Table 5. Cost variables of Conventional breeding and PPB

Cost variables of PPB	Cost variables of Conventional breeding
Site selection and land acquisition	Land preparation
Land rent (for establishing germplasm pool)	Layout
Constituting, establishing and maintaining germplasm pool village	Sowing
Diagnostic survey	Weeding 2x
Visit by farmers to germplasm pool and selection	Guarding
Seed multiplication	Harvesting
Seed preparation	Threshing, cleaning, weighing
Seed distribution	Seed cleaning and weighing
Land preparation	Data collection
Preparing layout and sowing	
Chemical fertilizer	
Weeding	
Evaluation with farmer selectors	
Harvesting, threshing, weighing and final evaluation	
Evaluation with farmer evaluators	
Land rent, establishment, management and harvesting of common on-farm plots	

Time of research

As can be analyzed from the breeding schemes followed for the two approaches, PPB shortened the breeding time by a year.

Number of varieties

In PPB, at least five bean lines were selected by farmers. These lines are already accepted by the users. In the conventional approach, only one or two bean genotypes will be proposed for release. It is not yet known whether these lines will be accepted by farmers or not.

Process impacts of PPB

PPB has process impacts that are not usually seen in conventional breeding. The impacts include effects on the formal breeding process, on farmer acceptance, on farmer production and income, on farmer-held diversity, on farmer breeding/seed processes (technical/social), on research organization cost, and on farmers' empowerment to solve their problems by research.

Assessing the demand for insect-resistant maize varieties in Kenya by combining Participatory Rural Appraisal with Geographic Information Systems

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Introduction

Africa has a hard time feeding its growing population. The population of Sub Saharan Africa grew in the 1990s at an average rate of 2.57% per year (FAOSTAT, htttp://apps.fao.org/page), a doubling of the population every 28 years. Food production per capita, as measured by the FAO food production index and cereal production, has decreased in the 1960s and 1970s and is now stable. Unfortunately, most of the increased food production came from increasing production area, a trend that cannot continue.

East Africa, and Kenya in particular, also shows a leveling of food production per person. Maize, the most important food crop, accounts for more than a third of calories and proteins in human nutrition in Kenya (FAOSTAT). While in the rest of Africa, maize production could more or less follow population growth, in East Africa this has not been the case, mostly because of decreasing yields. While maize yields increased from 1.25 tons/ha in the early 1960 to over 2 tons in 1982, they fell below 1.5 tons/ha in 2000. This alarming trend is cause for concern and it is important to analyze the factors leading to it.

The increase of maize yields in the 1960s and 1970s is generally attributed to a very successful maize research and extension program. New varieties, especially hybrids, were developed in a short period (Gerhart, 1975, Hassan and Karanja, 1997). This was combined with extensive agronomic trials leading to appropriate fertilizer and other recommendations. The new varieties spread fast and yields increased accordingly. In the 1980s, however, the adoption of improved maize varieties no longer increased, and nor did the use of fertilizer, resulting in stagnating yields. A number of factors can be readily identified as negatively influencing growth: a decrease in spending on research, a decline of extension and credit facilities, and a decrease in output price and increase in fertilizer prices, and a lack of new maize releases that captured farmers' interest.

The last factor is puzzling. Although each of the five major maize growing zones has a maize breeding program with several breeders, and there is a large commercial seed company with well established distribution lines all over the country, very few varieties have been released over the last 20 years, and almost none of those releases have been adopted widely. Why are farmers interested or not in these new varieties? Are breeders developing varieties that do well in farmers' conditions? Are they overlooking certain traits? Or are there other socioeconomic factors not conducive to adoption of new varieties?

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To answer these questions, maize scientists need to engage more in communication with farmers. Traditional adoption surveys, on top of being expensive, do not really help this type of communication. Scientists are therefore increasingly using participatory methods to improve their communication with farmers. One of the tools, Participatory Rural Appraisal (PRA), is very popular and useful to diagnose problems and elicit preferences. It came out of the farming systems research school (Chambers, 1994) and is a convenient and cheap way to incorporate the farmers' perspective in a research program (De Groote et al., 2001). Although PRAs produce useful insights, they also tend to produce mostly anecdotal information of a qualitative nature, that does not lead itself to extrapolation. Therefore, the information is less interesting to bio-physical scientists such as breeders and agronomists, who prefer data expressed in numbers, coefficients and standard errors (looking a bit down to the "soft" social sciences). As a result, PRAs are not very popular with breeders, who seems to prefer non-structured group or individual discussions. It is, however, possible to organize PRAs in a more systematic way to obtain representative results. Combined with GIS, in particular, PRAs can become a powerful tool to quantify farmers' preferences and selection criteria, as will be shown here. In this paper, we develop this combination and apply it to determine and analyze farmers' demand for insect-resistant varieties in Kenya.

The interest in developing insect-resistant varieties stems from the perception that insect pests are one of the major constraints to maize production in Kenya. Stem borers are estimated to cause crop losses of 12.9% nation wide, amounting to 0.39 million tons of maize, with an estimated value of 76 million US$ (De Groote, 2002). In 1999, the CIMMYT (*Centro Internacional de Mejoramiento de Maiz y Trigo*, International Maize and Wheat Improvement Centre) launched a new project to develop Insect-Resistant Maize for Africa (IRMA). To help guide the breeding effort, teams of economists, breeders, and agronomists conducted participatory rural appraisals in the six maize producing agro-ecological zones of Kenya. The major objectives of the PRAs were to understand the maize production systems, to estimate the potential demand for insect-resistant varieties, and to help maize breeders to incorporate farmers' preferences into new varieties. The major tool used was the group interview to identify the maize varieties currently grown, the criteria farmers use in selecting them, the constraints faced in maize production, and the major pest problems as perceived by the farmers.

This paper demonstrates the preliminary results of how the systematic quantification of farmers' perceptions allows for easy analysis of large numbers of data. Moreover, by geo-referencing the data, these perceptions and preferences can be integrated into a GIS framework to predict adoption and impact of new varieties, in this case for insect resistance.

Methodology

PRAs were conducted in each of the six agro-ecological zones as defined by Hassan (1998) (see map in Figure 1 and description in the next section). During the exploratory phase, the literature was reviewed for each zone and discussions held with key informants on farming systems and climate, and about projects, NGOs and services available. The key informants included maize researchers, experienced farmers, local leaders, as well as agricultural service and input providers.

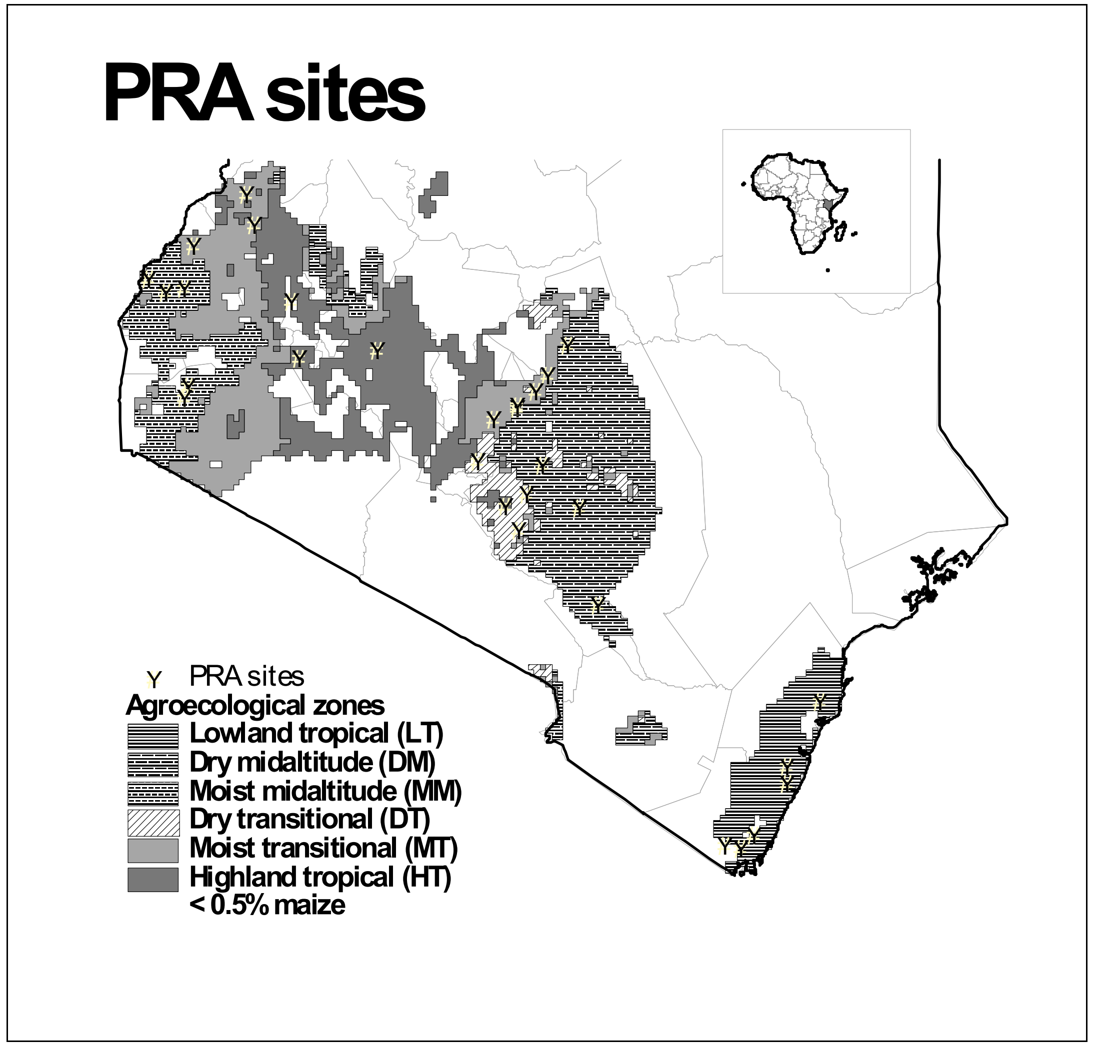

Figure 1. Sites of the Participatory Rural Appraisals

For each zone, five villages were selected, but the selection procedure differed slightly by zone. Either a 2- or 3-stage sampling procedure was used. In principle, a list of the divisions (administrative units below district level) was established for each zone, and three divisions were selected randomly in the first stage. For each division, a list of the sub-locations was established, and two villages selected randomly. In practice, some zones selected representative districts purposely first, and then continued with the 2-stage procedure. Some villages also had to be reassigned to a different zone after establishing its coordinates using a Global Positioning System (GPS). The division extension office was first visited to prepare the PRA, and the selected village was visited to explain the purpose of the meeting to the village elders and authorities, and to set the date for the visit.

A multi-disciplinary team existing of CIMMYT and KARI (Kenya Agricultural Research Institute) scientists and local extension staff visited the village for one day to conduct focused group discussions. The discussions were held in the local language and covered mainly the farming systems, maize production and its constraints, following a pre-tested guideline. Where possible, discussions were held separately with men and women.

First, farmers would present all the varieties they currently grow. They listed and ranked the criteria they use in selecting their varieties, and scored those criteria on a scale of 1 (slightly important) to 3 (very important). Further, they scored all varieties for each of these criteria on a scale of 1 (very poor) to 5 (very good). Farmers also ranked the major constraints they face in maize production, as well as the major pests they encounter. They also explained access to extension and credit, and support from NGOs and rural development projects. In total, more than 900 farmers, men and women participated in 43 group discussions from April to November 2000 (see map in Figure 1).

All data are incorporated in a database, where each group discussion represents one line in the database, and each variable a column. Each possible answer to a question becomes a variable in the database. All PRA sites were geo-referenced, making GIS analysis possible.

Maize production in Kenya

A study by CIMMYT and KARI defined six major agro-ecological zones for maize production in Kenya (Hassan, 1998), presented in Figure 1. Moving from East to West, there are the Lowland Tropics (LT) on the coast, followed by the Dry Midaltitudes and Dry Transitional zones around Machakos. These three zones are characterized by low yields (less than 1.5 t/ha); although they cover 29% of maize area in Kenya, they only produce 11% of the country's maize (Table 1). In Central and Western Kenya, we find zones that produce moderate yields (1.44 t/ha), cover 22% of the area and produce 9% of maize in the country.

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Scientist's Contributions
Contributions des chercheurs

By using production data from 1998 from the Ministry of Agriculture, and combining these with the population census of 1999, the food security situation in each zone can be assessed. Average maize production per person is calculated at 80 kg/per capita for the whole of Kenya. Only the high potential zones (MT and HL) have a higher per capita production. Together the two zones have a population of about 11 million people, 40% of the Kenyan population, but they produce 80% of the maize (Table 1).

Table 1. Agroecological zones and food security in Kenya

Zone	Area (1992)		Production (1992)		Population (1999)		Maize Production (1998)	
	1000 ha	%	1000 ton	%	1000	%	1000 ton	kg/person
Lowland Tropics	41	3	53	2	1,987	7	28	14
Dry Mid-altitude	166	15	162	6	2,342	8	87	37
Dry-Transitional	66	11	76	3	1,304	5	38	29
Moist-transitional	466	23	1234	46	7,537	26	1,024	136
Highlands	316	6	909	34	3,812	13	403	106
Moist Mid-altitude	173	22	231	9	3,018	11	210	70
< 0.5% maize					5,942	21	210	35
Other					2,637	9	423	160
Total	1244	100	2671	100	28,579	100	2,424	85

Results of the PRAs

Varieties and selection criteria for varieties

Farmers made a list of the varieties they grow, and how many farmers grow them. The results show that, over all zones, most farmers plant local varieties. Local varieties particularly dominate in the low-potential areas such as the lowlands, the moist mid-altitudes, the dry mid-altitudes and the dry transitional. Improved varieties, on the other hand, dominate in the high-potential areas of the highlands and the moist transitional zones.

Table 2. Maize varieties found during the PRAs, with type, origin and percentage of farmers growing them by zone

Name	Type	Percentage of farmers growing the variety						
		Overall	Moist transition	Moist mid-altitudes	Dry mid-altitudes	Dry transitional	High-lands	Low-lands
Local (not specified)	local OPV	22.0	31		45	56		
Pioneer/PHB3253	hybrid, Pioneer	18.3	57	24	13	10	5	
H614	hybrid, KSC	17.4	10	21			73	
KCB (Katumani)	improved OPV	15.4	19	26	19	20	2	6
DLC1 (Makueni)	improved OPV	15.0	71		16	1		2
H511	hybrid, KSC	14.9	50	12	0	6	21	
Shipindi/Sipindi	local OPV	13.9		64			19	
H625	hybrid, KSC	10.4	14	29			20	
Mdzihana	local OPV	8.3						50
Ke-Buganda	local OPV	6.4		39				
H627	hybrid, KSC	5.8					35	
H512	hybrid, KSC	5.7	30	3			1	
PH1 (Pwani Hybrid)	Hybrid	5.5		8	1			24
H513	hybrid, KSC	5.5	12	15			6	
Samaria	local OPV	4.8		29				
PH4 (Pwani)	hybrid, KSC	4.3		0				26
H626	hybrid, KSC	3.9		5			19	
Coast composite	improved OPV	3.8						23
CG4141	Hybrid, Cargill	3.7	22					
Kanjerenjere	local OPV	3.7						22
Mengawa	local OPV	3.5						21
Nyamula	local OPV	3.3		20				

Farmers presented a list of the criteria they use to select varieties, and then proceeded to score those criteria on a scale from 1 (of minor importance), over 2 (of medium importance) to 3 (very important). Criteria not mentioned were given a score of 0 (not important), which allowed for a statistical analysis and averaging scores by agro-ecological zone (Table 3). Two criteria receive an average score of importance between 2 (moderately important) and 3 (very important): early maturity and yield. While the score of early maturity is fairly even distributed, high yield is not that important in the dry areas. Three criteria have an average score between 1 (somewhat important) and 2 (moderately important): drought tolerance, tolerance to field pests, and tolerance to storage pests, but there are again important differences between regions. No other criteria have an average score higher than 1, although some regions have particular criteria. The moist mid-altitudes around Lake Victoria score resistance to striga, large grain size and resistance to low soil fertility as very important. The high potential area around Kitale also mentions compact grains and number of rows as moderately important.

Table 3. Farmers' criteria in selecting maize varieties, by zone

	Embu (MT)	Kakamega (MM)	Katumani		Kitale (MT, HT)	Mtwapa (LT)	Total
			(DM)	(DT)			
Early maturing/maturity period	2.7	2.7	2.0	2.7	2.2	2.6	2.5
High yield	3.0	3.0	1.6	1.3	3.0	2.4	2.4
Drought tolerant	1.3	2.4	2.1	1.9	0.9	2.4	1.8
Tolerant to Stem-borer/field pests	0.3	2.0	1.0	0.7	1.2	1.2	1.1
Tolerance to weevils	1.2	1.5	0.0	0.0	1.5	1.8	1.0
Tolerant to MSV/diseases	0.5	2.0	1.0	0.7	0.7	0.0	0.8
Compact grain/high flour density	0.0	2.2	0.0	0.0	2.2	0.0	0.7
Lodging	0.0	2.0	0.0	0.0	2.2	0.2	0.7
Number of rows per cob (high or fixed)	0.0	3.0	0.0	0.0	0.4	0.0	0.6
Seed, low price	0.0	2.3	0.0	0.0	0.7	0.0	0.5

Numbers represent average scores, where 3= very important, 2= important, 1= less important, 0 = not important, only criteria with score above 0.5 are shown

Constraints to maize production and pest problems

The three major constraints to maize production ranked by farmers throughout the zones were cash constraints, lack of technical know-how and extension, and problems with maize seed: high cost, poor quality and low availability. Pest problems usually ranked in the top six (Table 4).

Table 4. Farmers ranking of constraints in maize production

Constraint	Rank 1	Rank 2	Rank 3	Rank 4	Rank 5	Rank 6
Embu	cash	rain	Know-how	seed cost	stem borer	low fertility
Kakamega	farm implements	soil fertility	Cash	extension (know-how)	certified seed availability	pests
Katumani DM	Rain	pests & diseases	cost of inputs	seed availability	know-how	
Katumani DT	rain	know-how	pests and diseases	input cost	poverty	
Kitale	poor seed quality	seed price	fertility price	low maize price	cash	pests
Mtwapa	field pests	cash	soil fertility	wildlife	drought	

The two major pest problems farmers encounter all over the zones are stem borers and weevils (Table 5). Both pests rank in the top three in all the agro-ecological zones. Other major pests are chaffer grubs (dry zones), termites (dry zones and moist mid-altitude) and striga (moist mid-altitudes).

Table 5. Farmers ranking of pest problems in maize production

Pests	Rank 1	Rank 2	Rank 3	Rank 4	Rank 5
Embu	Stem borer	Weevils	Squirrels		
Kakamega	Striga	Weevils	Stem borer	Termites	Rodents
Katumani DM	Weevils	Stem borer	Chaffer grubs	Termites	
Katumani DT	Weevils	Chaffer grubs	Stem borer	Termites	Squirrels
Kitale	Stem borer	Weevils	Cutworms	Rodents	
Mtwapa	Rodents	Stem borer	Weevils	Beetles	Storage moths

Incorporating PRAs into GIS

Overview and procedure

Information from PRAs can easily be incorporated into a GIS framework, provided a systematic approach and some organization. First, the information needs to be structured in a matrix. In the PRA database, the data from each group interview forms a line or observation. The information from each group is then structured over different columns or variables. Second, all information needs to be geo-referenced, meaning that for each line the coordinates (latitude and longitude) of the place of the group interview needs to be entered as two separate variables or columns in the database. These coordinates can be measured with a Global Positioning System (GPS) device, or obtained from a map, and translated into decimal degrees. It is convenient to enter the data into a spreadsheet, save them into the standard dBase format file, which can then be read by most GIS software packages such as Arcview.

Some analysis GIS analysis can be done on qualitative data, such as mapping the different selection criteria mentioned, or which pests were ranked first or second. Unfortunately, in the present study this was complicated since not all group interviews were conducted separately with men and women. This made analysis by gender difficult, and it was therefore decided to restrict ourselves to analysis by location. For this type of analysis, it was necessary to obtain average values, which excluded the use of qualitative data. Qualitative data were therefore converted into quantitative approximations and average values were used for each site, reducing the database to one line per site.

In the next sections, three topics will be further analyzed: selection criteria for maize varieties, pest problems, and biodiversity. The variables used in the GIS analysis are presented in Table 6. Different types of variables are used for the different analyses: scores of importance for the criteria, scores derived from ranking for the pest problems, and number of improved and local varieties for the biodiversity analysis.

Table 6. Variables used in GIS analysis

Topic	Variable	Type	Definition
Importance of election criteria for maize	Yield	Score	0=not important; 1=somewhat important; 2=important; 3=very important
	Early maturity	Score	Same as above
Importance of pest problems	Stem-borer	Derived score (from ranking)	5=top score, if ranked 1st; 4=if ranked 2nd; 3=if ranked 3rd; 2=if ranked 4th; 1=ir ranked 5 or above; 0=if not mentioned
	Striga	Derived score	Same as above
	Weevils	Derived score	Same as above
Biodiversity in maize	Total varieties	Count	Total number of varieties as distinguished by the farmers
	Local varieties	Count	Number of local varieties as distinguished by the farmers
	Improved varieties	Count	Number of improved varieties as distinguished by the farmers

Selection criteria for maize

The GIS analysis of farmers' selection criteria uses the scores with which farmers indicate their importance (from 3 for very important, to 0 for not important). Where more than one group interview was conducted, averages were used. By geo-referencing the data a map can be constructed, presented in Figure 2. For ease of presentation, only the two most important criteria are presented here: yield and early maturity. The map shows the importance of the criteria as vertical bars, located at the site of the group interview.

The results show that both criteria are almost universally important to very important. In the moist-transitional zone and in Western Kenya, both criteria are equally important. In the dry areas and the coast, on the other hand, early maturity is generally more important than yield. Only in the central highlands is early maturity considered of minor importance. These results have important implications for breeding: early maturity should receive more weight in the breeding, and not only for the dry areas.

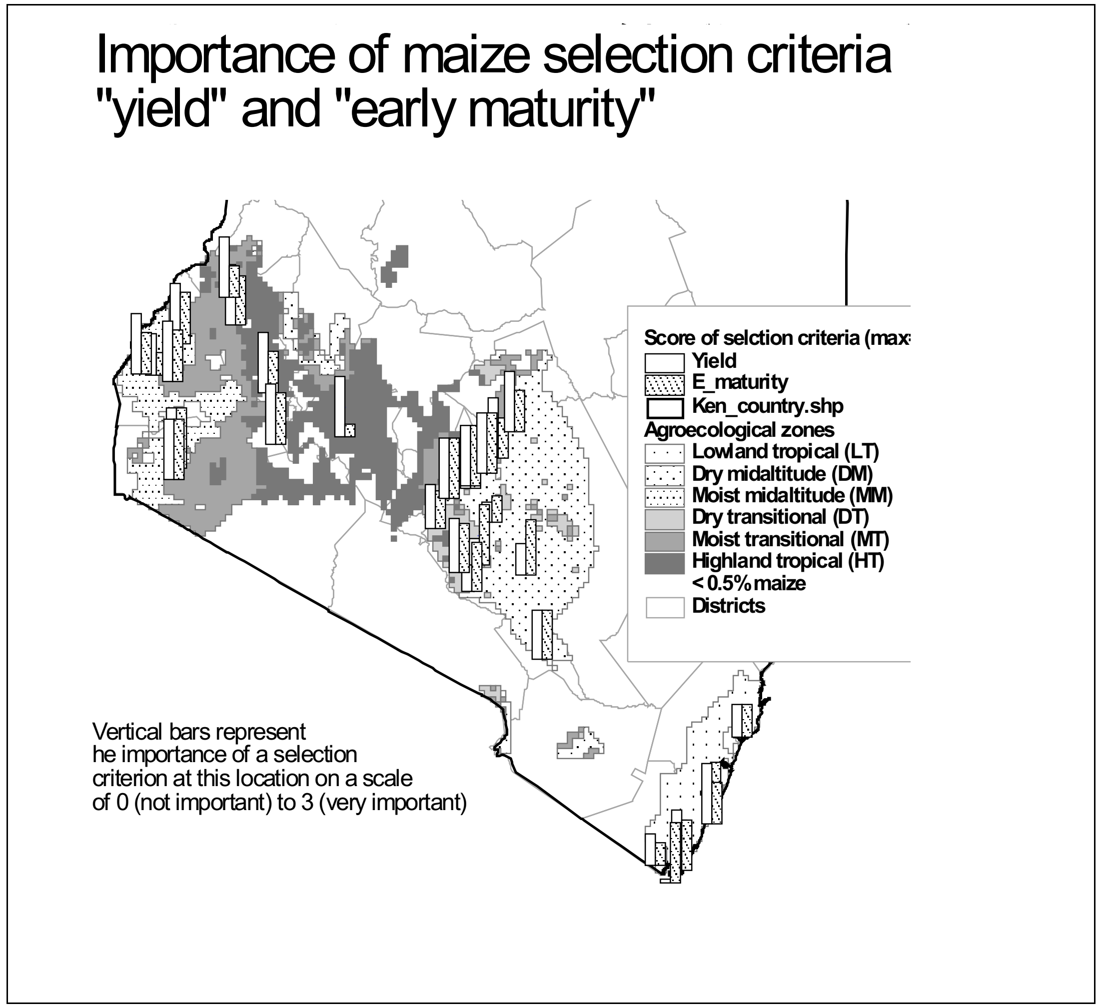

Figure 2. Importance of maize selection criteria "yield" and "early maturity

Importance of pest problems

For the GIS analysis, the two major pests were included: stem-borers and weevils (a storage pest), plus the major pest in Western Kenya: *Striga* (a parasitic weed). The PRA teams of all regions did obtain a ranking in importance for pests observed by farmers in the maize production. Not all teams obtained scores of importance, so it was necessary to convert the ranks into a score. Since a score is inversely related to a rank, those pests ranked from 1 to 4 received a score of 4 to 1 respectively. All pests ranked 5 or above received a score of 1, and all pests not mentioned received a score of 0. This conversion, although admittedly somewhat arbitrary, reflects the perception that there is not much difference between pests ranked 5th or more. The data were geo-referenced and the results are presented in Figure 3.

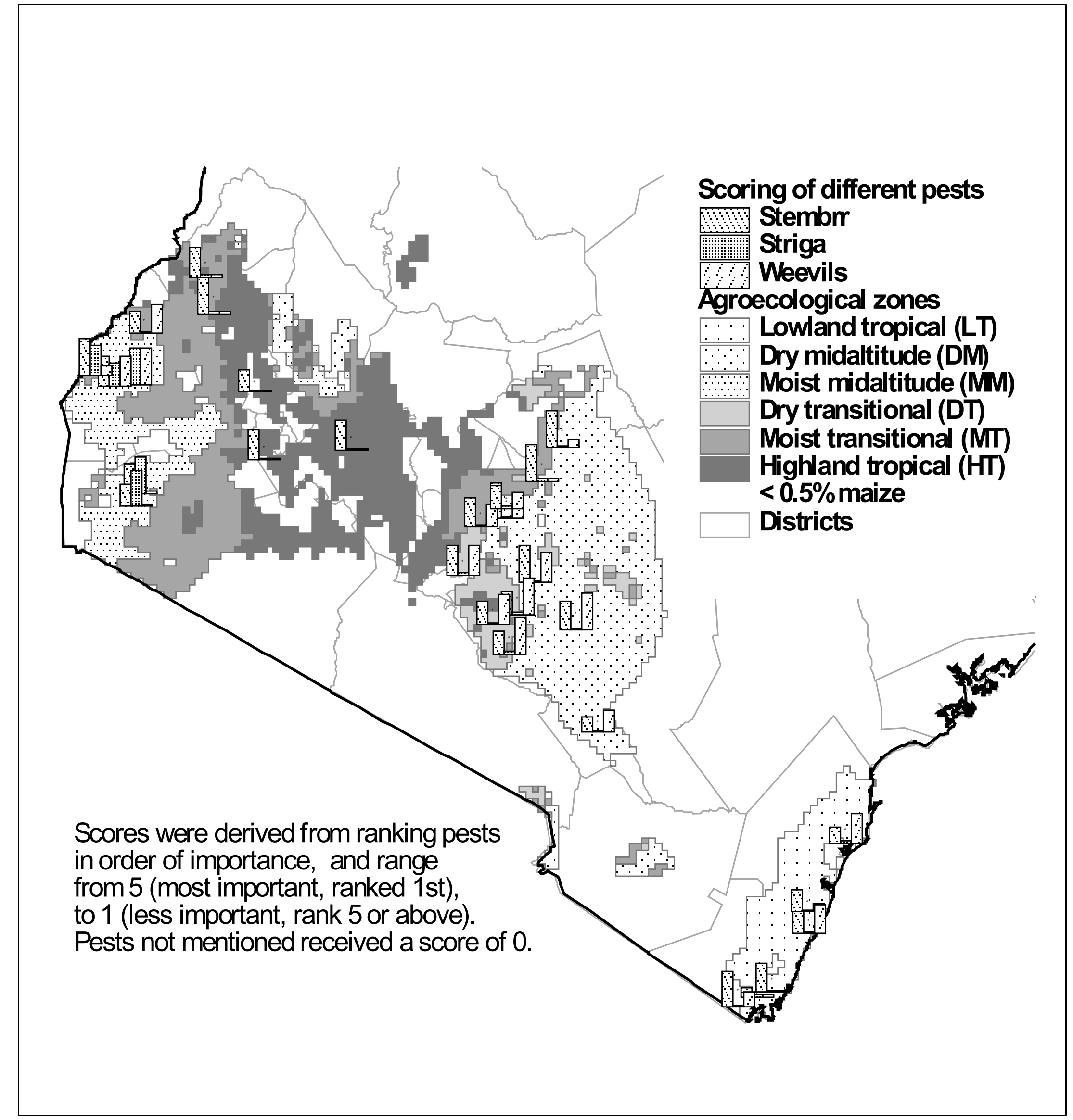

Figure 3. Pest problems in maize

By analyzing the map from West to East, some very important observations can be made. First, striga is only a problem in the moist-transitional zone of Western Kenya. There, however, it is the major problem, ranking first in 4 out of 5 sites. Storage pests are not a serious problem in the Western part of the moist transition zone and the highlands, but important in the other zones. In the dry areas, storage pests are important to very important, and rank equal or more important than stem-borers. The importance of stem-borers varies substantially over the different zones, and is clearly less in the highlands and certain sites at the coast.

The implications are quite clear: stem-borers are a very important pest in most of the country, and resistant varieties are likely to be popular. However, the striga problem needs to be addressed in Western Kenya, and new varieties should aim for a higher resistance to storage pests than the current varieties.

Biodiversity in maize

To analyze biodiversity in maize, simple counts were used of local and improved varieties, as distinguished by the farmers, as well as the total count of all varieties. Although more advanced methods can be used to distinguish varieties and to calculate biodiversity indices, these counts do offer a convenient first analysis. The total number of varieties varied from 4 to 13, and is represented in the map of Figure 4 by the size of the circle on each site.

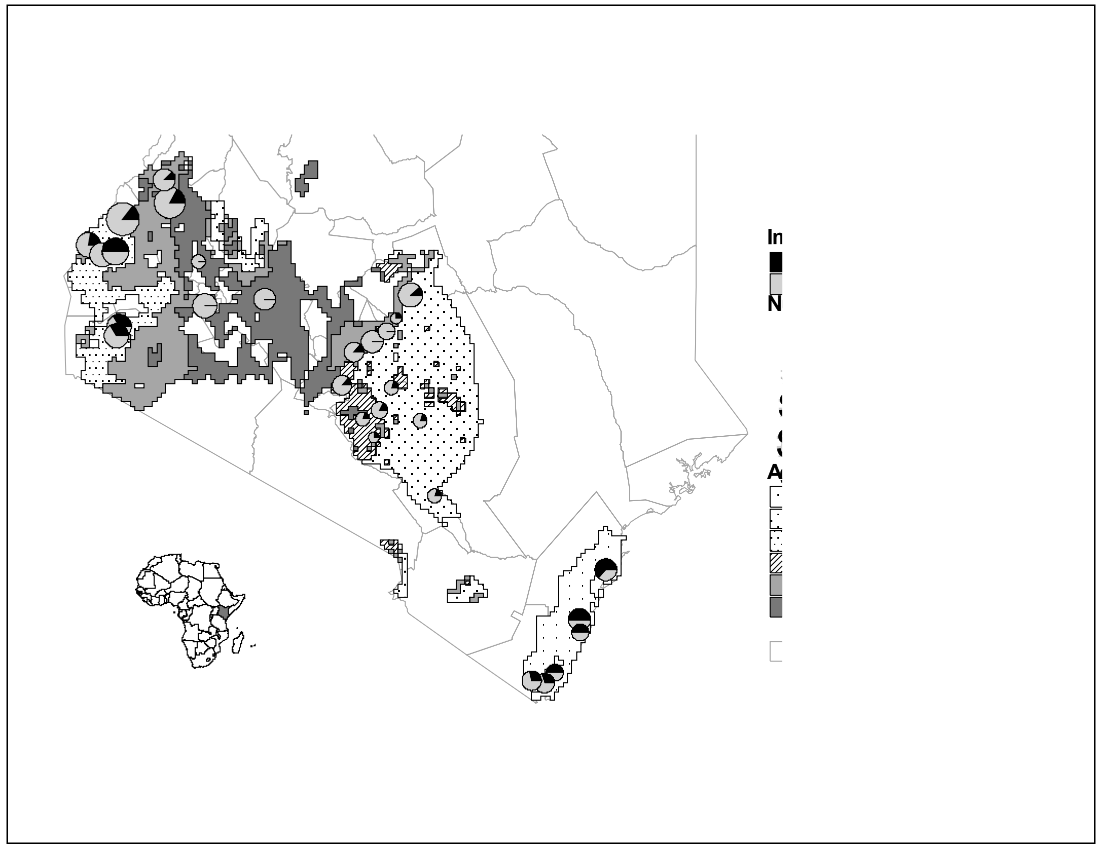

Figure 4. Biodiversity in maize

It is easily observed that the number is highest in the west and lowest in the dry zones. The highlands and the transitional zones have a medium number of varieties. The analysis of improved varieties shows that all sites have at least a few improved varieties, indicating that farmers in Kenya will adopt new varieties if they fit their preferences. The analysis of local varieties is also very revealing. At many sites at the coast and around the Lake a quarter to half of the varieties are local. In the dry and transitional zones, local varieties count for less than a quarter, and they are no longer grown in the highlands.

The popularity of local varieties also has implications for breeding. Breeding programs should consider improving local varieties around Lake Victoria and at the coast, instead of trying to replace them with new varieties. Similarly, insect resistance could be bred into the local varieties.

Conclusions

The analysis of farmers' preferences as obtained from PRA data is clearly helped by a GIS framework. It is, however, necessary to make some adjustments to the classical PRA methods, in particular with respect to geo-referencing, randomization, quantification, and harmonization.

For any mapping, geo-referencing is clearly essential. Because of the reduced cost of GPS devices, this technology is now widely available and should be used as much as possible. However, this is not sufficient. To draw conclusions for areas with particular geographic characteristics, the sites need to be representative. By far the best way is simple random sampling of sites, after stratification based on target zones. The conventional purposive sampling of PRA practitioners is not recommended, since it leads to concentration of sites close to the research centers, bias from previous imprecise knowledge, and fewer sites in further and less accessible zones. Multi-stage or clustered sampling, used in several zones for this study, is also less convenient, since it results in sites being not well distributed over the zone.

Geo-referencing and randomization provide representative sites, but to make meaningful analysis, especially extrapolation, the data need to be quantified and its collection harmonized. At first glance, this seems to be going against the flexible, qualitative nature of participatory research, and PRA in particular. However, this experience has shown that minor modifications, as well as minor negligence, can make a big difference. On the positive side, scoring is not much harder than ranking, and once farmers understand the concept, it is actually much faster than matrix ranking. Although more detailed comparisons do get lost in the synthesis, those details were usually only available to the members of the PRA team. The advantage of synthesis is the availability of compact information to decision makers and, in this case, breeders. The GIS analysis has the added advantage that detailed information remains available. Similar to scoring, simple counts can be observed and percentages calculated, as was shown with the varieties and biodiversity analysis.

To fully appreciate the advantages of synthesis and GIS analysis, it is important that basic procedures are followed. Different PRA teams still have the flexibility to expand the discussion to new topics or details, but they should not cut parts where they expect little new information. For example, several teams did not push for separate discussions with men and women, which subsequently made gender analysis difficult, thereby reducing the value of the information collected by those teams who did the effort. Similarly, some teams did not fully randomize the site selection so the map shows some clear gaps, especially in the western moist transitional zone and in the eastern highlands.

Finally, some sites turned out to fall outside the agro-ecological zone for which they were selected. To avoid this, they should be geo-referenced before the PRA is executed. In the next phase of this research, sites will therefore be added to fill the gaps. Further, the geo-references of all sites will be checked again, each site will be assigned to its proper zone regardless of the selection procedure, and the analysis by zone repeated.

Despite the shortcomings of the present analysis, the methodology is convenient and offers strong insights. The maps present allow visual inspection of all sites at glance, leading to synthesis without loss of detail. If the data are collected in a systematic way, the analysis does not need any particular quantitative skills. The maps are easy to understand and the information is relevant to the breeders. Most importantly, they reveal a general interest by farmers in new, insect-resistant varieties.

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