% for non-adopters) and District (in Kilifi 32% were adopters, in Kwale only 28%). Adopters also had significantly more household members than non-adopters, more area planted to maize, and higher total income. Farmers who had contact with extension services and participated in farmer courses and who listened regularly to agricultural programs on the radio were more likely to be adopters. There was no difference between farmers who had credit and those who did not.

Using age of household head, farm characteristics, and institutional environment as variables, a regression analysis was carried out to analyze factors that influence adoption of improved maize varieties (logit regression on a binary variable) and fertilizer (tobit model on a quantitative truncated variable). The regression analysis showed that adoption of new varieties was higher in Kilifi and negatively influenced by permanent off-farm employment. Major factors influencing adoption included availability of cash, expressed in off-farm income and hiring of labor. Important institutional factors were contact with extension and listening to agricultural programs on the radio. Availability of credit and participation in training courses also had an impact but only in Kilifi.

Adoption of fertilizer was also higher in Kilifi. In general, younger and more educated farmers used more fertilizer. More endowed farms, reflected by variables such as farm size, herd size, and off-farm income, also had a tendency to use more fertilizer. The institutional environment again played an important role–listening to radio programs and access to credit had significant impacts on adoption. Other significant factors were participation in training courses and membership in groups.

Experience with regression analysis calls for caution with interpretation of results. Many variables are closely related and can be seen as clusters. The close association of different variables and resulting autocorrelation makes the model very sensitive to specifications.

The leveling off of adoption below 40% indicates that there is still a large group of farmers whose needs are not met with available improved varieties. Breeders should be encouraged to communicate with farmers and include farmers' criteria for selecting varieties and incorporate attributes they want or are lacking in improved seeds. Varieties tolerant to nitrogen and drought stress should be made available as options to resource-poor farmers.

The very low adoption rate of fertilizer is cause for concern. Since high cost is by far the major constraint, alternative nutrients should be sought and extended to farmers who are not able to use inorganic fertilisers. Given the high variation of soils and climate at the coast, it is also important that site-specific recommendations are developed and implemented.

Poor adoption rates also call for policy changes. The seed industry has now been liberalized and new companies can now compete with the Kenya Seed Company. This will hopefully increase the supply of different varieties and reduce seed prices. However, these changes have not yet been observed at the coast since over 60% of farmers recycle seed irrespective of whether they are local races, hybrids or composites. The implication is that there is a need to involve farmers in community seed programs that include training on seed selection, multiplication, and storage.

The regression results show the major influence of the institutional environment, in particular extension and credit. Extension services need to be strengthened especially where lack of knowledge is cited as a hindrance to adoption. Availing credit for the purchase of farm inputs and implements and for hiring labour is likely to increase adoption of improved maize technologies and maize productivity in the region. Availability of new inputs could also be improved through better infrastructure and distribution networks.

The challenges of increasing adoption rates of improved maize production technologies are significant. Meeting them will require the concerted efforts of farmers, researchers, extension agents, seed companies, and other stakeholders. This calls for partnerships in the implementation of programs.

Adoption of Maize Production Technologies in the Coastal Lowlands of Kenya

E. Wekesa, W. Mwangi, H. Verkuijl, K. Danda, H. De Groote

Introduction

Maize is a major food for most households in Kenya and the main source of income and employment for the majority of rural households. Food security and welfare of the farming population are dependent on the productive capacity of maize farmers. More than 70% of maize area in Kenya is cultivated on farms of less than 20 acres[3] (Karanja 1990).

Maize is also the most important food crop at the coast, particularly in the Kwale (Kega et al. 1994) and Kilifi Districts (Otieno et al. 1994) of the Coast Province, which together account for half of all maize production in the region. Maize is grown in all agroecological zones of the Province including arid and semi-arid lowland areas more suited for sorghum and millet. Although maize is the most important food crop, the region only produces 50 million tons of maize per year, or 20 kg per person (Table 1), resulting in a large deficit. Most maize is grown to meet subsistence needs, although in some areas in the Kwale District, a significant proportion of green and dried maize is sold for cash.

In 1999, the Coast Province had an estimated population of 2.5 million (Central Bureau of Statistics 2001). The urban District of Mombasa has 665,000 people, while Kwale and Kilifi Districts together have 1 million.

Table 1. Population and maize production, Coast Province, Kenya.

		Maize production 1998-2000 ‡				
District	Population (1999)†	Acreage (ha)	Production (t)	Yield (t / ha)	Production in first season (%)	Food security (kg / person)
Kilifi	544,303	15,448	15,760	1.02	95	29.0
Kwale	496,133	10,450	11,962	1.15	90	24.1
Lamu	72,686	4,484	4,591	1.02	97	63.2
Malindi	281,552	10,730	11,081	1.03	99	39.4
Mombasa	665,018	315	355	1.02	86	0.5
Tana River	180,901	734	821	1.11	83	4.5
Taita Taveta	246,671	6,221	5,709	1.09	62	23.1
Total:	**2,487,264**	**48,381**	**50,279**	**1.06**	**91**	**20.2**

Note: †Central Bureau of Statistics (2001).
‡ Ministry of Agriculture, unpublished data.

[3] 1 acre = 0.405 ha.

The maize sub-sector in Kenya has changed dramatically over the last 40 years. Three phases of technological transformation can be identified (Hassan and Karanja 1997). Phase I (1964-73) was characterized by the release and adoption of first generation hybrid maize in high potential zones. The spread of hybrid maize was followed closely by fertilizer use. Phase II (1974-83) was characterized by the spread of improved maize seed to small-scale farmers in high and medium potential zones and increased use of fertilizer. In phase three (1984-92), there was greater increase in fertilizer adoption among small-scale farms than large-scale farms. Despite the rapid diffusion of maize hybrids in Kenya, fertilizer use has remained low particularly among smallholders in marginal environments (Hassan, Murithi, and Kamau 1998). Increased fertilizer use is considered important, particularly in the high and medium zones where more than 70% of Kenya's maize area is found, and where the potential for productivity growth is greatest.

Initially, maize research focused on highland areas. Maize improvement work at the coast began in 1952 at the Kibarani station in Kilifi. A breeding programme for the coastal lowlands was initiated in response to a maize rust (*Puccinia polysora*) epidemic in the 1960s along the East African coast. Although a resistant "Rpp" maize variety was developed and released in 1966, it did not have an impact on grain yield. Another variety, Pioneer x 105A , was released in 1973 but was later withdrawn due to proprietary rights conflict.

In 1974, the broad-based Coast Composite was released. The variety was developed from introduced tropical material with tolerance/resistance to maize rust. The first hybrid for the lowlands was released in 1989: Pwani hybrid 1 (PH1), a variety with short maturity (105 days) and higher yield potential than Coast Composite (Table 2). A second hybrid, Pwani hybrid 4 (PH4) with a higher yield potential followed in 1995. Despite these releases, average maize yields were low and ranged between 1t/ha to 1.5 t/ha when the potential for the area was estimated at over 3 t/ha. The low yield could partly be attributed to low adoption of new varieties and continued use of local varieties. It is therefore important to examine the current farming situation, estimate adoption rate of modern varieties, and factors that influence adoption.

Table 2. Recommended varieties for coastal lowlands, Kenya.

Variety	Year of release	Potential yield(t/ha)	Days to maturity
Coast Composite	1974	3.8	140
Pwani Hybrid 1	1989	4.8	105
Pwani Hybrid 4	1995	5.4	120

The major objective of this study is to identify technical and socioeconomic factors affecting adoption of improved maize technologies. Researchers can use the study results to modify research according to key technical and socioeconomic issues that farmers consider important in adopting maize technologies. The findings could also help extension services and has important implications for policy, especially in regards to input suppliers, credit, and storage. It is hoped that subsequent research, extension, and policy interventions will lead to an increase in maize productivity, improved household food security, and higher incomes for primary producers and secondary beneficiaries.

Study Area

This study covers two Districts in the Coast Province: Kilifi, north of Mombassa, and Kwale, south of Mombassa (Figure 1). Kilifi District occupies the area along the coast from Mombasa at the southern end to the Tana River Delta, and east of Tsavo East National Park. It covers an area of 12,414 km^2. Administratively, Kilifi is divided into four Divisions: Kaloleni, Bahari, Malindi, and Ganze. Topographically, it is divided into the Coastal Plain, the Foot Plateau, the Coastal Range, the Nyika Plateau, the Tana River Basin and Lowlands, and the Plateau. Altitudes range from sea level on the Coastal Plain to 705 m on the Coastal Range to a maximum of 900 m on the Plateau.

Kwale District stretches along the coast from Mombassa in the north to the Tanzanian border in the south. It covers an area of 8,332 km^2 and consists of four Divisions: Matuga, Kinango, Kubo, and Msambweni. Topographically, the area falls into four categories: the Coastal Plain, the Foot Plateau, the Coastal Range, and the Nyika Plateau. Altitudes range from sea level to about 420 m in the Shimba Hills, through to a gentle westward descent and subsequent ascent to about 849 m on Kilibasi hill on the border with the Taita-Taveta District. The Kwale District differs from the Kilifi District in altitude, soil types, and climatic conditions.

Average annual rainfall in the two Districts range from 400 mm in the hinterland to over 1,200 mm at the coast. Rainfall is highest at the coast and decreases northwards. This graduation is particularly pronounced in Kilifi District. Rainfall is bimodal; the major rainy season begins in April and ends in July, with a peak period in May. The minor rainy season, from October to November, is becoming increasingly unreliable for crop cultivation. The bimodal pattern is most prominent in the south but barely noticeable in the hinterland and the north, where rainfall is unreliable and varies widely from year to year. The minimum annual rainfall of 750 mm for permanent agriculture is guaranteed in nine out of ten years on the narrow coastal belt south of Kilifi District to Shimoni in Kwale District. Temperatures are generally high with small variations. Average temperatures range from 26-30°C on the coast to 30-34°C in the hinterland. Average relative humidity is about 65% but decreases with increasing distance from the coast.

There are several soil types in the two Districts. They differ in depth, texture, physical, and chemical properties. The eastern coastline has

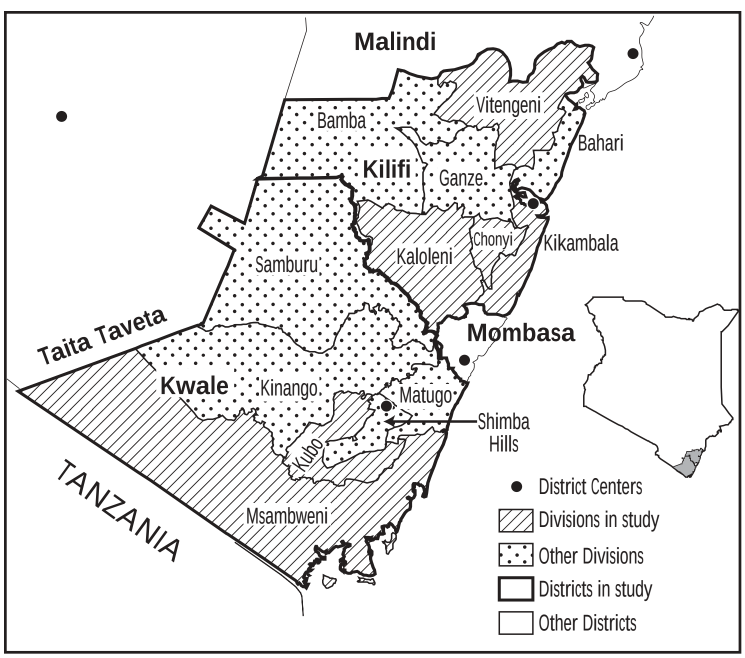

Figure 1. Kilifi and Kwale Districts and Divisions, Coast Province, Kenya.

heavily weathered soils called ferasols. There is gradual transition from acrisols, luvisols, and planosols to the less weathered cambisols and lithosols. This transition reflects the decreasing mean annual rainfall. Most soils are characterized by low structural stability and are sensitive to erosion. Soil fertility is generally low to very low because of the sandy topsoil and low organic matter content. However there are exceptions; for example in the coconut-cassava zone (see next section), soils are of medium fertility and less sandy, while heavy clay soils occur in other regions.

Agroecological Zones

According to the agroclimatic zoning for maize production environments (Hassan 1998), a classification used by the maize breeding programs of the International Maize and Wheat Improvement Center (CIMMYT) and the Kenya Agricultural Research Institute (KARI), about half of the two Districts under study fall in the lowland tropics (a band of about 80 km wide along the coast), while the rest is not considered suitable for maize production. According to the Farm Management Handbook of Kenya (Jaetzold 1983), the two Districts are distributed over five agroecological zones characterized by climatic, topographic, soil, and other environmental features that influence the potential of agricultural development.

The lowland sugar cane zone (coastal lowlands 2, CL2) occurs as a pocket in Kwale District only and is the wettest zone. It has an annual rainfall of more than 1,200 mm but has relatively poor soils and hence is classified as medium in its potential for crop cultivation. The CL2 covers about 23,500 hectares and is suitable for coconut and cassava production.

Both the coconut-cassava (CL3) and cashew nut-cassava zones (CL4) represent areas in the coastal lowlands where most agricultural activities take place. The CL3 zone occurs in both Districts and receives over 1,000 mm of rainfall. It is the main cropping zone of the two Districts and consists of pockets of land on or close to the Coastal Plain and on the Coastal Range. The CL4 zone occurs extensively in both Districts with a greater part in Kilifi. It has a mean annual rainfall of between 900 and 1,000 mm and low to medium potential for crop production.

The lowland livestock and millet zone (CL5) and the ranching zone (CL6) are located in the hinterland and are more suitable for livestock rearing than crop production. The CL5 is a semi-arid region with only 700 to 900 mm of annual rainfall. The CL6 has an average rainfall of less than 700 mm per year. It is characterized by poor soils and has the lowest potential for agricultural land use.

Farming Systems

A major feature of agriculture in the coastal zone has been the rapid change from sorghum and millet production to maize, cassava, and rice production over the course of the last century (Waaijenberg 1994). Maize has become the dominant staple while sorghum and millets have disappeared from the area. Agriculture is still the main activity of the region, and crop and livestock sales are the major source of income for most households. Money for school fees, labor for farm activities, and food in periods of scarcity is often secured from the sale of cash crops. Mixed cropping is practiced in all areas. Both tree and annual crops are grown and intercropping is common. This combination varies from place to place but in general, there is a decrease in the number of trees as compared to annual crops from the coast to the hinterland in the west.

Although annual crops can generate income, they are usually produced primarily for human consumption and only sold if there is a surplus or sudden need for cash. Maize, cassava, cowpea, green grams, sweet potatoes, and rice are major crops; pigeon pea, beans, bananas, and vegetables are minor crops. Maize is the most important annual staple crop. Current maize yields in CL2 and CL3 are estimated between 0.5 t/ha to 1.5 t/ha although they may be as low as 0.3 t / ha during the short (minor) rainy season. In zones CL4 and CL5, yields are estimated at between 0.3 t/ha and 1.0 t/ha.

Cassava is a subsidiary staple in the two Districts and is increasingly becoming an important cash crop. It is regarded as an important security crop because of its tolerance to drought, ability to give reasonable yields on poor soils, low external input and labor requirements, and the option of harvesting over a long period after the first season. The next most important annual crop is cowpea. However, even though cowpea is also drought tolerant, it is very vulnerable to pests and diseases, which often leads to very low yields.

Tree cultivation, which is very common and covers a large area in zones CL3 and CL4, is an important source of regular income. Major tree crops are coconuts, cashew nuts, citrus, Bixa, and mangoes. Trees grow easily without much labor input and the fruits are sold for cash. Coconuts were the most important tree crops in both Districts until recently; now farmers in Kwale rank Bixa as the number one cash crop. Some farmers rent out trees for a yearly fee to tenants who are entitled to harvest all the fruits during the season.

Citrus is important in Kwale District but faces marketing problems due to poor infrastructure and seasonality of production, which leads to low farm-gate prices. Both improved and local varieties are grown. Mangoes are grown in both Districts. Tree crops are estimated to contribute over 65% of farm produce value in zones CL2 and CL3, while in zone CL4, 60% of farm produce is from annual crops.

Distance from markets and the small number of marketing outlets are a major constraint to agricultural income generation. Poor infrastructure, perishable farm produce, lack of organized marketing, and the small number of middlemen in the area also mean that agricultural prices and consequently farm income, are low. Several commodities are handled through formal markets where prices and conditions are regulated by the government. They include maize, rice, sugar cane, cashew nut, Bixa, cotton, and copra. These markets are dominated by large purchasing organizations such as the National Cereals and Production Board, Kenya Cashew Nuts Limited, and Kenya Bixa Limited. Cooperatives, middlemen, and end-users are licensed buying agents for these organizations. Since the deregulation of cereal markets in the 1990s, however, food crops like maize and rice are mostly handled through informal markets (influenced only minimally by regulations) and where prices tend to be lower than in formal markets. Informal markets also handle vegetables and fruit, cassava, sweet potatoes, tomatoes, mangoes, bananas, papaya, pineapples, citrus, and fresh coconuts. Mombasa and export markets absorb most fruits and vegetables but seasonal surpluses occur for citrus, mangoes, and pineapples, especially in Kilifi.

Livestock is an important enterprise in both Districts, both for home consumption and as an income source. Income is earned through the sale of products such as eggs and milk or the occasional sale of animals, hides, and skins. Cattle and goats are sold to meet major or unexpected cash needs such as medical expenses and school fees. Cattle are also sold during periods of food scarcity to raise cash to purchase food.

The dry hinterlands CL5 and CL6 are particularly heavily stocked with indigenous cattle, goats, sheep, and poultry. The most common cattle breed is the small East African Zebu, which is kept under traditional rangeland husbandry systems. With the expansion of agriculture, there is increasing competition between crop production and livestock rearing. Tethering has therefore become a popular alternative method of managing livestock, particularly in the CL3 and CL4 zones. A variety of crossbreeds and pure European and Sahiwal cattle breeds are reared for milk production, particularly in the Kilifi coastal strip.

Small ruminants are very popular, especially goats (East African dwarf types) and sheep (red Masaai type). Poultry consists mainly of chickens though a number of farmers keep ducks, turkeys, and geese. Local breeds are common although a number of farmers and women's group rear improved poultry for commercial purposes.

Demographics

Kilifi and Kwale Districts are home to a mixture of people of different races and ethnic groups. The majority (over 80%) are Mijikenda, a collection of 9 ethnic groups consisting of the Giriama (who constitute a majority in Kilifi District), Chonyi, Jibana, Kambe, Ribe, Rabai, and Kauma, and the Digo and Duruma (the majority in Kwale district), a small component of the South Coast Mijikenda. Others groups include immigrant groups such as the Kamba (an important minority in Kwale District), Taita, Kikuyu, Luo, and Luhya. Swahili and Shirazi are indigenous people and occupy the coastal towns and trading centers. Non-African Kenyans and foreign residents constitute a negligible minority.

The Mijikenda settled in the Kilifi and Kwale Districts about 400 years ago (Waaijenberg 1994). Until the 19th century, they lived in nine *makaya* or fortified villages on top of wooded hilltops growing sorghum, millets, and cowpea. During the 19th century, they left the *makaya* to settle on the uplands and plateaus and adopted maize, rice, and cassava as staple foods.

In 1999, Kilifi District had a population of 544,000 people with a density of 114 people per km^2, while Kwale District had 496,000 people with a density of 60 people per km^2 (Central Bureau of Statistics 2001). Population densities vary widely, reflecting the diversity of climatic conditions and land productivity. The coastal strip has a population density of over 300 people per km^2 while the arid hinterland has less than 20 people per km^2.

Table 3. Household characteristics, Kilifi and Kwale Districts, Coast Province, Kenya.

Household characteristics	Kwale	Kilifi
Members per household (no.)	7.5	9.2
Female head of household (%)	38.2	21.5
Education of household head (yrs)	4.8	6.5
Head has non-farm activity (%)	44.7	41.8
Cash income (Ksh/month)†	5,913	14,045
Total land area (acres)††	**12.4**	**11.3**

Note: † Ksh = Kenyan shilling; US$1 = 60.26 Ksh (average for 1998)
†† 1 acre = 0.405 ha.
Source: KARI-ILRI detailed survey of dairy adoption history, March-May, 1998.

Two types of households are found in the area—extended and nuclear families. Extended families are popular among the Mijikenda, while non-Mijikenda communities tend to have nuclear families. The higher figure of average household members for Kilifi (Table 3) is due to polygamy.

Landholdings vary in size, according to personal wealth, agroecological zone, and settlement and legal status. In general, settlement areas and communal holdings tend to have large acreages. The land tenure system falls under a variety of legal regimes. Where land adjudication has taken place, residents hold freehold title deeds. In other areas, although adjudication has taken place or is in process, title deeds have not been issued or acquired. In places where land adjudication has not occurred, clans own land communally. Even where land is not adjudicated by the government, clearly defined and recognized individual or family ownership and land-use rights exist. A few households rent land on an annual basis where only food crops are grown. Squatters are also prominent in some parts of the District. With few exceptions, rights to land–whether adjudicated or not and whether occupied by coastal groups or immigrants–are held by male household heads and passed on through male inheritance according to customary tradition.

Gender roles vary with ethnicity in terms of time allocated to farm labor, livestock ownership and management, decision making on farm labor, and ownership and allocation of land for agricultural activities. The main source of labor for farm activities is the household. Most farming activities are allocated according to a strict gender code of labor where men, women and children all contribute. Men own livestock (cattle, sheep, goats), although in a few households, women and children own and are also responsible for rearing sheep, goats, and chickens, while men look after cattle.

Men tend to be responsible for growing and marketing tree crops while women are responsible for producing food crops. Generally decision-making is purely a man's responsibility in the Mijikenda community. However, there is some consultation among households members before final decisions are made. On the other hand, women (or any other responsible member of non-Mujikenda household) can make decisions in the absence of the man. In female-headed households women make all the decisions.

Maize Research

As stated earlier, three improved maize varieties were developed for the lowland coastal belt— the open-pollinated Coast Composite, the PH1 and PH4. These new varieties came with a set of recommendations with agronomic packages such as seed rates, spatial arrangements, plant populations, weed control measures, fertilizer levels, and insect pest control. Recommendations are for maize planted in pure stands (Table 4).

Table 4. Technology specifications for improved maize varieties, Kilifi and Kwale Districts, Coast Province, Kenya.

	Coast Composite	Pwani Hybrid 1 (PH1)	Pwani Hybrid 4 (PH4)
Seed rate (kg/ha)	7	10	10
Spacing (m)	0.9 x 0.3 (1 seed/hill) 0.9 x 0.6 (2 seeds/hill)	0.75 x 0.25 (1 seed/hill) 0.75 x 0.50 (2 seeds/hill)	0.75 x 0.25 (1 seed/hill) 0.75 x 0.50 (2 seeds/hill)
Plant population (plants /ha)	37,000	53,000	53,000
Fertilizer (kg/ha): Basal application	46 kg P_2O_5	46 kg P_2O_5	46 kg P_2O_5
Topdressing	60 kg N	60 kg N	60 kg N
Weed control	At least 2 weedings: at 4-5 leaves (3 weeks after sowing), the second weeding, and at 8-10 leaves	At least 2 weedings: at 4-5 leaves (3 weeks after sowing), the second weeding, and 8-10 leaves	At least 2 weedings: at 4-5 leaves (3 weeks after sowing), the second weeding, and 8-10 leaves
Stem borer control	Bulldock, 8 kg/ha[†]	Bulldock, 8 kg/ha	Bulldock, 8 kg/ha
Control of storage pests	Actellic super	Actellic super	Actellic super

† Bulldock is a granular insecticide sold in eastern Africa.

It was recommended that varieties should be planted before the onset of rains in rows at various spacings. Recommended spacing is 0.9 m x 0.3 m for Coast Composite, and 0.75 m x 0.25 m for hybrids. Lower plant populations are recommended for areas with low moisture or in marginal zones. Thinning might be necessary to remove extra plants resulting from extra seeds sown and two weedings are necessary. For stem-borer prevention a pinch (3.5g) of stemborer dust (Bulldog or Dipterex) in the funnel is recommended at the 3-4 leaf stage. A repeat application should be considered at the 8-10 leaf stage. For harvesting, maize should be at physiological maturity, indicated by the formation of a black layer on the maize kernel at the point of attachment to the cob. The maize should be properly dried, treated with storage insecticides such as Actellic super, and stored.

In the past, seeds of improved varieties were released to the Kenya Seed Company for bulking and packaging. The technology was then passed on to extension officers who transferred it to farmers through farm visits and demonstration plots. Some farmers learned about the technology from neighbors and friends. Field days and agricultural shows also served as means of dissemination.

The Agriculture Finance Cooperation (AFC) and the Cooperative Bank of Kenya are the primary sources of credit. However, most farmers in Kwale and Kilifi lack the required collateral for credit from the AFC. Formal credit is mainly dispensed through cooperatives.

Recovery of credit has been poor and can be attributed to inefficiencies within institutions as well as technical inefficiencies, such as inadequate crop packages, untimely distribution of inputs, and crop failure.

Methodology

Data collection

Kwale and Kilifi Districts were selected for the study because they constituted the two major maize production Districts at the coast. Two hundred households were selected using a multi-stage sampling procedure. First, five locations (administrative unit under division) were selected in each District. Two villages were then randomly selected in each location. Finally, a list of household heads was compiled and 20 households were selected from each village; 15 households were selected using systematic sampling and an additional 5 female-headed households were purposely selected.

The work program was discussed and the questionnaire refined during a preparatory meeting with study collaborators. The survey was carried out after the harvest of 1998 and covered farmers' experiences with maize over the last five years. The questionnaire was pre-tested against a sample of 20 households (both male- and female-headed) and necessary corrections made. Consideration on timing was observed to ensure that actual interviews took place before the harvest.

Analytical framework

For this study, adopters were defined as farmers who grew certified seed (Coast Composite, PH1, PH4, or Pioneer hybrid) on at least 1 acre of land during the study year, 1998. The sample population was divided into adopters and non-adopters and compared according to different variables. Differences were analyzed using Chi^2 tests. A more comprehensive model was then analyzed using qualitative response models (Feder, Just, and Zilberman 1985). The two models commonly used in adoption studies are the logit and probit models, both of which have a dependent variable bound between 0 and 1 and are convenient for dichotomous adoption variables (Amemiya 1981). Since both logit and probit models produce similar statistical results, the simpler logit model was used to study the effect of different factors on adoption.

The independent variable is a dichotomous variable indicating the adoption of improved maize varieties (1= yes and 0= no). Independent variables relate to farmers' resources (human and physical – age of household head, education, family size, and others) external support systems (extension and credit), characteristics of the technology, and geographical characteristics.

Hypotheses

It is hypothesized that household head, farm characteristics, and farmer's access to institutional support influence adoption of improved maize varieties. Specifically, the following key hypotheses were tested.

Characteristics of household head:

- The farmer's age has a direct bearing on his or her approach – open or conservative – and levels of exposure to new technologies. Furthermore, age has a bearing as some agricultural technologies need physical labor input. It is hypothesized that a farmer's age can increase or decrease the probability of adopting improved maize technologies.
- Gender of the household head is considered a factor in adoption since women often have less access to improved technologies.
- A household head's occupation has a corresponding implication on his or her income and on the amount of time spent on farm activities. A household head who is permanently employed has an assured income and is therefore more likely to hire labor and adopt recommended maize technologies.
- Education levels influence decision-making. A well-educated farmer can access and assimilate information better and is therefore more likely to adopt improved maize varieties.
- Non-Mijikenda farmers are more commercially oriented and more likely to adopt improved maize production technologies.
- The District of the farmer also influences adoption rates. Farmers in Kwale are hypothesized to be better adopters than those in Kilifi because many are migrants from other regions who have been exposed to improved technologies.

Characteristics of the farm:

- Farm size dictates the amount of maize grown and input levels. Small farms have a greater likelihood of adopting improved varieties as they are more intensively managed.
- The area under tree crops or number of trees grown has a positive relationship with income levels. Farms with a larger area under tree crops earn more income and this increases the probability of adopting maize technologies.
- Similarly, livestock ownership increases income levels and probability of adoption.
- Use of hired labor increases opportunities to undertake other farm activities. The ability to hire labor is also an indicator of wealth and hence increases probability of adoption.
- The purpose for which maize is grown–subsistence or the market– influences variety selection. A commercially oriented farmer would be more interested in high yields and is more likely to adopt improved maize varieties.
- A larger area under maize is considered to increase a farmer's interest in new technologies.

Institutional support:

- Extension services are a major source of technical information for farmers. It is, therefore, hypothesized that contact or proximity to extension agents increases adoption.
- Similarly, farmers who participate in farmer training courses and listen regularly to agricultural programs on the radio are assumed to be more likely adopters.
- Farmers who have access to credit have more options to acquire often costly new technologies such as improved seed or fertilizer.
- Membership in an organization, such as a farmers association, leads to better access to technical information. Members also receive preferential treatment from extension workers. Membership in a group is therefore hypothesized to be positively associated with adoption.

Current Maize Production Practices

Household Characteristics

Table 5 shows major characteristics of heads of households for adopters (80 farmers or 40%) and non-adopters (120 farmers or 60%). Nearly 67% of all respondents were literate and 28% were female heads of household. On average, respondents were 53 years of age and had 5 years of formal education. Two household head characteristics were different between the two groups: literacy and district. Literacy was higher among adopters (75%) than non-adopters (61%). Moreover, more adopters live in Kilifi than Kwale. Thirty-two out of 100 farmers in Kilifi are adopters, while in Kwale, only 28 out of 100 were adopters (Appendix 1).

Each household had an average of 9 members and an average farm size of 9.5 acres, of which 2.9 acres were grown to maize. Adopters had significantly more household members (11) than non-adopters (8), and more acreage in maize (3.7 acres for adopters and 2.6 acres for non-adopters). Adopters also had higher total income (43,000 Ksh/yr vs. 30,000 Ksh/yr)[4] and were more likely to hire tractors (67% vs. 51% of farmers, data not shown). Total on-farm (16,000 Ksh/yr) and off-farm incomes (18,000 Ksh/yr) were not significantly different between groups. The average acreage under maize was three acres. Most respondents (72%, data not shown) grew maize with other crops, such as cassava, cowpeas, green grams, and beans.

Farmers in the area also used a number of farm implements for maize production, such as hoes, oxen ploughs and carts, tractor ploughs, machete, slashers and sickles. Almost all respondents owned hand hoes with an average of 5 hoes per household.

Institutional variables other than credit were different between groups. The percentage of farmers who received credit was low for both adopters (21%) and non-adopters (15%). There were, however, significant differences in access to extension between the two groups as illustrated by variables such as the percentage of farmers who had contact with extension (54% adopters, 33% non-adopters), farmers who participated in farmer courses (34% adopters, 18% non-adopters), and farmers who regularly listened to agricultural programs on the radio (64% adopters, 43% non-adopters).

Maize Varieties

Farmers' actual practices differed from recommendations in many aspects. Recommended varieties, in particular, were not as popular as local varieties, which were grown by 70% of sample households (Table 6). A majority of households (70%) grew one variety at a time; 18% grew two varieties, and 2% grew three or four varieties. Among improved varieties, Coast Composite was the most popular (22%), followed by PH1 (21%) and PH4 (5%).

[4] Ksh = Kenya shilling; US$ 1 = 60.26 Ksh (1998)

Table 5. Demographic and socioeconomic characteristics of sample households, Kilifi and Kwale Districts, Coast Province, Kenya.

	Mean value			*t*-test	*X2* test	
Characteristic	Non-adopters	Adopters	Total	Significant difference (2-tail equal standard assumed)	Pearson's Chi Square	Significance of test (2-sided)
Household head:						
Age of household head (yrs)	52.01	55.44	53.04	0.107		
Female-headed household (% respondents)	30.8	22.5	27.5		1.67	0.196
Literacy (% farmers)	60.8	75.0	66.5		4.70	0.095*
Formal education (yrs)	4.86	4.32	4.69	0.414		
Mijikenda (% farmers)	69.2	68.8	69.0		0.004	0.95
Kilifi District (% farmers)	45.0	57.5	50.0		3	0.083*
Farm:						
Household members (no.)	8.45	11.45	9.35	0.002		***
Off-farm income (Ksh/yr)	13,770	21,538	16,100	0.156		
Farm income (Ksh/yr)	15,820	21,863	17,633	0.173		
Annual total income (Ksh/yr)	29,589	43,401	33,733	0.043		**
Farm size (acres)†	8.96	10.84	9.53	0.176		
Acreage in maize, 1998 (acres)†	2.56	3.72	2.91	0.001		***
Tractors (no.)	5.8	1.3	4.0	0.106		
Has cattle (% farmers)	28.3	36.3	31.5		1.39	0.238
Institutional:						
Farm has extension contact (% farmers)	32.5	53.8	41.0		9.00	0.003***
Listens to agricultural programs on radio (% farmers)	43.3	63.8	51.5		8.01	0.005**
Participated in course (% farmers)	18.3	33.8	24.5		6.17	0.013**
Received credit (% farmers)	15.0	21.3	17.5		1.30	0.254
Sample size	140	60	200			

Note: *= significantly different at 10%, **= significantly different at 5%, ***=significantly different at 1%.
†1 acre = 0.405 ha.

Figure 2 shows the average land under maize for different varieties grown between 1994-1998. This graph should be interpreted as the distribution of maize acreage over different varieties in the region and not at the farm level, since farmers usually only grow one variety. Local varieties had the highest acreage, between 2.3 and 2.7 acres per maize farm. Coast Composite was the most popular (between 0.3 and 0.4 acres), followed by PH1 and other varieties. Land area under PH4 was almost negligible. From 1994 to 1998, maize acreage decreased gradually.

Table 6. Maize varieties grown , Kilifi and Kwale Districts, Coast Province, Kenya.

Variety	Farmers (%)
Local varieties	70
Coast composite	22
Pwani Hybrid 1	21
Other varieties	1

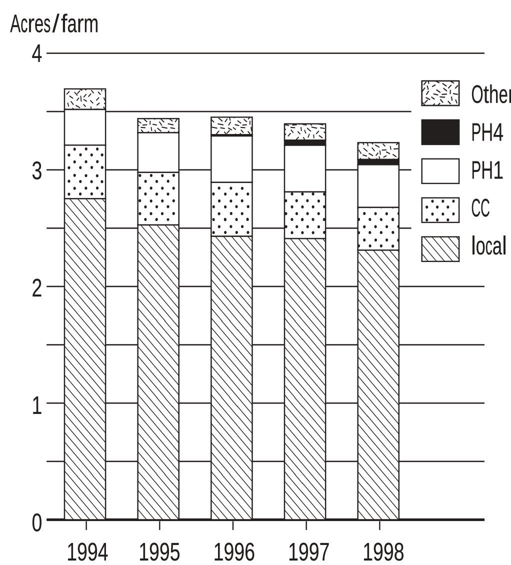

Figure 2. Average acreages of maize varieties, 1994-1998, over all maize-producing households (N=170 to 185), Kilifi and Kwale Districts, Coast Province, Kenya.

Table 7 presents characteristics of local and improved varieties, and reasons farmers gave for using them.

Table 7. Major varieties grown by farmers and reasons for their preferences, Kilifi and Kwale Districts, Coast Province, Kenya.

Variety	Type	Color / texture	Features
Mdzihana	Local	Purple	Drought tolerant. Competes with weeds favorably. Early maturing. Good storage qualities. Good taste. Good pounding qualities.
Kanjerenjere	Local	Yellow	Short maturity period. Mainly grown in short rain.
Mwangongo	Local	Red	Early maturing. Stores well. Good pounding qualities.
Mengawa	Local	White	Good yield. Stores well. Good pounding qualities.
Coast Composite	Improved, open- pollinated	White, semi- dent	Late maturing. Big cobs. Mainly sold as green maize. Does not store well. Poor pounding qualities.
Pwani Hybrid 1	Improved, hybrid	White, semi-flint	Early maturing (food availability early in the season). Drought tolerant. Good grain filling.
Pwani Hybrid 4	Improved, hybrid	White, semi-flint	Early maturing (food availability early in the season). Drought tolerant. Good grain filling.

More than half of farmers (54.4%) used their own recycled seed, while only 32.8% purchased seed. Only 65.2% of seed buyers bought certified seed. Neighbors, relief food projects within the locality, and cooperatives were sources of uncertified seed. Most farmers (67%) preferred 2-kg seed packages.

The most cited constraints to purchasing improved varieties were non-availability (29% of farmers) and high cost of seed (22.5%) (Table 8). The seed to grain price ratio was 10 to 1. Other reasons were lack of knowledge and exposure to varieties (13%).

Unfavorable characteristics, such as high susceptibility to storage pests and poor processing quality of improved varieties were mentioned by less than 10% of respondents. In the Mijikenda community, maize is generally pounded before milling to remove the hull, a process that is easier with flint varieties. Softer dent varieties break easily during pounding, leading to a loss in flour. Improved maize varieties tend to be more dented and hence have poor pounding characteristics.

Table 8. Constraints to using improved varieties, Kilifi and Kwale Districts, Coast Province, Kenya.

Constraint	Farmers (%)
Non-availability	29.0
High price of seed	22.5
Lack of knowledge	13.0
Unfavorable characteristic of varieties	6.0
Susceptibility to storage pests	4.5

Fertilizer and Other Production Techniques

The use of inorganic fertilizer was the least popular recommendation among farmers; only 6% of farmers adopted the practice. More farmers (23.5%) used organic manure, but most did not use any fertilizer. High cost (36.5% of respondents), a perception that soils had adequate fertility, and lack of knowledge were among reasons farmers gave for not applying fertilizer. Some respondents thought that fertilizer was bad for the soil, while some had never heard of fertilizers (Table 9).

Row planting was the most popular improved technology among farmers (72%). Twenty-eight percent of farmers grew maize in triangular configurations commonly referred to as *mafiga,* which is perceived as less time consuming and tiresome. Farmers used higher seed rates than the recommended 1-2 seeds per hill. Farmer seed rates varied between 1 and 5 seeds per hill. The most popular seed rate was 3 seeds per hill (55.3%), followed by 2 seeds per hill (24%), and 4 seeds per hill (15.6%). Still, plant density per acre is lower than recommended since farmers used wider spacing to allow for other crops. Pesticides are rarely used (15%) and consist mostly of bulldock or dipterex, which are used to control stemborers. Farmers in the region weed two or three times per season.

Table 9. Constraints to fertilizer use, Kilifi and Kwale Districts, Coast Province, Kenya.

Constraint	Farmers (%)
High price of fertilizer	36.5
Soil fertility adequate	20.5
Lack of knowledge	14.5
Not available when required	9.5
Lack of credit/cash to purchase	2.0

Harvesting is done manually using mostly family labor. Most farmers (66%) store maize in cobs with their husks in traditional storage structures called *Uchaga.* Few farmers (9%) used granaries. Shelled maize is also stored in plastic containers, sacks, pots, and steel containers (Table 10).

Most respondents (75.8%) reported that maize yields had decreased over the past five years. Unfavorable rains, low soil fertility, pests and diseases, and lack of cash to meet expenses for farming activities were among the reasons given for the decrease. Only 14.7% of farmers reported yield increases, which they attributed to adoption of better farming practices, good rainfall, more land available for maize, and use of oxen plough. Only 10% of farmers reported constant maize yields.

Table 10. Storage methods, Kilifi and Kwale Districts, Coast Province, Kenya.

Storage method	Farmers (%)
Uchaga	66
Plastic containers	13
Granary	9
Sacks	5
Pots	5
Steel containers	2

Adoption of Maize Production Technologies

Evolution of Adoption

Feder, Just, and Zilberman (1985) defined adoption as the degree of use of a new technology when a farmer has full information about the technology and its potential. On the other hand, aggregate adoption is the process by which a new technology spreads or diffuses within a region. A distinction exists between adoption at individual household levels and aggregate adoption within a targeted region. If an innovation is modified periodically, however, the equilibrium level of adoption will not be achieved. As the new technology is introduced some farmers will experiment with it before adopting. Farmers are also known to adopt technological packages in steps, beginning with simpler and cheaper technologies. These situations require the use of econometric procedures that can capture both the rate and process of adoption. The "rate of adoption" is defined as the proportion of farmers who have adopted a technology over time. "The incidence of adoption" is defined as the percentage of farmers using a technology at a specific point in time. "The intensity of adoption" is defined as the level of adoption of a given technology (for example, the number of hectares planted with improved seed or the amount of fertilizer applied per hectare).

A common procedure for assessing the evolution of the rate of adoption over time is the estimation of a logarithmic curve. If adoption changes by a rate of r per year, the adoption rate y_t at time t can be derived from y_t, the adoption rate at time *0,* with the following formula:

$$y_t = (1 + r)^t \; y_0$$

After logarithmic transformation, the adoption growth rate r can be conveniently estimated by linear regression of $\ln(y_t)$ on time t:

$$\ln(y_t) = \ln(y_0) + \ln(1 + r)t$$

The trend line was constructed using data on the proportion of farmers who adopted an improved technical innovation over time (CIMMYT 1993).

The cumulative rate of adoption for improved maize varieties evolved from zero in the 1970s to 38% in 1998 (Figure 3). Before 1994, only one improved variety, Coast Composite, was available. During this period, adoption rates stayed below 15%. After 1994, several other varieties became available which is likely to have influenced the rapid increase in adoption up to 38%.

Adoption of fertilizer in the coastal region is substantially less than for improved maize seed. In 1998, the cumulative adoption of fertilizer was only 9%. The use of fertilizers is not common mainly because of its cost and non-availability at the farm level. Moreover, many farmers who tried fertilizer reported having stopped the practice.

Factors Influencing Adoption of Improved Maize Varieties

To analyze factors that influence adoption of improved maize varieties (a binary variable), a logistic regression was used, with head of the household characteristics, farm characteristics, and institutional support variables as explanatory variables. Table 11 shows the logit output and contribution of each variable towards adoption of improved maize varieties. First, all farmers were pooled and a regression was run on all maize farmers without missing values for any of the variables.

Only two variables were significant for household head characteristics— permanent off-farm employment and district of residence. Off-farm employment had a negative impact on the use of improved varieties (probably reflecting the employed farmer's lowered interest in farming). Farmers in Kilifi District used more improved seed than those in Kwale. Gender did not have a significant impact on adoption. Farm characteristics that made a significant impact on uptake of the improved varieties were hiring of labor and off-farm income**.** Hiring labor might not directly influence adoption of improved varieties, but it is a proxy for available cash to invest in agricultural production. Off-farm income directly increased cash available for investment. The institutional environment also mattered: farmers who had extension contact and those who listened to agricultural radio programs were more likely to adopt new varieties, but availability of credit or membership in organizations did not seem to have an impact. Neither acreage nor commercialization of maize had significant impacts on adoption.

Since the two Districts had clear differences in adoption of improved varieties, separate regressions were run with interesting results. Two variables were significant, although they had contrasting differences–younger farmers in Kilifi used more new varieties than older farmers in Kwale, and while the number of trees had a positive effect in Kilifi, it had a negative effect in Kwale. While trees on farms increased revenue, they also decreased land available for maize. These divergent effects illustrate the difficulties of pooling data in adoption studies. In the two cases mentioned, the effect of the variables is cancelled out in the pooled data set.

In Kilifi, where more farmers adopted improved maize, the institutional environment clearly made a difference: credit and training courses had a significant impact. Also interestingly, farmers with larger maize acreage are less likely to adopt new varieties.

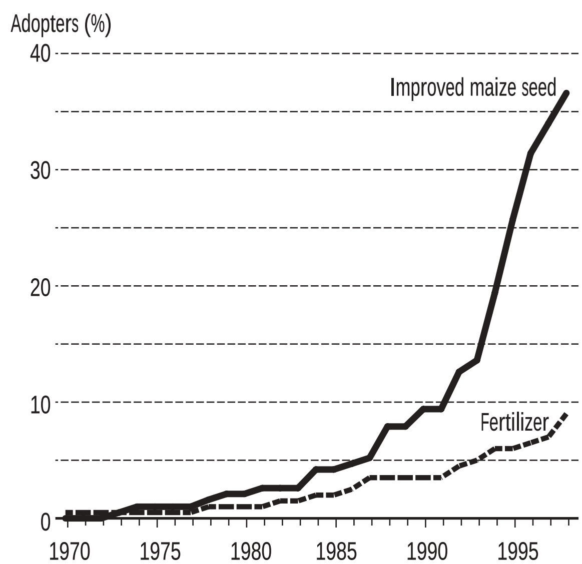

Figure 3. Cumulative rate of adoption of improved maize and fertilizer 1970-1998, Kilifi and Kwale Districts, Coast Province, Kenya.

Factors Influencing Fertilizer Adoption

Most farmers (94%) did not use fertilizer. Those who used fertilizer applied between 50 kg and 200 kg per farm. The amount of fertilizer used is a truncated variable and the most appropriate model for such a dependent quantitative variable is the tobit model. This model was estimated using the same explanatory variables as those for the adoption of maize varieties. The results are presented in Table 12.

Table 11. Factors affecting use of improved maize varieties (logistic regression), overall and by District (Kilifi and Kwale District, Coast Province), Kenya.

Variables	Overall Estimated coefficient	Standard error	*p*-value	Kilifi Estimated coefficient	Standard error	*p*-value	Kwale Estimated coefficient	Standard error	*p*-value
Household head:									
Age (yrs)	0.02	0.02	0.23	-0.10	0.05	0.05**	0.05	0.03	0.05**
Female-headed household (yes=1, no=0)	0.07	0.51	0.90	-0.24	1.12	0.83	0.22	0.84	0.79
Permanent employment	-1.60	0.84	0.06*	-7.00	2.97	0.02**	-1.62	1.26	0.20
Education (yrs)	-0.03	0.06	0.67	0.05	0.16	0.76	-0.01	0.09	0.92
Mijikenda (yes=1, no=0)	-0.55	0.59	0.35	-2.12	45.35	0.96	-0.19	0.74	0.79
District (Kilifi=1, Kwale=0)	1.24	0.54	0.02**						
Farm:									
Farm size(acres) †	0.02	0.03	0.55	0.02	0.10	0.85	0.04	0.04	0.34
Trees (no.)	0.00	0.00	0.90	0.02	0.01	0.01***	-0.001	0.001	0.07**
Cattle (no.)	-0.02	0.02	0.41	0.08	0.05	0.11	-0.10	0.10	0.33
Hires labor (yes =1, no=0)	1.09	0.49	0.03**	4.70	1.66	0.01***	0.56	0.70	0.42
On-farm income (Ksh 1,000)	0.00	0.01	0.79	-0.02	0.01	0.15	0.00	0.01	0.81
Off-farm income (Ksh 1,000)	0.02	0.01	0.01**	0.06	0.03	0.06**	0.03	0.02	0.09*
Tractors hired (no.)	-2.19	1.24	0.08	0.27	99.69	1.00	-9.09	22.09	0.68
Sells maize (yes=1, no=0)	-0.22	0.50	0.65	-1.74	1.74	0.32	0.24	0.60	0.69
Maize acreage (acres) †	-0.05	0.11	0.65	-1.24	0.50	0.01**	0.14	0.13	0.28
Institutional:									
Extension contact (yes=1, no=0)	0.73	0.42	0.08*	3.25	1.28	0.01**	-0.11	0.65	0.87
Farmers attended training course (yes=1, no=0)	0.63	0.47	0.18	3.02	1.31	0.02**	0.34	0.76	0.66
Listens to agricultural radio program (yes=1, no=0)	0.98	0.44	0.02**	2.17	1.04	0.04**	1.10	0.66	0.09*
Received credit (yes=1, no=0)	-0.20	0.55	0.72	-5.61	2.37	0.02**	0.28	0.74	0.71
Member of an organization (yes=1, no=0)	-0.12	0.45	0.79	-0.23	1.05	0.83	0.25	0.72	0.73
Constant	-3.08	1.12	0.01***	3.05	45.36	0.95	-4.65	1.72	0.01***
Correct no (%)	13			51			15		
Correct yes (%)	96			100			94		
Overall correct (%)	47			75			42		
-2 log likelihood	184			47			92		
N	172			77			95		

Note:*=significant at 10%, **=significant at 5%, ***=significant at 1%.
†1 acre = 0.405 ha.

The results show that more farmers in Kilifi used fertilizer. The significant coefficients also indicate that the Mijikenda and younger and more educated farmers used more fertilizer. Many farm characteristics are also significantly related to fertilizer use. Larger farms and farms with more cattle used more fertilizer although maize acreage had a negative impact. Higher off-farm income had a positive impact, but surprisingly, higher levels of on-farm income and hiring labor had negative effects. Institutional variables were all significant and positive except for extension contact. Listening to agricultural radio programs and having access to credit had the most impact.

Table 12. Factors affecting fertilizer use (tobit regression), Kilifi and Kwale Districts, Coast Province, Kenya.

Variable	Regression coefficient	*t*-ratio
Household head:		
Age (yrs)	-5.22	-2.92**
Female-headed household (yes =1, no=0)	-198.94	-0.06
Permanent employment income (yes=1, no=0)	-291.79	-0.15
Education (yrs)	13.99	2.76**
Mijikenda tribe member (yes-1, no=0)	77.33	2.78**
District (Kilifi=1, Kwale=0)	101.87	2.16**
Farm:		
Farm size (acres)†	7.49	2.68**
Trees (no.)	-0.004	-0.51
Cattle (no.)	3.13	2.23**
Hires labor (yes=1, no=0)	-168.24	-2.79**
On-farm income (Ksh 1,000)	-1.34	-2.28**
Off-farm income (Ksh 1,000)	0.67	2.89**
Tractors hired (no.)	-128.0	-0.02
Maize acreage (acres)†	-21.1	-2.53**
Institutional:		
Extension contact (yes=1, no=0)	-5.7	-0.52
Farmers training course attended (yes=1, no=0)	43.1	2.26**
Listens to agricultural program (yes=1, no=0)	176.3	2.99**
Received credit (yes=1, no=0)	171.8	2.87**
Member of an organization (yes=1, no=0)	37.2	1.91*
Constant	-120.8	-2.58**
Characteristics of regression:		
Sample size	183	
Number of iterations	18	
Log-likelihood function	-36.8	
Mean square error	1.63	
Squared correlation between observed and expected values	0.958	

Note: *= significant at 0.05%, ** =significant at 0.01%.
†1 acre = 0.405 ha.

Conclusion

Maize is a major food crop grown in the coastal region of Kenya and constitutes a major component of the diet of the population. Average yields however, are far below the potential of the region and low production levels create serious food deficits. Improved maize production techniques are key to resolving these deficits. Over the years, new technologies, such as new varieties and fertilizer have been introduced. Adoption has, however, remained low especially for fertilizer. This paper examined levels of adoption for different technologies, analyzed farmers' reasons for adoption or non-adoption and factors influencing adoption.

The study found that less than half of farmers grew improved varieties. Farmers preferred the cheaper and more readily available recycled seed. Poor availability of improved varieties, high cost, lack of knowledge, and unfavourable characteristics of improved varieties were among factors farmers mentioned for non-adoption. Other factors were unfavourable climatic conditions, lack of money and credit, and limited labor availability. Farmers who adopted improved varieties preferred them because they had significantly higher yields, larger cob sizes, more cobs per maize plant, and good grain filling.

Chemical fertilizers had the lowest adoption rates. Only 4.5% of respondents used them. The high price and poor availability of fertilizers, farmers' inexperience with the technology, and perception that soils were already fertile were among reasons farmers gave for not using fertilizer. Pesticide use was also low despite stemborers being major pests in the region. Only 15% of respondents controlled stalkborers in maize. Adoption of row planting was the only component of maize technologies farmers used, with over 70% adoption. No respondent adopted the entire recommended package for maize production in the region.

Regression analysis was used to analyze factors that influence adoption of improved maize varieties (logit regression on a binary variable) and fertilizer (tobit model on a quantitative truncated variable), with household head, farm characteristics and institutional environment as variables.

The results show that there was higher adoption of new varieties in Kilifi than Kwale and adoption was negatively influenced by permanent off-farm employment. A major factor influencing adoption was availability of cash. Contact with extension services, listening to agricultural radio programs, and availability of credit and training courses also had an impact.

Adoption of fertilizer was also higher in Kilifi than Kwale. In general, younger and more educated farmers used more fertilizer. Larger farms and farms with larger herd sizes and off-farm income used more fertilizer. The institutional environment–listening to radio programs and having access to credit–also had a significant impact. Other significant factors were farmers'participation in training courses and membership in groups.

The results showed that some of the earlier hypotheses could not be proved. Gender of household head did not seem to play a role in adoption. Although there were more female-headed households among non-adopters, the difference is not significant. The regression analysis did not find significant coefficients either, indicating that female-headed households are as likely to adopt as others, all other circumstances being equal. Given these results, it is therefore important that female-headed households receive equal institutional support from extension and credit services.

The hypothesis that the Mijikenda are slow adopters, a very common perception, also does not withstand scrutiny. Regression analysis on fertilizers found they adopt more than other groups. The regression on adoption of improved seed also found greater adoption in Kilifi, where the Mijikenda form the largest minority. These results show that the Mijikenda are keen adopters of new technologies if they deem them worthwhile.

Adopters had significantly more acreage in maize than non-adopters. This did not result in significant coefficients in the regressions, however. Similarly, commercialization of maize did not seem to influence adoption.

Experience with regression analysis calls for caution with interpretation of results. Many variables are closely related and can be seen as clusters. Level of education, permanent employment, and off-farm income is one such cluster: educated people are more likely to find permanent employment off the farm and earn more income. Extension variables form another cluster: farmers who have access to extension also attend more training courses and have more access to credit. Finally, District and ethnic group are closely related, with most of the non-Mijikenda living in Kwale, where they form 60% of the sample population. The close association of different variables and the resulting interrelation make the model very sensitive to specifications: dropping one variable can make another related variable significant and vice versa. Splitting the database or examining cross effects can also substantially affect results, as the example of improved maize by district shows. In general, these types of models should be used to test hypotheses that were obtained through informal surveys, induction or theory. The models should not be used to test a large number of variables that might somehow be related to adoption.

The leveling off of adoption below 40% indicates that there is still a large group of farmers whose needs are not met with available improved varieties. Breeders should be encouraged to communicate with and include farmers' criteria for selecting varieties, and incorporate attributes farmers want in improved seeds. Varieties tolerant to nitrogen and drought stress should also be made available as options to resource poor farmers.

The very low adoption rate of fertilizer is cause for concern. Since its high cost is by far the major constraint, alternative options should be sought and extended to farmers who are not able to use inorganic fertilizers. Given the high variation of soils and climate at the coast, it is also important that researchers develop site-specific recommendations.

Poor adoption rates of improved varieties also call for policy changes. The seed industry has been liberalized and new companies are now allowed to compete with the Kenya Seed Company. This will hopefully lead to an increase in supply of different varieties and reduction of seed prices. However, these changes have not yet been observed at the coast, where over 60% of farmers were recycling their own seed, whether there were local races, hybrids or composites. The implications are that there is need for involving farmers in community seed programs that include training on seed selection, multiplication, and storage.

The regression results show the major influence of the institutional environment, in particular extension and credit. Extension services need to be strengthened especially where lack of knowledge is cited as a hindrance to adoption. Availing credit for the purchase of farm inputs and implements and for hiring labour is likely to increase adoption of improved maize technologies and maize productivity as a whole in the region. Availability of new inputs could also be improved through better infrastructure and distribution networks.

The challenges of increasing the adoption rates of improved maize production technologies are great and will require the concerted efforts of farmers, researchers, extension agents, seed companies, and other stakeholders. This calls for partnerships in the implementation of such programs.

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Appendix 1.

Households in sample, Kilifi and Kwale Districts, Coast Province, Kenya.

District	Division	Location	Households in sample (no.)	Adopters[†]		Female-headed households	
				No.	%	No.	%
Kilifi	Kikambala	Mtwapa	12	9	75	1	8
			8	2	25	4	50
	Kaloleni	Ribe	10	1	10	3	30
			10	0	0	3	30
	Vitengeni	Vitengeni	12	4	33	4	33
			8	6	75	2	25
	Chonyi	Mwarakaya	10	1	10	4	40
			10	1	10	3	30
	Malindi	Goshi	1	0	0	0	0
			7	2	29	2	29
			12	6	50	3	25
	Sub-total:		**100**	**32**	**32**	**29**	**29**
Kwale	Kubo	Lukore	8	3	38	2	25
			12	4	33	3	25
		Mangawani	10	1	10	2	20
			10	0	0	3	30
	Msambweni	Dzombo	1	0	0	0	0
			10	2	20	2	20
			9	5	56	4	44
		Vanga	8	4	50	2	25
			12	3	25	4	33
		Kikoneni	10	3	30	3	30
			10	3	30	1	10
	Subtotal:		**100**	**28**	**28**	**26**	**26**
Total:			**200**	**60**	**30**	**55**	**27**

Note: [†]Defined as farmers who grew certified seed on at least one acre during 1998.

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