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Full Length Research Paper

Descriptive Study of Maize Storage Methods (*Zea Mays*) Used in Rural Environment in Three Zones of Cote D'ivoire

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Descriptive surveys were conducted among 200 farmers in 17 towns and villages of 5 different localities maize production. Fundamental characteristics data such as profile of farmers, cultural practices and harvesting maize, crop varietal, types and conservation methods, causes of post-harvest losses were collected. Survey showed that maize crop was the men activity (77%) and yellow ecotype variety (95.5%) was the most widely grown, followed by the white ecotype representing 3.5% and purple maize grain, local variety of the department of Katiola representing only 1%. About cultivated areas, 63.5% of surveyed farmers grew maize on parcels of less than 1 ha, 22% on plots between 1 and 2 ha, 14% of 2 5 ha and only 0.5% on areas of more than 5 ha. Production yields were lower and vary from 1 ton to 5 ton for 63% to 3% of respondents respectively. Drying was carried out in the course of villages (82%). Maize cobs and maize with husks were dried by 47.5% of the farmers on plastic sheeting, 22.5% on wooden racks (platform 1 m above the ground), 13.5% on the cement floor and 10, 5% on the floor for a period not exceeding two weeks for 75.5% of the farmers. The study also identified 13 different types of storage and list 13 different postharvest processes storage of maize product. These methods vary from one zone to another with a predominance of polypropylene bags (26%), cylindrical clay granaries (17%), storehouse in brick or clay (15.5%), rooms of the house (corner living room or bedroom) (12%) and granaries in bamboo (11.5%). Despite this diversity of storage, all farmers across different zones identified insect infestation (38.8%), rodent (23.5%), fungal (22.3%) and termites (17.4%) attack as the main problems in their stored maize.

Keywords: Maize, Participatory rural survey, storage methods

INTRODUCTION

Maize, *Zea mays* L. (Poaceae), makes a substantial contribution to the diets of rural and urban populations. Its cultivation in the region has gradually increased over the years (FAOSTAT, 2011; Smale et al., 2011) thanks to adoption of better production technologies and improved varieties (Baoua et al., 2014). In Côte d'Ivoire, it is cultivated globally by small-scale farmers and is widely grown across the different ecological zones, ranging from

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the northern savannah to the rain forest belt in the south (Kouakou et al., 2010) with a production of 654.738 tons in 2012/2013 for total planted area of 327.800 ha (N'da et al., 2013). Regarded a long time as a simple product of subsistence, maize is now subject to an agricultural speculation, that intensifies in Cote d'Ivoire, because of large economic stakes that it causes (Johnson et al., 2012; Blassonny, 2013). In fact, maize serves as a major source of food, feed and raw material for agro-allied industries (Deffan et al., 2015).

A recent USAID study (Boone et al., 2008) highlighted the constraints of the maize sector in West Africa, one of which is postharvest storage. Indeed, after harvest, inadequate infrastructure, and lack of economic means, constrains smallholder farmers to store the maize crop either shelled or unshelled using traditional storage structures and procedures (Markham et al., 1994), such as living rooms, cribs, baskets, polypropylene bags, earthen ware and granaries (Ukeh et al., 2012). Crops generally kept in these inadequate conditions and structures are subject to insects, rodents and fungi attack and farmers are often obliged to dispose of a significant proportion of the stored grain due to deterioration (Dejenea et al., 2006).

In general, infestations start at fields and continue throughout the storage period (Johnson et al., 2012). A commonly used method for controlling pests in stored products is the application of synthetic contact insecticides (Nukenine et al., 2013) despite many risks to health of users and consumers and environmental pollution (Regnault-Roger, 2008; Camara, 2009;.Tia, 2012). However methods of storage and conservation exist, they could be improved in order to find an alternative use of pesticides to reduce post-harvest losses. It's in this context that the present study was carried out to make an inventory of maize post-harvest methods and maize storage systems using by farmers.

MATERIAL AND METHODS

Study area

The study was carried out in three maize production zones of Côte d'Ivoire. It's the North, Central and East zones (Table I).

Central and East zones have bimodal climate; two rainy seasons corresponding to maize growing season (March to July and October to November) alternating with two dry seasons (December to February and August to September). The average annual rainfall is respectively 1200 mm and 1300 mm. Maximum temperatures range from 25°C to 31°C for the Center and 24°C to 29°C for the Easter. As for northern zone, it's characterized by a dry season (November to March) and rainy season (April to October) during which rainfall is abundant and frequent from August to September corresponding to the Maize growth season. The average annual rainfall is 1100 mm and maximum temperatures range from 26°C to 35°C (Kouassi et al., 2013; N'da et al., 2013).

Descriptive surveys

A survey by administering questionnaire was carried out over a period of 10 months (February to December 2013), with 200 farmers in different zones (Table I). It was conducted with the helper of the agents of the National Agency for Assistance and Rural Development (ANADER). To this end, a guide questionnaire approaching profile of farmers, farming practices, harvesting, varietal crop, types of storage structures, conservation methods and causes of post harvest losses were subjected to each of the farmers surveyed. Data were collected through individual interviews and/or grouped (structured and unstructured).

Statistical analysis

The collected data were coded, entered using the Sphinx Plus software (version 4.5) and analyzed using the SPSS software (version 20). The main parameters were compared by Chi-square test of Pearson and also using dynamic cross tables. The results were presented in the form of tables made using the Excel software (version 2010). Factorial Analysis of Correspondences (AFC) was also performed using the Statistica software (version 7.1).

RESULTS

Socio-demographic status of farmers surveyed

Table II shows the different characteristics of farmers surveyed. Maize crop is the activity of men (77%) albeit with female participation (23%). The dominant age groups in maize crops are 30 to 40 years (42.5%) and 40-50 years (33%). The level of education is lower for most farmers with a percentage of 71% for illetarate. Regarding years of experience, 28% have an experience under 5 years, 20% 5 to 10 years, 39.5% from 10 to 20 years and 14.5% over 20 years. In addition, eleven ethnic groups were identified. Sénoufo ethnic group with 24% that proved dominant; then come the Burkinabe (with several sub groups) (13.5%), the Baoulé (13%) and Tagbana (12%). Peul and Guéré are the least represented with 1.5% and 0.5% respectively. Other ethnic groups are divided as follows: Agni (9%), Malinké (8.5%), Koulango (8%), Abron (7.5%) and Nafanan (2.5%).

Maize Production

Maize production in Côte d'Ivoire by the surveyed farmers of three zones is depicted in table III. Maize variety the most cultivated was the yellow ecotype grain (95.5%), white ecotype represents 3.5% and the purple maize grain,

Table I: Zones and surveyed villages

Zones surveyed	Villages	Number of farmers
Northern	Sékonkaha	79
	Tchaliga	
	Nangakaha	
	Timbé	
	Ourougbankaha	
Central	Djédou	38
	Pokou-yaokro	
	Abengourou village	
East	Wélékéhi	83
	Motamo	
	Sorobango,	
	Abema	
	Soko	
	Gouméré	
	Agnibilékro	
	Assikasso	
	Tanguélan	
Total		200

Table II: Characteristics of surveyed farmers

Gender	Age	Education level	Experience	Ethnic group
77 % Male	8.5% 20-30 years	71.5% Illiterate	28% 1-5 years	24% Sénoufo
23 % Female	42.5% 30-40 years	23% Primary	20% 5-10 years	13.5% Burkinabé
	33% 40-50 years	5% Secondary	22.5% 10-15 years	13% Baoulé
	14% 50-60 years	0.5% High	15% 15-20 years	12%Tagbana
	2% more than 60 years		14.5% more than 20 years	9% Agni
				8.5% Malinké
				8% Koulango
				7.5% Abron
				2.5% Nafanan
				1.5% Peul
				0.5% Guéré

Table III: Maize production parameters

Type of Seed variety	Produced varieties colors	Acquisition mode of Seed	Reason for seeds choosing	Cultivated areas	Quantities produced	Inputs in maize production
69% Improved	95.5% Yellow ecotype	48% Market Purchase	46.2% Production efficiency	63.5% < 1 ha	65% <1 ton	45.5% Herbicides
31% Traditional or local	3.5% White ecotype	35.5% ANADER	45% Seed availability	22% 1-2 ha	16.5% 1-2 tons	40.5% Fertilizer
	1% Purple of Katiola	9.5% Parents	8.8% Others	7.5% 2-3 ha	9% 2-3 tons	14% No input
		7% Donate		4.5% 3-4 ha	6,5% 3-5 tons	
				2.5% 4-5 ha	3% > 5 tons	
				0.5% > 5 ha		

Table IV: Farmers' responses concerning their maize drying

Drying mode	Drying areas	Drying place	Length of drying
54.5% Cobs	82% Village	47.5% Sheeting Plastic	7% 1-3 days
45.5% Husks	18% Field	22.5% Rack	22.5% 4-7 days
		13.5% Cement floor	27% 7-10 days
		10.5% Floor	19% 10-15 days
		6% Appatam	24.5% > 15 days

local variety of Katiola department represents only 1 %. Improved seeds are preferred by all farmers surveyed (69%). The reasons cited for this choice focus on production performance (46.2%) and seed availability (45%). These seeds are purchased on the market (48%) or obtained from the National Agency for Assistance and Rural Development (ANADER) (35.5%) or with a parent (9.5%) or a donation (7%).

About cultivated areas, 63.5% of respondents grow maize on smaller lands than 1 ha, 22% on lands between 1 and 2 ha, 14% of 2 to 5 ha, and only 0.5% on areas greater than 5 ha. Maize cultivation is carried out according to the cycle of rainy seasons. Thus, in the northern zones, maize is grown once a year while in other regions the culture is carried out 2 times a year. Production yields are weak and vary from 1 ton to 5 ton for 63% to 3% of respondents respectively. Producers use herbicides (45.5%) and fertilizers (40.5%) but they don't follow good agricultural practices for the use of chemical treatments.

Maize drying

Table IV presents the responses of farmers on post-harvest activities. Maize is harvested late, approximately one month after deadline for all producers who also practice a pre-drying. Drying is carried out in the village courtyard (82%). Thus, maize cobs and maize with husks are dried by 47.5% of the farmers on plastic sheeting, 22.5% on wooden racks raised platform (about 1.5-2.0 m above the ground), 13.5% on the cement floor and 10.5% to the floor for a period not exceeding 2 weeks for 75.5% of respondents. A statistical analysis (Pearson chi-square $p = 0.006 < 0.05$) showed a significant relationship between the drying time and the study areas (Table V).

Table V: Distribution of storage type based on surveyed zones

Type of storage	North	Center	East	Total
Cylindrical clay granary	100%	-	-	**17%**
Polypropylene bag	23.8%	27.4%	48.8%	**26%**
Storehouses (brick or clay)	25.8%	22,6%	51.6%	**15.5%**
Granary with shelf in bamboo from forest	-	-	100%	**11.5%**
Parts of the house (living room or bedroom)	40%	40%	20%	**12%**
Kitchen (cluster or shelf above the fireplace)	-	20.8%	79.2%	**5%**
Fences or Paling (hoarding)	32.9%	67.1%	-	**3.5%**
Tree	100%	-	-	**3%**
Huts made of palm leaves	-	50%	50%	**3%**
Post near an outdoor fire place	-	-	100%	**1%**
Smoking granary in clay	-	-	100%	**0.5%**
Raffia basket	-	100%	-	**1%**
Metal barrel	-	100%	-	**1%**
Total	**40%**	**19%**	**41%**	**100%**

Table VI: Relationship between conservation methods and the survey zones

Methods of conservation	North	Center	East	Total
Maize cobs kept in cylindrical clay granary	10.5%	-	-	**10.5%**
Maize husks kept in cylindrical clay granary	6%	-	-	**6%**
Maize kernels kept in polypropylene bag	12.5%	8%	10%	**30.5%**
Maize husks kept as cluster in tree	5%	-	-	**5%**
Maize cobs kept in storehouse (in bricks or clay)	4%	3.5%	6.5%	**14%**
Maize husks kept in fences or paling	2%	1.5%	-	**3.5%**
Maize cobs kept in bamboo granary with shelf	-	-	17%	**17%**
Maize cobs kept in cluster or shelf above the fireplace in kitchen	-	2.5%	4.5%	**7%**
Maize husks kept in smoking granary in clay with shelf	-	-	0.5%	**0.5%**
Maize husks kept in huts made of palm leaves	-	1.5%	1.5%	**3%**
Maize husks kept on a post near an outdoor fire place	-	-	1%	**1%**
Maize cobs kept in raffia basket	-	1%	-	**1%**
Maize kernels kept in metal barrel	-	1%	-	**1%**
Total	**40%**	**19%**	**41%**	**100%**

Table VII: Relationship between maize form and storage type based on surveyed zones

Type of storage	Maize husks	Maize cobs	Maize kernels	Total
Cylindrical clay granary	38.2%	61.8%	-	**17%**
Polypropylene bag	-	15.4%	84.6%	**26%**
Storehouses (brick or clay)	-	83.9%	16.1%	**15.5%**
Granary with shelf in bamboo from forest	-	100%	-	**11.5%**
Parts of the house (living room or bedroom)	-	30%	70%	**12%**
Kitchen (cluster or shelf above the fireplace)	45.2%	50%	4.2%	**5%**
Fences or Paling (hoarding)	100%	-	-	**3.5%**
Tree	100%	-	-	**3%**
Huts made of palm leaves	100%	-	-	**3%**
Post near an outdoor fire place	100%	-	-	**1%**
Smoking granary in clay	100%	-	-	**0.5%**
Raffia basket	-	100%	-	**1%**
Metal barrel	-	-	100%	**1%**
Total	**23%**	**49%**	**28%**	**100%**

Different methods of maize storage

Thirteen types of storage corresponding to thirteen different methods of maize conservation were surveyed (Tables VI and VII). These structures are different from one zone to another with a predominance of 6 types of storage which are polypropylene bags (26%), cylindrical clay granaries (17%), storehouse in brick or clay (15.5%), parts of the house (corner living room or bedroom) (12%) and bamboo granaries with shelf (11.5%). Maize is retained in these structures as cobs (49%), grain (28%) and husks (23%). Table VIII shows the relationship between the form of corn and types of storage.

Statistical analysis on the one hand, to the type of storage and study areas (Pearson chi-square $p = 0.000 < 0.05$; $V = 0.762$ Cramer) and, secondly, to methods conservation and study areas (Pearson chi-square $p = 0.000 < 0.05$, Cramer $V = 0.694$) showed a significant relationship. It reveals specificity between types of storage and conservation methods depending on the zone. Thus, in the northern zone, six types of storage were identified. The most frequently used are the cylindrical clay granaries, in which maize cobs and maize with husks are stored. These granaries are isolated from soil moisture by an underbody consists of large balls of dried mud or pebbles. The use of trees whose branches serve as supports for hanging maize with husks cluster was also identified (Figure 1E).

In the central zone, it was identified eight types of storage structures with a predominance to polypropylene bags that store the maize cobs and maize kernels then stored in storehouses (brick or clay) or parts of the house (Figure. 1B). The use of fences (Figure. 1F) and huts made of palm leaves for maize with husks stored was noted.

The survey also revealed the existence of marginal types of storage in this area. It's about maize kernels storage in metal barrel (1%) and cobs in raffia baskets (1%).

In the East, eight types of storage have also been identified. Farmers surveyed of this area store maize in granaries with a shelf made in bamboo from forest (Figure. 1D). They also store their maize crops in polypropylene bags or in storehouses (Figure. 1A). Other farmers interviewed say that they use parts of the house or the kitchen above the fireplace in the form of cluster or raised platform (Figure. 1C). Some farmers surveyed say that they use huts made of palm leaves. The existence of wooden pole near an outdoor fireplace (1%) and fumigate granary clay with shelf inside (0.5%) for maize with husks conservation was also reported.

Tableau VIII: Farmers' responses concerning the length of their storage periods

Length of storage	North	Center	East	Total
1-2 months	6.7%	73.3%	20%	**42%**
2-4 months	22.2%	11.8%	66%	**36.5%**
4-6 months	58.4%	9.1%	32.5%	**15.5%**
> 6 months	79.7%	-	20.3%	**6%**
Total	**40%**	**19%**	**41%**	**100%**

Figure 1: Different storages facilities in the zones surveyed
(A) maize cobs on cement floor in a storehouse of brick; (B) maize kernels and cobs stored in an accommodation chamber; (C) maize cobs kept on wooden shelf above a kitchen hearth; (D) maize cobs kept in a granary with a shelf made in bamboo from forest (E) maize with husks suspended as cluster on tree; (F) maize with husks attached to a wooden fence post

Length of storage

Table IX presents the results of the maize storage periods in the different zones. The crossing of the statistical parameters storage time and study areas showed a significant relationship (Pearson chi-square p = 0.000 <0.05) but weak (V Cramer = 0.404).

Thus, farmers of the Northern zone say storing maize during 6 months (79.7%) with synthetic pesticides. Farmers surveyed in East zone (66%) store maize over a period of 2 to 4 months and farmers interviewed in the Central zone (73.3%) indicated that their maize stocks do not exceed more than 2 months.

Tableau IIX: Maize storage problems in the surveyed zones

Storage problems	North	Center	East	Total
Insects	39.2%	19.2%	41.4%	**36.8%**
Rodents	25.2%	24.5%	53.9%	**23.5%**
Fungi	32.2%	21.9%	45.9%	**22.3%**
Termites	26.4%	20.9%	52.8%	**17.4%**
Total	**40%**	**19%**	**41%**	**100%**

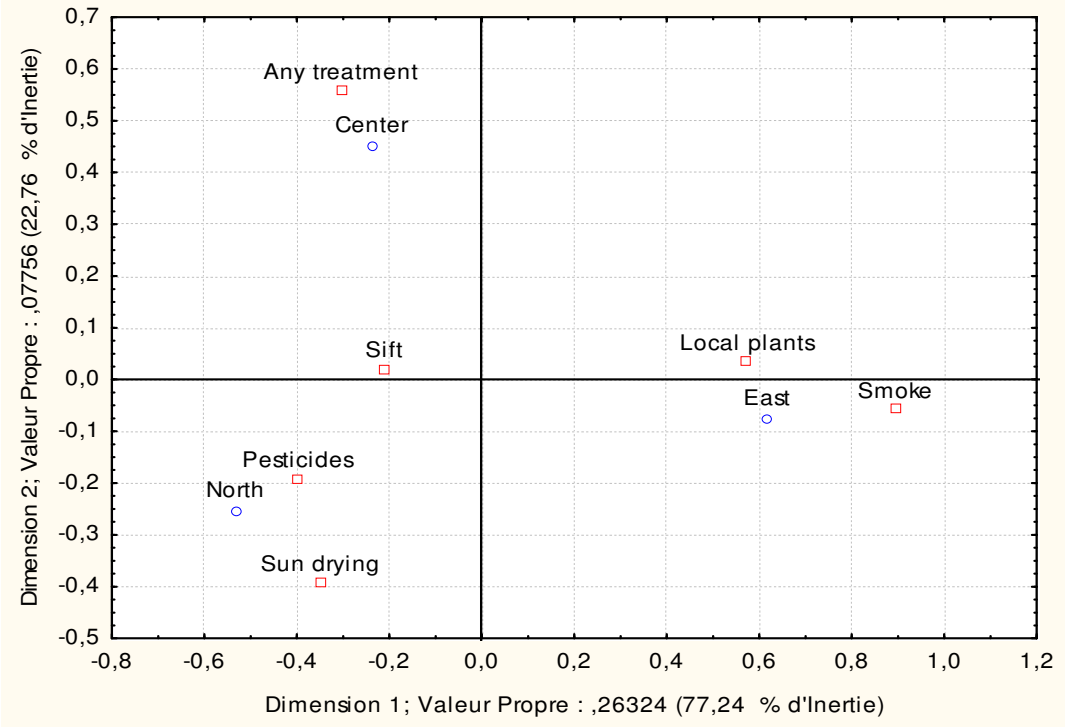

Figure 2: Relations between storage treatment and surveyed zones

Storage problems and treatment

The frequency of main storage problems mentioned is summarized in Table X. Farmers focus mainly on pests such as insects (38.8%), rodents (23.5%), mold (22.3%) and termites (17.4%) that destroy stocks. Eighty-two percent (82%) of surveyed farmers say record losses during storage. Therefore, a factorial correspondence analysis (Figure 2) was performed to show the relationship between the different treatments applied against pests by the farmers. The factorial trained two axes that define two treatment groups of stocks. Group 1 consists of farmers in eastern zone and Group 2 consists of farmers in the central and northern zones. Thus, in the East zone, farmers use household smoke to fight against pests. Maize is usually suspended or store on a raised platform on the top of the households where it is regularly smoked out during the culinary activities. In addition, farmers use local plants with insecticidal properties. The leaves or barks of these plants in the case of the latter storage practice is mixed with maize crops and stored.

In the Northern zone, farmers interviewed say using synthetic pesticides to protect their maize crops. The most pesticides commonly mentioned are the K-Othrine with active molecule of deltamethrin, the Percal with active molecule of permethrin; and the pesticides commonly used against cotton plants pests. Farmers also say using the sun drying as well as the sifting to stored maize.

In the center, the farmers surveyed said that they use any treatment to address storage issues. They prefer to sell their stocks before completely destroyed by pests.

DISCUSSION

This survey covering three agro-ecological zones of Côte d'Ivoire helped highlight maize storage methods of farmers about the conservation of their harvest.

Improved variety of yellow maize grain purchased on the market is the most cultivated by all the surveyed farmers in the entire zone. Similar observations were made by N'da et al (2013) in the area of the north-central zone of Côte d'Ivoire. These authors showed that local maize varieties were abandoned in favor of improved varieties because of their weak productivity and susceptibility to drought.

Results of survey reveal that the majority of farmers leave maize dry up for several weeks in their field before bringing them back to the village, allowing pre-drying or drying in part of kernels. This step favors infestation of maize insect causing huge losses (Foua-Bi, 1982).

Thirteen types of storage and conservation methods were identified during the survey with a predominance of polypropylene bags for maize kernels storage in different zones. The result obtained is consistent with the findings of Udoh et al. (2000) in Nigeria and Kankologo et al. (2009) in Zambia who reported that the bags were less expensive, easy to handle and could contain a large amount of grain for storage and sale in local markets.

The investigation also revealed the use of structures of storage and methods of conservation which different according to zones. However, there are some differences in the types of storage and preservation methods among surveyed zones. The different storage structures encountered could be explained by the availability of local building materials, expertise and especially the financial resources and control used against pests stocks by the farmers (Gueye et al, 2012; Waongo et al. 2013).

The storage of maize is an important step in preserving food security and increasing rural incomes. Maize is not only cultivated for food for the family to switch without too many problems in the lean season, but also to increase incomes. The farmers interviewed recognized the difficulties of preserving maize after harvest. In fact, different types of storage encountered are mostly rudimentary. Farmers often assist powerless to the degradation of their stocks by pests. They didn't have information or effective means to cope losses (Mikolo et al., 2007). Indeed, Gueye et al. (2012) found that the basic principles such as maize drying, deposit on shelf and aeration of storage premises were often not respected.

Maize is preserved in its various forms (cobs, kernels and husks). In the opinion of the surveyed farmers, conservation in cobs (49%) is the most way used among all farmers; this result can be explained by the fact that cobs allow better conservation. Similar observations were made by Gueye et al. (2012) in eastern and southern Senegal who reported that most producers believe the maize cobs offers some protection against the grain attacks insects.

Concerning storage problems, investigation indicates that maize is attacked by insects, rodents, mold and termites. However, insects are perceived by farmers as the main causes of the losses. Johnson et al. (2012) identified the major insect pests of maize in Côte d'Ivoire that are: *Sitophilus zeamais* or maize weevil, *Tribolium castaneum*, *Rhizopertha dominican* and *Catharthus dimidiatus*. The damage they cause includes weight loss and decrease of market and nutritious qualities of maize grains and sometimes loss of germination (Waongo et al., 2013). The proliferation of these insects inside stocks creates a favorable environment for the development of micro-organisms that produce mycotoxins like the *Aspergillus*, *Penicillium* and *Fusarium* (Cardwell et al., 2000; Hell et al, 2000; Fandohan et al, 2005; Amadi et al, 2009; Kankologo et al, 2009).

Method for controlling pests in stored products differs among zones. The use of chemical pesticides is cited by farmers in the northern zones. This observation was made by Albert (1992) who showed that the use of chemical insecticides is the cause of the decline, in large part of traditionally methods, non-chemical crop protection used by farmers.

CONCLUSION

This study carried out in northern, Central and East Zones of Côte d'Ivoire allowed an inventory of thirteen types of storage and thirteen methods of maize conservation. The survey showed that the storage structures differ from one zone to another and depend on available materials. Despite this diversity of storage facilities, all farmers surveyed are confronted with the same problems of conservation of stocks which are attacked by pests such as insects, fungi and rodents. This work, far from being exhaustive, should be a starting point of sensitizing program on good practices of storage among stakeholders of maize sector in Côte d'Ivoire.

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