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Farmers' Perceptions of Socio - Economic Biosafety Considerations Regarding Adoption and Use of Biotechnology: A Case Study of Sithobeleni and Lesibovu Communities in Swaziland

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Authors' contributions

This work was carried out in collaboration among all authors. Author AMD contributed the biotechnology and animal science component of the study and also wrote the protocol and first draft of the manuscript. Author CM contributed the agronomy component of the study and also organized the farmer visit groups. Author ZH contributed the socio- economic component of the study including development of the research guide. The authors worked as a team during the project implementation and final write up of the manuscript. All authors read and approved the final manuscript.

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ABSTRACT

Agriculture plays a great role in the economy of Swaziland. It is also important for food production. Over 70% of the agriculture is practiced in the rural sector where mainly food crops are produced under subsistence farming systems characterized by large hectares cultivated with corn and a high cattle population producing low yields. Biotechnology has potential to improve agricultural production. Biosafety procedures have been developed to ensure safe handling of products of modern biotechnology. The aim of this study was to determine socio economic considerations for risk assessment when products of modern biotechnology are introduced into the environment.

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Information was obtained from key informants and focus discussion groups of cotton, maize and cattle farmers from Lesibovu and Sithobeleni communities. Key biotechnologies already practiced in the communities included production and use F1 hybrid maize seeds as well as artificial insemination in dairy cattle. The major socio economic factors that should be considered when new technologies are introduced include consideration of community norms and values such as seed sharing and seed saving, considerations of cultural and religious beliefs such as objection to eating of some animal species, and acceptability of products of modern biotechnology by markets. Major constraints limiting implementation of technologies in the communities include difficulties with acquisition of inputs, drought and shortage of advisory services. It was observed that farmers were willing to adopt modern biotechnology provided that it was safe to public health, animal health and the environment. The technology should be legally acceptable in the country and be approved for use elsewhere. It was concluded that there is need to ensure that socio-economic factors form part of the risk assessment protocol when applications are considered for the release of products of modern biotechnology to the environment. Socio economic considerations should also form part of public awareness campaigns and training prior to the introduction of modern biotechnology into communities.

Keywords: Biosafety; modern biotechnology; socio-economic; genetically modified; risk assessment.

1. INTRODUCTION

The role of agriculture in the economic development of Swaziland cannot be overemphasized. Besides contributing a sizeable fraction to the country's gross domestic product (GDP), 8% [1], it also plays a significant role in: Income generation particularly for the rural community; food production; provision of raw materials for the manufacturing industries; and generation of export products for foreign exchange [2,3]. Both crop and animal agriculture are practiced in Swaziland. The major cash crops produced in the country include sugar cane, pineapples and cotton and the main income earner livestock product is beef. Beef exports contribute 1% of the country's GDP [4]. Agriculture in the rural sector is mostly subsistence and production is characterized by low yields although, however, the Ministry of Agriculture [5] has developed strategies for farmers to graduate from subsistence to commercial farming [5]. One of the technologies that are explored for improvement of agricultural yields is biotechnology.

Biotechnology in the broad sense has been defined [6] as 'techniques that use organisms or their parts or product thereof to produce or alter a product'. It involves manipulation of micro-organisms, plants and animals. Its importance in environmental management is well documented. It is useful in the control and utilisation of industrial waste for the production of value added products [7,8,9]. It is used for reclaiming degraded environments [10,11,12]. It is also used for producing environmentally friendlier products.

A significant contribution of biotechnology to agriculture is its potential to improve crops and animal yields. As reported elsewhere [13], the numbers of people living in developing countries are increasing and over the next decades agriculture will face formidable challenges from providing adequate nutrition for the billions of people. Under conventional agricultural conditions in the developing world, the shortage of technologies needed to double or triple food production is already a threat. Farmers may irreparably damage the resource base as they seek to feed more and more people [13]. Success in meeting these challenges depends on the discovery of new knowledge and the development of new technologies, which could allow for greater intensification of crop and animal production on a sustainable basis. Biotechnology, particularly modern bio-technology, has potential to contribute to increases in agricultural productivity in developing countries [14].

Article 2 of the Convention on Biological Diversity (CBD) has defined modern biotechnology as the 'application of *in vitro* nucleic acid techniques, including recombinant deoxyribonucleic acid (rDNA) and direct injection of nucleic acid into cells or organelles, fusion of cells beyond the taxonomic family' [6]. Modern biotechnology includes use of DNA probes, recombinant DNA technology, several forms of genetic engineering, production of stem cell cultures and animal cloning. In agriculture, modern biotechnology has potential to contribute to crop and animal yields, poverty alleviation, combating food insecurity, production of novel products and leverage on national economy [14]. Over the past decade, scientists have developed several transgenic crops. A few of these have been commercialized. These include both cash crops and food crops. Included amongst the commercialized cash crops are cotton, soybean, and canola. Maize is the major transgenic food crop that has been commercialized [15]. Current modern bio-technology trends indicate growth in adoption and use of the technology. In 2013, cultivation of biotech crops grew by 3 percent or 5 million hectares from the 2012 statistics to reach 175 million hectares. The percent increase was even higher, 6.3%, in the developing world than in industrialized countries. Since commercialization in 1996, biotech crop hectares have increased by more than 100 fold, from 1.7 million to 175 million hectares, thus making their adoption the fastest in recent time [15]. Currently, in Africa there are three biotech mega countries confirmed growing 50,000 hectares or more of transgenic crops namely, South Africa, Burkina Faso, and Sudan. Many other countries are still investigating the technology by either conducting confined or field trials [15]. In Swaziland, following the enactment of the Biosafety Act of 2012, Swaziland Cotton Board obtained permission and is conducting confined field trials for genetically modified cotton in six different stations.

The Convention on Biological Diversity specifies that products of modern biotechnology, “living modified organisms (LMOs),” should be subjected to Biosafety assessment as prescribe by the Cartagena Protocol on Biosafety (CPB). As reported before [16], Biosafety can be defined as the ‘regulatory system and risk analysis procedures designed to perform proper risk assessments, mitigation and communication of risk profile of products of modern biotechnology in order to ensure their safe use’. The implementation of the biosafety protocol depends on individual country’s infrastructural, technical and human capacities. Over Forty-five member states of the African Union recognized the need for agricultural biosafety by signing or acceding to the CPB. By doing so, countries committed themselves to develop national biosafety systems. Swaziland acceded to the CBD on January 13, 2006 and has almost completed development of the National Biosafety Framework (NBF) after having the biotechnology and biosafety policy approved and the biosafety Act receiving Royal ascent in December 2012.

The decision making process on production of transgenic crops is depended on risk assessments, which are generally based on scientific procedures and factors. Article 26 of the CPB however, states that ‘parties in reaching a decision on imports, may take into account socio-economic consideration arising from the impact of the living modified organism on the conservation and sustainable use of biological diversity especially with regard to the value of biological diversity to indigenous and local communities.’ Congruent with the CPB, Swaziland, as enshrined in the Biosafety Act, 2012, advocates that socio – economic considerations will be taken into account when a decision is made regarding introduction of LMOs in the country. The country however, needs to identify the key socio-economic factors worthy consideration when doing risk assessments prior to introduction of products of modern biotechnology to the environment

As the country is already in the process of introducing living modified organisms (LMOs) to the local environment, the aim of this study was to get a clear understanding of biosafety socio-economic considerations that should be noted when assessment of the potential risks and benefits of modern biotechnology are done. Specifically the objective was: to identify and unpack socio- economic issues that should be considered when carrying out biosafety socio – economic risk assessment.

2. METHODOLOGY

2.1 Site Selection

The study sites were selected based on the experience of respondents to biotechnology surveys, and on the practice of agricultural production activities. Two communities were selected according to this criterion, and both were involved in maize, cotton and livestock production. The areas selected were Sithobeleni and Lesibovu communities located between latitude 26° 36’ and 26° 53’ South and longitude 31° 26’ and 31° 36’ East. The altitude of the study area was 378 m above sea level.

2.2 Desktop Study

Desktop literature review was conducted by the team with special emphasis on studies about the various aspects of genetically modified organisms (GMOs) relevant to crop and animal production as Swaziland’s agriculture is crop and animal production oriented. Policy documents on biotechnology, agricultural technologies, biosafety, and published literature were reviewed in order to get a deeper insight into the socio-economic concerns of the users of the technologies. Material on food security and livelihoods were also reviewed to understand the adoption and use of such technologies in order to weigh whether issues of biosafety are addressed in the face of other pressing needs. The literature review assisted researchers in gaining a deeper understanding of the issues to be pursued.

2.3 Data Collection

The study employed qualitative data collection methods, which are, focus group discussions with farmers and in-depth interviews with key informants. The team consulted extensively with relevant stakeholders from various sectors such as the Ministry of Agriculture, University of Swaziland (UNISWA), Cotton Board, Agro-based industries, farmers, None Governmental Organizations (NGOs) and Swaziland Environment Authority (SEA). This was done through focus group discussants and workshop. The major research activities involved: Identification of potential respondents (focus groups); Mobilisation of focus groups; Provision of information on the subject as key informants. Perceptions of respondents were also quantified as percentages where appropriate. The results were subjected to the Chi square (x^2) test to measure differences between variables. Computation was done using the Chi square rows by column contingency Table (2x2) method.

2.4 Sampling

Respondents were drawn from the areas stipulated above in order to provide a sample representation of the farming community and the different agricultural production patterns thereof. Two focus group discussions were conducted in each zone targeting the different farming patterns and were comprised of women, men and young farmers.

2.5 Research Guide

Two research guides were prepared, one for stakeholders as key informants and one for the farmers as focus group discussants. The guides enabled researchers to focus their discussion and guide respondents on the direction of the interview. The two guides were pre-tested in two subsets of the communities, one from each of the target areas. The focus group discussion method was used to obtain general information on the subject. Collaborators were requested to assist in the identification of focus group participants, farmers in the case study areas, and these comprised of women, men, young girls and boys who share certain commonalities such as age, occupation and status in the household. This allowed the free flow of information without limiting expression. General group discussions were considered as a supplement to the focus group methodology when need arose. Groups were organized on sites irrespective of their characteristics. Stakeholder interviews with key informants were done with people who have a stake in biotechnology and biosafety issues as well as those who are in positions of bringing about change where needed. These were identified because of their position and included government personnel, NGO personnel and the private sector personnel. Stakeholder validation and endorsement were done through a consultative workshop, in which a total of about 60 participants discussed, expanded on the perceptions of the informants and focus groups of socio – economic factors that should be considered when technologies are introduced. The data were then analyzed and interpreted to identify the socio - economic factors that should be considered when Biosafety risk assessments are done. A comparative analysis of the status quo as determined above was done along the expectation of the CPB on socio – economic considerations.

3. RESULTS AND DISCUSSION

A case of two communities was studied to determine their perceptions of socio economic factors that should be considered when technologies are introduced in farming communities. The case study was done in these communities because of their previous involvement in biotechnology studies [17]. Farmers were asked about their experiences in crop production including cotton and maize and in livestock production such as cattle. Stakeholder validation and endorsement was done through a consultative workshop, in which a total of about 60 participants discussed and further elucidated the identified socio economic factors. Socio economic status and bio-data of the respondents from these communities are presented in Table 1. A majority of the farmers, over 60%, have done at least secondary school education. The farmers are mainly small scale farmers owning less than 10 hectares. As shown in the results, farm produce is the major source of income, although a combination of sources is not uncommon. Over 50% of the farmers that participated in the study were women and this signifies the significant socio economic role women played in communities.

3.1 Status of Technology Application in Cotton and Maize Production

Cotton production is mainly done in the lowveld under dry-land irrigation farming system. There has been a significant decrease in cotton production from 7500 tons in 1999 to less than 1000 tons in 2009 [18]. Reasons for this drop are not explicit. It could be due to marketing problems, or a switch by many cotton farmers to sugar cultivation or dry weather conditions. The farmers in both areas of the case study were growers of cotton. Although the neighbouring state, South Africa has commercialized production of genetically engineered cotton commonly known as Bt cotton, the cotton legally grown in Swaziland during the period of the study, 2009 to 2012 was non GMO. A majority of cotton farmers are found on Swazi nation land (SNL).

Table 1. General description of farmers characteristics from Lesibovu and Sithobeleni communities

Description	**Frequency**	
	Sithobeleni	**Lesibovu**
Number of famers	**50**	**40**
Sex	**M = 22 F = 28**	**M = 20 F = 20**
Age distribution groups:		
Less than 20 years	4	3
21 -39 years	16	12
40 – 59 years	21	18
60 years and above	9	7
Marital status of farmers:		
Married	31	23
Single Parent	9	10
Widower	2	1
Widow	5	2
Single	3	4
Farming experience:		
less than 5 years	8	6
5 to 10 years	13	9
10 to 20 years	19	15
More than 20 years	10	10
Education status of farmers:		
Literacy class	3	2
Primary (grade 1-7)	13	9
Secondary (grade 8-10)	18	18
High school (grade 11 -12)	12	8
Tertiary (College, University)	4	3
Source of family income:		
Sale of farm produce	40	32
Employed elsewhere	6	4
Supported by relatives	18	4
Other home business	15	10
Pension	9	7
Farm size:		
Less than 1 ha	3	2
1 to 2 ha	18	13
2 to 4 ha	20	17
4 to 10 ha	4	8
More than 10 ha	1	0

As reported before [4,19], over 75% of the Swazi nation lives in the SNL. Under this tenure system, each homestead is allocated land for building family houses and cultivation. The land is communally own, it is held by the Monarch in trust of the Swazi nation. Grazing is on communally owned rangelands during day and the livestock are kraaled at night [19]. This accounts for the comparatively smaller individual farm areas reported above. The farming system generally practiced on SNL is mainly substance farming comprising of mixed crop and livestock farming. Sales are incidental, when the production has exceeded family consumption needs [2,4,19].

Maize is the staple food crop for Swaziland. It is grown in all the ecological zones of the country. In the lowveld, some farmers grow maize under irrigation throughout the year. It is grown on both tittle deed land (TDL) and SNL, whereby over 90% of the cultivation is on the SNL. Maize has high moisture demand particularly at the flowering stage. The growing season is summer, when there is plenty of rainfall [19]. It is grown mainly as a food crop and is not exported. The country is not self-sufficient in maize production hence a large proportion of the maize consumed locally is imported. Maize production in the country decreased from 125,205 tons in 1999 to 75,070 tons in 2009 [18]. The reasons for this decrease are not clear, it could be due to erratic climatic conditions or due to a deliberate shift from the less profitable food crop, maize, to a more profitable cash crop like sugar cane [19].

The findings presented on Table 2 have shown that land preparation and planting requirements in both areas are met through use of tractor or animal drawn implements. Although the tractor or oxen are used for planting, these are primarily used for opening ridges; the actual planting is mainly done by hand. Weeding is also done by hand with the help of inter - row animal drawn cultivator. Some farmers are using conventional herbicides and some believe that the use of herbicides is incompatible with the intercropping system they use where they intercrop maize with pumpkins or ground nuts. A combination of organic fertilizer (kraal manure) and inorganic fertilizer containing nitrogen, phosphorus and potassium (NPK) are used to improve soil fertility.

The choice of seed varieties is broader with maize farmers and very limited in cotton farmers. The latter are provided the seed varieties by the Swaziland Cotton Board, either Albacala or Delta opal. Whereas the maize farmers make their own choice on the variety they would like to buy from several that are available in the market, or may choose to use their own home produced open pollinated seed variety saved from previous harvest. The farmers were aware that all the commercial maize seed varieties are F1 hybrids and therefore are effectively used once. Insecticides were more extensively used in cotton production than in maize production. In the former, several cycles of insecticide spraying were used with different types of insecticides used, while in the latter very limited insecticides were used, as a matter of fact, some of the maize farmers were not using any insecticides at all. It was also noted that traditional pest control in the form of aloe ash was used to control

Table 2. Technologies and operation systems used during production of cotton and maize at Lesibovu and Sithobeleni

Operation	Technology or system used in cotton production	Technology or system used in maize production
Ploughing	Tractor hire, oxen, donkeys	Tractor hire, oxen
Planting	Oxen marking lines, hand planting	Hand, oxen drawn planters
Fertilizer	NPK - 2:3:2 (22); NPK - 2:3:2 (38) kraal manure	NPK - 2:3:2 (22); NPK - 2:3:2 (38) kraal manure
Seeds used	Albacala, Delta opal, (supplied by Cotton Board)	Hybrid maize seeds, local mix (sintfu); local opv
Weeding	Animal drawn cultivators, hand weeding (hoes), herbicides	Hand weeding, oxen drawn cultivators, herbicides
Pest control	Chemicals for: Aphids-marshal; Bollworms, Red spidermites, agromectic; jassids , volamiprid	Cutworm bait, stalk borer granules, weevil tablets, aloe ash for grains
Harvesting	Hand picking using family or hired labour	Hand harvesting, rented shelling machine
Storage	Cotton bales	200L drums, baskets, sacks, metal tanks, Maize cribs

weevils in stored maize grains. This could be a safer traditional method of weevil control that is worth investigation.

Although some farmers, particularly cotton farmers hired additional labour force for picking and weeding the cotton, the family was the major labour source, particularly for maize production. Maize farmers also used neighbours labour to a limited extent, known as lilima, whereby the neighbours will come to assist with the weeding or harvesting and be paid in kind, using beer or sugar or salt or bread. Cotton storage is not a serious problem because after harvesting the cash crop is packed in the bales supplied by Cotton Board and then transported to the ginnery. Before shelling, maize is stored in the cribs to complete drying, and then the kernels are stored in varied containers, thus presenting high vulnerability to bad weather spoilage, pest and mold attack.

3.2 Status of Technologies Application in Cattle Production

The trend in livestock production in Swaziland over the past two decades has shown a gradual decrease [5]. Non-dairy cattle decreased from 640,000 in 1995 to 590,000 in 2002. Over the same period, the dairy herd decreased from 8,000 to 3,000. The majority, 85%, of livestock farmers, is found on SNL and they rely on traditional management methods and use farming knowledge obtained informally. Swaziland's current milk requirements amount to 61.5 million litres per annum. However, local production is a mere 37.6 million litres indicating a 38% of shortfall that is satisfied through imports. Meat consumption per capita in Swaziland is 15 kg, amounting to a national requirement of 16,800 tons of meat per year. The contribution to the available meat is 75% as beef, 19% poultry, 6% goats and sheep, and 3% from pigs and other meats [20,5]. Swaziland has consistently failed to meet its export quota of beef to the European Union (EU), suggesting the need to increase livestock productivity, particularly in the rural sector. Livestock production has to grow and must become more competitive for the country to avoid continuous deficits and having to import to cover gaps [20].

The results presented on Table 3 shows that the farmers practiced community ranching mixed farming system. In this system each farmer keeps the cattle in a community ranch, shared with other farmers during the day and in the evening the cattle are brought to the kraal [19]. This is practiced every day in summer but in winter, in some homesteads, the cattle are not kraaled at night. The major disadvantage of communal ranching is that nobody is responsible for the management of the ranch; hence the ranches are often overstocked and overgrazed. The farmers from both communities keep a mixture of exotic breeds and the indigenous breed. They either kept the Nguni with dairy breeds or with beef breeds. The major dairy breeds kept were the Friesian and the Jersey breeds whereas the major beef breed was the Brahman.

Farmers were crossbreeding the Nguni with the dairy breeds to improve milk production and some were crossbreeding the Nguni with the Brahman to improve beef production. It was also observed that various classes of animals were kept in the farms, young stock, suckler cows, bulls and oxen. The cattle were kept mainly for family use, and not strictly for sale. Selling was only done when there was need or, in the case of milk, when the production surpassed family needs. The cattle are normally sold when there is extra demand for money, such as when money for paying school fees is required.

Besides using cattle for meat and milk production, there are also several uses of cattle in the communities. One major use is the social and cultural role. Cattle are used for paying dowry, commonly known as lobola. This is a cultural requirement that a man should fulfil before he can marry a woman. Cattle are used for celebrations and traditional ceremonies where they are slaughtered for the guests to feast. They are also used for draft power and transport. The common breeding system is natural service. Each farmer may keep his bull or he may depend on the neighbour's bulls that may mate with his cows in the communal grazing areas. Specialized dairy farmers use artificial insemination services provided by Government officers. It is because of this reason that dairy farmers are required to keep their cattle in their own fenced grazing areas, so that the breeding can be more controlled.

The major pests that are controlled in cattle are ticks. Ticks are responsible for causing several tick borne diseases and the government assists in their control by providing acaricides. Each community has a dip tank, where farmers take their cattle for dipping once a week in summer and once a month in winter. Dairy farmers are trained on mastitis control at farm level. In the communal ranching system of rearing cattle, the cattle have surplus fodder for grazing in summer, and a scarcity of grazing fodder in winter because the natural pastures are dry. In winter the animals scavenge for maize stover that remains in the maize fields at communal level. A few farmers have capacity to preserve fodder for winter feeding in the form of hay or silage. The maize stover is supplemented with molasses or mineral salt licks.

Table 3. Technologies used by cattle farmers at Lesibovu and Sithobeleni

Operation	Technology or system used
Breed of cattle used	Nguni (indigenous); Friesian, Jersey, Brahman (exotic); crossbreeds
Rearing system	Community ranching with night kraaling, mixed farming, subsistence farming
Classes of animals kept	Suckler cows, heifers, oxen, bulls, calves
Uses of cattle	Milk production; beef production; sales (money for school fees); cultural – lobola, celebrations; draft power, manure, status, fines
Breeding system used	Natural service using the bull in most herds, artificial insemination in dairy herds.
Pest and disease control	Dipping to control ticks and tick borne diseases, strip cup to control mastitis in the dairy
Feeding	Natural pastures in summer, maize stover, hay in winter, mineral licks

3.3 Constraints Faced by Crop Production Farmers

The major constraints faced by the crop production farmers are presented below (Fig. 1). As can be seen from the list, some of the problems are socio-economic oriented. They range from acquisition and costs of inputs to marketing of their products. It was noted that farmers travel long distances to purchase farm inputs such as fertilizers, seeds and insecticide. Farmers also mentioned that the tractor hire programme run by the government delays the commencement of their ploughing period thus exposing their crop to the imminent dry period.

Another administrative problem is the shortage of extension officers (EOs). As a result, one EO is shared by 800 farmers. Drought is still a major problem in the lowveld particularly during the past decade. This has resulted in many farmers failing to get a harvest in some parts of the lowveld. Culture has also been cited as constraint to crop production because when there is death in the chiefdom, people are expected to refrain from ploughing or tilling the soil in whatever method, either planting or weeding. This has delayed field preparations and many farm operations because the prohibition is enforced mainly on weekends when most funerals are done yet unfortunately this coincides with the period when most people are not engaged at their places of employment and are at home to do farm work.

3.4 Constraints Faced by the Cattle Farmers

The constraints faced by the cattle farmers from Lesibovu and Sithobeleni communities are presented in Fig. 2. The problems are husbandry based, animal health oriented, socio economic and management based. The breeding problems can be addressed by development of a clearly defined breeding strategy. There are marketing problems where the farmers felt butcheries were demanding to pay very low prizes for their cattle, insisting on buying from the neighbouring state where beef cattle were comparatively cheaper. Animal health was affected by shortage of veterinarians and veterinary medicines. Famers were traveling long distanced to source these services from the city. Several farmers lost many cattle during the drought period. Winter feeding is a serious problem faced by the SNL farmers because of lack of fodder conservation techniques. Social and cultural problems are also prevalent emanating from beliefs that people belonging to some clans or religious groups should not eat meat of specific species. This may clash with modern biotechnology where genes may cross over the species barrier.

3.5 Biotechnology at Lesibovu and Sithobeleni

Table 4 present findings about the biotechnologies that are already practiced by farmers at Lesibovu and Sithobeleni. Although the respondents were not aware that they were already practicing some aspect of conventional biotechnology, the responses to the investigations showed that they were already practicing some form of biotechnology. As reported before, the biotechnology is mainly traditional and conventional [21]. This confirms previous reports that the country is classified in the third category of countries that are engaged in the second generation of biotechnology such as conventional breeding, fermentation and livestock artificial insemination and are not producing modern biotechnology products [22].

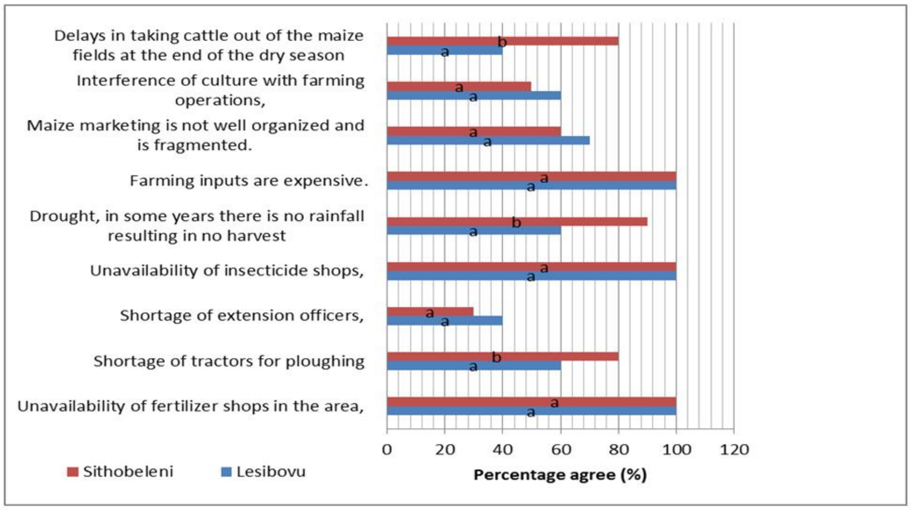

Fig. 1. Constraints faced by crop producing farmers of Lesibovu (N=40) and Sithobeleni (N=50)
Percentages on the same statement with different superscripts ([a, b]) differ significantly (P=.05)

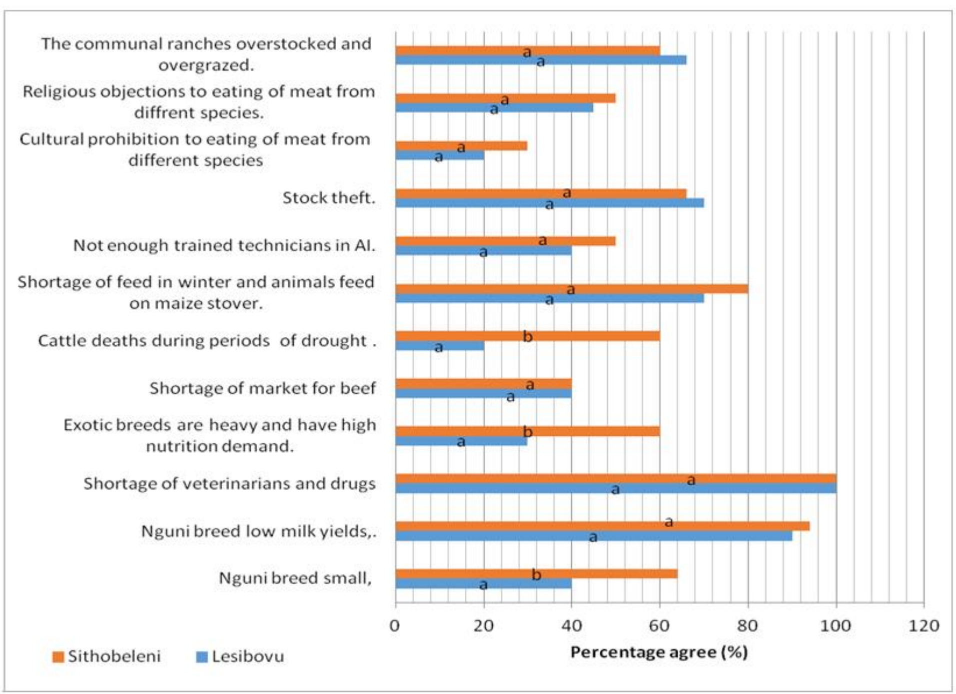

Fig. 2. Constraints experienced by cattle farmers from Lesibovu (N=40) and Sithobeleni (N=50) communities
Percentages on the same statement with different superscripts ([a, b]) differ significantly (P=.05)

The biotechnologies practiced in the study communities included production of F1 hybrid seeds, use of F1 hybrid seeds, artificial insemination, fermentation and cross breeding. The fact that the farmers are using and propagating F1 hybrid maize seeds mean that they are now familiar with the concept of not saving seeds after harvesting, which is a condition with genetically engineered (GE) seeds. It is worth mentioning that previously, reports have been made about farmers' perceptions of key problems that should be addressed by modern biotechnology in the country [21]. Table 4 also shows that female farmers were significantly highly involved in the biotechnology of production of F1 maize hybrid seeds, propagation of open pollinated maize varieties, and milk fermentation than the male farmers. Whereas crossbreeding of cattle was significantly (P=.05) practiced by male farmers than their female counterparts. All the farmers were practicing artificial insemination in the dairy herds. This could be attributed to the fact that this technology is made readily available by Swaziland Dairy Board extension officers.

3.6 Identification of Biotechnology Gaps at Lesibovu and Sithobeleni

Although some aspect of traditional biotechnology are practiced at Lesibovu and Sithobeleni, Table 5 lists some aspects of conventional biotechnology that have potential to improve both crop and animal performance if adopted in these communities. The findings have shown that both male and female farmers are not practicing these biotechnologies. Artificial insemination could be extended to the beef herd, to improve genetic makeup of the herd. Liquid fertilizer technology could be exploited by the crop producing farmers. Hormones such as the recombinant bovine growth hormone are used elsewhere to improve milk yields. The limitation is that the local farmers may lack capacity to manage this technology. Farmers were complaining about shortage of winter feed for their cattle. This could be addressed by production of conserved fodder in the form of silage. The disadvantage however of the silage making is that it is made from corn, hence there is competition between animal feed and human food. Probably possibilities of producing the silage from different type of fodder could be explored. Although there were no GMO crops officially cultivated in the country during the period of the study, the farmers were suspicious that genetically engineered cotton and maize could be illegally grown in the communities. Women farmers were significantly more (P=.05) suspicious than their male counterparts. Previous studies have reported that farmers in Swaziland would readily approve genetically engineered (GE) cotton to curtail the costs of spraying, and may accept GE technology in maize to address drought problems [21].

Although there is no evidence that transgenic crops are used in the study area, the potential benefits of this modern biotechnology tool cannot be overlooked. Modern biotechnology has resulted in the production of transgenic plants specifically developed for micronutrients enrichment, crop pests, disease, herbicide and abiotic stress resistance. Insecticidal genes from *Bacillus thuringiensis* have been inserted into cotton to develop resistance against Lepidopteran pests, and into cauliflower to develop resistance against *Helicovorpa armigera* [23,24]. Results from China have shown that there are cost benefits of Bt cotton when compared to non-Bt cotton [14]. The findings of the present study have also shown that there is extensive usage of insecticide for the control of cotton pests in the study areas. This extensive usage of pesticides is costly and could be a serious threat to the environment, a problem that can be addressed by the planting of Bt cotton.

Recombinant DNA technology has also been used to produce plants that have abiotic stress resistance. Such plants have the ability to survive harsh climatic or soil conditions such as moisture stress and soil salinity [14]. For an example, transgenic rice containing genes that regulate production of trehalose isolated from Indica rice have been produced. It is claimed that these transgenes may increase yield under drought conditions by 20% [25]. Current works are attempting to produce drought tolerant maize [15]. Genetic modifications of crops have also been done to produce crops that contain higher levels of essential nutrients for human nutrition. Transgenic rice that has high levels of ß-carotene in the rice endosperm [14] has been produced.

The great concern however, regarding the use of transgenic plants for pest control is development of resistant pests [23,26]. It is feared that transgenic plants may rapidly select for resistant insect pests. Recent reports from elsewhere [27], have shown that bollworms resistant to Bt cotton have been identified. Another fear is loss to biological diversity and fears of the unknown when the transgenes are released to the environment [23,28]. On the aspect of human health, there are concerns about development of antibiotic resistant gut pathogens when antibiotic resistant selection gene markers have been used, cause of allergic reactions and violation of individual religious ethics [29]

3.7 Biosafety Socio – Economic Considerations

Findings of this study presented in Fig. 3, identifies the socio-economic factors that should be taken into consideration when technologies are introduced, particularly products of modern biotechnology. It is appreciated that Biosafety emphasizes a regulatory system and risk analysis procedures designed to ensure proper risk assessment, mitigation and ensure safe handling GMOs [27]. It is also acknowledged that the farming communities studied in this work are officially not yet participating in commercial modern biotechnology. Their perceptions however, on socio-economic factors that should be considered when agricultural technologies are introduced, could be adapted for Biosafety socio economic considerations. The list of socio economic factors presented in Fig. 3, shows that public awareness should precede introduction of a new technology. This will enable the public to make informed decision about the product.

The socio economic factors range from acceptable norms and values in the communities such as seed sharing, seed saving to cultural and religious belief violations and marketing considerations. Seed saving here means keeping the seeds purchased in current year for use in the subsequent years. Both male and female farmers unanimously agreed that seed saving should be allowed; farmers' rights to use the seeds should be respected; farmers ownership rights should be promoted; and the technology must be clearly explained before introduction. More women farmers were concerned about losing their markets after the introduction of the technology, and also more female farmers favoured sharing their GE seed with their relatives and neighbours. A significantly higher percentage (*P*=.05) of the males were concerned about the technology interfering with their cultural beliefs and norms. The religious and cultural beliefs include objection to eating of meat or products of some animal species. This means that consumers need to be clearly informed when cross species barrier genetic modification has been done so that they make appropriate decisions. The market considerations are important, particularly export markets. As developing nations, the export market detect terms on the type of product they may like. If the market does not prefer a certain product of modern biotechnology, no matter how good it may appear, the communities could be wasting their resources if they can continue producing that product.

Concerns are also raised about interference with natural biodiversity. The technology should not result in the extinction of indigenous breeds or varieties. As mentioned above, the communities prefer to keep their open pollinated maize varieties in coexistence with the improved F1 hybrids. They also prefer keeping their indigenous cattle breed, the Nguni, despite the introduction of exotic breeds. The Nguni is believed to be a hardy breed that can tolerate the local harsh environmental conditions.

Table 4. Biotechnologies practiced by farmers of Lesibovu and Sithobeleni communities

Biotechnology practiced	Specific farmer practicing it	Percentage agreeing (%)			
		Males (N=42)	Females (N=48)	(χ^2)	*P*
Production of F1 maize hybrid seeds	Lesibovu maize farmers (ZM521)	50^a	70^b	8.33	.004
Propagation of indigenous open pollinated variety maize seeds	Maize farmers from both communities	85^a	95^b	5.56	.0184
Pest control of weevil using product from aloe	Maize farmers	20^a	40^b	9.52	.002
Cross breeding of cattle breeds	Livestock farmers	90^b	50^a	38.1	.0001
Artificial insemination	Dairy farmers	100^a	100^a	0	1
Fermentation of milk	Cattle farmers	42^a	70^b	15.9	.001

Percentages on the same row with different superscripts ($^{a,\ b}$) differ significantly (P=.05)

Table 5. Biotechnologies not used by farmers of Lesibovu and Sithobeleni communities

Biotechnology	Specific farmer	Percentage agreeing (%)			
		Males (N=42)	Females (N48)	(χ^2)	*P*
Artificial insemination	Beef farmers	100[a]	100[a]	0	1
Embryo transfer	Livestock farmers	100[a]	100[a]	0	1
Hormonal manipulation	Dairy farmers	100[a]	100[a]	0	1
Liquid fertilizers	Cotton and maize farmers	100[a]	100[a]	0	1
GE technology	Cotton and maize farmers Not sure whether these have been illegally introduced.	40[a]	80[b]	33.3	.0001

Percentages on the same row with different superscripts ([a, b]) differ significantly (P=.05)

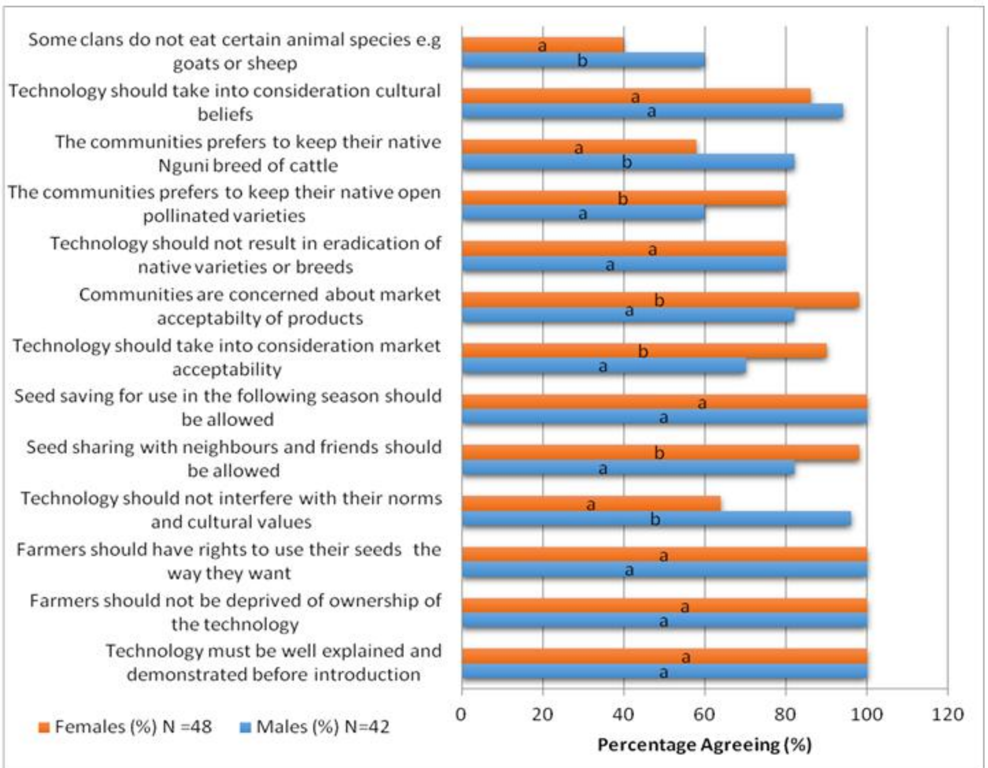

Fig. 3. Socio economic factors that should be taken into consideration when a technology is introduced, perceptions of Lesibovu and Sithobeleni farmers

Percentages on the same statement with different superscripts ([a, b]) differ significantly (P=.05)

Key informants perceptions of socio economic factors are presented on Table 6. As can be seen from the responses, public awareness should be done preceding any introduction of new technologies. Key informants felt that the country should hasten development of the regulatory framework to monitor the introduction of GMOs.

Scientific research on biotechnology and conducting of field trial on products of modern technology should be approved and monitored by both the NRC and the NBAC. Key informants also felt that although the precautionary approach in not bad, the country should also weigh the risk and consequences of not adopting biotechnology.

The responses from the key informants have shown that biotechnology would be acceptable if the technology is addressing both social and economic needs of the country. Key informants also felt that application of the technology in enhancing performance of cash crops like cotton

Table 6. Perceptions of key informants of socio economic factors that should be taken into consideration when a technology is introduced

Perceived factors	Ranking as: Lowly important; important; very important
Low adoption rates of biotechnology in the country could be attributed to low awareness level, lack of authoritative information and biotechnology knowledge, causing fears and uncertainties.	important
The country should have the national Biosafety framework in place to ensure implementation of regulatory mechanism in line with CBD.	very important
The introduction of genetically modified organisms in the country should be well monitored by the competent authority.	very important
All research involving modern biotechnology should be approved by the National Research Council and the National Biosafety Advisory Committee.	important
Biotechnology as scientific advancement is good in the areas of Health, Agriculture, Environment and Energy.	important
Care should be given to the way in which precautionary approach principle is employed.	lowly important
Possible costs, benefits and associated risks should be assessed on a case by case or product by product basis	very important
Technology should be acceptable to the community	very important

could be more acceptable than its application in food crops. Precaution should be always taken to ensure that the technology does not cause harm to public health, animal health and environment biodiversity.

The national biosafety framework for the country emphasises the precautionary approach principle in the adoption and implementation of modern biotechnology. It specifies that the policy of the country is to benefit from modern biotechnology, while ensuring safety of the public, environment and animal health. The field trials on GMO cotton already conducted by the cotton board, and the responses by stakeholders in this study and previous studies [17,21], is an indication that some stakeholders, farmers perceive the technology as a possible solution to some of their problems and are willing to take the risk and adopt it. The concerns raised by the farmers in this study about seed saving and seed sharing may need to be addressed by the regulator and the developers of the technology with the farmers so that a compromise can be reached. A balanced understanding may be required from all three groups to ensure co-existence.

4. CONCLUSION

The farming communities studied in these two cases have showed that consideration of socio – economic factors and public awareness are important when new technologies are introduced. This study has revealed that there are some aspects of conventional biotechnology practiced in the communities. These included production of F1 hybrid maize seed, cross breeding, propagation of open pollinated varieties, biological control of pests, artificial insemination in dairy cattle and fermentation of dairy products. Some conventional biotechnologies are not practised in the communities and these included tissue culture and embryo transfer. Artificial insemination is not extended to beef cattle, and production of hybrid seeds are not extended to other crops. There was no evidence of modern biotechnology practiced in the study area during the period of the study. The socio – economic considerations identified however, can be adapted for Biosafety assessments. Key factors identified include consideration of community norms and values such as seed sharing and saving, considerations of cultural and religious beliefs such as objection to eating of some species, and acceptability of products by markets. The Biosafety Act of 2012 specifies that risk assessment should take into consideration socio – economic factor. Information from this work will be helpful to the regulator when conducting risk assessment during the processing of applications for introduction of LMO to the environment.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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