Potential markets for herbicide resistant maize seed for *Striga* control in Africa

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Abstract

Striga is an obligate parasitic weed attacking cereal crops in Subsaharan Africa. In Western Keny, it is identified by farmers as their major pest problem in maize. A new technology, consisting of seed coating of herbicide tolerant maize varieties, has prove to be very effective in farmer fields. To bring this technology to the farmer, a sustainable delivery system needs to be developed, preferably through the private sector. To help of the seed companies develop a strategy, the potential market for this technology is hereby calculated, combines different data sources into a Geographic Information System (GIS). Superimposing secondary data, field surveys, agricultural statistics and farmer surveys makes it possible to clearly identify the *Striga*-prone areas in western Kenya. According to the analysis, the area has 212,000 ha in maize annually, with a population of 5.9 million people amd a maize production of 480,000 kg, or 81 kg/person. Population density is high at 359 people/km^2. A farmer survey reveals that 70% of farmers in this zone have *Striga* in their fields. Contingent valuation methods indicate that farmers' would be willing to buy on average 3.67 kg of the new seed each. This translates into a potential demand of 3,400 to 5,200 tons annually. Similar calculations, but based on much less precise data and expert opinion, not farmer surveys, estimate the potential market for herbicide tolerant maize against *Striga* at 64,600 tons annually, with an estimated value of $129 million.

Keywords: maize, *Striga*, Africa, weeds, pest control (JEL Q12)

1. Introduction

The parasitic weed *Striga* is a parasitic weed of the tropics that attacks cereal crops such as maize and sorghum. It is found in most countries in sub-Saharan Africa (Berner, Kling, and Singh 1995). The *Striga* flower produces large amounts of seed that are triggered into germination when they are close to potential host plants. Otherwise, the seed can stay dormant in the soil for over 20 years. Infestation is related to poor soil fertility, and the parasite does most damage to weak plants. Therefore, it is a particular problem areas where soil fertility is being eroded through increased population pressure, decreased use of fallow and minimal use of organic or inorganic fertilizer. Most importantly, it mostly affects the livelihoods of poor subsistence farmers in cereal-based agricultural systems in Africa.

Striga research has been conducted for many years, and several technologies have been developed and proposed for dissemination (See (Oswald 2004), for an overview). However, most of these technologies are feasible for the main target group: resource-poor farmers. Different options are known to be effective, but have had little success in adoption. Hand weeding has been promoted for decennia, but it is labor intensive and the effect is only felt in the next season. In Kenya, four seasons of hand-pulling were found necessary for sufficient control Fallows decreases the *Striga* seed bank and the soil and improves soil fertility. However, in most *Striga* prone areas, population pressure is too high for this option to work. Proper rotation scheme also reduces *Striga* (Carsky et al. 2000; Oswald and Ransom 2001).Maize varieties show highly variable tolerance to *Striga* (Odhiambo and Ransom 1994), and some varieties with reasonable tolerance have been brought to the market and are appreciated by farmers in Western Kenya. A relatively new development is intercropping with the legume desmodium (Khan et al. 2002). The technology is very effective in farmers' fields, but commercial seed is still very expensive and might be out of reach for poor farmers. *Striga* can also be controlled by spraying herbicides (Carsky, Singh, and Ndikawa 1994) in particular on herbicide resistance crops, but this is generally considered too expensive for subsistence farmers.

Over the last few years, a new and promising technology has been developed by the International Maize and Wheat Improvement Centre, in collaboration with the Weizmann Institute of Science and BASF. A natural mutant of maize provides the maize with resistance to certain types of herbicides, including imazapyr (Kanampiu et al. 2003). Seed dressing with the systemic chemical provides good protection for the plant for several weeks after emerging, largely sufficient to ward off damage (Kanampiu, Ransom, and Gressel 2001). Unlike herbicide spraying, the technology allows intercropping with legumes, a common practice in many sub-Saharan countries (Kanampiu et al. 2002). The technology has proven to be very efficient, confirmed in farmers' fields. The genes that confer the resistant have been transferred to varieties adopted to the region. Several OPVs as well as hybrids are available. The varieties have been accepted for pre-release in Kenya, and are being tested in different countries in East and West Africa.

The draw-back of the technology is that it requires the purchase of new seed each year. Recycling the seed, without seed coating, would not provide any protection against *Striga*. It is therefore essential to engage appropriate seed systems in the production, treatment and distribution of the herbicide resistant maize varieties towards the successful deployment of this technology. However, for a seed company, be it public or private, to take on a new technology, it is important to be able to estimate the likely size of the market. The market for the new seed is determined by several factor: i) the extent of the problem, in particular the area infested, ii) the intensity of the problem, especially the damage level and the crop loss, iii) the cost of the technology and economics of size in production, and iv) the perception of the farmers towards the pest and the control options and their willingness to pay for the new technology.

In this paper we attempt to determine the potential market of herbicide resistant maize in Africa. Since good data are available for Kenya now, a detailed analysis is made for this country. Based on national statistics, expert opinion and literature review, we extend the analysis towards a preliminary assessment of the market for the whole of Africa.

2. Methodology

2.1. Calculating the market for seed

Assuming that farmers are profit maximizers, they will adopt new technologies if the benefits of the technology outweigh its costs, within the constraints they are facing. To invest in a pest reduction technology, farmers take into consideration the level of infestation, the crop loss caused by the pest, the cost of the technology and the cash constraint (or access to credit) at the time of application. According to this optimization process, a proportion π_a of farmers will adopt the technology. Obviously, farmers will only adopt the *Striga* reducing technology in areas where this is a problem. If we define geographical units i where *Striga* is found, and N_i is the number of farmers in that area, A the average area under maize, and ρ the average seed rate per ha, the market for seed can be calculated as:

$$M = \sum_j N_j \, A_j \pi_i \rho_j$$

To estimate the parameters, we use both primary and secondary data. The secondary data come from different sources, in particular different CIMMYT surveys, demographic and agricultural statistics. First there are the results of a farmer survey conducted by CIMMYT in 1993 (Frost 1994), covering 367 farmers in Western Kenya, and interviewed specifically on *Striga*. All farmers were geo-referenced and this survey presents a geographically well distributed sample of the whole *Striga* infested zone. A second survey of 1300 farmers covering all maize production areas in Kenya was conducted in 1992 (Hassan, Lynam, and Okoth 1998). This survey used a multi-stage stratified sampling design, based on the National Sampling Frame, but only the 65 sampling units or survey sites were geo-referenced. In each site, 20 farmers were interviewed with a structured questionnaire, focusing on their maize production, inputs and outputs, and constraints. A third survey consisted of participatory rural appraisals (PRAs) including 43 group discussions with more than 900 farmers, conducted in randomly selected villages in all maize production zones during 2000 (De Groote et al. 2004). These discussions followed a loose guide and included farmers' perceptions on maize production, preferences, and constraints. In the *Striga* -prone areas, this problem was treated in particular detail. This research also used of unpublished agricultural statistics obtained from the

Ministry of Agriculture, mostly district level data, and agricultural statistics at the division level, compiled by the International Livestock Research Institute (ILRI). Population data were obtained from the 1999 population census (Central Bureau of Statistics 2001).

Specific to this research, the economic analysis and potential market for *Striga*., two sets of primary data were also collected. First, on-farm trials were conducted with the herbicide-resistant varieties in 2001 (researcher managed) and 2002 (farmer managed). Secondly, using a two-stage sampling design, 123 farmers were randomly selected and interviewed concerning their interest and willingness to pay for this new technology.

3. The target area: Western Kenya

3.1. Defining the Striga-prone area

Combining GIS data with the 1992 farmer survey, incorporating farmers preferences, seed use and constraints, five major agro-ecological zones relevant to maize production can be distinguished (Hassan et al. 1998). The zone around Lake Victoria is called the Moist Mid-altitude zone (the barred area on the map in Figure 1). According to the farmers, *Striga* was the major constraint in this zone, but the limited number of geo-referenced points only allowed some preliminary analysis (Hassan, Ransom, and Ojiem 1994) without estimation of areas affected. The 1993-1994 farmer survey from Western Kenya, on the other hand, covered 367 farmers, geographically well distributed and all geo-referenced.

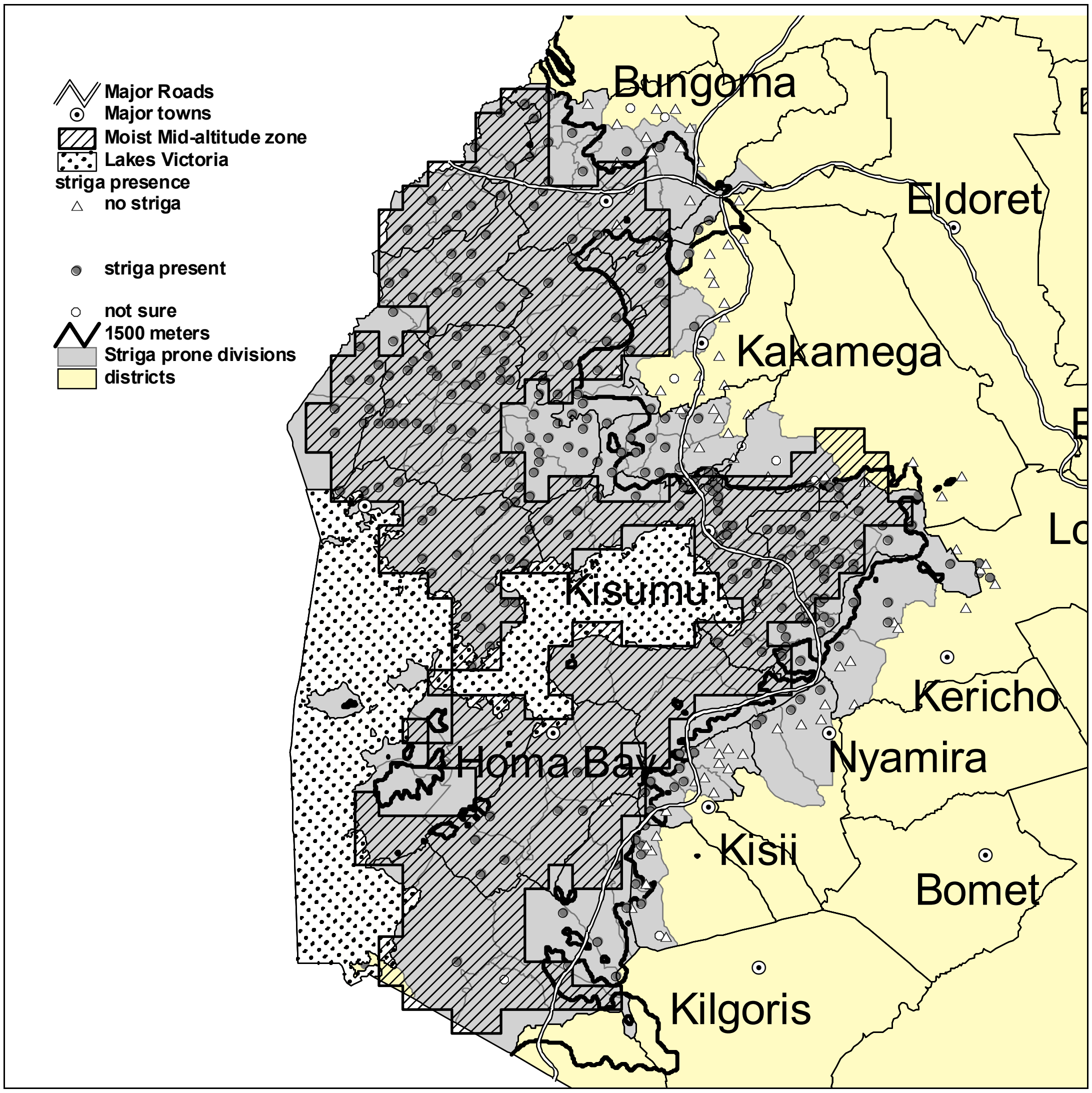

Figure 1. *Striga*-prone area and the Moist Mid-altitude zone.

Mapping farmers' experience with *Striga* clearly reveals, in sufficient detail, the *Striga* area (Figure 1). On the map, farmers with *Striga* in their fields are marked by a circle, those without *Striga* with a triangle. The thick line represents the 1500 m altitude line. It is clear that all farmers falling between Lake Victoria (1150 m) and the 1500 m line face *Striga* problems, some farmers between the 1500 and 1600 m have *Striga*, but none above the 1600m. This can likely be explained by the susceptibility of *Striga* to low temperatures. The area covers well the Moist Mid-altitude zone, and is just slight wider in the North and middle. Finally, the map can expanded with the 1999 population census, per division (administrative unit in Kenya, just below district), and those division falling at least partly in the *Striga* prone zone identified (grey area on the map). In total, 80 divisions in 20 districts were found to fall in the area, mostly in Nyanza and Western Provinces.

3.2. Characteristics of the area (PRA and secondary data)

Specific analysis of the Participatory Rural Appraisals (PRAs), consisting of eight group discussions with 143 farmers (60 women), key informants and secondary data analysis, resulted in a better understanding of the maize production conditions in this zone (Odendo, Groote, and Odongo 2001).

Rainfall in the Moist Mid-altitudes increases with altitude from 700 mm annual by the lake shore up to 1800 mm, in a bimodal pattern. Mean annual temperature is 22.1 °C, with an average minimum temperature of 13 °C and an average maximum of 30 °C. Soils are mainly clay-loam and sandy-loam and not fertile, since there is very little volcanic or other young parent materials.

Farmers have diverse selection criteria for maize varieties and use them in diverse combinations. The top three criteria are high yield, early maturity, and tolerance to *Striga.* Other important criteria are, in order of importance, the low cost of acquiring the seed, grain characteristics, low external input demand and resistance to field and storage pests. More than twenty different maize varieties were identified in this zone, of which 8 are local. Shipindi and Nyamula are popular yellow varieties, although their price is generally lower than for white maize varieties. In the 1992 survey, farmers identified Nyamula as a *Striga* tolerant variety (Hassan, Ransom, and Ojiem 1994).

The most important constraints to maize production, as reported by the farmers, are low soil fertility, cash constraints and poor extension service. The cash constraint is a major problem, and its alleviation would lead to alleviation of many other constraints. The next group of constraints is the lack of farm implements and the related lack of labor. The first pest, *Striga*, is mentioned next. As a result of cash and other constraints, farmers recycle varieties for long period of time, especially the local varieties but also the hybrids. They apply little or no fertilizers and no pesticides in maize fields.

3.3. Estimation of the parameters

The main statistics of the divisions in the Moist Mid-altitude zone were aggregated by district (Table 1). From there, we can calculate the total population at 5.8 million, in 1.3 million households, living on 16,000 km2, or a very high average density of 359 people /km2. Maize production data provided by ILRI, although not complete for all districts, provide an estimate for 1994-1999 of almost 0.5 million ton maize on 212,000 ha, an average yield or 2.26 tons/ha. The maize area is similar to that estimated from the 1992 survey (173,000 ha), although the production (231,000 tons) and the yields (1.34 tons/ha) were then estimated at lower levels (Hassan 1998).

Table 1. Population and Agricultural Statistics of *Striga* prone area in Western Kenya

Province	District	Number of Divisions	population	area km^2	pop density	maize production (tons)	maize area (ha)	maize yield	maize production kg/person
Nyanza	Bondo	4	238,780	987	242	15,244	7,985	1.91	64
	Gucha	2	126,712	200	633	82,990	26,450	3.14	655
	Homa-Bay	5	307,975	1,160	265	38,563	14,178	2.72	125
	Kisii Central	3	238,492	337	707	37,278	5,370	6.94	156
	Kisii North	2	267,887	396	676	25,773	10,840	2.38	96
	Kisumu	4	504,359	919	549	7,267	5,641	1.29	14
	Migori	7	498,015	1,961	254	26,662	18,237	1.46	54
	Nyando	5	299,930	1,168	257	18,859	8,490	2.22	63
	Rachuonyo	4	307,126	945	325	42,039	28,892	1.46	137
	Siaya	7	480,184	1,520	316	65,884	31,120	2.12	137
	Suba	5	155,666	1,056	147	16,731	9,295	1.80	107
	Total	48	3,425,126	10,650	322	294,300	140,047	2.10	86
Rift Valley	Kericho	2	87,571	498	176				0
	Nandi	1	96,220	386	249	31,776	8,224	3.86	330
	Total	3	183,791	884	208	31,776	8,224	3.86	173
Western	Bungoma	6	548,011	1,295	423	77,706	16,730	4.64	142
	Busia	6	370,608	1,124	330	17,365	11,571	1.50	47
	Butere-Mumias	4	476,928	939	508	14,269	7,012	2.03	30
	Kakamega	3	225,315	417	540	13,688	7,176	1.91	61
	Lugari	1	44,578	102	437				0
	Teso	4	181,491	559	325	8,640	3,200	2.70	48
	Vihiga	5	438,940	466	942	21,480	17,900	1.20	49
	Total	29	2,285,871	4,903	466	153,147	63,589	2.41	67
Grand Total		80	5,894,788	16,437	359	479,223	211,860	2.26	81

Overall, the area is deficient in maize, with an average production of 81 kg/person, compared to an estimated consumption of 105 kg/person (Pingali 2001), although there are many districts with surplus production. From the estimated maize area, 212,000 ha, we can estimate, at the recommended seed rate of 25kg/ha, those farmers in the *Striga* prone areas use annually about 5300 tons of seed. This can be considered the upper limit for the herbicide resistant maize seed market.

4. Farmers' perceptions

As discussed above, the interest of the farmers will be determined by their crop loss, their interest in the new varieties, and their cash constraints. Crop loss, or yield reduction in maize due to *Striga*, is very difficult to measure in the field. Most empirical studies rely on controlled experiments.

Table 2. Maize production and losses due to *Striga* (Source: farmer survey 2002, N=123)

district	Long rains				short rains				total	
	area (ha)	production (kg/hh)	yield (kg/ha)	crop loss (%)	area (ha)	production (kg/hh)	yield (kg/ha)	crop loss (%)	area (ha)	pro (kg/hh)
Vihiga	0.26	240	921	56	0.22	176	801	53	0.48	416
Siaya	0.55	249	454	52	0.50	330	531	13	1.05	579
Rachuonyo	0.65	322	495	44	0.34	204	757	73	0.99	526
Homabay	0.76	349	460	55	0.54	285	805	59	1.30	635
Bondo	0.23	146	636	75	0.18	92	2375	68	0.41	239
Kisumu	0.82	563	686	40	0.62	367	617	42	1.44	929
Total	0.57	301	528	52	0.41	251.5	786.8	55.04	0.98	552

Studies in West Africa compare yields of susceptible and tolerant varieties in fields under natural *Striga* infestation with yields of the same varieties in non-infested fields (Kim et al. 2002). In the savannahs of Nigeria, yield reduction in the tolerant varieties of 31% was found, in the susceptible varieties 62% (1985 trials). Trials in Cameroon in the same year produced lower estimates: 21% for the tolerant varieties, and 41% for the susceptible varieties. Under artificial infestation at different levels, in Nigeria, yield loss for the tolerant varieties varied between 27% (at 2250 *Striga* seeds/hill) to 35% (at 4500 seeds/hill), for the susceptible varieties yield loss ranged from 43% (at 750 seeds/hill) to 74% (at 3750 seeds/hill) (Kim and Adetimirin 1997).

In Kenya, no empirical studies on crop loss due to *Striga* were conducted, but the different farmer surveys shed important light on the issue. First, all surveys come to the conclusion that *Striga* is the major pest problem in the moist mid-altitude zone. From the 1992 farmer survey, the area under *Striga* in this zone was estimated at 39%, with an average percentage loss of 51% in infested areas (Hassan and Ransom 1998). The 1993-1994 survey of 367 farmers in the zone (Frost 1994), on the other hand, observes 77% of the farmers with *Striga* in their fields. Our own survey of 2002, with 123 farmers, found an estimated 70% of maize area under *Striga*. Farmers were asked to estimate their current production, and their estimate of what the production would have been without *Striga*. From these estimate, average crop loss due to *Striga* could be calculated at 53% (Table 2). Estimates vary considerably between districts, from 35% in Siaya to 72% in Bondo.

Farmers in 1992 planted 51% of their area in improved seed, and 79% of those interviewed had bought improved seed at one point in time. In the 2002 survey, but we found 28% of farmers growing from those in the 2002 survey did so. Based on their use of improved maize seed, 7.3 kg in the first season and 5.3 in the second season, the area in improved seed can be calculated at 51%, in both seasons (Table 3).

Table 3. Farmers' Willingness to Pay (WTP) for herbicide resistant maize

variable	mean
number of farmers in survey (N)	123.00
% willing to buy at 125 Ksh/kg	66.67
amount farmers would buy at 125 KSh/kg (kg/farmer willing to buy)	5.63
amount farmers would buy at 125 KSh/kg (kg/all farmers)	3.76
average maize seed rate (kg/ha)	18.60
expected area in herbicide resistant maize (ha/farmer)	0.30
average maize area (ha/farmer)	0.68
expected area in herbicide resistant maize (% of maize area)	44.04
total seed bought by farmers	888.00
seed purchases (kg/farmer)	7.22
current area in improve seed (ha)	0.39
current area in improve seed (% of maize area)	57.08

Farmers were also explained the new technology and asked if they would be interested in purchasing the seed of the new variety. At the current price for seed of improved varieties (125 KSh/kg), 66.7% of the farmers would buy it, on average 5.6 kg each, or 3.8 kg/farmer over all farmers. The average seed rate calculated from the survey was 18.6 kg/ha, less than the recommended dose of 25 kg/ha. Using the actual seed rate, the expected area in herbicide resistant maize can be estimated at 44%, as compared to their current area in improved maize, 57%. However, the demand for the new seed is highly elastic: at 50 KSh/kg the average purchase per farmer would be 5.5 kg, at 200 KSh only 2 kg/farmer (Figure 2).

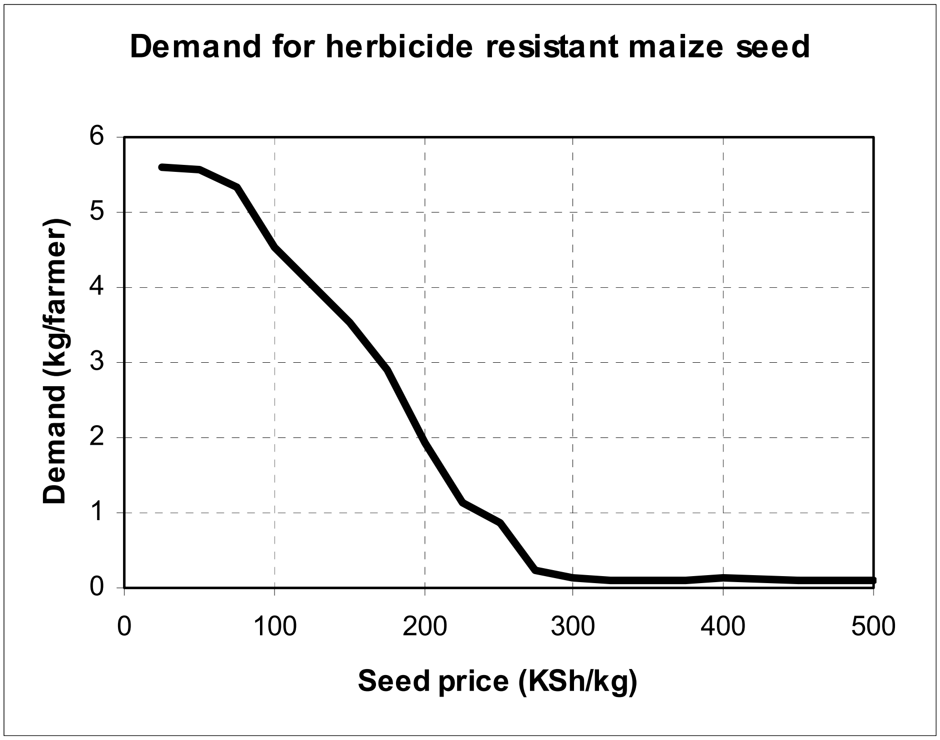

Figure 2. Demand curve for herbicide resistant maize seed.

Fortunately, the herbicide can be added in the regular seed treatment. Therefore, the added cost would be small and, during discussions, seed companies are most interested in selling the seed of the new varieties at the going rates.

4. Potential demand for herbicide resistant maize

Bringing all these estimations together provides us with several options to estimate the potential market. First, we can start from the total maize area in the region, 212,000 ha, and multiply by the 44% expected area in herbicide resistant varieties, leading to an estimate of 93,000 ha. At the current seed rate of 18.6 kg/ha, this would lead to seed sales of 5,200 tons; at 25 kg/ha the seed sales would be 3,700 tons. From another angle, we can multiply the average expected seed purchase of 3.76 kg /farmer, with the about 0.6 million maize producing households, leading to a seed sales estimate of 3,400 tons.

Unfortunately, good data for other African countries are not available, especially on the extent of *Striga* areas, the intensity of the infestation and the damage levels. Based on our own experience, combined with expert opinion, literature, and discussions with colleagues, an attempt was made to estimate the percentage of maize area infested by *Striga*. Maize area was obtained from FAOSTAT, and infestation levels were estimated for first and the second season. For Kenya, the figures differ from what was calculated above since the expert opinions were gathered before the above analysis. The total area infested by *Striga* in Sub-Saharan Africa, over 23 countries, can therefore be estimated to be around 2.5 million ha annually. At a 25 kg/ha seed rate, the potential market for herbicide resistant seed can be calculated at 64,600 tons annually. At the current price of about US$2/kg, this would be a total of $129 million.

5. Conclusion

This paper demonstrates the power of GIS to combine data from totally different sources to analyze them and come to important conclusions. Superimposing secondary data, field surveys, agricultural statistics and farmer surveys makes it possible to clearly identify the *Striga*-prone areas in western Kenya., estimated at 212,000 ha in maize. The area has a population of 5.9 million people amd a maize production of 480,000 kg, or 81 kg/person. These statistics were combined with PRAs indicating that *Striga* is the major pest problem to maize production, and with a farmer survey revealing that 70% of farmers in this zone have *Striga* in their fields. Contingent valuation methods indicate that farmers' would be willing to buy on average 3.67 kg of the new seed each. This translates into a potential demand of 3,400 to 5,200 tons annually. Similar calculations, but based on much less precise data and expert opinion, not farmer surveys, estimate the potential market for herbicide tolerant maize against *Striga* at 64,600 tons annually, with an estimated value of $129 million.

The analysis shows that even poor farmers are interested in a technology that addresses their needs, and that they can form a profitable market for the private seed sector. Especially in East and Southern Africa, where seed companies are well established, there is a large potential. However, this research needs to be followed up by monitoring farmers interest through demonstration trials, and adoption surveys to verify if the potential is realized after the release and dissemination of the new varieties. In Kenya, large-scale demonstrations are planned for the first season of 2005, and commercial release for the second season.

In Western Africa, where seed companies are not well established, special attention needs to be given to develop sustainable seed systems to bring this technology to the farmers.

Attential also needs to be given to the potential drawbacks of the technology. First, it does not address the next constraint, poor soil fertility. Therefore, research is needed to design appropriate combinations of seed with organic or inorganic fertilizers, and how to dessiminate these packages.Second, resistance management needs to be developed to avoid *Striga* developing resistance to the herbicide. One option, the slow release formula, is currently under development.

Table 4. Market for herbicide resistant maize seed in Sub-Saharan Africa.

Country	maize area ('000s ha) [a]	Estimated *Striga* infested area[a]				Total potential area in *Striga* ('000s ha/yr)	Total potential herbicide resistant maize seed sales (t/yr)
		% tot	'000s ha	% tot	'000s ha		
Benin	607	15	91	20	18	109	2,732
Botswana	20	10	2	0	0	2	50
Burkina Faso	261	10	26	0	0	26	653
Cameroon	392	10	39	30	12	51	1,274
Cote d'Ivoire	700	5	35	30	11	46	1,138
Ethiopia	1,606	5	80	0	0	80	2,008
Ghana	683	15	102	30	31	133	3,330
Kenya	1,502	10	150	50	75	225	5,633
Lesotho	134	5	7	0	0	7	168
Malawi	1,342	20	268	0	0	268	6,710
Mali	195	10	20	0	0	20	488
Mozambique	1,221	10	122	0	0	122	3,053
Namibia	39	10	4	0	0	4	98
Nigeria	4,111	20	822	10	82	904	22,611
Senegal	61	5	3	0	0	3	76
South Africa	3,691	1	37	0	0	37	923
Sudan	169	10	17	0	0	17	423
Swaziland	83	5	4	0	0	4	104
Tanzania	1,785	10	179	20	36	214	5,355
Togo	377	10	38	20	8	45	1,131
Uganda	615	10	62	10	6	68	1,691
Zambia	553	10	55	0	0	55	1,383
Zimbabwe	1,437	10	144	0	0	144	3,593
Subtotal ECA	5,677		487		117	604	15,109
Subtotal SA	8,520		643		0	643	16,079
Subtotal WA	7,387		1,176		161	1,337	33,430
TOTAL	21,584		2,307		278	2,585	64,618

[a] prepared by BASF and CIMMYT-Kenya.
[b] Pingali 2001
[c] conservative estimates of %maize area infested with *Striga*.

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