Estimating On-Farm Storage Losses in Maize Using Community Surveys in Kenya

by Hugo De Groote and Francisca Muteti

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Abstract

In Sub Saharan Africa (SSA), storage losses threaten households' food security and undermine their market returns. National studies showing the estimation of postharvest losses are lacking in Kenya. Scientific surveys which have been used in other countries may not be economical to use. This study therefore used community based survey to determine farmers' knowledge of storage pests, specifically maize weevil and larger grain borer, to determine the percentage of farmers affected and subsequent reduction in yield, and to estimate the total grain loss from storage pests. The study was conducted in the six maize growing zones of Kenya. Results showed that storage losses varied within zones.

Keywords: maize weevil, larger grain borer, storage pests, losses, maize, Kenya

JEL classification: Q11, Q12, Q19

1. **Introductio**n

Postharvest losses (PHL) are a key focus area of dialogue especially in Sub Saharan countries where most households rely heavily on farm produce for their income (Sheahan and Barrett, 2017). Food losses have an implication of reduced food available to feed the growing population especially in developing countries. In Sub Saharan Africa (SSA), storage losses threaten households' food security and undermine their market returns (Midega *et al.,* 2016; Stathers *et al.*, 2008). Farmers have adopted various technologies of preventing postharvest losses. However, national studies showing the estimation of losses are lacking in Kenya. Determining the extent of losses caused by storage pests such as weevils and LGB could help in evaluating the costs versus benefits associated with grain storage.

Previous studies have shown that PHL could range from 20% to 40% in African countries (Abass *et al., 2014; Kumar and Kalita, 2017).* Therefore, reducing post-harvest losses has been identified as one of the sustainable strategies to reduce hunger and improve grain farmers' livelihoods without increasing pressure on the natural environment (Affognon *et al.,* 2015; Tefera, 2012). To achieve this, there is need for good statistics and estimates of losses so as to compare costs and benefits of interventions and control technologies.

According to De Groote et al. (2013), grain losses due to storage insects have remained significantly high. Some of the common pests associated with this damage are maize weevils (Sitophilus zeamais) and large grain borers (Prostephanus truncates). The maize weevil is a pest of economic importance that infests in the field but most damage is experienced during storage (Giga and Mazarura, 1991; Muzemu et al., 2013; Suleiman and Rosentrater, 2015)

The Larger Grain Borer (LGB) has its history in Africa from its first observation in Tanzania in the 1970s and its subsequent spread in the East Africa, followed by West Africa. Severe losses were experienced by farmers who had stored their maize, which were about three to four times higher compared to the losses before arrival of LGB (Farrell and Schulten, 2002). In Kenya, LGB was first reported in 1983 in Taveta division which borders Tanzania (Kega and Warui, 1983). Several studies have been conducted on LGB and the losses associated with the pest, which has given scientists and innovators an upper end (Boxall, 2003; Kaminski and Christiaensen, 2014)

To reduce the PHL from storage pests, several innovations have been developed. These include chemical pesticides specifically developed for grain storage (Urono, 1999) but also more environmentally friendly approaches such as botanicals (Eticha and Tadesse, 1998; Isman, 2006) and hermetic storage containers including metal silos (Tefera *et al.*, 2011) and hermetic bags (Quezada *et al.,* 2006) were developed to provide a weevil resistant storage for maize farmers. The effectiveness of this technology has been tested and positive results recorded (De Groote *et al.*, 2013; Ndegwa *et al.*, 2016) conducted similar trials among 300 farmers and reported that hermetic bags were potentially profitable if farmers stored maize for four months per season and the bags lasted for a period of four years.

Despite the many researches providing literature on the spread, losses and losses from storage pests, national studies on the economic impact of these pests on maize farmers have not often been conducted, and none in Kenya. Loss estimations have been conducted in in Living standards Measurement (LSM) surveys in some countries such as Ethiopia (Hengsdijk, 2017), Malawi, Uganda and Tanzania (Kaminski and Christiaensen, 2014). Close monitoring could help in determining the losses caused by storage pests, especially the common maize weevil and LGB which cause substantial losses. However, scientific and systematic observations of storage losses on a national scale would be expensive, and so are surveys of individual farmers also. Estimates obtained from systematic and representative Focus Group Discussion, on the other hand, are much more economical and provide good results, as studies on Maize Lethal Necrosis (MLN) (De Groote *et al.*, 2016; De Groote *et al.*, 2020b) and fall army worms (FAW) (De Groote *et al.*, 2020a) have shown .

In this study, we therefore used focus group discussions, conducted at randomly selected communities, representative of the different maize agro ecological zones in Kenya, to assess farmers' knowledge of maize weevils and LGB, and their observations of the pests in the in the last two seasons. The study also asks participants to estimate the proportion of farmers affected by these two storage pests and the maize lost in storage on affected farms in the long and short seasons of 2017. In addition, we estimate the total relative loss on all farms by multiplying these two variables, and extrapolate the results to estimate the absolute loss in each of the six agro ecological zones.

2. Methods

2.1. Storage loss estimation

Storage loss is defined as the difference in maize quantity at the beginning of the storage period Y_0 and at the end Y_t, expressed as a proportion or percentage: $r = \frac{(Y_0 - Y_t)}{Y_0}(\times\ 100)$. Instead of trying to measure Y_0 and Y_t directly, we asked farmers, during group discussions, to estimate the proportion of farmers affected by storage insect pests (F_a) in their community, and the estimated storage loss (in %) experienced by the affected farmers (L). Total loss in the community was then calculated as L = F_a x r. As the communities were selected randomly from the major maize production zones, average storage losses can be multiplied by the estimated maize stored in each zone to estimate maize quantities lost. The quantity of maize stored is the quantity produced minus the quantity marketed. A similar method was previously used to estimate crop yield loss and its distribution caused by the maize lethal necrosis (MLN) disease (De Groote et al., 2016), and was based on previous experience to assess the importance of different maize pests through group discussions (de Groote 2014).

2.2. Design of the community survey

A community survey was designed similar to the community survey of 2013, from which the losses due to maize lethal necrosis (MLN) were estimated (De Groote et al., 2016). Thus, the same 121 communities that were interviewed in 2013 were targeted (see map in Figure 1). These communities were randomly selected to represent the six main maize production areas in Kenya. The main purpose of the community survey was to assess farmer prioritization of various stresses and to measure the impact of these for the Stress Tolerant Maize for Africa (STMA) project. Prioritization is especially important due to the arrival of new pest problems, in particular the larger grain borer (LGB), MLN disease and the current fall armyworm (FAW). Data were collected through focus group discussions (FGDs). The results for MLN and FAW have been presented in other papers (De Groote et al.; De Groote et al., 2020), where the methodology is also presented in more detail.

[Figure 1]

2.3. Development of tools

CIMMYT contracted Agri-Food Economics Africa, a research company based in Kenya, to undertake the study. The development of the questionnaire was a consultative process undertaken during the first half of 2018, involving CIMMYT and partners who had a special interest in FAW. These partners were the International Centre of Insect Physiology and Ecology (icipe), the Food and Agriculture Organization (FAO) and the CAB International (CABI), as well as CIMMYT economists and entomologists. Comments from these partners were taken into consideration, and efforts were made to harmonize sections of the tools with those of the partners, such as the FAO's FAW modules.

The primary goal of the study was to assess the importance of different maize production and storage stresses, as perceived by farmers in the different agro ecological zones where maize is produced. A draft questionnaire was developed and tested; separate modules discussed various stresses, including FAW, MLN, maize stem borer, maize weevil, larger grain borer, drought, and soil fertility.

The questionnaire was pre-tested for two days, 7th and 8th June 2018, with two communities that were not participating in the survey, one in Machakos County and the other in Embu County. In addition to economists from CIMMYT and Agri-Food Economics Africa, a CIMMYT entomologist and an economist from ICIPE participated in the pre-test. Following the pre-testing, adjustments were made to the questionnaire, and a version developed that was used for training enumerators. This version also formed the basis of the electronic questionnaire designed using the Survey CTO platform, as enumerator training was based on both paper and electronic questionnaires. After two days of training, the team of enumerators, field supervisors and researchers piloted the survey in Murang'a County. This was followed by a recap to raise and discuss all the issues observed. The team of researchers discussed all additional issues observed during training and piloting, and developed a final version of the questionnaire that was to be used for data collection (Appendix 1). The electronic questionnaire was also updated to reflect the final paper version.

Since the community survey dealt with biotic and abiotic stresses, it was important to have pictures that represented the various biotic stresses (insect pests) so that the farmers could recognize the specific pest that they were being asked about (Figure 2). In addition, the photos were important in helping to gauge farmers' awareness of the weevils and larger grain borer. CIMMYT entomologists assisted in gathering these pictures and in refining the descriptions of the various stresses. The final version of the pictures was printed and laminated for use in data collection.

[Figure 2]

2.4. Site selection

The survey targeted the same communities that were interviewed for a study in 2013 (De Groote *et al.*, 2016). Each field team was given a list of the communities that they were to interview, with the previously allocated identification number, location details (division, location and sub location), and contacts of the members who participated in the 2013 FGD. The contacts in the communities, usually a leader from a farmer group or from the local administration, were each asked to invite between 10-15 maize farmers.

2.5. Data collection

Ethical clearance for the survey was sought by CIMMYT from CIMMYT's Institutional Research Ethics Committee (IREC), and the research was cleared for implementation on 11th June 2018 (clearance number IREC 2018.004).

Data collection was undertaken by Agri-Food Economics Africa, which recruited two teams, each consisting of an experienced supervisor and two experienced enumerators. The minimum qualification for supervisors was at least three years of experience in managing or conducting household surveys, as well as having served as enumerators themselves. The minimum qualification for an enumerator was a university degree in agricultural or related sciences. All team members were properly trained in the different aspects of the survey and the questionnaire and participated in the survey pilot as part of the training and preparation. Data collection took place from 18th June to 28th July 2018 (41 days). A detailed explanation of the exercise is provided in the study on FAW and MLN (De Groote, 2020a). At the end of the data collection, all targeted 121 communities were interviewed, representing 100% coverage with no replacements. In total, 1439 farmers participated.

2.6. Analysis

Kenya does not produce regional maize statistics. To estimate maize production by agro ecological zone, we used the definition of the zones as developed by Hassan (Hassan *et al.*, 1998). We compared Hassan's area- and production statistics with the data from the 2005 and 2010 Spatial Production Allocation Map (SPAM) (Yu *et al*., 2017; You *et al*., 2014), and calculated the maize area and production for 2005 and 2010 for the different agro ecological zones (AEZs). To estimate the population in each agricultural zone, we used the 2015 population density dataset from WorldPop (www.worldpop.org) (Stevens *et al.*, 2015). Finally, we allocated the annual production data for each zone to the two seasons, proportionate to the distribution found in the household survey undertaken by CIMMYT in 2013.

3. Results

3.1. Knowledge and recognition of maize weevil and LGB by communities

Focus Group Discussions were conducted on 121 communities in six agro ecological regions. In total, 1439 participants were interviewed. At the beginning of the discussions, participants were shown pictures of maize weevil and LGB, and asked if they could clearly recognize the pests. Most of the participants (96.6%) could clearly recognize maize weevil, and 74.25% could recognize the LGB (Figure 3). There was however a difference across regions, where weevils were more recognized in the Moist mid altitudes (98%) and lower in the Dry mid altitude and Dry transitional (94%). In the case of LGB, pest recognition was high among participants in the costal lowland (82%) and lowest in the high tropics, recorded at 38%.

[Figure 3]

3.2. Occurrence and spread of maize weevil and LGB in maize growing regions

After storage pest identification, participants were asked whether they had observed the pest (maize weevil and LGB) in the community before, and over the last two seasons (Figure 4). On average, 98% of the participants agreed that they had observed weevils in the community. Over the last two seasons of 2017, maize weevils had been observed by 89% of participants in all the six zones. The pest was observed mostly in the moist mid altitudes (100%) and less in the dry mid altitude (65%). In the case of LGB, 82% of participants had observed it in the community while only 60% had an observation of the pest in the last two seasons. More observation of LGB was recorded in the moist mid altitudes (89%) and 17% in the dry transitional. Both maize weevil and LGB were recorded more in the short rain season compared to the long rain season. This implies that more effort is required in developing cost effective technologies of reducing storage losses.

[Figure 4]

3.3. Farmers affected and percentage of loss caused by weevils and LGB

The results of the farmers affected and amount of maize lost on the affected farms in each zone are shown in Figure 5 for maize weevils and in Figure 6 for LGB. During the long rains, 62% of farmers were affected by weevils and 13% loss was experienced among the affected farms. The highest number of farmers affected was in the moist mid altitudes (73%) and lowest in the high tropics (9%). In the same season, 32% of farmers were affected by LGB and a total loss of 14% experienced overall. Most farms (48%) in the moist mid altitudes were affected, with a few cases in the high tropics (6%). The total loss on affected farms caused by both maize weevils and LGB did not differ much in that season.

[Figure 5]

[Figure 6]

During the short rain season, the percentage of farmers affected by weevil was 75% contributing to 29% maize loss. Moist mid altitudes recorded the highest total loss of 37%, with the least amount of maize lost being recorded in the high tropics (17%). In addition, 42% of farmers were affected by LGB in the short rains and contributed to a loss of 29% in the six zones. The highest percentage of attack was reported in the moist altitudes (68%) with a total loss of 53%. Generally, more storage losses were experienced during the short rains compared to the long rains, with LGB causing more damage compared to maize weevils.

3.5. Geographic distribution of relative losses cause by maize weevil and LGB

First, we estimated the relative losses for both maize weevil and LGB by multiplying the % farmers affected by the % loss, and this for each season and for both species. We combined the short and long rainy season to calculate the annual relative losses (Figure 7). The results show clearly that the more humid areas are most affected, and this for both species. The moist mid-altitudes have the highest relative losses (40-50%), followed by the coast and the moist transitional zone (about a quarter). Colder climates like the highlands (15%) and especially dyer (even though warmer) climates like the drylands (10%) are less affected.

[Figure 7]

The point estimates for relative losses were extrapolated using kriging for both maize weevil (Figure 8) and LG (Figure 9). Both graphs are very similar and indicate a much stronger activity and resulting losses by both insects in the Western part of the country.

[Figure 8]

[Figure 9]

3.6. Total annual losses cause by maize weevil and LGB

The total annual maize losses over the different agro ecological zones were estimated (short rains and long rains) and results presented in Table 2. The results show that the total annual loss as a percentage was on the same range of 18% for both maize weevil and LGB. Further, both pests caused significant losses in the moist mid altitudes, followed by the coastal lowlands, and moist transitional. In the dry mid altitudes, 12% total loss was recorded from both pests. In the dry transitional altitudes, maize weevil had a greater impact (14%) compared to LGB (7%). The least percentage loss from the two pests was experienced less in the high tropics, estimated at 3%.

Geographical extapolation was done to show the spread of relative losses from each storage pest across different agro ecological regions (Figure 10). The results show clearly how most of the losses occur in the Western part of the country.

4. Discussion

The results of the study show that many farmers correctly identified maize weevil and larger grain borer, especially from the coastal lowlands and moist mid altitudes. In Kenya, larger grain borer made its first attack in Taveta division along the coastal lowlands (Kega and Warui, 1983). This could imply that residents of the area have lived to know the pest and can clearly identify its image from pictures. On the other hand, maize production is higher in the Kenyan highlands, and the coastal lowlands are last in national maize production (Wekesa *et al.*, 2003). From the results, losses from weevils and LGB are also reported to be high in the moist mid altitudes and coastal lowlands. This could suggest that the amount of grain storage losses are directly proportional to the total production. According to a study on PHL in Malawi, Uganda and Tanzania (Kaminski and Christiaensen, 2014), on-farm PHL accounted for 1.4 to 5.9 percent of the national maize harvest. Hodges et al.(2011) further added that wetter conditions foster early pest infestation during storage which escalates PHL. More so, the study shows that favorable climatic conditions for maize production could possibly provide a conducive environment for storage pests. Moreover, the high tropics had the least number of farmers affected in 2017 and also recorded the lowest reduction in yield due to storage pests. This therefore means that technologies developed for reducing postharvest losses should be tailored to suit different agro ecological zones as the impact of the pests varies from zone to zone. Similar observations were reported by Meikle et al. (1998) and Boxall (2003) who suggested that forecasts for grain damage should be made for different stores and geographical regions.

Conclusion

Storage pests are a great threat to the grain sector which greatly contributes to the livelihoods of the farming communities. Maize weevil and the larger grain borer cause significant storage losses, which vary within the six maize growing regions in Kenya. This study therefore concludes that statistics on storage losses in different zones are key to comparing the costs and benefits of postharvest loss reducing technologies that are tailored to address the challenges of each agro ecological region.

References

Abass, A. B., Ndunguru, G., Mamiro, P., Alenkhe, B., Mlingi, N., & Bekunda, M. (2014). Post-harvest food losses in a maize-based farming system of semi-arid savannah area of Tanzania. *Journal of Stored Products Research*, *57*, 49–57. https://doi.org/10.1016/j.jspr.2013.12.004

Affognon, H., Mutungi, C., Sanginga, P., & Borgemeister, C. (2015). Unpacking postharvest losses in sub-Saharan Africa: A Meta-Analysis. *World Development*, *66*, 49–68. https://doi.org/10.1016/j.worlddev.2014.08.002

Boxall, R. A. (2003). Damage and loss caused by the Larger Grain Borer Prostephanus truncatus. *Integrated Pest Management Reviews*, 105–121.

De Groote, H., Kimenju, S. C., Likhayo, P., Kanampiu, F., Tefera, T., & Hellin, J. (2013). Effectiveness of hermetic systems in controlling maize storage pests in Kenya. *Journal of Stored Products Research*, *53*, 27–36. https://doi.org/10.1016/j.jspr.2013.01.001

De Groote, H., Kimenju, S. C., Munyua, B., Palmas, S., Kassie, M., & Bruce, A. (2020). Agriculture , Ecosystems and Environment Spread and impact of fall armyworm (Spodoptera frugiperda J . E . Smith) in maize production areas of Kenya. *Agriculture, Ecosystems and Environment*, *292*(July 2019), 106804. https://doi.org/10.1016/j.agee.2019.106804

De Groote, H., Oloo, F., Tongruksawattana, S., & Das, B. (2016). Community-survey based assessment of the geographic distribution and impact of maize lethal necrosis (MLN) disease in Kenya. *Crop Protection*, *82*, 30–35. https://doi.org/10.1016/j.cropro.2015.12.003

Farrell, G., & Schulten, G. G. M. (2002). Larger grain borer in Africa; a history of efforts to limit its impact. *Integrated Pest Management Reviews*, *7*(2), 67–84. https://doi.org/10.1023/A:1026345131876

Giga, D. P., & Mazarura, U. W. (1991). Levels of Resistance to the Maize Weevil, Sitophilus Zeamais (Motsch.) in Exotic, Local Open-Pollinated and Hybrid Maize Germplasm. *International Journal of Tropical Insect Science*, *12*(1-2–3), 159–169. https://doi.org/10.1017/s1742758400020646

Hengsdijk, H. (2017). Post-harvest management and post-harvest losses of cereals in Ethiopia. *Food Security*, 945–958. https://doi.org/10.1007/s12571-017-0714-y

Hodges, R. J., Buzby, J. C., & Bennett, B. (2011). Postharvest losses and waste in developed and less developed countries: Opportunities to improve resource use. *Journal of Agricultural Science*, *149*(S1), 37–45. https://doi.org/10.1017/S0021859610000936

Kaminski, J., & Christiaensen, L. (2014). Post-harvest loss in sub-Saharan Africa — what do farmers say ? *Global Food Security*, *3*(3–4), 149–158. https://doi.org/10.1016/j.gfs.2014.10.002

Kumar, D., & Kalita, P. (2017). Reducing Postharvest Losses during Storage of Grain Crops to Strengthen Food Security in Developing Countries. *Foods*, *6*(1), 8. https://doi.org/10.3390/foods6010008

Meikle, W. G., Holst, N., Scholz, D., & Markham, R. H. (1998). Simulation Model of Prostephanus truncatus (Coleoptera: Bostrichidae) in Rural Maize Stores in the Republic of Benin. *Environmental Entomology*, *27*(1), 59–69. https://doi.org/10.1093/ee/27.1.59

Midega, C. A. O., Murage, A. W., Pittchar, J. O., & Khan, Z. R. (2016). Managing storage pests of maize: Farmers' knowledge, perceptions and practices in western Kenya. *Crop Protection*, *90*, 142–149. https://doi.org/10.1016/j.cropro.2016.08.033

Muzemu, S., Chitamba, J., & Goto, S. (2013). Screening of Stored Maize (Zea mays L.) Varieties Grain for Tolerance Against Maize Weevil, Sitophilus zeamais (Motsch.). *International Journal of Plant Research*, *2013*(3), 17–22. https://doi.org/10.5923/j.plant.20130303.01

Ndegwa, M. K., De Groote, H., Gitonga, Z. M., & Bruce, A. Y. (2016). Effectiveness and economics of hermetic bags for maize storage: Results of a randomized controlled trial in Kenya. *Crop Protection*, *90*, 17–26. https://doi.org/10.1016/j.cropro.2016.08.007

Nduku, T. M., De Groote, H., & Nzuma, J. (2013). Comparative Analysis of Maize Storage Structures in Kenya. *4th Conference of the African Association of Agricultural Economists (AAAE), 22-25 September 2013, Tunisia*, (September), 22–25.

Quezada, M. Y., Moreno, J., Mario, E. V, Abraham, M., & Moreno-mart, E. (2006). Hermetic storage system preventing the proliferation of Prostephanus truncatus Horn and storage fungi in maize with different moisture contents. *Postharvest Biology and Technology, 39*, 321–326. https://doi.org/10.1016/j.postharvbio.2005.10.004

Sheahan, M., & Barrett, C. B. (2017). Food loss and waste in Sub-Saharan Africa: A critical review. *Food Policy, 70*, 1–12. https://doi.org/10.1016/j.foodpol.2017.03.012

Stathers, T. E., Riwa, W., Mvumi, B. M., Mosha, R., Kitandu, L., Mngara, K., … Morris, M. (2008). Do diatomaceous earths have potential as grain protectants for small-holder farmers in sub-Saharan Africa? The case of Tanzania. *Crop Protection*, *27*(1), 44–70. https://doi.org/10.1016/j.cropro.2007.04.020

Suleiman, R., & Rosentrater, K. (2015). Current maize production, postharvest losses and the risk of Mycotoxins contamination in Tanzania. *American Society of Agricultural and Biological Engineers Annual International Meeting 2015*, *4*, 3289–3414. https://doi.org/10.13031/aim.20152189434

Tefera, T. (2012). Post-harvest losses in African maize in the face of increasing food shortage. *Food Security*, *4*(2), 267–277. https://doi.org/10.1007/s12571-012-0182-3

Tefera, T., Kanampiu, F., De Groote, H., Hellin, J., Mugo, S., Kimenju, S., … Banziger, M. (2011). The metal silo: An effective grain storage technology for reducing post-harvest insect and pathogen losses in maize while improving smallholder farmers' food security in developing countries. *Crop Protection*, *30*(3), 240–245. https://doi.org/10.1016/j.cropro.2010.11.015

Tables

Table 1. Maize agroecological zones in Kenya, with estimated maize area and production in 1992, 2005 and 2010

Agroecological zone	Elevation	Maize 2017			Population	Weights			
	(masl)	Area (1000 ha)	Production (1000 tonnes)	Yield (t/ha)	(1000)	Area	Production	Population	Maize production long rains
Lowland Tropics	0-700	58	37	0.65	2,857	0.03	0.01	0.06	0.621
Dry Mid-altitude	700-1400	401	196	0.49	3,825	0.19	0.06	0.08	0.415
Dry-Transitional	1100-1700	588	486	0.83	5,403	0.28	0.15	0.12	0.510
Moist-transitional	1200-2000	386	524	1.36	7,931	0.19	0.16	0.17	0.738
Highlands	1600-2900	248	586	2.36	1,801	0.12	0.18	0.04	0.990
Moist Mid-altitude	1110-1500	103	109	1.06	12,137	0.05	0.03	0.26	0.608
< 5%		91	119	1.30	1,858	0.04	0.04	0.04	0.71
Other		210	326	1.55	10,076	0.10	0.10	0.22	
Total		2,086	3,186	1.53	45,890	1.00	1.00	1.00	

Table 2. Total annual relative Losses from weevils and LGB

AEZ	Maize weevil			Larger grain borer			Maize weevil	Larger grain borer	Regional %
	Long rains	Short rains	Total	Long rains	Short rains	Total			
Coastal lowlands	25.0	26.0	25.4	19.8	27.6	22.8	9	9	2.52
Dry mid-altitudes	12.6	13.3	13.0	11.1	14.3	13.0	25	26	7.14
Dry transitional	12.8	16.1	14.4	7.0	7.2	7.1	70	35	14.65
Moist transitional	28.3	16.4	25.2	26.9	17.5	24.4	132	128	36.35
High tropics	17.5	3.3	17.3	15.3	3.3	15.1	101	89	26.58
Moist mid-altitudes	37.9	33.3	36.1	53.3	38.4	47.5	39	52	12.76
Total	24.5	20.5	23.9	24.5	21.1	23.9	378	337	100.00

Table 3. Annual absolute losses from weevils an LGB

Species	Zone	Production (1000 tonnes)		Storage losses (%)			Losses (tonnes)		
		Long rains	Short rains	Long rains	Short rains	Annual	Long rains	Short rains	Annual
Weevils	Coastal lowlands	25.9	15.8	25.0	26.0	25.4	6.5	4.1	10.6
	Dry mid-altitudes	17.2	24.3	12.6	13.3	13.0	2.2	3.2	5.4
	Dry transitional	110.6	106.4	12.8	16.1	14.4	14.2	17.1	31.3
	Moist transitional	1,081.2	383.4	28.3	16.4	25.2	305.6	63.1	368.7
	High tropics	898.2	9.4	17.5	3.3	17.3	156.9	0.3	157.2
	Moist mid-altitudes	278.8	179.7	37.9	33.3	36.1	105.8	59.8	165.5
	Total	2,411.9	719.0	24.51	20.53	23.6	591.1	147.6	738.8
LGB	Coastal lowlands	25.9	15.8	19.8	27.6	19.9	5.1	3.2	8.3
	Dry mid-altitudes	17.2	24.3	11.1	14.3	9.7	1.9	2.1	4.0
	Dry transitional	110.6	106.4	7.0	7.2	7.0	7.7	7.4	15.2
	Moist transitional	1,081.2	383.4	26.9	17.5	26.0	290.7	89.7	380.4
	High tropics	898.2	9.4	15.3	3.3	15.2	137.0	1.3	138.3
	Moist mid-altitudes	278.8	179.7	53.3	38.4	46.8	148.6	66.0	214.6
	Total	2,411.9	719.0	24.51	23.61	24.3	591.1	169.7	760.9

Figures

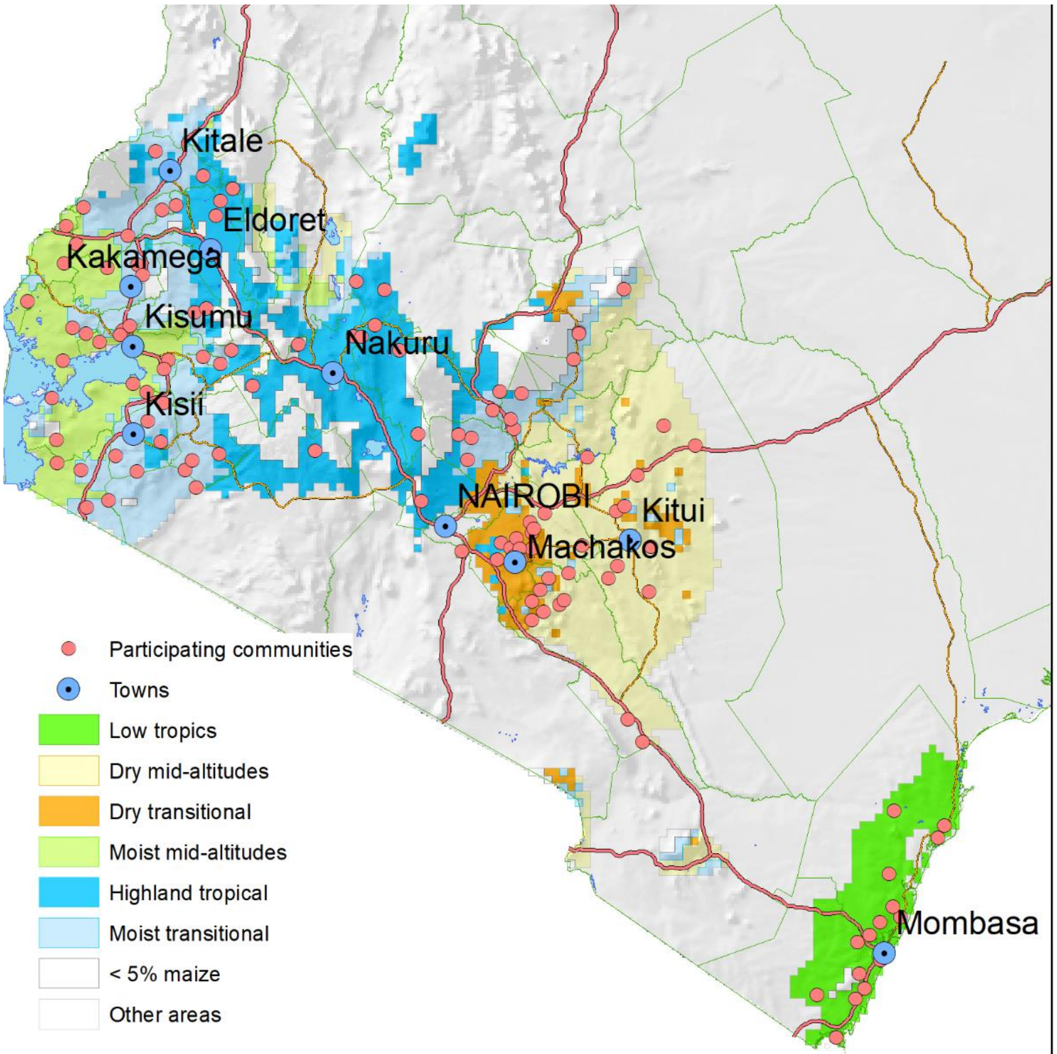

Figure 1. Map with the agroecological zones, the sites of the FGDs and the severity of storage pests

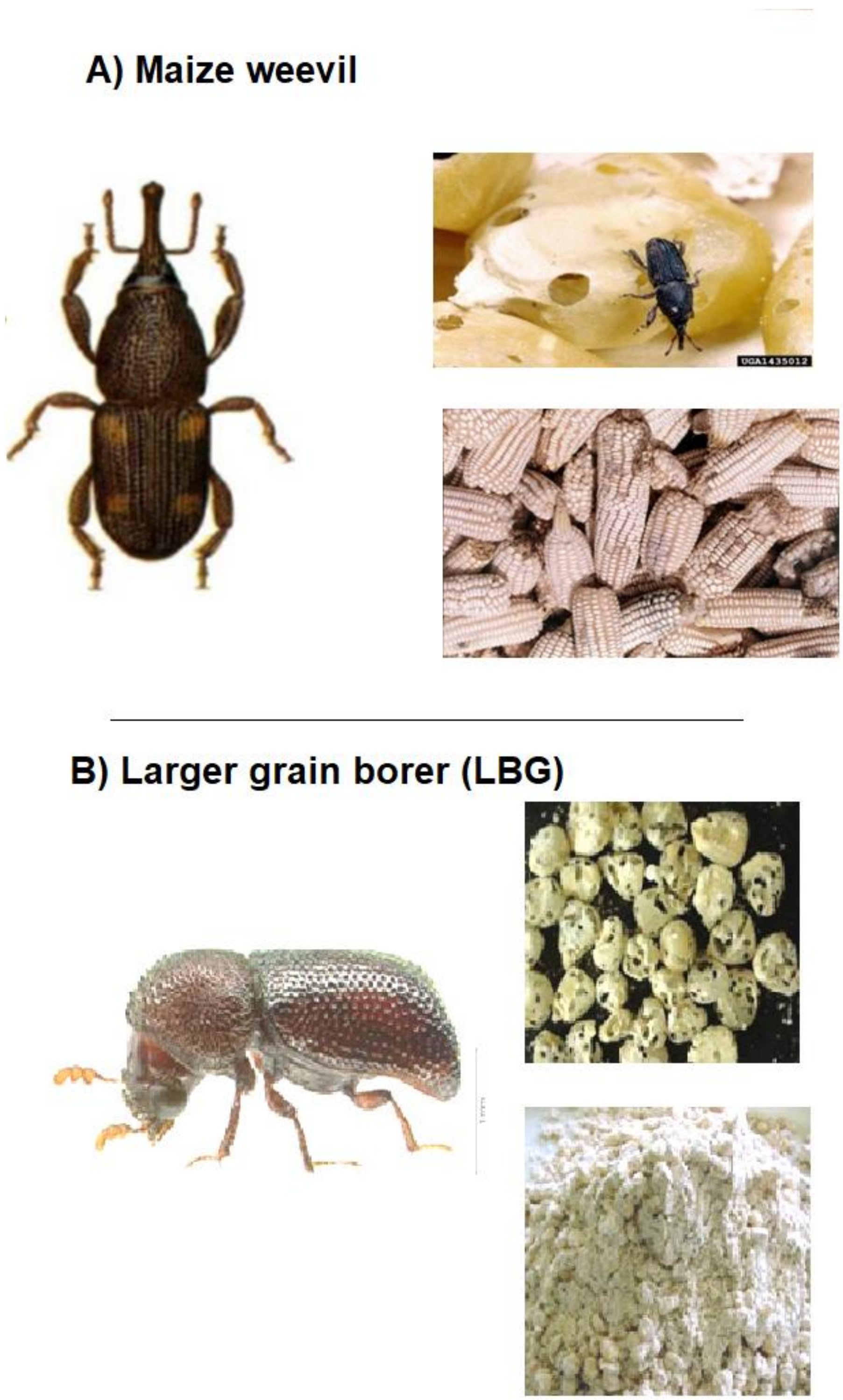

Figure 2. Pictures shown to participants to correctly indentify maize weevil (Panel A) and larger grain borer (Panel B).

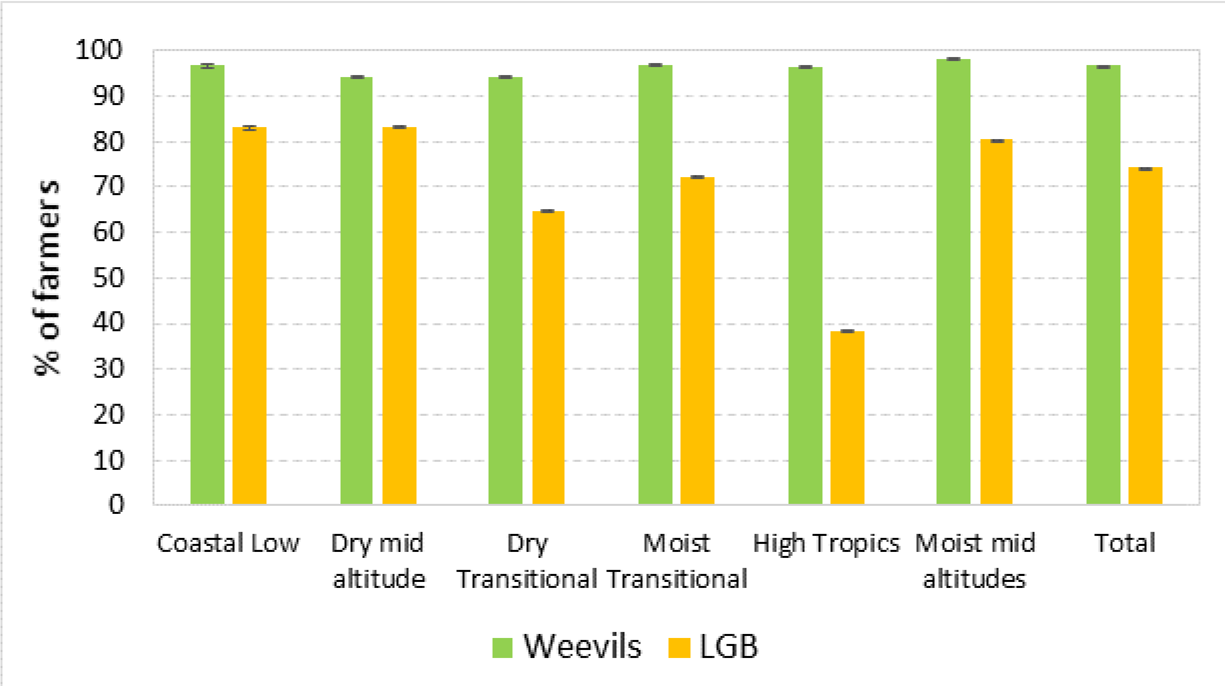

Figure 3. Percentage of farmers who correctly identified maize weevils and LGB

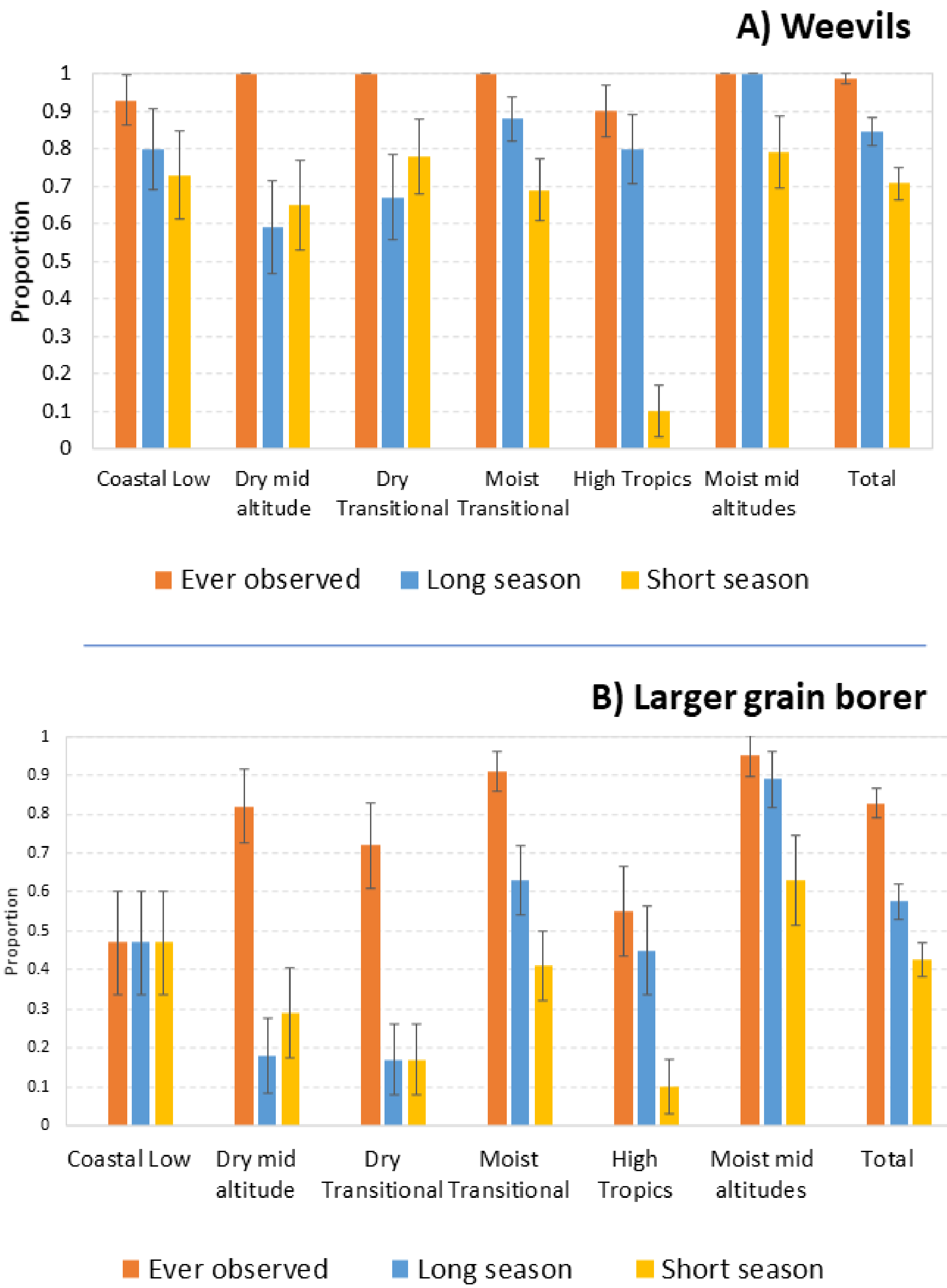

Figure 4. Proportion of farmers who knew maize weevils, percentage of communitis that had observed weevils and LGB.

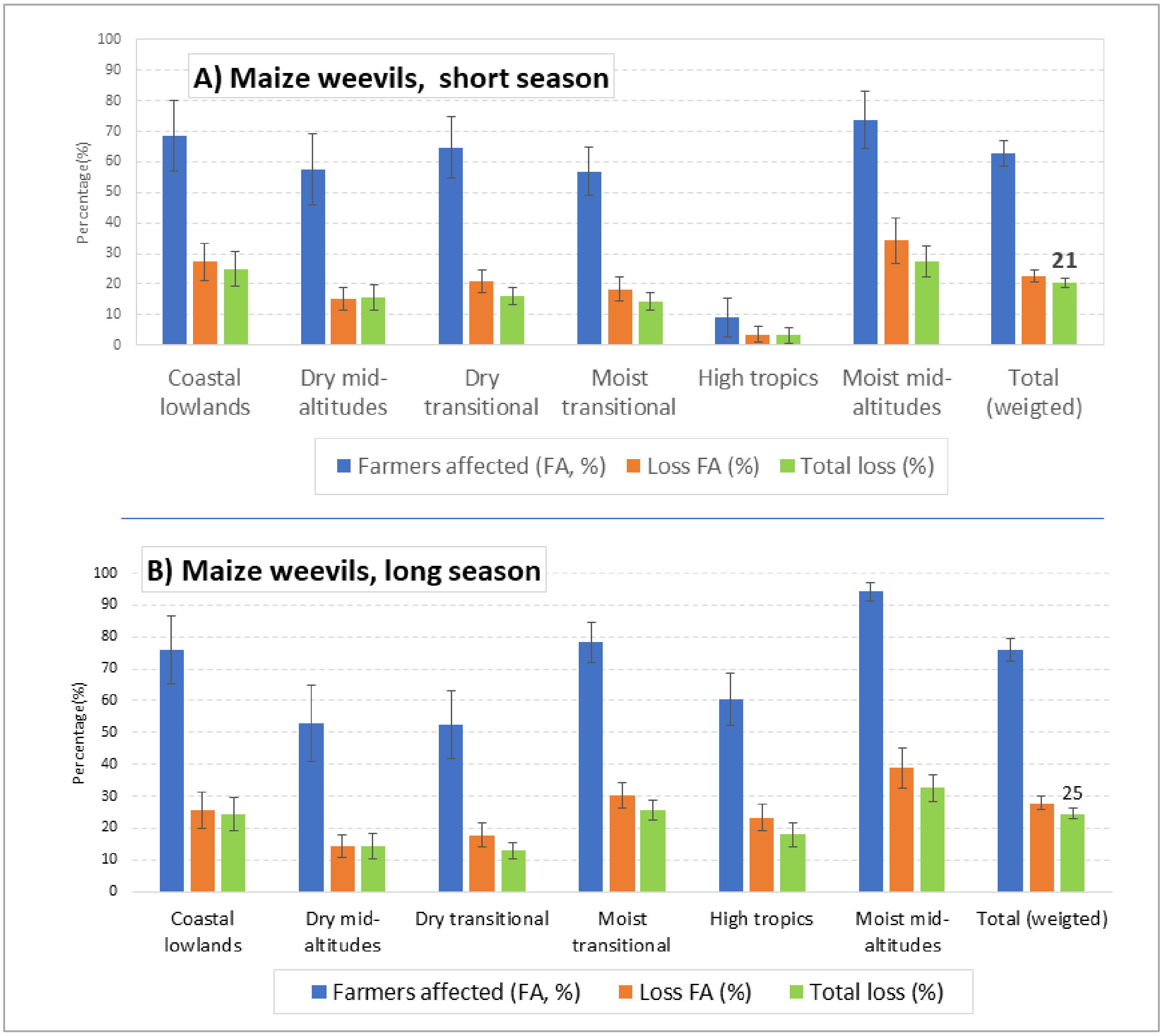

Figure 5. Farmers affected by weevils/storage pests(%), loss on affected farms (%) and Total yield loss from all affected farms.

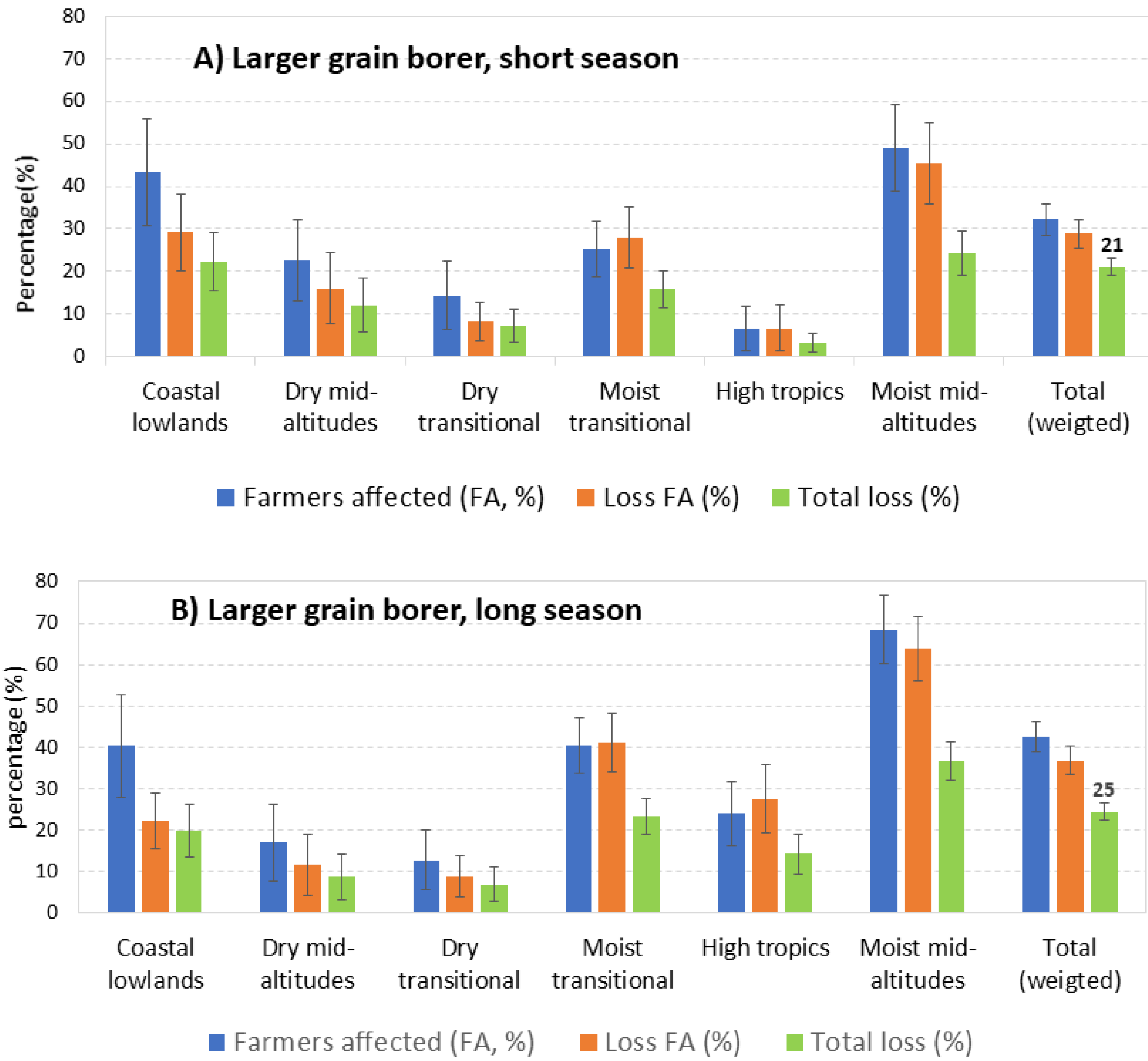

Figure 6. Impact of larger grain borer on stored maize: farmers affected, loss on affected farms (%) and total loss in stored maize, by season and AEZ

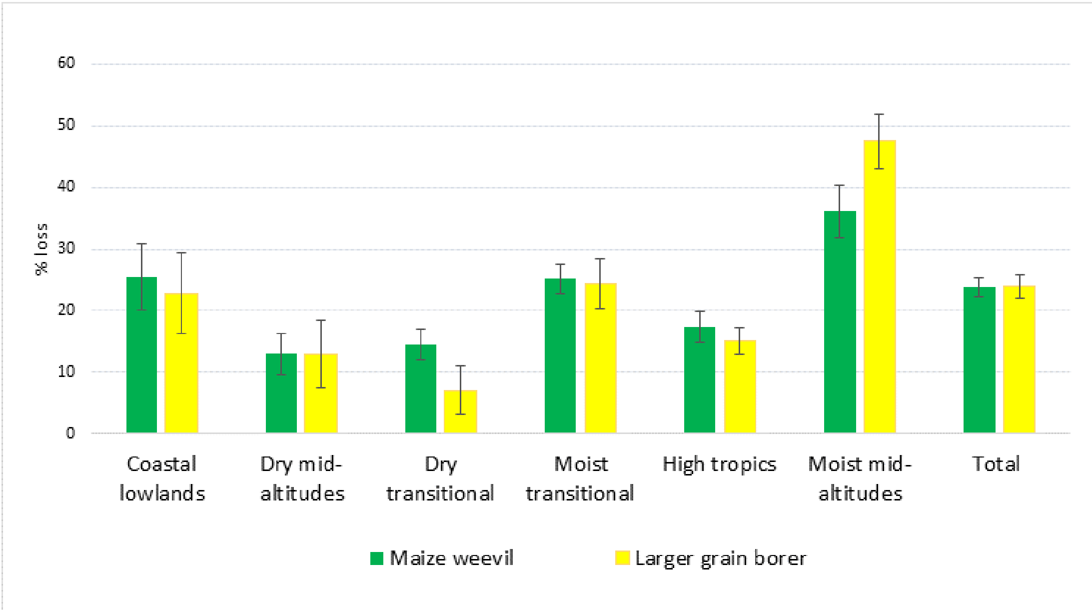

Figure 7. Total annual relative loss in storage, from both weevils and LGB (in %)

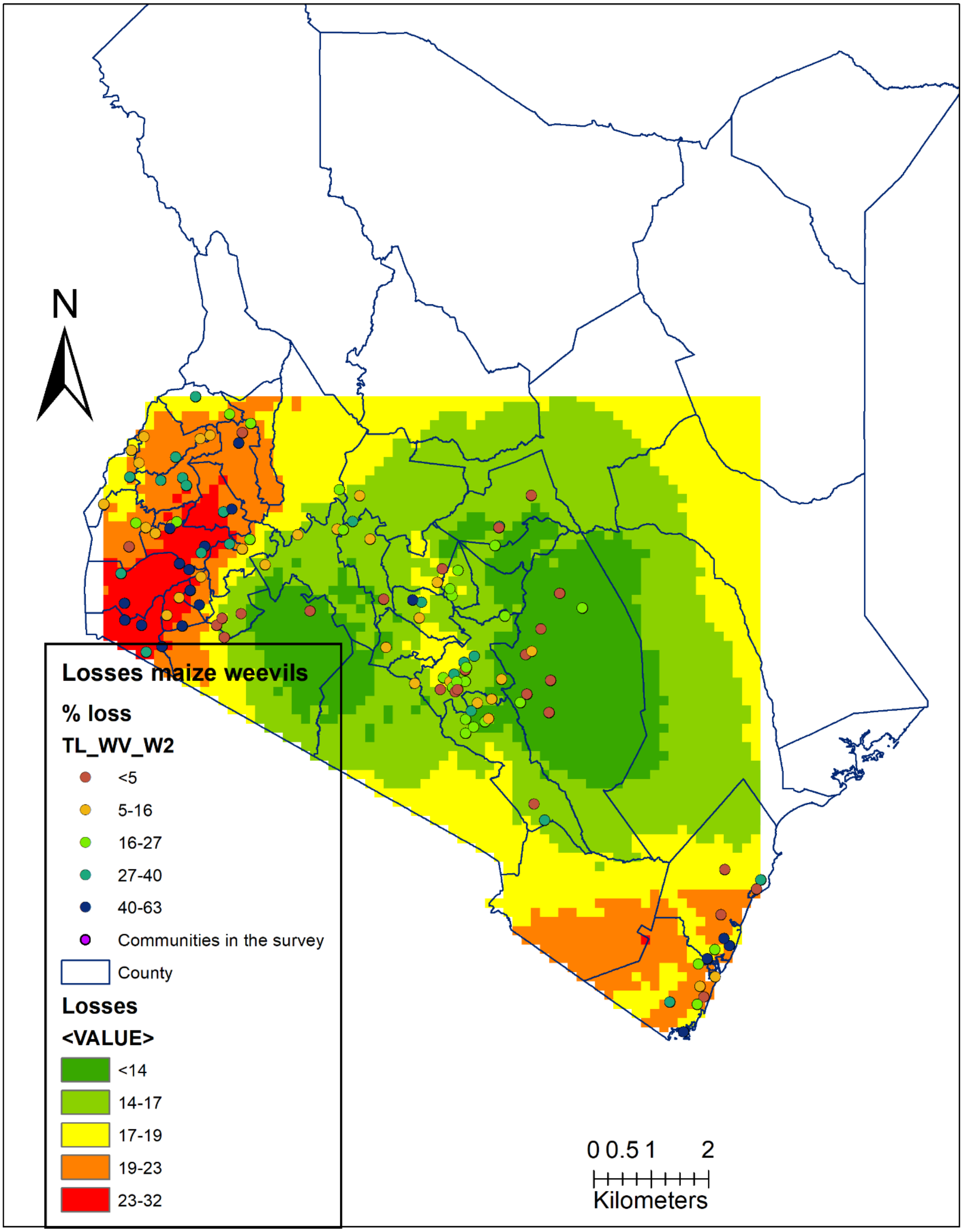

Figure 8: Geographical distribution of maize losses due to weevils in 2017; proportion of farmers affected, % maize loss and quantity of maize lost.

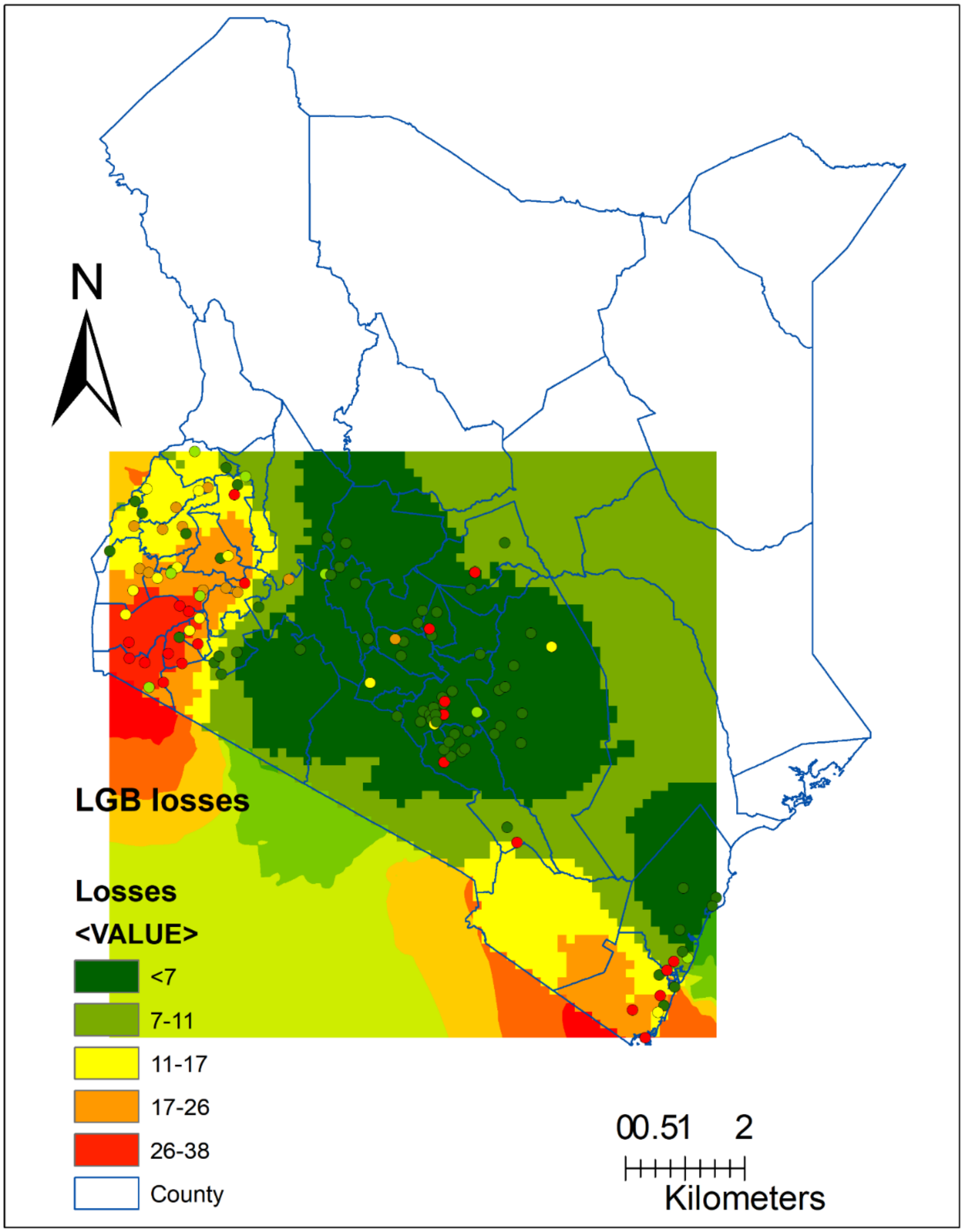

Figure 9. Geographical distribution of relative maize losses due to LGB in 2017

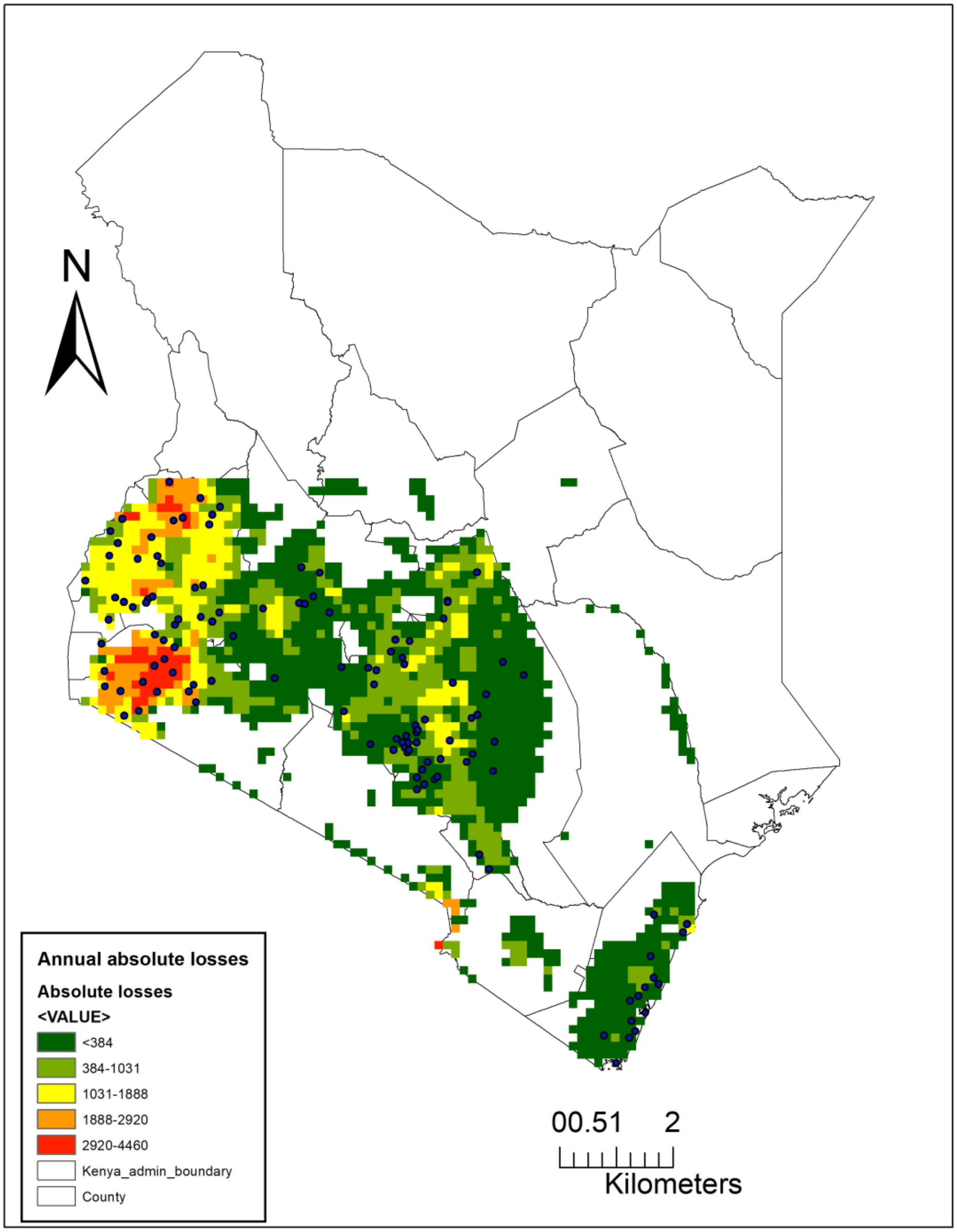

Figure 10. Absolute annual storage losses (weevils and LGB combined), in tonnes per pixel (10 km x 10 km)