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Public perception and environmental concerns on genetically modified maize production in Kenya

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Abstract. *Mbugua AW, Mwaura F, Thenya T. 2018. Public perception and environmental concerns on genetically modified maize production in Kenya. Bioteknologi 15: 38-50.* The purpose of this study was to establish: (i) the public's perception towards the importance of biotechnology on maize production for food security in Kenya, (ii) the environmental implications of maize-related agro-biotechnology on national biodiversity conservation and biosafety and (iii) the public health concerns on the introduction of maize-related agro-biotechnology in Kenya. The study population included two clusters, namely maize farmers and consumers. The farmers were interviewed from two maize farming zones, namely Githunguri Ward (Kiambu County) as a small-scale production area and Moiben Ward (Uasin Gishu County) as a large-scale production area. The consumers, on the other hand, were interviewed from Umoja 1 Ward (Nairobi County). The number of enumeration areas (EAs) was based on planned 10-household interviews per EA, resulting in a total of 12 EAs; 6 from Umoja 1, 3 from Githunguri and 3 from Moiben with a total of 120 respondents including 60 maize producers and 60 consumers. The data analysis was undertaken using descriptive statistics and inferential statistics, like Man U Whitney test, with the initial phase using frequencies and cross-tabulations. The findings showed that majority of consumers believe that genetically modified (GM) maize will solve the problem of food insecurity in the country because there is a critical need to produce more maize to meet the increasing food demand. Out of the 120 surveyed respondents, 69% agreed that GM maize would play a significant role in solving food insecurity in Kenya. Only 34% of the respondents agreed that current maize production methods are sufficient to meet Kenya's food security needs. The respondents portrayed confidence that GM maize will be beneficial to farmers. 65% of the respondents agreed that GM maize would improve the profitability of the growers due to the increased yields per unit area. 60% of the respondents believed that GM maize would benefit society because it will allow farmers to produce food more efficiently. 51% thought GMO foods would play a significant role in solving malnutrition problem in Kenya. On the flip side, the majority of the respondents were concerned about the likely environmental and health risks. 76% of the respondents were concerned that GM maize will contaminate the conventional crops through cross-pollination. More than 6 in every 10 respondents believed that GM maize would be harmful to non-target insects, while 49 % thought that some of the GM maize would invade the environment and become uncontrollable. With regards to public health and religious concerns on the introduction of GM maize, it was established that 90% of the respondents were in favor of food labeling to show the presence of biotech ingredients. 55% of the respondents believed that GM maize might lead to human sickness and death. The study concluded that Kenyans would like a more integrated approach to address the food security issue without relying on any particular technology.

Keywords: Genetically Modified Organism, GMO, Kenya, maize

INTRODUCTION

Kenya's population is predicted to double by the year 2050; therefore, there is a need to more than double the food production to be a secure food country. Several ways exist in which agricultural output can be improved sustainably. These include, but are not limited to, the reliance on food imports from other countries, expansion of agricultural land including and irrigation in arid areas, use of biological fertilizers, better pest control, soil and water management, and the use of enhanced plant varieties, increased production either by conventional or biotechnological means.

Applications of biotechnology in crop production include tissue culture, genetic engineering, and molecular transformations. This study was primarily focused on genetic engineering, which has, over time, generated concerns. Confirmation from the survey by Kimenju et al. (2005), indicates that consumer groups, conservationists and other non-governmental organizations are apprehensive about genetically modified (GM) foods based on food safety, ethical grounds, religious concerns and the possible side effects on the environment.

If consumer acceptance matters are not sufficiently addressed, then the prospective economic and social profits of modern biotechnology may not be achieved (Stenholm and Waggoner 1992). It is therefore essential to institute the level of consumers' consciousness, perception, and apprehensions about GM foods since the acceptance of GM food is one of the most critical success factors with regards to the future of this technology.

Although numerous studies have analyzed consumer reception of GM foods in the industrialized countries and Asia, there is negligible evaluation work done in Sub-

Saharan Africa, though this expanse could advance significantly from this technology (De Groote et al. 2003). Generally, it is agreed that opinions of risks and benefits are a crucial driver of people's reactions to a specific activity or technology, such as GM food (Slovic 2000).

In Kenya, corn is the staple food crop. The overall consumption is valued at 98-125 kilograms per person per year, which converts to about 2700 thousand metric tons annually (Nyoro et al. 2007). And as such, it plays a significant part in food security; and for any technology to be successfully introduced in maize production, acceptance by the society is vital. Currently, the government of Kenya is investing in research, development, and capacity building on modern biotechnology. There are several on-going biotechnology projects on 5 crops under confined field trials (CFT). The plants include cotton, corn, cassava, sorghum, and sweet potatoes. As this development continues, it calls for more studies to be done to gauge the public's perception of the adoption of genetic engineering as a tool towards sustained food security. Understanding the society's perspective will be instrumental in coming up with a proper strategy as the world moves towards genetic engineering. Scientific studies on this issue are necessary to establish the degree of public willingness to embrace and adopt biotechnology as an acceptable solution to the problem of food insecurity. This kind of research has not been undertaken because most discussions on the matter are usually conducted at high levels by upstream experts, technocrats, and scientists. This study aims to fill this gap.

MATERIALS AND METHODS

Study area

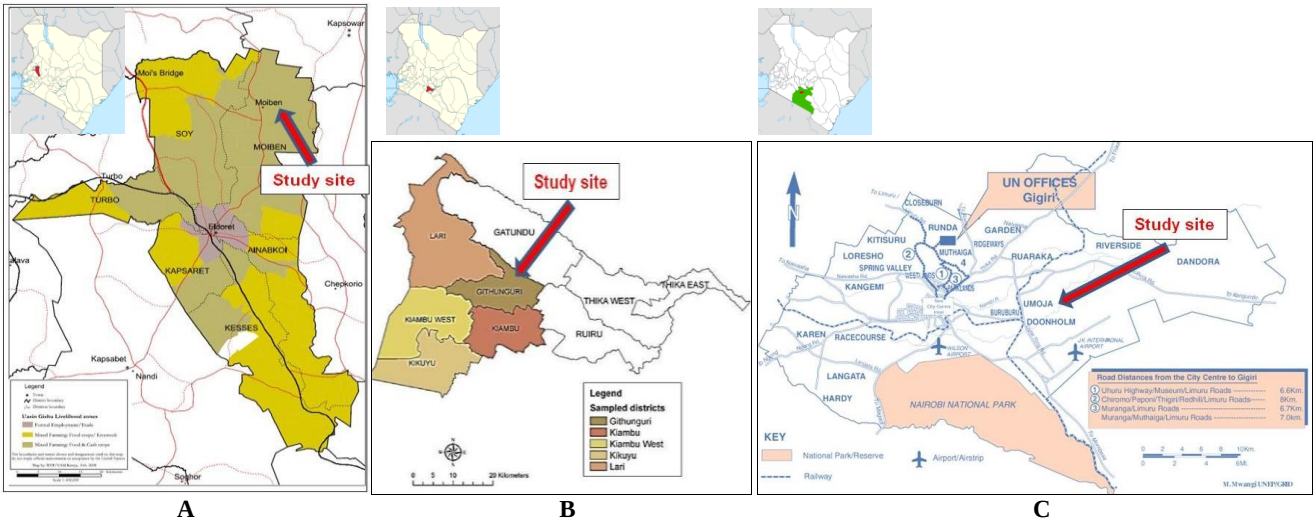
The study was conducted in three areas, including two potential GM maize production areas, namely, Uasin Gishu and Kiambu and one possible GM maize consumption area, namely Nairobi.

Uasin Gishu

Uasin Gishu County is a highland plateau whose altitudes extending from 2,700 m to about 1,500 m above sea level. Uasin Gishu County lies between longitudes 34 degrees 5'' East and 35 degrees 3'' West and latitudes 0 degrees 0'' South and 0 degrees 5'' North. The county shares conventional boundaries with Trans Nzoia County to the North, Elgeyo Marakwet County to the East, Baringo County to the Southeast, Kericho County to the South, Nandi County to the Southwest and Kakamega County to the Northwest. It occupies an overall area of 3,345.2 km^2. The county is one of the vital large-scale maize growing zones in Kenya with typical farm size at 2-10 acres and up to 224,890 acres under maize farming. The study was restricted to the Moiben Sub-County which located in the northern part of the County (Figure 1.A).

Kiambu

Kiambu County is situated in central Kenya. It borders Murang'a County to the North and Northeast, Machakos County to the East, Nairobi and Kajiado counties to the South, Nakuru County to the West, and Nyandarua County to the Northwest (Figure 1.B). The county lies between latitudes 00 25' and 10 20' South of the Equator and Longitude 360 31'and 370 15'East. According to 2009 census, Kiambu County has a population of 1,623,282, with a total area of 2,543 km^2. Up to 60.8% of Kiambu's population lives in urban areas. The study was conducted in the Githunguri Sub-County.



A **B** **C**

Figure 1. Map of study sites in Kenya. A. Uasin Gishu County (Yego 2013), B. Kiambu County (Omwenga et al. 2016), C. Nairobi County (UN-Habitat – www. unhabitat.org)(Wikipedia 2016).

Nairobi

Nairobi County borders Kiambu County to the North and West, Kajiado to the South and Machakos to the East. The county has an overall area of 696.1 km^2 and is situated between longitudes 36o 45‘ East and latitudes 1o 18‘ South (Figure 1.C). It lies at an altitude of 1,798 meters above sea level. Umoja estate is a middle-income residential area. Many of the houses were owner-occupied, but this has now shifted to most of them being let while others demolished the houses and built flats. The average asking rental price is about KES 20, 000 per month for the standalone dwellings. The servant's quarters go for about KES 5, 000. One-bedroom apartments are about KES10,000 and KES15,000 for two-bedroom apartments. About 150,000 people are residing in Umoja I, according to the National Population Census of the year 2009. Maize remains to be the vital staple food in Nairobi, based on the kilograms consumed per adult equivalent. Muyanga et al. (2004) established that up to 97% of the middle-income people in Nairobi used maize related products (maize meal, grain, or green maize) regularly.

Procedure

Research design

A household survey design was used in this study. The respondents (N= 120) were drawn from 3 counties: Githunguri (Kiambu), Moiben (Uasin Gishu), and Umoja 1 (Nairobi). Data on individual perceptions towards GM maize was generated from self-completed questionnaires that were administered.

Study population

To provide a sub-national assessment of public perception about the production and consumption of GM maize, the study population included two clusters: farmers and consumers. The farmers were interviewed from two maize farming zones, Githunguri ward (Kiambu County) and Moiben ward (Uasin Gishu County). The population of Githunguri ward and Moiben ward is 36,378 and 25,774 people respectively (2009 Housing and population census). The former represented small-scale maize growers while the latter represented the large-scale producers. On the other hand, the consumers were interviewed from a stand-alone livelihood cluster zone in Umoja 1 ward (Nairobi County). The population in Umoja 1 ward was 50,739 at the time of the survey (2009 Housing and population census).

Sampling strategy

In an ideal situation, one would like to study the whole population. However, in most cases, it is not possible or not feasible to do this, and therefore, one must take a sample. According to Black and Champion (1976), a sample is a portion of elements taken from a population that is deliberated to be representative of the community. Cochran (1977) tackled this subject of representation by affirming that "One method of defining sample size is to stipulate margins of error for the items that are regarded as most critical to the study. An estimate of the sample size required is first made separately for each of these vital items. When these calculations are finalized, researchers will have a range of n's, typically ranging from smaller n's for scaled, continuous variables, to larger n's for dichotomous or categorical variables. More frequently, there is an adequate variation among the n so that we are hesitant to choose the largest, either from budgetary concerns or because this will give an over-all standard of precision significantly higher than originally intended. In this event, the preferred standard of accuracy may be relaxed for some of the items, to allow the use of a smaller value of n (Cochran 1977).

To determine the correct sample size for continuous data (unknown population) at 95% confidence, with value of the selected α=.025 being 1.96 and margin of error of .03, Cochran’s sample table for population size more than 10,000 yielded a sample size of 119; rounded off to 120 for purposes of convenience in allocation. Since the study involved a household survey, determining the households was informed by the 2009 Population and Housing Census in Kenya (KNBS NASSEP IV Sampling Manual, 2009). In each stratum, representative enumeration areas (EAs) were randomly selected from a list of all EAs using a simple random sampling method. Each enumeration area had 150 households (KNBS NASSEP IV Sampling Manual, 2009). Ten homes were selected for interviews in each EA, to reduce the sample ratio to population. The selection is outstanding because it reduces cluster variability (United Nations Statistics Manual, 2005). According to the KNBS Housing and Population Census (2009), Umoja 1 has approximately 15,000 households, which are about 100 EAs. Githunguri and Moiben each have around 7000 households. Therefore, the sample was distributed according to the ratio of the number of enumeration areas. In Umoja 1, 6 EAs were randomly selected, while in both Githunguri and Moiben, 3 EAs each were selected. The distribution of the sample size is presented in Table 1.

Data collection

Data collection was commenced using a semi-structured questionnaire administered through informed adult consent with the household as the primary sampling unit. The standard questionnaire was structured following the Likert Scale, whereby the respondents were given a choice of five pre-coded answers with the neutral point being neither agree nor disagree (Joshi et al. 2015). The questionnaire was structured to enable the assessment of the level of public acceptance and public views on maize related biotechnology, including GM maize concerning biodiversity conservation and biosafety, public health, and religious ethics.

Table 1. Sample distribution across regions (clusters).

Region	Sample size	Clusters of the respondents
Umoja 1 (Nairobi County)	60	Maize consumers
Moiben (Uasin Gishu County)	30	Maize farmers
Githunguri (Kiambu County)	30	Maize farmers
Total	120	

Interviews

Five field interviewers were selected, and they were trained on the objectives of the project and the methodology of fieldwork. It was a directive that during fieldwork, each interviewer was to identify a landmark from the sampling point and skip 10 households in urban and 5 households in the rural as directed by KNBS NASSEP IV methodology. Since the questionnaire was short, each interviewer was expected to conduct 10 interviews daily. With the help of an additional hand, the supervision was stringent to ensure that the interviewers observed all research ethics, as required. Every evening, the questionnaires were collected from the interviewers and challenges discussed. One of the key challenges that came out was that many of the respondents did not have substantial prior knowledge of GM maize. However, the interviewers made sufficient effort to explain the GM concept before the field questionnaire was administered. However, the state of ignorance resulted in several skip routines in search of relevant respondents. A total of 120 questionnaires were collected from the field which translated to a 100% response rate.

Questionnaire

The first data collection was undertaken using a self-administered questionnaire in accordance with Orodho (2004). The general configuration of the survey included a preliminary section on the respondent's profile. The other three parts focused on assessing the respondents' views and perception on (i) The role/importance of biotechnology on food security, (ii) Environmental implication of biotechnology, (iii) Public health and religious concerns on the introduction of maize related agro biotech in Kenya.

The questionnaire was structured following the Likert Scale, whereby the respondents were given a choice of five pre-coded answers with the neutral point being neither agree nor disagree. The Likert Scale is a psychometric response scale which is predominantly used in questionnaires to acquire participant's inclinations or level of agreement with a statement or set of announcements. Likert scales are a non-comparative scaling technique and are unidimensional (only measure a single trait) in nature. Respondents are asked to specify their degree of agreement with a defined statement by way of an ordinal scale. The Likert Scale was used in the study to allow the individual to demonstrate the level of agreement or disagreement with various statements concerning the adoption of GM maize.

Data analysis

Once the questionnaires were collected from the field, they were cross-checked and screened for missing information, especially on the demographics section. Data coding then followed on individual parts of the demographics (occupation, religion, Home County) and additional comments on food security, environmental implications, and public health. Here, responses were allotted specific numerical codes to be entered into the statistical software and for purposes of uniformity and time saving, during data entry. All data was entered using CSPro software, which is best for data entry because it allows for skips and lock of specific values outside the scope of coding. The data was then exported to SPSS for ease of data cleaning and analysis. Data cleaning was done through checking of missing information, wrongly entered codes, and joining similar responses. The scales that were used for food security, environment, and health were then tested for validity and internal consistency (reliability) using Cronbach's alpha. The Cronbach's alpha (α) generated from IBM SPSS 20 for the overall scale was 0.759 while the Cronbach's alpha for various subscales for the following perceptions was also measured; food security (0.750), environmental concerns & biodiversity (0.731) and public health concerns (0.760). This indicated an excellent internal consistency of the data collection instrument. According to Cronbach (1951), an alpha (α) in the range $0.7 \leq \alpha < 0.9$ indicates right internal consistency of the data collection instrument. The data analysis was undertaken using basic summary statistics means, frequencies, and standard deviation. Descriptive data was analyzed in the initial phase using frequencies and cross-tabulations.

Non-parametric tests-Mann Whitney U test - was used to test the hypotheses. Non-parametric tests assume that data do not follow a normal distribution. The dependent variable was subjected to Shapiro- Wilk tests to check the normality. The results at 95% confidence showed that the data did not follow a normal distribution. Therefore, to compare the differences of any two of the independent variable (consumers, small-scale and large-scale growers), a non-parametric test was most appropriate. A Mann-Whitney U test was employed to compare differences between two independent groups, when the dependent variable is ordinal or continuous but not normally distributed. For this study, the data was constant but not normally distributed. As such, only median could be used as a central tendency measure statistic, which made the Mann-Whitney U test most appropriate for testing the difference in any two of the three independent variables.

RESULTS AND DISCUSSION

Response rate

The study targeted a sample of 120 respondents, and a total of 120 questionnaires were filled, giving a response rate of 100%. This response rate was quite representative since it adapts to Mugenda and Mugenda (1999) view that a response rate of 50% is satisfactory for analysis and reporting; a 60% response is rated as useful, while a response rate of 70% and above is rated as excellent.

Data reliability

Cronbach's alpha was used to measure the internal consistency of the data collected. Since each participant was viewed as independent from all others, Cronbach's alpha was calculated for the overall scale and the subscales. The Cronbach's alpha (α) generated for the whole scale was 0.759 while the Cronbach's alpha for various subscales for the distinct perception was also measured as follows; food security (0.750), environmental concerns & biodiversity (0.731) and public health concerns (0.760). These statistics

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Respondents demographic profile

The demographic profiles of the respondents were analyzed using descriptive methods, including frequencies and cross-tabulations. The patterns were segmented, as shown in Table 2.

Age and gender

Table 2 shows the breakdown of the key demographic characteristics: age, gender, and the highest level of education. The sample consisted of 59.2% males and 40.8% females. The majority of the respondents consisted of the youth between the ages of 25-34 (29%; 35/120) followed by those between the ages of 35-44 (27%; 32/120). There is a slight similarity in the distribution of respondents' ages across the respondents surveyed in Moiben and Githunguri, perhaps because these regions consisted of many farmers. The respondents surveyed in Umoja 1 however, including of those below 65 years old with an overwhelming majority (45%; 27/60) indicating that they were between 25-34 years old. According to the 2009 housing and census data, about 63% of the population in Umoja 1 were between the ages of 18-64 years, with only 2% having 65 years and above (KNHBS, 2010). This age variation in composition is perhaps due to low income and the compelling high cost of living around the urban area, which only favors the young and energetic population.

Education

The Government of Kenya is devoted to the delivery of quality education and training for all Kenyans in harmony with the constitution and international conventions such as the Education for All (EFA) goal. They are keen to develop policies for moving the country in the direction of the realization of this objective. Approximations from Kenya's 2009 Housing and Population Census, show that over 85% of Kenyans aged over 15 years can read and write with over 90% of men being literate as paralleled to 80% of women. Illiteracy was established to be more common among the underprivileged, predominantly poor women who constitute 61% of the total illiterate population.

The present research findings indicate that only 2% (2/120) of the total respondents had informal education. Table 2 shows that these respondents were interviewed in Moiben ward. The majority of those surveyed in Githunguri, consisted of those with secondary education levels. In Umoja 1, 3 in every 4 respondents surveyed indicated that they had tertiary education. This may be because a more significant portion of the population is engaged in a white-collar job.

Occupational analysis

There is a mix of occupations among the respondents. The majority (53%) of the urban respondents in Umoja I was dominated by respondents engaged in small and medium enterprises In the case of the rural areas, 50% of the respondents associated themselves with agriculture as their primary occupation with 20% indicating that they also engaged in small and medium enterprises (Table 3).

Rural farm size and urban household size

Table 4 shows the findings on rural farm size and urban household size respondent characteristics. In Moiben and Githunguri, since all the respondents were farmers, the key point of interest was to determine the farm size as principal maize production factor whereas, in Umoja 1, the key focus was on the household size as a key maize consumption factor.

Table 2. Breakdown of key demographic characteristics of the respondents.

Sample size (n)		Study area		
		Moiben	Githunguri	Umoja 1
		30	30	60
Age	18-24	0%	7%	20%
	25-34	7%	20%	45%
	35-44	27%	33%	23%
	45-54	30%	20%	8%
	55-64	13%	13%	3%
	65+	23%	7%	%
Gender	Male	60%	70%	53%
	Female	40%	30%	47%
Level of education	Informal	7%	-	-
	Primary	-	20%	-
	Secondary	40%	60%	25%
	Tertiary	53%	20%	75%

Table 3. Respondents' occupational analysis.

Primary occupation	Overall	Farmers (Githunguri & Moiben)	Non farmers (Umoja 1)
Agriculture	**26%**	**50%**	2%
Road transport	1%	2%	-
Administrative services	5%	2%	8%
Auxiliary finance and insurance services	2%	-	3%
Student	3%	2%	5%
Teaching	6%	8%	3%
Medical and health care services	3%	2%	5%
Social assistance services	2%	2%	2%
Artistic activities	1%	-	2%
Defense	2%	3%	-
Public services	3%	3%	3%
Computer system design and related services	1%	-	2%
Engineering (Civic, chemical, and mechanical)	6%	2%	10%
Religious services	2%	3%	-
Sales and marketing	1%	-	2%
Small and medium enterprises	37%	20%	53%
Retiree	1%	2%	-
Sample size (n)	120	60	60

Table 4. Farm size and household size characteristics.

Area	Mean	Std Dev.	Min.	Max.
Moiben Farm size (acres)	211.33	524.76	4.0	2,000.0
Githunguri	1.67	2.07	0.25	8.0
Household size of Umoja 1	3.22	1.52	1	7

The large-scale farmers in Moiben were found to own great tracks of land (Mean=211.33 acres, SD=524.76) compared to Githunguri small-scale farmers (Mean=1.67 acres, SD=2.07). The average household size of occupants of Umoja 1 was approximately three people per household, which is an approximate value of the 2009 housing and population census results. The difference among the maize producers was considered suitable for the perception of comparative analysis.

Public perception of GM maize and food security

The respondents were requested to show the extent to which they agree or disagree with statements of public perception on GM and food security items on a 5-point Likert scale. The overall findings by all the respondents considered GM maize as a possible solution to the food insecurity problems in Kenya. 69% of the respondents agreed that GM maize will play a significant role in solving food insecurity in Kenya (Figure 2). The respondents agreed on the need to produce sufficient maize for the increasingly growing population. These respondents viewed the sole cause of food insecurity in the country as associated with the domination of the country by arid and semi-arid areas; which are unproductive, hence produce insufficient food. However, some of the respondents attributed the food insecurity problem with widespread laziness and believed that GM maize would not be the sole solution. Others thought that the youth's overreliance on white-collar jobs affects innovation in the agricultural sector. The respondents suggested that the government needs to advise farmers on the best modern farming methods, while also searching for other safer ways of curbing the issue of food insecurity without necessarily relying on GM maize. Figure 2 shows that 65% of all the respondents agreed with the Likert Scale statement that GM maize could improve the profitability of the growers. Up to 60% believed that GM maize would benefit society by permitting growers to produce food more efficiently.

The statements met mixed reactions from various stakeholders (consumers, small and large holder farmers) surveyed. For instance, the small-scale maize farmers from Githunguri believed that GM food campaigns only focused on the benefits, without unearthing and disclosing the side effects. At the same time, these farmers are optimistic that GM maize will solve the problem of food insecurity stated by more than 73% of the surveyed farmers from the region. The small-scale farmers also believe that with GM maize, difficulties of malnutrition will be solved citing that farmers will significantly improve profitability from growing GM maize as a state by 60% and 70% of the respondents, respectively. This cluster of farmers is a little hesitant that the current maize production methods are sufficient to meet Kenya's food insecurity needs. However, they warn that if farmers rely on GM maize, and it fails, more hunger is more likely to be experienced.

On the flip side, large-scale maize farmers from Moiben believed that the current maize production approach and technology are sufficient to meet Kenya's food security needs. This was indicated by 60% of the farmers surveyed from the region. Many of them were hesitant that GM maize will solve food insecurity and malnutrition problems in Kenya. However, 43% appreciate the fact that GM maize will benefit the society, by allowing farmers to produce more and to a certain level, solve food insecurity level in the country.

Maize consumers from Umoja 1 showed their optimism and trust in the GM maize. More than 80% indicated that GM maize would help solve food insecurity in Kenya, as shown in Figure 3. Similarly, more than 60% of the consumers surveyed believe that GM maize allows farmers to produce food more efficiently, improve farmers profitability/income, and solve the problem of malnutrition in the country.

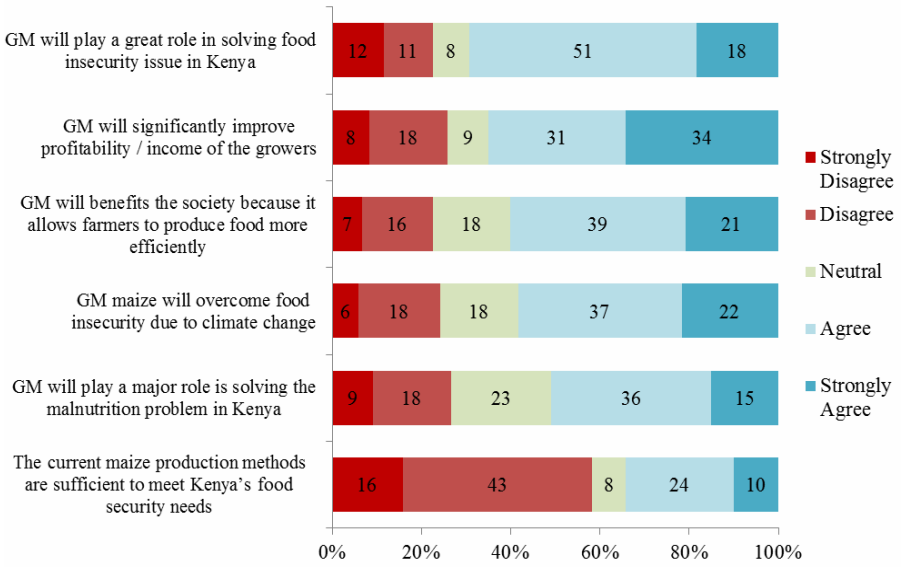

Figure 2. Perception towards the role of biotechnology on food security.

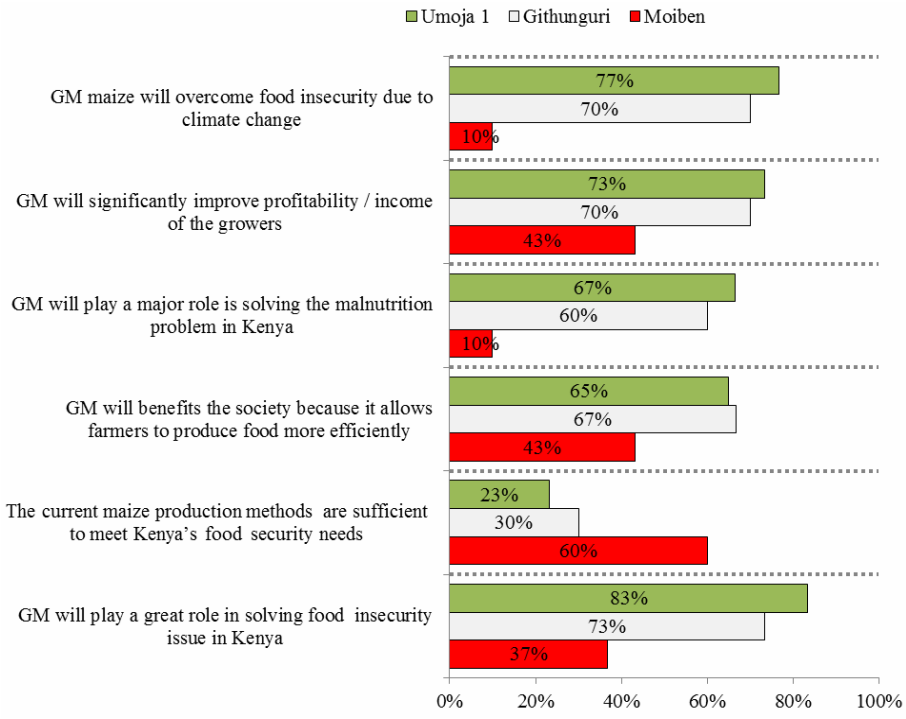

Figure 3. Regional analysis of perception towards the role of biotechnology on food security (Agree + Agree strongly).

Analyzing further comments from the consumers revealed that most of these consumers feel that GM maize is superior and would grow quickly and provide quick earnings, thereby resolving the issue of food insecurity in the long run. Some of them also cited that GM maize would require less fertilizer and biocides, thereby reducing the production costs, which would probably also reduce the cost of maize related products. Some of the consumer respondents, however, had the view that GM maize will create unnecessary competition with the traditional maize.

Environmental implications on national biodiversity conservation and biosafety

The respondents were asked to rank the extent they agree or disagree on whether GM maize affects the environment, especially on national biodiversity conservation and biosafety. The results indicated that 76% of the respondents feared that the introduction of the GM maize would contaminate the conventional crops through uncontrollable cross-pollination. Similarly, more than 50% of the respondents also agree that introduction of GM maize will cause increased pesticide use, which would contaminate the environment (Figure 4).

Small-scale farmers from Githunguri believe that despite the positive attributes expected from the introduction of GM maize, more than 60% of the GM maize would invade the environment and become uncontrollable with the majority (73%) of the surveyed small-scale farmers citing GM maize will contaminate the conventional maize through cross-pollination.

Just as smallholder growers, more than 50% of the large-scale growers from Moiben stated that they agree with the fact that GM maize is likely to affect the environment. They specifically stated that the introduction of GM maize is likely to contaminate the conventional maize through cross-pollination. These farmers added their concerns that harmful herbicides sprayed to control GM related maize weeds would kill beneficial insects like bees and decomposers. As such, large-scale farmers suggest that additional research on the environmental impact of GM maize is required because this is not known in Kenya. These large-scale farmers from Moiben felt that since maize farms will always be fenced, GM maize is likely to have significant effects on wildlife. As most of the farmers demand for a thorough scientific proof to unearth the real side effects of GM maize on wildlife, some claim that research findings found out that GM maize causes animal ulcers (to livestock).

In an equal measure of the magnitude of their optimism with GM maize, consumers were open to the expected adverse effects of GM maize especially on the fact that GM maize would contaminate the conventional maize through pollination, cited by 83% of the surveyed consumers. Similarly, more than 70% of the consumers are deeply concerned that GM maize may be harmful to non-target insects since they believe that GM maize would increase the use of pesticides which will then be detrimental to the environment. The consumers also added other expected effects of GM maize. Some believe that after consuming GM maize, some animals become ill or die, adding that since GM maize is artificially made, it has some genes that affect plants, animals, and even humans. Some of the consumers surveyed from Umoja 1, who claim that GM maize would create unnecessary competition for water and nutrients with other crops, fear that traditional maize varieties may be lost forever.

Additional probing revealed the following public environmental concerns: (i)The GM maize would lead to increased invasion of pests such as weevils. (ii) The GM maize is likely to affect the quality of dairy milk and bee honey. (iii) The GM maize will cause increased use of pesticides, thus contaminating the environment. However, some of the consumers believe that GM maize is pest resistant and will require limited use of pesticides, which is good for the environment. (iv) The GM maize will change the soil structure and mineral composition, thereby affecting the production of traditional indigenous maize. (v) The excessive spraying of the GM maize will contaminate rivers. (vi) The GM maize may lead to desertification. (vii) The GM maize may have adverse effects on wildlife. (viii) The GM maize will invade the environment and become uncontrollable (Figure 5).

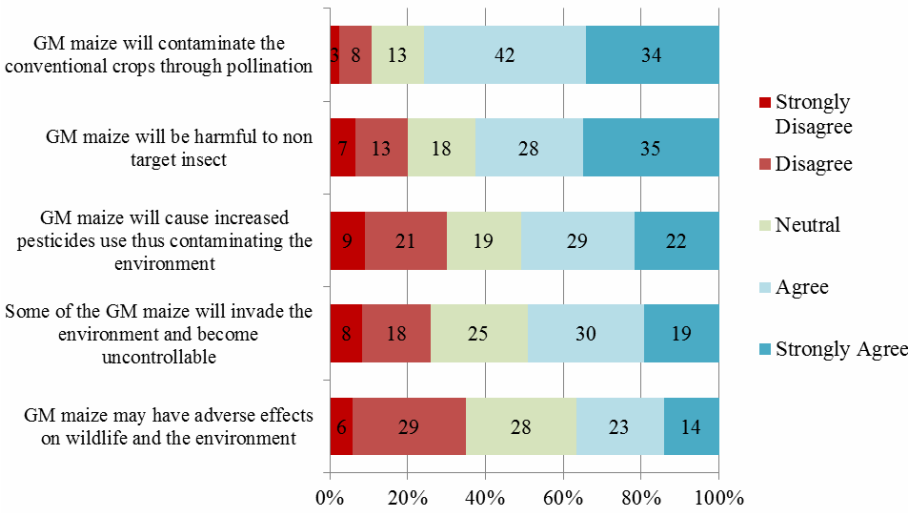

Figure 4. Public perception on the environmental implications of GM maize on national biodiversity conservation and biosafety.

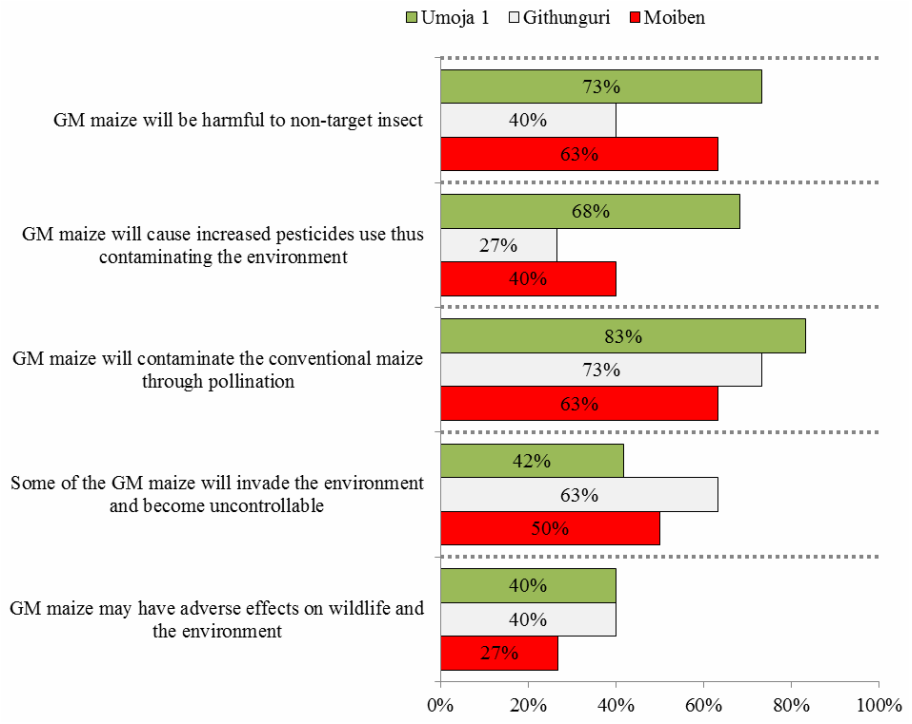

Figure 5. Regional analysis of public perception on the environmental implications of GM maize on national biodiversity conservation and biosafety (Agree + Agree Strongly).

Public health and religious concerns on GM maize

The key message from the survey findings was that GM maize labels need to show the presence of biotech ingredients, because consumers need to understand the health risks associated with this maize. On the contrary, about half of the surveyed respondents feel that GM maize has promising benefits, one of which is its high nutritional value even as others think that GM maize risks undermining God by modifying the conventional crops (Figure 6).

Small-scale farmers from Githunguri showed their support for GM maize, stating that GM maize will benefit the society due to its high nutritional values while also stating that GM maize is reasonably safe for human consumption. However, these small-scale farmers are part of those campaigning for labeling of GM foods to show the presence of biotech ingredients to expose the level of health risks that these foods have on their consumers.

More than 90% of the consumers posed their concerns about labeling every GM food to show the contents. While many are optimistic that GM maize will solve malnutrition problems due to its nutritional value, 60% of the consumers fear that GM maize might be harmful for human consumption. Above all, the consumers fear that GM food might lead interfere with God's ordinary creation of the crops.

Just like the other respondents, large-scale farmers from Moiben expressed their wish for labeling GM foods. Moreover, most of these farmers (50%) feel that GM foods aren't suitable for human consumption. The most outstanding negative perception towards GM maize in the large-scale growers sector is that GM maize is likely to interfere with God's creation of conventional crops cited by 67% of the respondents. Only 23% of large-scale growers believe that GM foods will benefit society due to better nutritional value.

Additional probing revealed the following public environmental concerns: (i) There is a need to increase health awareness campaign on GM maize with some calling for in-depth research on the impact of GM maize on human health. (ii) GM maize has a lot of nutrients that lack in traditional maize. On the flipside, some of the consumers raised deep concerns about GM foods stating that GM food accelerates aging of individuals, it may lead to a physically weak generation and that GM maize may cause allergic reactions to some people. (iii) There were claims that GM maize may make people resistant to drugs with others, suggesting that due to many demerits than merits, we. (iv) While others feel that GM interferes with God's creation, some consumers believe that GM is just human improvements of what God already created and as such does not interfere with God's creation at all. (v) Other respondents believe that GM maize being hybrid maize is not harmful to humans at all with others claiming that no reports of serious effects have been received from other countries that use GM maize. Preferred alternative instead of introduction of GM foods

The respondents were asked to give out a choice to be resorted to instead of introducing GM foods. They were presented with 7 options in the order of inclination with 1 being the most favored and 7 the least preferred. The results of Figure 7 indicate that the option with the highest number of 1 is the most preferred while the one with the highest number of 7 considered as the least favorite. The respondents felt that key focus points should be an expansion of agricultural lands including irrigating arid areas, advocating for soil and water preservation, use of better-quality plant varieties and the use of biological fertilizers as measures replacing GM foods.

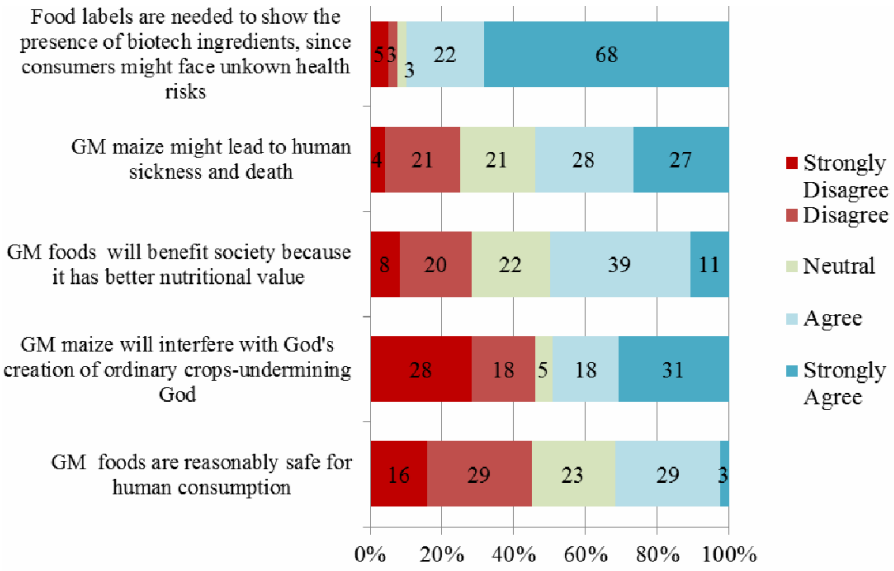

Figure 6. Perceived public health concerns on the introduction of maize related agro biotech.

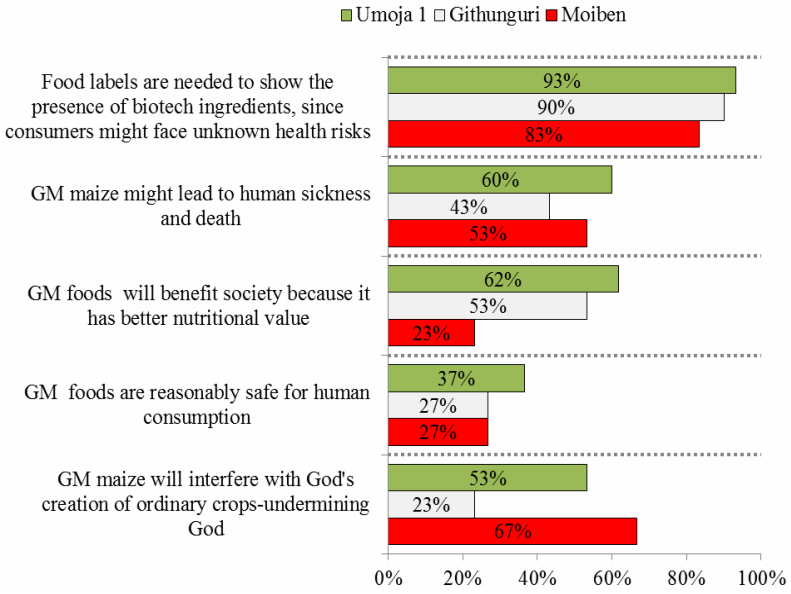

Figure 7. Regional analysis of perceived public health concerns on the introduction of maize related agro biotech (Agree +Agree Strongly).

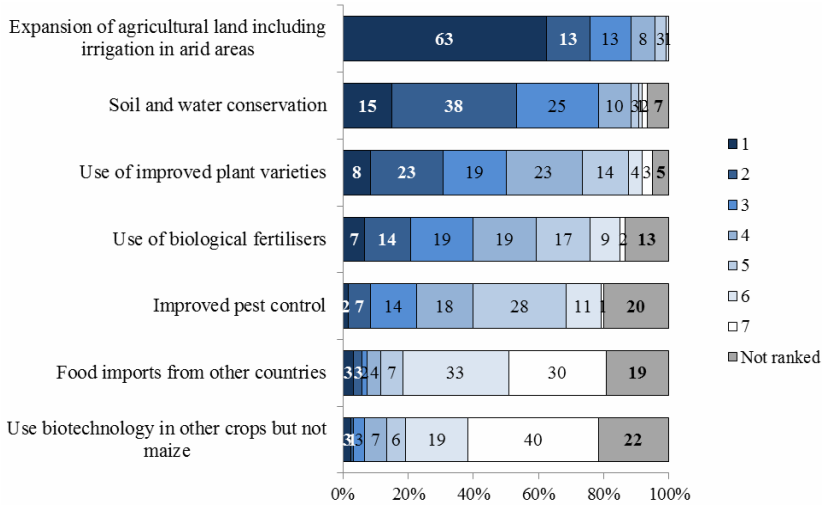

Figure 8. Rank of suggested alternatives to GM foods.

However, due to significant concerns about the side effects of GM foods, most respondents felt that the use of biotechnology on other crops and not maize would solve the problem of replacing GM maize. The other method that respondents felt least comfortable with was the option of importing food from other countries. Lastly, the respondents showed that another option that would be considered is the use of improved pest control methods. However, this is not a method that many would prefer. The ranking of options that would replace GM foods is shown in Figure 8.

Test of hypotheses

The four hypotheses that were to be tested included: (i) There is a public perception that GM maize may not play a significant role in solving the food insecurity issue in Kenya. (ii) There is a public perception that GM maize may not have adverse effects on the environment. (iii) There is a public perception that GM maize may not lead to human sickness and death. (iv) There is a public perception that GM maize may not interfere with God's creation of ordinary crops-undermining God.

Non-parametric test, using a Mann Whitney U test, was used to understand the hypotheses above. This is because the test variables were ordinal.

Hypothesis 1: There is a public perception that GM maize will not play a significant role in solving food insecurity issue in Kenya

The results of Table 5 indicates that there is a statistically significant difference in perception that GM maize will address food insecurity between small-scale farmers and large-scale farmers at 95% confidence

(W=712.5, Z=-3.12, p<.005). Similarly, there was a significant difference in perception of the same between large-scale farmers and consumers (W=939, Z=-3.921, p<.005). Finally, the difference between small-scale farmers and consumers over the fact that GM maize would help in solving food insecurity in the country was not significant at 95% confidence. This implies that while both small-scale farmers and consumers are optimistic that GM maize will solve food insecurity in the country, their counterpart large-scale maize producers warn that introducing GM maize would not address food insecurity in Kenya. Since the 69% agree and 23% disagree that introduction of GM maize into the country will improve food security, the hypothesis that there is a public perception that GM maize will not play a significant role in solving food insecurity issue in Kenya is rejected at 95% confidence. It can, therefore, be concluded that there is sufficient evidence that the introduction of GM maize will help solve food insecurity in the country.

Hypothesis 2: There is a public perception that GM maize may not have adverse effects on the environment

There is no statistically significant difference in perception that GM maize will solve food insecurity between small-scale farmers and large-scale farmers (W=907, Z=-.122, p>.005), large-scale farmers and consumers (W=1304.5, Z=-.538, p>.005) and small-scale farmers and consumers (W=1308.5, Z=-.497, p>.005) at 95% confidence (Table 6). Since only about 37% of the respondents agree while 35% disagree that GM maize may have adverse effects on wildlife and the environment, a difference of 2% which is insignificant (within the margin of error of 3%), the hypothesis that there is a public perception that GM maize may not have severe effects on wildlife and the environment is therefore accepted at 95% confidence. The results indicate that there is not sufficient proof to conclude that there is a public perception that GM maize may have adverse effects on the environment.

Hypothesis 3: There is a public perception that GM maize might not lead to human sickness and death

The results of Table 7 indicates that there is no statistically significant difference in perception that GM maize might lead to human sickness and death between small-scale farmers and large-scale farmers (W=866, Z=-.746, p>.005), large-scale farmers and consumers (W=1235, Z=-1.151, p>.005) and small-scale farmers and consumers (W=1181, Z=-1.624, p>.005) at 95% confidence. Since 56% of the respondents agree, while only 25% disagree that GM maize might not lead to human sickness and death, a difference of 31% which is very significant (far much more than the margin of error of 3%). The hypothesis that GM maize might not lead to human sickness and death is therefore accepted at 95% confidence. The results indicate that there is sufficient proof to conclude that there is a public perception that GM maize might lead to human sickness and death.

The results of Table 8 indicates that there is a statistically significant difference in perception that GM maize will interfere with God's creation of ordinary crops-undermining God between: small-scale farmers and large-scale farmers (W=661, Z=-.3.928, p<.005), large-scale farmers and consumers (W=2527, Z=-1.794, p>.005) and small-scale farmers and consumers (W=1014.5, Z=-3.113, p<.005) at 95% confidence. Due to mixed perceptions among the respondent groups, it is necessary to check the actual descriptive scores. It is shown that 49% agree , while 46% disagree that GM maize will interfere with God's creation of ordinary crops-undermining God, which is a difference of 3%, therefore insignificant. The hypothesis that GM maize will not interfere with God's production of usual crops or undermining God is accepted at 95% confidence. The results, therefore, indicate that there is not sufficient proof to conclude that there is a public perception that GM maize will interfere with God's creation of ordinary crops-undermining God between.

Hypothesis 4: There is a public perception that GM maize may not interfere with God's creation of ordinary crops-undermining God.

Table 5. Mann Whitney U test on perception differences between groups (small-scale farmers, large-scale farmers and consumers) on the public perception that GM maize will solve food insecurity in the country.

Test variable 1	Test variable 2	Mann-Whitney U	Wilcoxon W	Z	p-value
Small-scale farmers	Large-scale farmers	247.5	712.5	-3.12	0.002
Large-scale farmers	Consumers	474	939	-3.921	0.001
Small-scale farmers	Consumers	828	1293	-0.695	0.487

Table 6. Mann Whitney U test on perception differences between groups (small-scale farmers, large-scale farmers and consumers) on the public perception that GM maize may have adverse effects on the environment.

Test variable 1	Test variable 2	Mann-Whitney U	Wilcoxon W	Z	p-value
Small-scale farmers	Large-scale farmers	442	907	-0.122	0.903
Large-scale farmers	Consumers	839.5	1304.5	-0.538	0.591
Small-scale farmers	Consumers	843.5	1308.5	-0.497	0.619

Table 7. Mann Whitney U test on perception differences between groups (small-scale farmers, large-scale farmers and consumers) on the public perception that GM maize might not lead to human sickness and death.

Test variable 1	Test variable 2	Mann-Whitney U	Wilcoxon W	Z	p-value
Small-scale farmers	Large-scale farmers	401	866	-0.746	0.456
Large-scale farmers	Consumers	770	1235	-1.151	0.25
Small-scale farmers	Consumers	716	1181	-1.624	0.104

Table 8. Mann Whitney U test on perception differences between groups (small-scale farmers, large-scale farmers and consumers) on the public perception that GM maize may not interfere with God's creation of ordinary crops-undermining God.

Test variable 1	Test variable 2	Mann-Whitney U	Wilcoxon W	Z	p-value
Large-scale farmers	Consumers	697.5	2527.5	-1.794	0.073
Small-scale farmers	Consumers	549.5	1014.5	-3.113	0.002

Discussion

Public perception on GM maize and food security

The findings in this study showed that the majority (69%) of the respondents considered the introduction of GM maize as a possible solution to the food insecurity problems in Kenya. This finding is like the study conducted in Kenya by Kimenju et al. (2005), in which most people believed that the adoption of the GM technology would have positive impacts, with above than 80% approving that it can offer an answer to the world's food production hitches. Similarly, the study conducted by Anunda (2009) showed that majority (79%) of the respondents from all the four clusters (consumers, farmers, academia, and scientists) believed that the introduction of GM drought-tolerant beans in arid areas of Kenya was desirable.

Anunda (2009) asked the respondents if genetically modified crops (GMCs) will improve yields and offer an answer to Kenya's food issue, 50% of the respondents felt that GMCs could improve yields which portrayed some level of public confidence with GM crops performance. In this study when we asked respondents if they believe growing GM maize will significantly improve profitability/income of growers, 65% of them were positive about it which was quite like the findings by Anunda (2009).

In an opinion survey conducted by Ombewa and Otunge (2012), on awareness and perceptions of agricultural biotechnology by the Seed Traders Association of Kenya (STAK) members, the study sought to know whether the respondents would be willing to produce, package and sell genetically modified crops. 100% of the respondents indicated that they would be ready, implying that they are aware of the benefits of biotechnology crops.

In the 2010, Eurobarometer which is a sequence of public opinion surveys carried out frequently on behalf of the European Commission, 53% of respondents in Europe expected biotechnology and genetic engineering to have a positive effect in twenty years, while 11% expected no impact, and only 20% expected a negative effect. Although this is not directly linked to food security, there is an overall agreement that biotechnology will have a positive effect.

Environmental implications of biotechnology on national biodiversity conservation and biosafety

Findings from this study established there are various public ecological concerns that the introduction of GM maize is likely to contaminate the conventional crops through pollination, as suggested by 76% of the surveyed respondents. The study by Kimenju et al. (2005), established that 51% of the respondents believed the introduction of GM crops would lead to loss of original plant varieties while 40% were of a contrary view.

More than 6 in every 10 respondents in this study believed that the introduction of GM maize would be harmful to non-target insects. The level of public environmental concern in this study was, therefore, is slightly above a survey conducted by Anunda (2009), where respondents were asked if 'Genetically Modified crops that are insect resistant might lead to the death of beneficial insects/non-pests and other non-targeted insects such as bee's or even birds.' The responses showed that a significant number (47%) of respondents disagreed that GMCs that are insect resistant may be detrimental to birds and bees with only 38% agreeing while 15% were undecided.

There was a substantial public environmental concern in this study about the possible contamination of traditional crops through cross-pollination with GM maize. Scientific studies have shown that best way of preventing cross-pollination between adjacent non-GM and GM crop fields is probably by maintaining sufficient distance between the two or engaging in human-pollination of GM crop under controlled conditions which is feasible. The application of GM buffer zones might be difficult in Kenya, where small-scale farmers' seldom have any land to spare. There is a significant likelihood that the risks of non-GM contamination by GM crop will come with numerous controversies and court cases in Kenya and the Biosafety Act does not appear to have adequate legal mechanisms to deal with these issues especially the livelihood damages on the emerging organic farmers whose model will almost be rendered impossible.

Public health and religious concerns on the introduction GM maize

In this study, 32% of the respondents agreed that GM foods are reasonably safe for human consumption. This was like the survey conducted in the USA on public perceptions of labeling genetically modified foods by Hallman et al. (2013), in which 45% of the respondents agreed that GM food was safe for human consumption with 8% strongly agreeing that such food was safe. However, 63% of the respondents in the study indicated that they would be distraught if they were served GM food without disclosure. In addition, 54% of the respondents reported that they would be enthusiastic about paying more for non-GM food.

One of the issues raised by the opponents of the GM technology was that GM maize may cause allergic reactions to some people and that GM maize may make people resistant to medical drugs. These public health concerns are similar with the results of the study conducted by the Centre for Disease Control and Prevention (2001), which suggested that there is potential for the unintentional transfer of allergens to formerly hypoallergenic foods.

Up to 68 % of the respondents in this study strongly agreed that food labels are required to confirm the presence

of biotech ingredients, to avoid the likelihood of consumers facing undisclosed health risks in the future. This finding concurs with the results of the study by Hallman et al. (2013), in which up to 59% of the respondents felt that it was tremendously important to inform the consumers whether food products have GM ingredients on a label. An almost similar percentage indicated that it was necessary to disclose information on whether a food product was cultivated while using hormones (63%), pesticides (62%), or antibiotics (61%).

Finally, the findings in this study established that majority of the respondents believed that the development and introduction of GM crops would interfere with God's creation of conventional plants, thereby undermining God as the Creator of the Universe and all the plants in the world as indicated in the Book of Genesis. Up to 49% of the respondents were concerned, while 46 % were not, and 5% were non-committal on this matter. From a study conducted by Anunda (2006), most of the consumers (64%) disagreed that genetic modification of crop plants can be considered as an act of "Playing God." In the study by Kimenju *et al*. (2005), it was established that 23% of the respondents were concerned that of the adoption of GM foods was tantamount to "playing God." This indicated a significant similarity with this study. Elsewhere in the world, a study was conducted in India by Gene Campaign and the University of Hyderabad to assess the level of public awareness, attitudes, and perceptions on the adoption of GM technology and GMOs among farmers, consumers, and other stakeholders. The findings showed that farmers across all ages and education levels felt that they would never offer 'genetically modified' food in temples or use it in religious ceremonies and festivals and were also unwilling to serve such food in weddings.

In conclusion, there is a robust public willingness on the introduction of GM maize in Kenya to deal with recurrent food insecurity, which might increase under the expected impacts of climate change. Kenya's vulnerability to climate change is predominantly acute due to its geographic exposure, low incomes, and more dependence on climate-sensitive sectors like agriculture, tourism, health, and energy. The agricultural industry in Kenya is already under pressure from climate change. It is anticipated that climate change will lead to a temperature rise of about 4^{o}C and a rainfall variability of up to 20% by the year 2100. This will seriously affect many economic sectors, especially agriculture, where a production decline of between 1- 22% is expected within the humid and dryland zones. Climate change is likely to increase challenges in the economic and social fabric of society. The government should, therefore, explore ways of enhancing the application of environmentally sustainable methods biotechnology for food security in the country as an intervention against increasing food demand, shrinking available arable land, and the looming climate change. There is substantial public fear and concerns on the likely environmental impacts of GM technology in the country. However, much of this is associated with inadequate public awareness and misinformation on biotechnology. This might also stem from insufficient scientific knowledge on the environmental impacts of biotechnology in the world, with most of the studies so far having been conducted in the developed world, which also controls the technology. There was apperception that introduction of GM maize might lead to human sickness and eventual death after consumption, and almost a similar weight was given to GM foods having better nutrition and eventually benefitting the society. This shows that fear and admiration of GM technology adoption are present in almost equal measure. The community is split between the possible benefits as well as the potential downside of GM technology. However, there is no doubt that there is a strong preference to have food labels indicating the presence of biotech ingredients. This is an indication that people still want to have the liberty to make a choice and have free will as far as consumption of bioengineered foods is concerned. There is also a strong indication that the introduction of GM maize in Kenya, like in other parts of the world could result in some resistance from some religious circles.

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