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The Role of Farmers in Biodiversity Conservation of Maize Landraces through Farming Systems in Kenya

Benard Musyoka Mwololo*

Graduate School of Life and Environmental Sciences, University of Tsukuba,
Tsukuba, Ibaraki 305–8572, Japan

Maize is a major Kenyan crop that contributes greatly to food and livelihood security. About 90% of Kenya's population depends on corn for their income. Small-scale farmers account for 75% of Kenya's total maize production. Maize accounts for 3% of Kenya's GDP and 25% of agricultural employment. Average yields are far below the regional level, creating serious food deficits, especially when rain is limited. Kenya's government has promoted the use of high-yield varieties (hybrids), but farmer needs have been ignored in developing these varieties. Farmers therefore continue to plant traditional landraces and varieties to reduce costs and harness the benefits of locally evolved genetic traits. Here, I studied whether promoting hybrid varieties has improved livelihoods and food security, and estimated the value of the traditional landraces.

I analyzed data from small-scale maize producers in the Taita District of Kenya's Coast Province. The hybrids generally had superior quantitative traits (height, grain yield, stover yield, and grain size) when their agro-ecological requirements were met, but their potential cannot be achieved by rural farmers because of poor management, a lack of agricultural inputs, unfavorable biotic and abiotic factors, or a combination of these factors. In contrast, the landraces had superior qualitative traits (early maturation, drought tolerance, disease resistance, and good cooking and eating qualities). They are thus important sources of traits required for local adaptation, economic stability, and sustainability. Farmers conserve and sustain important genetic resources by maintaining maize landraces. This farm-level conservation allows continuing selection, environmental interactions, and gene exchange with wild species that sustain evolution of the landraces. Their performance demonstrates the necessity of strengthening and expanding *in situ* conservation programs to maximize the diversity and utility of these plants as source materials for crop-improvement programs. Involving farmers in managing a country's indigenous genetic resources is essential, as is "participatory" plant breeding, in which farmers guide the selection of new varieties.

Key words: Biodiversity conservation, Maize landraces, Farming systems, Taita District

Introduction

Zea mays (maize or corn) is one of the oldest food grains. It belongs to tribe Maydeae of the Poaceae (Gramineae) grass family, and is the only cultivated species in its genus. Cultivated maize is a fully domesticated plant, since humans and maize have lived and evolved together since ancient times. It does not grow in the wild, cannot survive in nature, and is completely dependent on humans (Galinat, 1988; Dowswell *et al.,* 1996). Maize originated in Mexico, and spread throughout the world after Columbus's voyage to America at the end of the 15th century. The yield of maize is significantly higher under temperate than under tropical conditions, and temperate maize has a longer cultivation cycle than most tropical maize (CIMMYT, 1994). The situation for tropical maize is changing rapidly, and the potential for heterosis is beginning to be exploited on a large scale in developing countries.

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* Corresponding author: Graduate School of Life and Environmental Sciences, University of Tsukuba, Tsukuba, Ibaraki 305–8572, Japan.
E-mail: benmwololo@yahoo.com

Maize grows in a wide range of environments, and can be classified into two types, depending on the latitude and environment in which it is grown. Maize grown in warmer environments, typically between 30° N and 30° S is referred to as tropical maize; that grown under cooler climates at latitudes above 34° N and 34° S is classified as temperate maize (Dowswell *et al.,* 1996). Tropical maize can be further sub classified based on its environment: lowland, mid-altitude, and highland.

Maize Production in Kenya

Maize was introduced into Kenya in the 16th century by Portuguese traders on the east African coast, from where it slowly moved inland along with slave traders, who valued maize as an easily storable and processed grain (Smale *et al.,* 2006). Maize is a strategic food security crop, and poor yields commonly result in food shortages and famine. Today, it is Kenya's major staple food crop and is synonymous with food security, since about 90% of the population depends on it for their survival and as a source of income. As maize is Kenya's staple food, high emphasis is placed on its production. The area under maize cultivation is approximately 1.6 million ha, but the potential for future expansion is limited because of high population pressures. The average maize yield is about 2 t/ha, which is much lower than the global average of 4.2 t/ha (CIMMYT, 1994). However, the yield could potentially be increased to more than 6 t/ha (CIMMYT, 1994) through increased use of improved seeds (excluding genetically modified seeds), fertilizers, and good crop and water management.

Currently, small-scale farmers account for about 75% of the total maize production in Kenya. Maize is produced in most parts of the country for home consumption, and the surplus is sold to meet household cash needs. These sales account for 3% of Kenya's GDP and about 25% of agricultural employment. Kenya's Ministry of Agriculture, the National Cereals and Produce Board, and other sources estimate that maize consumption totals around 30 million 90-kg bags per year (TDAO, 2009).

During the past decade, Kenya's agricultural performance and that of the maize sector have been unsatisfactory, with the agricultural growth rate lagging behind the population growth rate. This trend has increased food insecurity, exacerbated poverty, decreased farmer income, and led to a loss of employment and a shift from self-sufficiency to reliance on imported food and food aid. Kenya's average poverty rate now exceeds 50% of the population. The causes of this poverty and food insecurity include low agricultural productivity, inadequate access to productive assets (land, capital), inadequate infrastructure, limited marketing opportunities, high population pressure, inadequate access to appropriate technologies, the effects of global trade, and slow institutional and sectoral reform processes.

The most prominent maize kernel types around the world (Dowswell *et al.,* 1996) are flint (*Z. mays* var. *indurata*), pop (*Z. mays* var. *everta*), dent (*Z. mays* var. *indentata*), floury (*Z. mays* var. *amylacea*), waxy (*Z. mays* var. *ceratina*), sweet (*Z. mays* var. *saccharata*), and baby ear shoot (*Z. mays* var. *tunicata*). In Kenya, the most economically important maize types grown for grain or fodder and silage production belong to the flint, dent, and floury categories. However, some quality protein maize (QPM) has been bred for improved protein quality, and is also important in some areas. Pop maize is of minor importance, but generates significant value-added when it can be sold.

Uses of Maize in Kenya

Maize in Kenya is used in various ways: as a human food source, livestock feed, and in industrial processing. As a source of food, it is used in many ways (Fig. 1a-d). The green ears are roasted on coals or boiled in salty water, with or without the leaves, and are eaten immediately on the cob. Mature dry grains are boiled and eaten whole, preferably mixed with pulses and vegetables, to produce a dish known as *githeri.* Dry grain is milled to produce a course maize meal or fine flour, which is used to make a cooked paste known as *ugali.* The grain is also soaked and cooked in water, and is then ground to make dough that is converted into a sweet drink or an alcoholic drink by fermentation. Maize flour is used to supplement wheat flour for making bread and chapatis, at a maximum of 10% to 20% of the total flour. Pop kernels are subjected to high temperatures of about 177℃ (Watson, 1988) in a hot plate to make them pop, since popcorn is a popular snack in Kenya. Baby ear shoots (baby corn) are harvested when the silk is about to

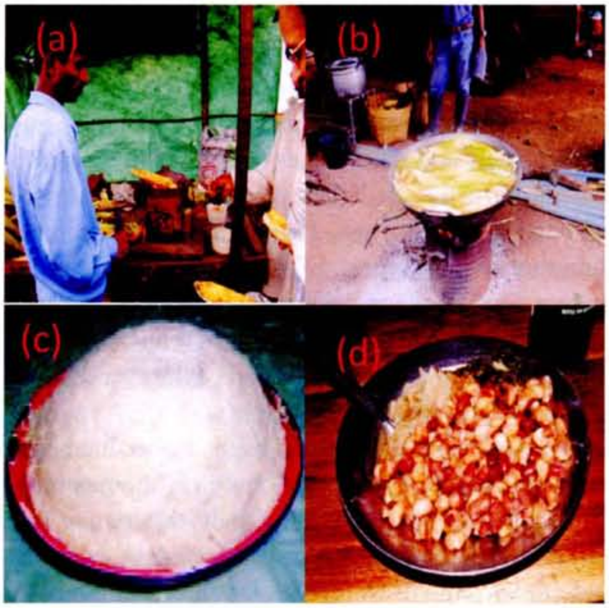

Fig. 1. Photos of some typical uses of maize in Kenya. (a) roasted, (b) boiled, (c) *ugali,* (d) *githeri.*

emerge above the leaves, and are used fresh as a salad vegetable. QPM has much better protein quality than normal maize, and its nutritional superiority has been repeatedly demonstrated in the diet of infants, small children, and also adults, particularly women (Vasal, 1994). However, this type of corn is not yet a common crop in Kenya.

The maize plant also provides excellent fodder for livestock, particularly from the tasseling stage onwards. Maize whose ears are at the doughy stage of grain development provides the best fodder; at this stage, maize surpasses all other fodder crops in dry matter production and digestible nutrients per hectare (Perry, 1988). This is also the best stage for preparing maize silage. Stover left after harvesting of the grain is also used as fodder. Maize gives a higher conversion ratio than other grains to produce meat, milk, and eggs (Lopez-Pereira, 1992). Its high starch and low fiber content make it a highly concentrated source of energy for livestock. Precise statistics on the use of maize for livestock and poultry feed are not available, but government researchers in the livestock industry believe that the largest proportion is used as poultry feed.

Industrial processing of maize through wet or dry milling is used industrially to create various food, feed, and industrial products. The wet milling process is used to produce pure starch, sweeteners (e.g., dextrose, fructose, glucose, and syrups), high-protein industrial starch, fiber, ethanol, maize oil, sweet corn milk, and creamed corn. Maize starch is the most important product of the wet milling process, and it is used for numerous food and industrial applications (Watson, 1988). The dry milling process is used to produce corn meal and other whole maize meals that are rich in bran and germ. Whole kernels are also used in the brewing industry to produce beer and distilled liquors. This industry is the largest consumer of the dry milled products.

Biotic and Abiotic Factors that Affect Maize Production in Kenya

Maize in tropical environments is attacked by a wide array of pathogens that cause significant economic damage. Wellman (1972) lists 130 diseases that affect maize crops in the tropics, versus only 85 in temperate environments. Yield losses as high as 70% have been recorded but typically range from 15 to 30% (Wellman, 1972).

Most Kenyan maize improvement programs have concentrated on the development of genetically improved high-yield maize varieties, with little emphasis on developing stable resistance to most maize diseases. However, large areas of Kenya are still planted with traditional landraces, including varieties developed by individual farmers and unimproved seed. This is one reason why the disease situation may be severe in Kenya.

Some common disease problems include root rot caused by fungal pathogens of the *Fusarium* and *pythium* species, stalk rots caused by *Helminthosporium turcicum,* leaf spots caused by *Helminthosporium carbonum,* and common leaf rust caused by *Puccinia sorghi.* Storage molds, particularly *Aspergillus flavus,* damage the grains during storage; fungi cause the most damage when the grain's moisture content is between 14% and 18% (D.R. Smith and White, 1988). Consumption of infected maize can cause severe infections and even death as a result of aflatoxin poisoning.

Striga hermonthica is a parasitic weed that damages maize crops by attaching itself to the roots of the maize, thereby robbing the maize plant of water and nutrients. The parasite also exerts a potent phytotoxic effect on the maize plants, further reducing yields (Berner *et al.,* 1997).

Many insects infest maize plants throughout their life cycle and in storage. The most common insects are the seed maize maggot (*Hylemya* spp.), white grubs (*Phyllophaga* spp.), cutworms (*Agrotis ipsilon*), the African maize stem borer (*Busseola fusca*), and thrips (*Frankliniella* spp.). Grain insects found in the field and in storage include the granary weevil (*Sitophilus granarius*), lesser grain borer (*Rhyzopertha dominica*), larger grain borer (*Prostephanus truncatus*), red flower beetle (*Tribolium castaneum*), and the Angoumois grain moth (*Sitotroga cerealella*).

Drought, excess moisture, nutrient deficiency (N, Ca, Mg, and P), acidic soils, manganese toxicity, aluminum toxicity, and salinity are some of the most common abiotic stresses of tropical maize. Drought affects agricultural production in about 60% of the land area of the tropics (Sanchez *et al.*, 1977). Drought sometimes reduces maize yields by 60%, resulting in tremendous human suffering as well as in economic and political problems. Natural variability in the amount and distribution of rainfall means that drought stress can occur at any point during the life cycle of the maize crop. Based on statistics provided by the Kenya meteorological station (www.climatetemp.info/kenya/), mean rainfall ranges from 19 to 206 mm per month with 40% of the rain falling between March and May (long rain season) and 20% between October and December (short rain season). However, intra-year variability is high; rainfall can vary by as much as 250% between years.

Diversity Within the Maize Crop

Maize has tremendous variability in kernel color, texture, nutrient composition, and appearance. Maize exists in a continuum of plant types ranging from wild relatives and primitive races to more advanced landraces, varieties maintained by farmers for generations, genetically improved cultivars, and professionally bred improved cultivars based on open pollination using many parent lines. There is an increasing appreciation among maize professionals of the need to broaden the search for useful genes and to augment genetic variability to increase the likelihood of sustainable productivity. There is also an increased appreciation of the need to conserve traditional genetic resources for future use.

The original landraces, including varieties preserved by individual farmers and local varieties, were largely flint types, which generally produce round, hard, and smooth grains. Flint maize germinates better than other maize types, usually matures earlier, and dries faster after reaching physiological maturity. It is less prone to damage in the field and during storage. However, its yield is lower than that of dent types. Flint maize is preferred for human food and for corn meal. Most of the flint maize grown commercially has a wide range of colors, including yellow, orange, white or cream, green, purple, red, blue, and black.

The landraces that have been maintained and improved *in situ* by farmers based on their perception of their own needs and their experience and natural skills have not been subjected to selection and improvement by professional breeders. The landraces may not represent a reservoir of genetic diversity as large as the diversity present in professionally maintained germplasm banks, but they are nonetheless sources of traits that are important to farmers for local adaptation, economic stability, and sustainability. They may therefore contain many traits that are not available in the improved varieties developed by professional breeders, for whom yield is the most important trait; in addition, these commercial varieties are most suitable for use in favorable environments where better management and cultivation practices are available. Some local cultivars are excellent sources of genes for disease and insect resistance and for resistance to other stresses.

The current improved maize cultivars are mostly dent types, and provide higher yield than other maize types. However, they tend to be more susceptible to insects and diseases in the field and in storage, and dry much more slowly than kernel types such as flint, which have a hard endosperm. Most cultivated dent maize has either white grains (as for Kenyan hybrid varieties), which are preferred for human food, or yellow grains, which are preferred for animal feed. The current improved cultivars represent the most widely used resources in most Kenyan maize improvement programs. Although such cultivars represent only a tiny fraction of overall maize genetic diversity, they provide high immediate yield gains.

Unfortunately, though the government's promotion of hybrid varieties continues in Kenya, farmers have not been consulted during the selection of new and improved varieties. Most of these hybrids require the use of chemical fertilizers as well as insecticides, herbicides, and fungicides, which increases the production cost beyond what small-scale farmers can afford. These practices also have negative environmental impacts on agricultural systems, and can reduce their sustainability. Farmers therefore continue to plant the traditional landraces and varieties that have been preserved by local farmers to reduce costs and harness the benefits derived from the unique genetic traits of these plants. The government has provided free hybrid seeds over the last 10 years, but farmers who used them have faced frequent crop failures and been forced to depend on food relief each year; because they cannot produce seed grains, these crop failures lead to a vicious cycle of dependency on government handouts. However, there have been no studies on the social and economic value of the landraces in terms of providing a sustained livelihood and food security.

The purpose of my study was to investigate whether the promotion of hybrid maize has significantly affected the livelihood and food security of small-scale maize producers in the Taita District of Kenya's Coast Province. In particular, I wanted to document the value of growing traditional maize varieties rather than the improved maize varieties that are currently being promoted. I also wanted to document the performance of the various maize varieties grown in the district's different ecological regions and develop recommendations of specific varieties for use in specific agro-ecological regions based on their performance and farmer preferences.

Materials and Methods

The Study Area

Taita District is one of 21 districts in Kenya's Coast Province. It is bordered by Tana River, Kitui and Makueni districts to the north; by Kwale district to the East; by Kajiado District to the northwest; and by Taveta District to the southwest (Fig. 2a). Taita District covers an area of more than 16 000 km^2 and lies between latitudes 2°46′ S and 4°10′ S and between longitudes 37°36′ E and 30°14′ E. Administratively, the district is divided into the Wundanyi, Mwatate, Mwambirwa, Tausa, and Voi divisions (Fig. 2b).

The district has a population of about 225 636 (2008 projection), and is predominantly inhabited by the Taita ethnic community, with a small population of other ethnic communities (mainly migrant workers and business people residing in towns). About 80% of the population lives in rural areas and depends directly on agriculture. Data from the district development office indicate that 63.5% of the district's population lives below the poverty line (TDDO, 2009).

The district ranges in altitude from 481 m above sea level in the lowlands of Voi to 2200 m above sea level in the highlands of Wundanyi. The average annual rainfall ranges between 480 and 1200 mm. Rainfall is highest in the highlands and decreases moving southward into the lowlands. The rainfall is bimodal, with the long rainy season between March and May and the short rainy season between October and December (Fig. 3). The short rainy season is the main crop season in Taita because of the higher total rainfall and better distribution of the rains. Temperatures range between 18.2 and 36.6℃, with temperatures increasing as one moves from the highlands to the lowlands. The soils range from stony sandy clay loams with moderate fertility in the highlands to well-drained, dark red, friable, coarse sandy clay loams with high fertility in the lowlands.

The main economic activity is farming, with small businesses and off-farm employment. A multi-cropping system of production is mostly practiced, with different crops grown in the same plot of land under intensive cultivation. The main food crops are maize, beans (*Phaseolus vulgaris*), garden peas (*Pisum sativum*), bananas (*Musa* spp.), Irish potatoes (*Solanum tuberosum*), sweet potatoes (*Ipomea batatas*), millet (*Eleusine coracana*), sorghum (*Sorghum bicolor*), cassava (*Manihot esculenta*), cowpeas (*Vigna unguiculata*), green grams (*Vigna radiata*), pigeon peas (*Cajanus cajan*), pumpkin (*Cucurbita* spp.), and sugarcane (*Saccharum officinarum*). The main vegetable crops grown under irrigation are kale (*Brassica oleracea* var. *acephala*), cabbage (*Brassica oleracea* var. *capitata*), spinach (*Spinacia oleracea*), tomatoes (*Lycopersicon esculentum*), onions (*Allium cepa*), eggplant (*Solanum melongena*), cauliflower (*Brassica oleracea* var. *botrytis*), French beans (*Phaseolus vulgaris*), and chilies (*Capsicum annuum*). The fruit trees that

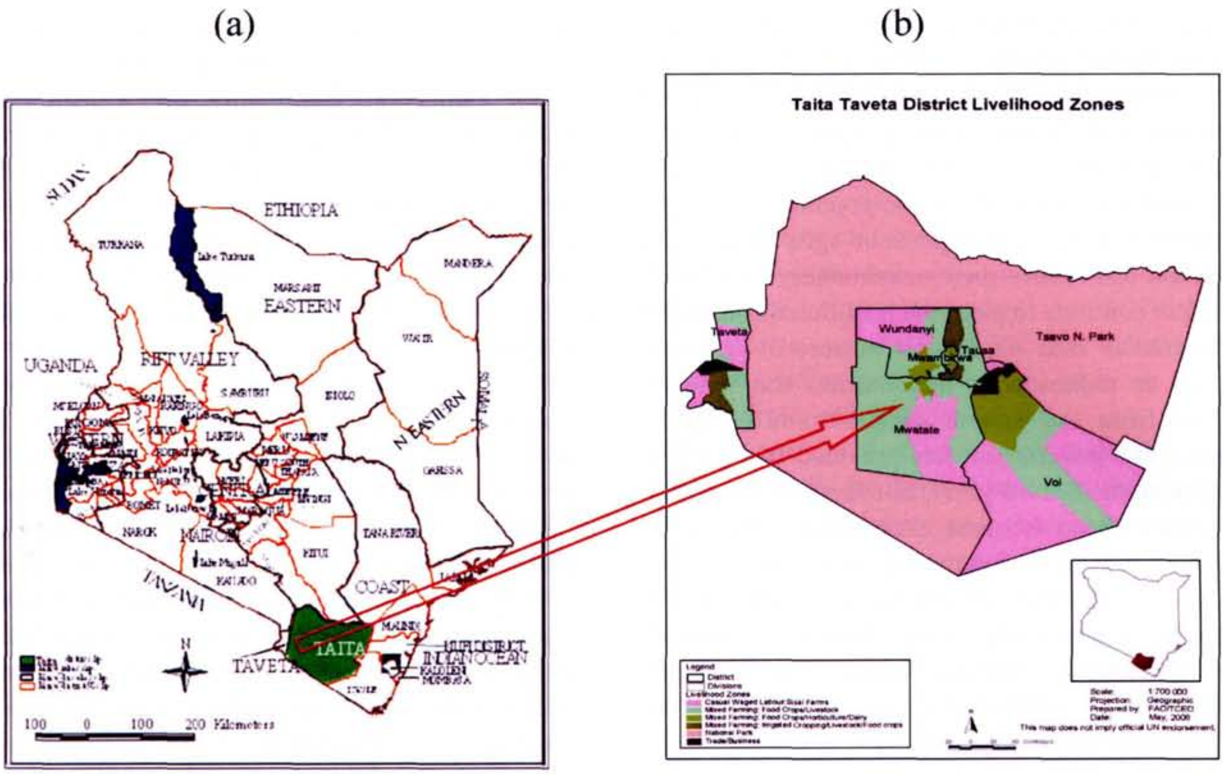

Fig. 2. (a) The location of Taita District in Kenya, and (b) the different land use and cover type zones and data collection points; Wundanyi, Mwatate, Tausa, Mwambirwa, and Voi. (Source: Arid Lands Resource Management Project, Taita office for map (a) and FAO/CEO for map (b).

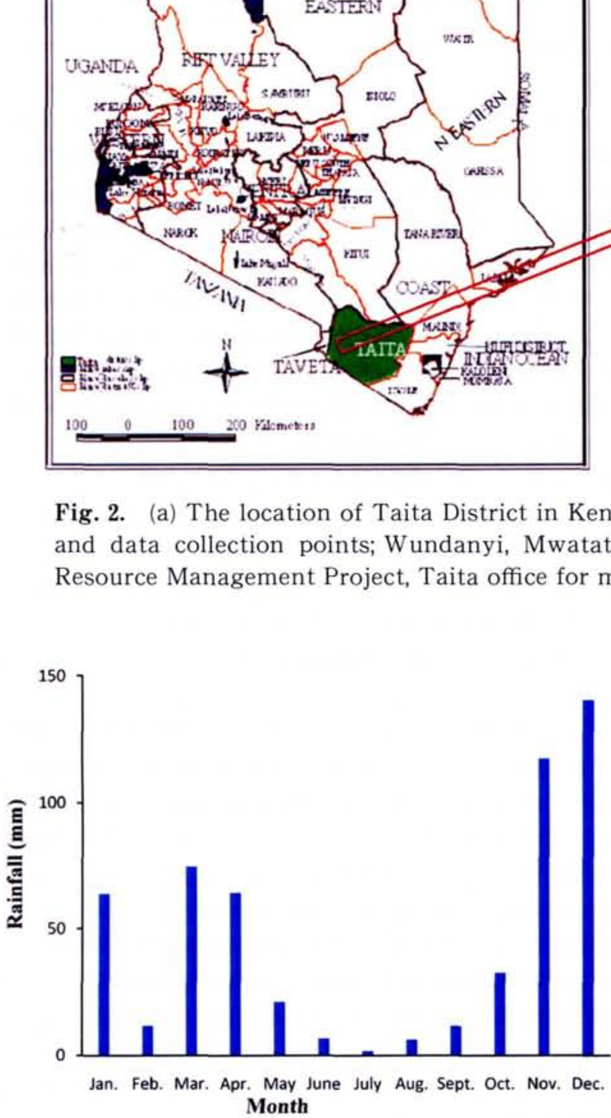

Fig. 3. Average monthly rainfall from 2000 to 2009 (Source: Voi Meteorological Station, Kenya).

are grown include avocado (*Persea americana*), mangoes (*Mangifera indica*), oranges (*Citrus sinensis*), pawpaw (*Carica papaya*), water melon (*Citrullus lanatus*), passion fruit (*Passiflora edulis*) and guavas (*Psidium guajava*). A few cash crops are grown in this area, including coffee (*Coffea arabica*), sisal (*Agave sisalame*), macadamia (*Macadamia integrifolia*), and coconut (*Cocos nucifera*). Livestock are kept by many households, including the indigenous species of cattle (*Bos primigenius indicus*), goats (*Capra aegagrus hircus*), and poultry (*Gallus gallus domesticus*). Sales of crop and livestock products provide the major source of income for most households.

Maize is the most important staple food crop in Taita District. The Kenya Seed Company has steadily increased the production of certified seed from hybrid varieties that are suitable for all of Kenya's agro-ecological zones. For example, Hybrid 614 and Hybrid 513 have been developed for use in high-altitude areas (more than 1000 m above sea level), whereas Pwani Hybrid 1 and Pwani Hybrid 4 are suitable for the hot and humid coastal lowlands and Dry Land Hybrid 04 has been developed for use in arid and semi-arid regions. These hybrids have been promoted in Taita District because of their high yield. However, local farmers have maintained and improved *in situ* some of their local varieties for many years, and continue to grow them alongside other crops (Fig. 4a-d) despite a lack of selection and improvement by professional maize scientists.

Data Collection

I used a survey design based on a structured household questionnaire (Appendix 1). Eight agricultural extension officers in the study area helped to administer the questionnaire during 1 week of the February 2010 maize harvesting season. I randomly selected 50 farmers in each of four divisions, for a total sample size of 200 interviews. The four regions were stratified by ecological zones (Table 1), population densities, farming systems, and farm sizes. A variety of maize crops are grown in the different eco-zones. I selected these focal areas based on the lack of development programs, high human population densities, and high poverty levels.

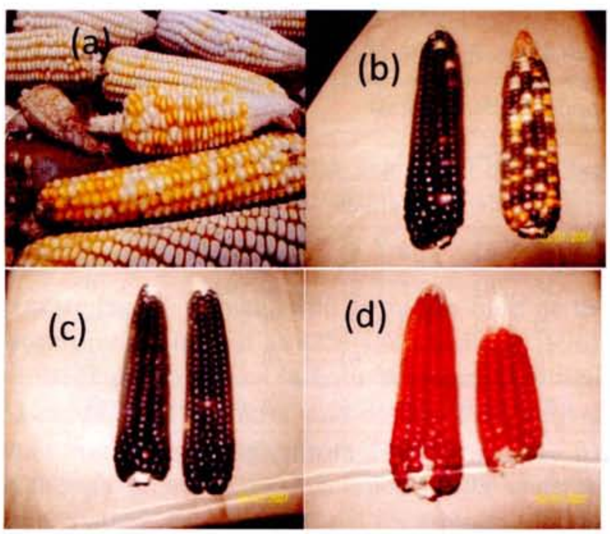

Fig. 4. Photos of some of the maize landraces grown in Taita District. (a) Mdawida, (b) Kiduruma, (c) Kiteka, and (d) Mulunguja.

The questionnaire was divided into four major parts. Part A covered the personal profile of the respondents (name, gender, education level, locality, and family characteristics). Part B covered farm information, including size, land preparation method, fertilizer use, crops grown, and livestock ownership. Part C covered maize quantitative traits, particularly plant height, grain yield, grain size, and stover yield. The last part (D) covered maize qualitative traits, including drought tolerance, disease resistance, maturation durations, eating and cooking qualities, and response to low soil fertility.

I analyzed the data using two way ANOVA, with one factor (division). Where significant differences were identified among divisions, i compared the divisions using Bonferroni post-tests using Graphpad prism version 5 for windows software, California, USA. www.graphpad.com

Results and Discussion

Socioeconomic and Demographic Factors

Overall, 51.5% of the farmers who participated in most agricultural activities and who were involved in making important farm decisions were women (Fig. 5a, b). This is in agreement with Karanja (1996), who reported that Kenya's women are responsible for most of the agricultural activities in rural areas. This emphasizes that rural women play a vital role in the conservation and

Table 1. Ecological Zones of Taita District

	Ecological factors			
Division	Ecological zone	Mean altitude (meters above sea level)	Mean temperature (℃)	Mean annual rainfall (mm)
Wundanyi	LH2-UM3	1370–1680	18.2–20.1	900–1300
Mwatate	LM4-LM5	790–1220	20.9–22.9	700–900
Tausa	LM5-LH6	790–980	22.4–23.5	480–620
Voi	L5-L6	480–790	23.5–24.6	480–600

Note: LH, Lower highland; UM, Upper middle; LM, Lower middle; LH, lower highland; L, Lowland (Source: Voi Meteorological Station, Kenya).

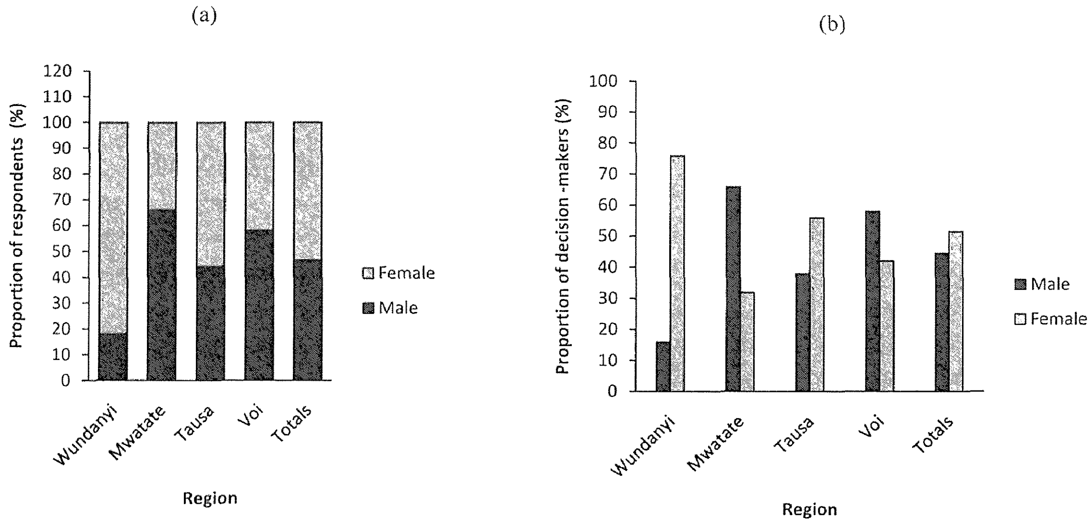

Fig. 5. Proportions of survey respondents by (a) gender and (b) decision-making status.

Table 2. Education Level of Respondents

	Number of respondents (% of total)							
Region	Not Educated		Primary		Secondary		College & University	
	Male	Female	Male	Female	Male	Female	Male	Female
Wundanyi	1 (2)	14 (28)	4 (8)	22 (44)*	3 (6)	3 (6)	2 (4)	1 (2)
Mwatate	0 (0)	2 (4)	20 (40)*	14 (28)	13 (26)	1 (2)	0 (0)	0 (0)
Tausa	1 (2)	3 (6)	15 (30)	18 (36)	5 (10)	6 (12)	1 (2)	1 (2)
Voi	9 (18)	8 (16)	14 (28)	10 (20)	6 (12)	3 (6)	0 (0)	0 (0)
Totals	11 (5.5)	27 (13.5)	53 (26.5)	64 (32)	27 (13.5)	13 (6.5)	3 (1.5)	2 (1)

Note: Asterisk symbol (*) in the same column indicate that values differ significantly ($p < 0.05$).

sustainable use of biodiversity and that full participation by women at all levels of policy-making and implementation is needed in future maize biodiversity conservation programs.

The majority of the farmers had attained at least the minimum basic primary education; 52% women and 18% men in Wundanyi, 30% women and 53% men in Mwatate, 50% women and 42% men in Tausa, and lastly 26% women and 40% men in Voi (Table 2). The number of respondents (both male and female) who had attained at least a primary education was significantly greater ($p < 0.05$) than the number who remained uneducated in Wundanyi (women) and Mwatate (men) divisions. This can be attributed to the free basic primary education that has been compulsory in Kenya since 1970s. However, the results also showed that more women remained uneducated (13.5%) than men (5.5%). A National Adult Literacy survey conducted in 2007 revealed that 61.5% of the adult population had attained the minimum desired literacy level, leaving 38.5% of adults illiterate; the majority of the illiterate were women living in rural areas (http://www.iiz-dvv.de). This may explain why most farmers have continued to maintain the maize landraces using their traditional experience and natural skills: most are not aware of the technologies that are required to cultivate hybrid maize varieties because they have not attained sufficient education.

Livelihood and Farming Systems

Small-scale farming remains the largest form of employment in Taita, and is central to the em-

Table 3. Main form of employment

	Proportion of respondents (%)			
Region	Farming	Self -employment within the community	Employment by someone else within the community	Employment by an external agency (NGO & GOK)[a]
Wundanyi	88	10	0	2
Mwatate	48	50	0	2
Tausa	80	4	6	10
Voi	64	24	6	6

([a]); NGO, non-governmental organization; GOK, government of Kenya.

Table 4. Ownership of land in Taita District

	Number of respondents (% of total) by area category (ha)				
Region	0 tol	1.1 to 2	2.1 to 3	3.1 to 4	>4
Wundanyi	30 (60)	10 (20)	7 (14)	2 (4)	1 (2)
Mwatate	34 (68)*	12 (24)	3 (6)	1 (2)	0 (0)
Tausa	19 (38)	22 (44)	8 (16)	1 (2)	0 (0)
Voi	6 (12)	21 (42)	9 (18)	10 (20)	4 (8)

Note: Asterisk symbol (*) in the same column indicate that values differ significantly ($p < 0.05$).

powerment of women, who form the bulk of the workforce, estimated at 82% (World Bank 1996). Most of the farmers (88% in Wundanyi, 48% in Mwatate, 80% in Tausa, and 64% in Voi) derived their livelihood mainly from farming (Table 3). Although annual crops can potentially generate income, they were mostly used for consumption by the farmer and were only sold when there was a surplus (seldom) or a sudden need for cash (data not shown). The income generated by these sales paid for food, education, clothing, and medicine. The agriculture in Taita District is dominated by a growing small-scale sector that accounts for 75% of the total agricultural output and 70% of the marketed agricultural produce (TDAO, 2009). Production is carried out mostly on small farms; 80% of the farmers in Wundanyi, 92% in Mwatate, 82% in Tausa, and 54% in Voi owned less than 2 ha of farmland (Table 4). The number of farmers who owned less than 1 ha of land was significantly higher for Mwatate than in all other divisions ($p < 0.05$). This is because Mwatate is more densely populated than the other divisions. Since farmland is also used for other purposes, such as construction of the homestead, the maize crop often occupies only a small portion of the farmland. Moreover, owing to rapid increases in population and the cultural practice in which farmers subdivide their farmland into smaller portions for their children, large farms have become progressively smaller, further reducing the area in which maize is grown in individual farms. Karanja (1996) observed that the population increase has been a leading factor in the declining amount of land available for crop production in Kenya. Farmers with small holdings remain resource-poor because they lack off-farm income sources. As a result, most farmers cannot afford to plant maize hybrids, which require costly inputs such as fertilizer and chemicals to sustain their high yields.

Farmers grew maize in a complex, intensively managed system in which the maize is one crop among many other crops grown throughout the year to achieve high overall productivity and thereby reduce the risk of crop failures and the resulting lack of food. Tausa Division had the second-largest area of maize (52.3 hectares), which was significantly higher than the area of other crops in that

Table 5. Crops grown during the short rain season (October-December 2009)

Region	Area Planted (hectares)							
	Maize	Millet	Beans	Cow peas	Pigeon peas	Green grams	Cassava	Sweet potato
Wundanyi	32.6	0	7.8	0	0	0	0	0
Mwatate	27.0	0	9.5	1.6	1.2	0	5.9	0.7
Tausa	52.3*	0.9	0	34.1	0	7.2	0	0
Voi	95.2***	4.3	1.0	35.6	0	34.5	0	0

Note: Asterisk symbols (*) and (***) in the same column indicate that values differ significantly at ($p < 0.05$) and ($p < 0.001$) respectively.

division ($p < 0.05$); Voi Division had the highest area of maize cultivation (95.2 hectares), which was significantly higher than the area of other crops in the same division ($p < 0.001$). These divisions have lower population densities and larger areas of farmland than the other divisions. As the staple food crop, maize generally occupied more land than the other crops (Table 5). This can be attributed to the government's strong support for maize compared with other traditional food crops. Moreover, the traditional belief that maize cultivation equals food security has significantly increased planting of maize and steadily decreased planting of other food crops. Maize has therefore become the dominant food crop, whereas sorghum and millet are disappearing from the study area. Eyzaguirre and Iwanaga (1996) noted that maize in Kenya had continued to replace other crops for more than 10 years owing to the government's promotion of hybrid varieties. The combination of the government's emphasis on maize and the food security perceptions of local farmers therefore seem to have reduced crop diversity both in terms of the different kinds of plants that are grown and in the area of each crop under production.

Fertilizer Use and Sustainability

To sustain the high yields associated with improved maize varieties, small-scale farmers must buy inorganic fertilizers to compensate for the low soil fertility in the study area. Table 6 shows farmer perceptions of fertilizer use and sustainability. The majority of the farmers (76% in Wundanyi, 76% in Mwatate, 98% in Tausa, and 94% in Voi) did not use any kind of fertilizer during the planting season. Similar proportions (80% in Wundanyi, 78% in Mwatate, 100% in Tausa, and 92% in Voi) considered fertilizer use to be unsustainable. Furthermore, few farmers actually used fertilizers (organic or inorganic) during the short rainy season from October to December 2009 (the primary cultivation season); most did not use any fertilizer (66% in Wundanyi, 60% in Mwatate, 98% in Tausa, and 78% in Voi).

The low use of inorganic fertilizer can be attributed to its high cost. In Taita, fertilizer costs about 12 500 Kenya shillings (about US$150) per hectare. Given that 63.5% of the population lives below the poverty line of less than US$1 income per day, inorganic fertilizers are unaffordable to most farmers. To obtain organic fertilizer (manure), a farmer must own sufficient livestock. However, more than 80% of the farmers own only 1 or 2 cows (TDLPO, 2009) because of the limited area available to sustain the animals. The amount of organic manure generated by these livestock is insufficient to sustain maize production.

These results indicate that it is nearly impossible to achieve the full potential of improved cultivars in Taita District. For hybrids to achieve their potential, they should be grown in pure plantings and provided with high levels of management, particularly the use of fertilizers combined with pest and disease control. Given the multi-cropping system practiced by the farmers and the lack of management inputs due to high poverty levels, current hybrids are likely to exhibit reduced grain yields. Under the current management system, however, the landraces respond well with minimal or no fertilizer inputs, as discussed later in this paper. This is because they are better adapted to exploiting the available resources. When grown with legumes

Table 6. Farmer perception of fertilizer use and sustainability

Region	Number of respondents (% of total)						
	Seasonality of Fertilizer Use		sustainability of Fertilizer Use		Actual fertilizer use		
	Use Each Season	Do not Use Each Season	Sustainable	Not Sustainable	Organic	Inorganic	None
Wundanyi	12 (24)	38 (76)	10 (20)	40 (80)	16 (32)	1 (2)	33 (66)
Mwatate	12 (24)	38 (76)	11 (22)	39 (78)	18 (36)	2 (4)	30 (60)
Tausa	1 (2)	49 (98)	0 (0)	50 (100)	1 (2)	0 (0)	49 (98)
Voi	3 (6)	47 (94)	4 (8)	46 (92)	11 (22)	0 (0)	39 (78)

Table 7. The maize varieties preferred by farmers, the period they have been grown and the regions where they are grown

Maize Variety	Number of farmers	Period they have been grown (years)	Region mostly grown
Pwani Hybrid 4	38	4.4	W, M
Pwani Hybrid 1	63	6.6	W, M, T, V
Hybrid 614	0	0	0
Hybrid 513	3	5.0	W, M
Dryland Hybrid 04	2	2.5	T
Mdawida	26	8.3	W, M
Kiduruma	54	16.0	T, V
Makueni	2	4.0	T
Kiteka	9	12.0	V
Mulunguja	0	0	0
Mwezimwenga	1	7.0	V
Kito	1	10.0	V

Note: W, Wundanyi; M, Mwatate; T, Tausa; V, Voi.

such as cowpeas, the maize can benefit from the nitrogen fixed by the legume. Based on the present results, the use of local maize landraces should be promoted, possibly enhanced by the use of improved soil and water management systems.

Maize Varieties that are Grown and Farmer Preferences

Table 7 categorizes the maize varieties that are grown (i.e., farmer preferences), the period during which they have been grown, and regions where they are grown. Pwani hybrid 4 was the preferred improved variety at high altitudes in Wundanyi and Mwatate, whereas Pwani hybrid 1 was preferred in all four regions. Pwani hybrid 4 was particularly liked because of its high yield, and Pwani Hybrid 1 was preferred because of its ability to withstand drought. These two hybrids have been grown for about 5 years. All other hybrids that have been promoted in the area had generally low levels of acceptance by farmers. The Mdawida landrace (mostly grown in Wundanyi and Mwatate) and the Kiduruma landrace (mostly grown in Tausa and Voi) were preferred by many farmers and had been maintained and conserved for a long time (more than 8 years) using local knowledge and experience. Table 7 shows the diversity of the maize landraces that have been grown and maintained by farmers, especially at medium and low altitudes (Mwatate, Tausa and Voi). The Mulunguja landrace seems to have disappeared from most farms.

The government's promotion of hybrid varieties in an effort to increase yields seems to have resulted in a rapid loss of genetic diversity (i.e., reduced numbers of landraces). The breakdown of traditional cultivation systems and loss of local plant varieties, and the associated loss of cultural knowledge, can be blamed for the loss of maize biodiversity among rural farmers.

Kenya's government believes that most of the landraces have been collected and are being preserved *ex situ* in maize banks for future use. However, *ex situ* conservation should be, at best, a supplement to *in situ* conservation of landraces and the varieties conserved by farmers, not a substitute for *in situ* conservation. Farmers want to accumulate and conserve such diversity and to continue using the resulting crop structure because their experience has shown that these plants and plant combinations are best adapted to local conditions. There is a growing appreciation of the need for *in situ* conservation of landraces and "primitive" local cultivars that could continue to evolve in association with the actual stresses faced by these crops and in response to farmer needs (Worede, 1993; Brush, 1995).

The farmers often grew both improved varieties and local landraces or varieties that they and other farmers had conserved adjacent to each other, resulting in the creation of new varieties with desirable gene combinations from both sources. This introgression of genes can be a good thing if it results in the improvement of the local varieties, but it also creates a risk of loss of beneficial locally evolved gene combinations. This aspect of maize growing has been used by ethno-botanists to stress the importance of and need for *in situ* conservation of diversity (Worede, 1993; Brush, 1995). It is also being used to emphasize the need for "participatory" plant breeding in which farmers participate in the process of selecting new varieties (Hardon, 1995).

Maize Production Statistics

The area cultivated with different maize varieties differed significantly among the varieties and regions (Table 8). The area cultivated with hybrid maize varieties was greater at higher altitudes (Wundanyi and Mwatate), whereas the local landraces dominated at lower altitudes (Tausa and Voi). The Kinduruma landrace occupied the biggest area (87.6 hectares). This area was significantly higher ($p < 0.01$) in Voi Division than in the other divisions. The area that was fertilized depended on the maize variety being grown (Table 9). The Kiduruma landrace had the highest area under fertilization (36.8 hectares), and was significantly higher in Voi Division than in all other divisions ($p < 0.001$). Other varieties had much lower areas under fertilization. Both the area of maize

Table 8. Maize cultivation (area and varieties) in the four regions during the short rain season in 2009

	Area (hectares)				
Maize Variety	Wundanyi	Mwatate	Tausa	Voi	Total (all regions)
Pwani Hybrid 4	9.8	15.4	3.7	2.5	31.5
Pwani Hybrid 1	18.8	12.0	11.7	17.8	60.4
Hybrid 614	1.2	0.6	0	0	1.8
Hybrid 513	0.5	1.4	0	0	2.0
Dryland Hybrid 04	0.2	0	0.2	0.4	0.8
Mdawida	1.4	8.2	1.2	1.8	12.6
Kiduruma	0	1.6	33.8	52.2**	87.6
Makueni	0	0	5.8	6.0	11.8
Kiteka	0	0	0	10.4	10.4
Mulunguja	0	0	0	2.8	2.8

Note: Asterisk symbol (**) in the same column indicate that values differ significantly ($p < 0.01$).

Table 9. Area of cultivated maize that was fertilized during the short rain season in 2009

	Area fertilized (hectares)				
Maize Variety	Wundanyi	Mwatate	Tausa	Voi	Total (all regions)
Pwani Hybrid 4	2.5	6.2	0	0.8	9.4
Pwani Hybrid 1	7.8	4.6	0	3.4	15.8
Hybrid 614	0.4	0	0	0	0.4
Hybrid 513	0	1.4	0	0	1.4
Dryland Hybrid 04	0	0	0	0	0
Mdawida	0	3.6	0	0.8	4.4
Kiduruma	0	0.8	2.0	34.0***	36.8
Makueni	0	0	0	0	0
Kiteka	0	0	0	0	0
Mulunguja	0	0	0	0	0

Note: Asterisk symbol (***) in the same column indicate that values differ significantly ($p < 0.001$).

Table 10. Comparison of maize yields in the four regions during the short rain season of 2009

	Total yield (t)				
Maize Variety	Wundanyi	Mwatate	Tausa	Voi	Total (all regions)
Pwani Hybrid 4	3.3	5.3	2.8	1.3	12.7
Pwani Hybrid 1	6.1	5.6	5.5	27.6	44.8
Hybrid 614	0.8	0.4	0	0	1.2
Hybrid 513	0.3	1.3	0	0	1.6
Dryland Hybrid 04	0.04	0	0.09	0.09	0.22
Mdawida	0.9	5.7	0.3	0.2	7.1
Kiduruma	0	0.8	13.2	157.0***	171.0
Makueni	0	0	1.1	31.5	32.6
Kiteka	0	0	0	5.0	5.0
Mulunguja	0	0	0	0.6	0.6

Note: Asterisk symbol (***) in the same column indicate that values differ significantly ($p < 0.001$).

cultivation and the portion of this area that was fertilized significantly affected the yields that were achieved. Table 10 shows that the Kinduruma landrace had the highest yield (171 tonnes). The yield in Voi Division was significantly higher than that in the other divisions ($p < 0.001$). Thus, maize contributed more to food security than the other varieties.

These results indicate that there was a strong relationship between farmer preference for particular maize varieties and the land area cultivated with those varieties, with the area fertilized, and with the yield provided by the varieties. This explains why Kinduruma was the most preferred maize variety, with the highest areas planted and fertilized and the highest yield. Farmers tended to invest more in growing the Kinduruma landrace because they believed it was mostly likely to provide food securi-

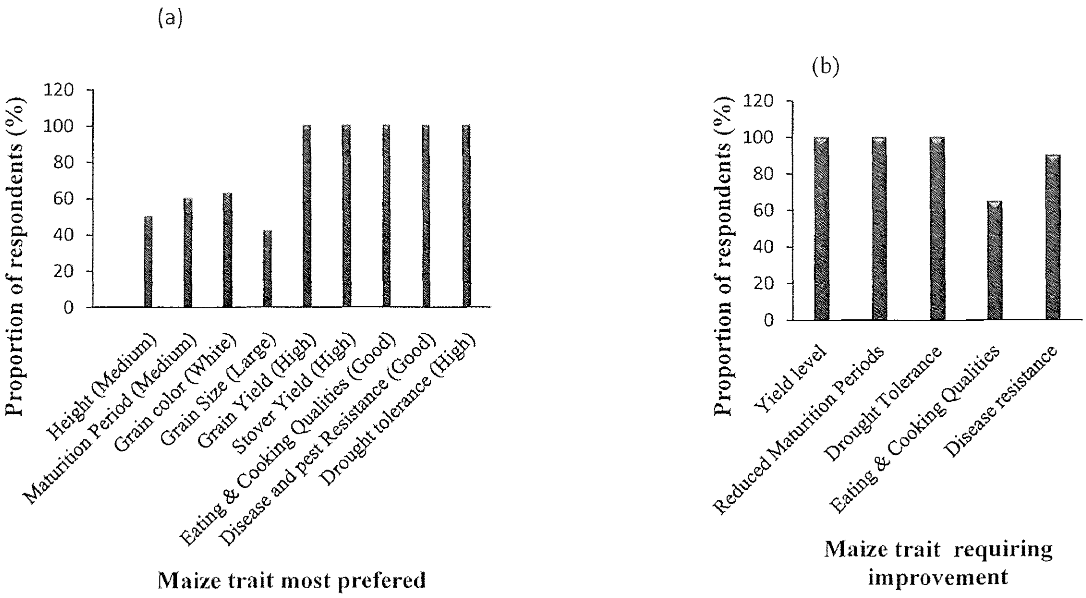

Fig. 6. Proportions of farmers who (a) preferred specific maize traits and (b) most desired improvements in certain maize traits.

ty owing to its high adaptability and lower input requirements.

Variation of Maize Genetic Traits and Farmer Preferences

Maize varieties differ in the levels of the genetic traits they express as a result of evolution caused by continuous selection and breeding by plant breeders (for the hybrids) or by local farmers (for the landraces). Local farmers have specific preferences for these traits, depending on how a variety meets their demands in terms of food and livelihood security.

Figure 6a shows that 50% of the respondents preferred varieties with medium height and above, 60% preferred varieties with an intermediate maturation period (between 2.5 and 3 months), and 63% preferred maize varieties with white grains. Only 42% preferred maize varieties with big grains. However, all respondents preferred maize varieties with high grain yields, high stover yields, good cooking and eating qualities, and high disease and pest resistance, as well as high drought tolerance. Figure 6b shows the maize traits farmers most desired to be improved in their current maize varieties. All the respondents (100%) expressed a need to improve yields, maturation period, and drought tolerance. In addition, 65% wanted to improve the eating and cooking qualities and 90% wanted to improve the disease resistance levels.

The results show that the hybrids have not met farmer expectations in terms of food and livelihood security, since they have been developed to prioritize yield and require a favorable environment with a better quality of management. This explains why Pwani hybrid 1 is preferred in all four ecological zones: it combines high drought tolerance with high yield. Pwani hybrid 4 has very good yield, but matures late, cannot withstand drought, and is susceptible to storage pests. In contrast, the landraces are excellent sources of genes for disease and insect resistance, drought tolerance, good taste, and early maturity. This explains why the local farmers have continued to conserve and maintain these landraces: because of their significant contribution to food security. These results also demonstrate the need for further research to improve the current hybrid varieties so that they account for farmer needs and preferences. This finding agrees with Hardon (1995), who indicated that where variability in micro-environment and farmer selection criteria are too great to be adequately addressed through centralized crop breeding, close interaction with farmers to account for their local crop and environmental knowledge may improve the ability of breeders to account for genotype × environment interactions and develop varieties that are more

Table 11. Comparison of maize quantitative traits among the four regions

Region	Pwani Hybrid 4	Pwani Hybrid 1	Hybrid 614	Hybrid 513	Dry land hybrid 04	Mdawida	Kiduruma	Makueni	Kiteka	Mulunguja
	Number of respondents (% of total)									
Plant height (medium versus tall)										
Wundanyi	35 (70)	1 (2)	6 (12)	1 (2)	1 (2)	3 (6)	1 (2)	0 (0)	0 (0)	0 (0)
Mwatate	31 (62)	22 (44)	1 (2)	4 (8)	1 (2)	22 (44)	3 (6)	0 (0)	0 (0)	0 (0)
Tausa	9 (18)	4 (8)	0 (0)	0 (0)	0 (0)	2 (4)	39 (78)	4 (8)	0 (0)	0 (0)
Voi	5 (10)	34 (68)	0 (0)	0 (0)	0 (0)	2 (4)	19 (38)	3 (6)	12 (24)	3 (6)
High grain yield										
Wundanyi	33 (66)	4 (8)	6 (12)	1 (2)	1 (2)	3 (6)	0 (0)	0 (0)	0 (0)	0 (0)
Mwatate	30 (60)	4 (8)	1 (2)	2 (4)	0 (0)	18 (36)	3 (6)	0 (0)	0 (0)	0 (0)
Tausa	9 (18)	16 (32)	0 (0)	0 (0)	1 (2)	2 (4)	37 (74)	2 (4)	0 (0)	0 (0)
Voi	4 (8)	29 (58)	0 (0)	0 (0)	0 (0)	1 (2)	14 (28)	3 (6)	7 (14)	2 (4)
High Stover yield										
Wundanyi	35 (70)	2 (4)	6 (12)	1 (2)	1 (2)	3 (6)	0 (0)	0 (0)	0 (0)	0 (0)
Mwatate	30 (60)	4 (8)	1 (2)	2 (4)	0 (0)	20 (40)	3 (6)	0 (0)	0 (0)	0 (0)
Tausa	9 (18)	8 (16)	0 (0)	0 (0)	0 (0)	2 (4)	37 (74)	2 (4)	0 (0)	0 (0)
Voi	4 (8)	29 (58)	0 (0)	0 (0)	0 (0)	1 (2)	14 (28)	3 (6)	7 (14)	2 (4)
Large Grain size										
Wundanyi	34 (68)*	26 (52)	5 (10)	2 (4)	2 (4)	3 (6)	0 (0)	0 (0)	0 (0)	0 (0)
Mwatate	29 (58)	13 (26)	1 (2)	2 (4)	0 (0)	21 (42)	1 (2)	0 (0)	0 (0)	0 (0)
Tausa	9 (18)	14 (28)	0 (0)	0 (0)	1 (2)	1 (2)	31 (62)	3 (6)	0 (0)	0 (0)
Voi	3 (6)	30 (60)	0 (0)	0 (0)	1 (2)	4 (8)	21 (42)	5 (10)	7 (14)	3 (6)

Note: Asterisk symbol (*) in the same column indicate that values differ significantly ($p < 0.05$).

acceptable to farmers and suitable for their needs.

Regional Comparison of Maize Quantitative Traits

The maize varieties grown in Taita District vary greatly in their expression of quantitative traits. Most farmers preferred maize varieties that ensured food and livelihood security. Table 11 shows farmer assessments of the maize varieties in terms of their expression of quantitative traits. Pwani hybrid 4 was perceived by many farmers as being the tallest variety at medium and high altitudes (70% in Wundanyi and 62% in Mwatate), whereas the heights of Kiduruma and Pwani hybrid 1 were preferred by more farmers at lower altitudes, in Tausa (78%) and Voi (68%) divisions, respectively. Similar variation among divisions and varieties can be seen for the other quantitative traits (high grain yield, high stover yield, and large grain size). Most farmers believed that Pwani hybrid 4 had higher expression of these quantitative traits at high and medium altitudes (i.e., in Wundanyi and Mwatate), but that the Kiduruma landrace was superior at lower altitudes (i.e., Tausa) and that Pwani hybrid 1 was superior in drier areas at low altitude (i.e., Voi). Pwani hybrid 4 had significantly larger grain size in Wundanyi than in other divisions ($p < 0.05$).

These results indicate that the hybrids generally had a higher expression of the quantitative traits than the landraces. This has resulted from continuous improvement by breeding programs with higher yields as the driving factor. Dowswell *et al.* (1996) indicated that the immediate gains from maize breeding for high yield are much higher using current elite cultivars. These cultivars will therefore continue to be important genetic resources for maize improvement, particularly if breeders have access to a good collection of such germplasm from various sources. However, the Kinduruma landrace was perceived as having a higher expression of

Table 12. Comparison of maize qualitative traits among the four regions

Region	Pwani Hybrid 4	Pwani Hybrid 1	Hybrid 614	Hybrid 513	Dry land hybrid 04	Mdawida	Kiduruma	Makueni	Kiteka	Mulunguja
	Number of respondents (% of total)									
Early Maturation										
Wundanyi	3 (6)	31 (62)	0 (0)	1 (2)	3 (6)	6 (12)	1 (2)	0 (0)	0 (0)	0 (0)
Mwatate	1 (2)	26 (52)	0 (0)	0 (0)	1 (2)	22 (44)	3 (6)	0 (0)	0 (0)	0 (0)
Tausa	0 (0)	15 (30)	0 (0)	0 (0)	1 (2)	3 (6)	41 (82)**	6 (12)	0 (0)	0 (0)
Voi	0 (0)	8 (16)	0 (0)	0 (0)	1 (2)	4 (8)	21 (42)	5 (10)	14 (28)	3 (6)
High disease tolerance										
Wundanyi	1 (2)	32 (64)	0 (0)	0 (0)	3 (6)	6 (12)	1 (2)	0 (0)	0 (0)	0 (0)
Mwatate	0 (0)	24 (48)	0 (0)	0 (0)	1 (2)	22 (44)	3 (6)	0 (0)	0 (0)	0 (0)
Tausa	0 (0)	11 (22)	0 (0)	0 (0)	1 (2)	3 (6)	41 (82)	6 (12)	0 (0)	0 (0)
Voi	1 (2)	1 (2)	0 (0)	0 (0)	1 (2)	4 (8)	22 (44)	4 (8)	14 (28)	3 (6)
High drought tolerance										
Wundanyi	1 (2)	30 (60)	0 (0)	1 (2)	3 (6)	5 (10)	1 (2)	0 (0)	0 (0)	0 (0)
Mwatate	0 (0)	25 (50)	0 (0)	0 (0)	1 (2)	22 (44)	3 (6)	0 (0)	0 (0)	0 (0)
Tausa	0 (0)	11 (22)	0 (0)	0 (0)	1 (2)	3 (6)	41 (82)**	6 (12)	0 (0)	0 (0)
Voi	1 (2)	1 (2)	0 (0)	0 (0)	0 (0)	4 (8)	22 (44)	4 (8)	14 (28)	3 (6)
Good eating quality										
Wundanyi	36 (72)*	34 (68)	5 (10)	1 (2)	3 (6)	6 (12)	1 (2)	0 (0)	0 (0)	0 (0)
Mwatate	30 (60)	26 (52)	1 (2)	2 (4)	1 (2)	22 (44)	3 (6)	0 (0)	0 (0)	0 (0)
Tausa	9 (18)	16 (32)	0 (0)	0 (0)	1 (2)	3 (6)	40 (80)**	5 (10)	0 (0)	0 (0)
Voi	3 (6)	31 (62)	0 (0)	0 (0)	1 (2)	4 (8)	24 (48)	5 (10)	14 (28)	3 (8)
Good cooking quality										
Wundanyi	34 (68)	34 (68)	4 (8)	1 (2)	3 (6)	6 (12)	1 (2)	0 (0)	0 (0)	0 (0)
Mwatate	31 (62)	27 (54)	1 (2)	2 (4)	1 (2)	22 (44)	3 (6)	0 (0)	0 (0)	0 (0)
Tausa	9 (18)	16 (32)	0 (0)	0 (0)	1 (2)	3 (6)	38 (76)	5 (10)	0 (0)	0 (0)
Voi	3 (6)	31 (62)	0 (0)	0 (0)	1 (2)	4 (8)	24 (48)	5 (10)	14 (28)	3 (6)
Best performance with no fertilizer application										
Wundanyi	20 (40)	19 (38)	0 (0)	1 (2)	2 (4)	3 (6)	0 (0)	0 (0)	0 (0)	0 (0)
Mwatate	10 (20)	7 (14)	0 (0)	0 (0)	0 (0)	13 (26)	0 (0)	0 (0)	0 (0)	0 (0)
Tausa	4 (8)	5 (10)	0 (0)	0 (0)	0 (0)	2 (4)	35 (70)	5 (10)	0 (0)	0 (0)
Voi	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	3 (6)	28 (56)	0 (0)	22 (44)	4 (4)

Note: Asterisk symbols (*) and (**) in the same column indicate that values differ significantly at ($p<0.05$) and ($p<0.01$) respectively.

the quantitative traits than the other varieties at low altitudes (i.e., Tausa). This has resulted from continuous selection and improvement by farmers based on their knowledge of and experience with local conditions.

Regional Comparison of Maize Qualitative Traits

Table 12 compares the maize varieties based on their expression of qualitative traits. At lower altitudes (i.e., Tausa), most farmers believed that the Kinduruma landrace had excellent traits in terms of early maturity (82%), disease tolerance (82%), drought tolerance (82%), good eating qualities (80%), good cooking qualities (76%), and high performance with no fertilizer application (70%). Its maturation period and drought tolerance in Voi

Division were significantly higher than in other divisions ($p < 0.01$). Mdawida was perceived as having better expression of these traits in Mwatate (at medium altitude), whereas Pwani hybrid 1 was the only hybrid perceived as having a high expression of early maturity (62%), disease resistance (64%), and drought tolerance (60%) at high altitude (i.e., Wundanyi). However, Pwani hybrid 4 at high altitude had good eating and cooking qualities (72 and 68%, respectively), and the eating quality was significantly higher in Wundanyi than in other divisions ($p < 0.05$). The Kinduruma landrace was reported as having better performance than the hybrids without fertilizer.

These results indicate that the local landraces are sources of traits that farmers perceive as being important for local adaptation, economic stability, and sustainability. Some of the landraces appear to be excellent sources of genes for disease and pest resistance and genes for tolerance of other stresses, and thus represent important resources for maize breeders. Through continuous selection, the local farmers have been able to maintain these traits in the local varieties. This indicates the need for continued improvement and conservation of the local maize varieties. Worede (1993) indicated that there is a growing appreciation of the need for *in situ* conservation of landraces and "primitive" local cultivars that can continue to evolve in association with crop stresses and farmer needs.

Conclusions

Maize is a major staple food crop grown by the farmers of Taita District in Kenya's coastal region, and contributes greatly to their food and livelihood security. Unfortunately, average yields are far below the region's potential, creating serious food deficits, especially when rain is limited. Kenya's government has promoted the use of hybrid varieties to increase yields, but adoption of these varieties has decreased genetic diversity by decreasing the use of local landraces. To sustain their high yields, hybrids require chemical fertilizers as well as insecticides, herbicides, and fungicides, which increase the costs beyond what most farmers can afford, while also having adverse environmental impacts on agricultural ecosystems. Unfortunately, the needs of Kenyan farmers have been mostly ignored in the process of developing new varieties. Farmers must therefore continue planting local landraces and varieties developed by individual farmers to reduce costs and harness the benefits derived from the genetic traits possessed by these local varieties.

In this study, I analyzed household survey data from small-scale maize producers in Taita District to learn whether the promotion of hybrid cultivars has significantly affected their livelihood and food security, and to learn the perceived value of growing traditional maize varieties rather than the currently promoted improved varieties.

Most of the farmers (>50%) involved in making important farming decisions and who participated in most agricultural activities were women, many of whom were illiterate. They were thus not aware of the technologies that must be used to cultivate hybrid maize varieties, and instead conserved and utilized local genetic resources based on their traditional knowledge and experience.

More than 70% of the farmers derived their livelihood mainly from farming, and cultivated less than 2 ha. These farmers remained resource-poor and could not afford to use maize hybrids that required additional costly inputs. Most of the farmers (86%) had not used fertilizers during the planting season and considered the use of these fertilizers to be unsustainable. The full potential of improved cultivars cannot be achieved under such conditions, and the landraces were believed to perform better under these conditions. The Kinduruma landrace appears particularly promising, with a large area planted (52.5 hectares) and a high total yields (171 t), thereby contributing most to food security.

The hybrids generally had a higher expression of quantitative traits (plant height, grain yield, stover yield, and grain size) than the landraces, though the Kinduruma landrace had higher expression of these parameters at low altitudes. Most farmers indicated that maize landraces, and particularly Kinduruma and Mdawida, performed better than the hybrids in terms of qualitative traits such as early maturation, disease tolerance, and drought tolerance, and that they had better cooking and eating qualities. They also performed better at low soil fertility. The landraces thus appear to be important sources of qualitative traits that are important for local adaptation and for the economic stability and sustainability of the farmers.

In many cases where maize has been a traditional crop for a long time, landraces or varieties developed by individual farmers continue to be maintained and improved by the farmers. These varieties possess traits that are important to the farmers for economic stability and sustainability. In any breeding scheme for maize improvement in the tropics, a wide range of varieties must be considered to meet the needs of farmers under diverse situations. Understanding the current crop diversity at the level of individual farmers is a good starting point for identifying appropriate actions to conserve this diversity. Worede (1993) reported a growing appreciation of the need for *in situ* conservation of landraces and primitive local cultivars that can continue to evolve in association with crop stresses and farmer needs.

The potential of many improved cultivars that have been adopted by farmers in this region has not often been achieved, mostly because of poor management, a lack of inputs such as fertilizer, unfavorable biotic and abiotic factors, or a combination of these problems. In this context, the use of indigenous maize varieties (landraces and varieties developed by farmers) must be considered in the development of any solution to the problem of poverty and food security in Kenya.

Recommendations

Increased maize productivity, production, and utilization in Taita District are essential because of the heavy population pressure and high rate of population increase. It is insufficient to support thousands of people at a sustenance level; there is an urgent need to improve the nutrition level, particularly among the rural poor. An increased emphasis on developing varieties that are suited to specific farming situations rather than focusing solely on yield is a good start, but better post-harvest management (e.g., storage), the development of an improved marketing infrastructure, and greater utilization of maize by the livestock feed industry and other industries will boost the level of farmer income. M.E. Smith & Paliwal, R.L. (1996) reported that, there are positive indications that production could be increased to meet these challenges through a revolution of corn, which can be glimpsed on the horizon and need to be stimulated-side to materialize.

On the basis of the present results, I propose the following recommendations for further development of maize varieties for farmers in Taita:

Breeders must develop germplasm that will be acceptable to the farmers and that will provide them with adequate harvests in terms of both the quantity and the quality of the corn. Breeders must look beyond high yield to consider traits that will improve the adaptability, stability, and economic performance of maize under local conditions. This will require an approach based on "participatory" plant breeding, in which farmers guide breeders in the process of selecting and improving varieties (Hardon, 1995). This is crucial because the microenvironmental variability and wide range of farmer selection criteria are too great to be adequately addressed through centralized crop breeding. For such a scheme to succeed, breeders must work with farmers to understand the environmental and socioeconomic conditions the farmers face, and the breeding work must be done in the environment where the cultivars will be grown rather than at a centralized facility.

I recommend that Kenya's Ministry of Agriculture begin to promote the maize varieties that have been shown to perform well in each agro-ecological zone and that have met the criteria of local farmers; these include Pwani hybrid 4 and Pwani hybrid 1 in Wundanyi; Pwani hybrid 4, Pwani hybrid 1, and the Mdawida landrace in Mwatate; and Pwani hybrid 1, and the Kinduruma and Kiteka landraces, in the Tausa and Voi divisions. In addition, the government should support breeding programs that will cross these landraces with existing hybrids in an effort to make those hybrids more suitable for the study area and for the ability of the farmers to provide the necessary inputs of fertilizer and other agrochemicals.

The Ministry of Agriculture should also promote technologies that can conserve moisture and fertility to compensate for the decreasing soil fertility and inadequate rains being experienced in the study area.

The Ministry of Agriculture should also develop the skills of farmers though training so the farmers can learn how to conserve rare maize varieties that may survive only in small quantities. The government should, through the Kenya National Seed

Bank, support efforts at *ex situ* conservation of these rare maize varieties and other indigenous crop varieties that may otherwise disappear. The government should also help farmers to develop community seed banks that can be used to produce high-quality seeds. Training should be carried out to empower local farmer committees to run and manage community seed banks effectively. Incentives to support on-farm management of crop diversity would include community seed fairs, formal training programs, field days, and demonstrations, and should link farmers to appropriate markets for their produce so that once crop yields begin to improve, farmers will have opportunities to sell surplus harvests to generate income. Additional research should be conducted to learn how agricultural extension service staff can improve their understanding of the roles of men and women in the management of plant genetic resources.

Farmers in Kenya play an important role in the conservation and sustainable use of local plant genetic resources. Conservation at the farm level allows for continuing farmer selection of promising genetic resources based on close observation of the interaction between landraces and the environment, and allows for gene exchange with wild species to sustain evolution of the landraces. Therefore, *ex situ* conservation efforts must be designed to complement *in situ* efforts, thereby maximizing the retention and continued evolution of important local genetic resources and mitigating the loss of variation that occurs during the sampling and maintenance that occur in formal breeding programs. The present results emphasize the necessity of strengthening and expanding *in situ* conservation programs across a broad range of agro-ecological conditions to maximize the diversity and utility of these source materials and encourage their use in future crop-improvement programs. This will require participation by the farmers who manage the bulk of Kenya's indigenous crop genetic resources, and who currently practice *in situ* conservation as a part of their traditional management strategies.

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APPENDIX 1: SAMPLE INDIVIDUAL HOUSEHOLD QUESTIONNAIRE

PART A: PERSONAL PROFILE OF RESPONDENTS

1. Farmer's name--
2. Gender---
3. Educational level ---
4. Date of discussion--
5. Division---
6. Location--
7. Sub-location--
8. Village---

9. Family Structure

	Family member name	Relationship	Sex	Yrs of education	Dependent (Y/N)	Independent (Y/N)
1						
2						
3						

10. Are you the one who makes decisions on the farm? Yes/No--------------
11. How many children are in your family -------------------------------------
12. How many of your children are dependent on you-------------------------
13. Of those dependent on you, how many do you involve in farming?
    Directly--------------------------- Indirectly---------------------------

14. How do you earn your livelihood in this community? (Please tick)

a) Farming within the community--
b) Self employed within the community----------------------------------
c) Non-self-employment within the community-------------------------
d) Employment outside the area e.g. GOK/NGO employee-----------
e) Other employment (specify) ---

PART B: FARM INFORMATION

15. Please provide the following information for a typical cropping season

Crop grown	Output consumed	Output sold	Unit price	Remarks

16. How many livestock do you own (list in order of importance—use table below)

	Livestock type	Number	Remarks

17. What was the total farm land size in the previous season?
    Total (acres) ------------- Cultivated area (acres) ----- Un-cultivated area (acres) --------
    Owned (acres) -------------- Rented (acres) --------- Shared (acres) --------
    Other (acres) ----------
18. What crops did you grow in the previous season? Mention them in the order of importance. (use table below)

	Crop	Planted area (acre)	Cropping season		Total harvest	Cash crop / food crop
			From	To		

19. Did you fertilize your maize crops? Yes------------------------No-----------------------------
20. If yes, how much land under maize was fertilized in 2009
    Long rains (acre) --------------------------Short rains (acre) --------------------------

21. If yes, what did you use to fertilize your maize crop? Please tick
Farm yard manure---
Compost manure---
Commercial fertilizers (specify) ------------------------------
Combinations (indicate which) -------------------------------

22. What was the response of maize to fertilizer? Mention which cultivar responded well to which fertilizer treatment? ---
23. Do you have to apply fertilizer (whether organic or inorganic) to your farm each cropping season? Yes/No-------------------
24. In the absence of fertilizer application, which maize cultivars (s) show better performance in such a situation? (list in order)
a) ------------------------- b)------------------------ c)---------------------- d)----------------------

25. How sustainable is the use of fertilizer in the farming of maize crop? ----------------------
26. If not sustainable what advice can you provide? --
27. How do you open up your land? Please tick
a) By hand----------------------------- b) By oxen------------------------------ c) By tractor---------
d) Don't open------------------------- e) Other (specify) -----------------------------------

PART C: MAIZE QUANTITATIVE DATA

28. What maize varieties did you grow on your farm during the long and short rains (List in order of importance)

	Maize variety (Long rain season)	Maize variety (short rain season)
1		
2		
3		

29. Which of the maize varieties above do you like most? ---------------------------------------

30. Name the attributes that make you prefer/cultivate the above variety more than the other cultivars that are grown in this area?
Attribute (a) ------------------ Attribute (b) ------------------ Attribute (c) ------------------
Attribute (d) ------------------Attribute (e) ------------------

31. Do you grow more than one cultivar of maize? if so give reasons why you choose to grow many varieties instead of only one variety you like most:
a) --------------- ---- b) ----------- ---- c) ---------------------- d) -------------------------

32. Please give details of maize production on your farms

Maize variety	Long rain season (LR)		Short rain season (SR)	
	Area planted (acre)	Amount harvested (kg)	Area planted (acre)	Amount harvested (kg)

PART D: MAIZE QUALITATIVE TRAITS

33. Indicate the maize cultivar grown (tick appropriate box)

Variety	LR season		SR Season	
	Improved cultivar	Local cultivar	Improved cultivar	Local cultivar

34. Please describe all the maize varieties you grow (use the table below)

Variety	Height	Earliness to maturity	Yield (grain)	Yield (stover)	Grain color

Variety	Grain size	Cooking quality	Eating quality

35. Which is your best maize variety---
36. For how long have you been growing this variety (your best variety)-------------
37. What is the most striking feature of your best variety---------------------------------
38. Which of your maize varieties is most tolerant to drought? -------------------------
39. Which of your maize varieties is most tolerant to disease? --------------------------
40. In your view, which qualities do you consider to be more important in the maize cultivar that you grow? Please tick

Disease tolerance----------------------Drought tolerance--- --------------Maturity rate-----------
Yield performance---------------------Eating quality---------------------- Thresh ability-----------