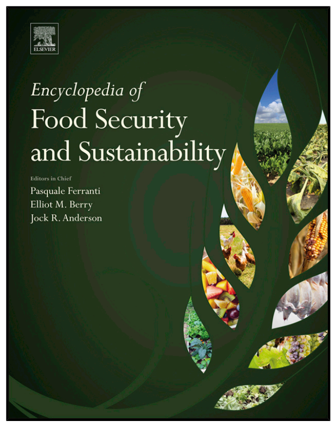

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Food Storage as a Source of Stress for Seed Farmers in the Tropics

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Abstract

Crop storage is essential for seed smallholder farmers in the tropics and for maintaining the genetic diversity of crop materials cultivated worldwide. In latitudes with contrasted seasonal fluctuations and increasing extreme climatic episodes, controlling food stock is critical to renew seed production for upcoming plantings and to tackle inter-annual fluctuations of resources and to overcome hard times in food supply by disposing of quantitatively sufficient and qualitatively acceptable food reserves. Many factors of diverse origins interact and converge to make the storage life of food reserves very challenging to farmers. Despite the mobilization of elaborated indigenous knowledge and know-how and complex stratified sociopolitical frameworks aiming to reinforce the control and conservation of their crop production, seed farmers have to cope with a recurrent stress caused by the instability of food storage, that comes in addition to overall stressful conditions, which are inherent to increasingly capricious environmental and climatic hazards.

Introduction

The conservation of seeds (mainly cereals, grain legumes and oleo-proteaginous nuts) through storage has been a recurrent research concern over the past 60 years. It is of prior interest for archaeologists, especially since the pioneer works of Reynolds (1974), as a means to better understand the sedentarism transition that marked the shift from nomadic hunting and gathering to a sedentary farming lifestyles during the Neolithic age. It is also a fascinating research topic in cultural technology and anthropology to analyze the diverse socio-political frameworks that underpin production activities among farming societies (Sigaut, 1989). In times of worldwide food insecurity increased by acute food price crises and recurrent environmental hazards and disasters, the issue of food storage has entered the political and sustainable development preoccupations with the raising need for sharper thinking about seed security strategy in itself but also about its causal links with seed security (McGuire and Sperling, 2011). Seed security initiatives are proliferating in both developmental and crisis contexts as means to meet humanitarian needs in response to intensified natural disasters induced by global and climatic change (Byrne et al., 2013).

Storage is known to operate at many intertwined facets of the functioning of pre-industrial societies and it is a daily concern for the great majority of rural seed producers throughout the intertropical zone. Crop storage addresses seasonal activities as well as attempts to reduce inter-annual fluctuations of resources. Development agencies now concur to strategically invest in better seed storage that would help farmers preventatively save their seeds (Goletti, 2003). Particularly with vulnerable farmers and in high stress regions, better seed storage options may mitigate the need for emergency assistance when situational crises occur, for example, when drought or flood or other stresses require multiple sowings. Maintaining the capacity of local farmers in storing their own seed production has several advantages: cash outlays are reduced, seed is available on time and just nearby, and varieties and management requirements are familiar to them (Walsh et al., 2014). But ensuring that this storage is conducted in optimal conditions, especially when it addresses long-term food reserve, is per se a considerable matter of stress: Rural farmers of the tropics persistently struggle to reduce their storage losses, which routinely represents one fifth of their production (Meikle et al., 2002).

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What Is at Stake

Seed is a fragile living organism that is the foundation for the production of cereals and grain legumes that underpins farm family food security and income of a majority of smallholder farmers around the world. Since the early ages of agriculture adoption, humans have continually improved methods of storing their crop production for future use. As agriculture developed, cultivators expanded their knowledge regarding both the requirements of seed for maintenance of viability as well as ways of providing suitable storage conditions for their staple food grains. Through an incredible variation of cropping systems, tropical seed farmers currently produce, manage and select at least 80% of the worldwide existing seeds of both local and improved varieties. Their central role in maintaining a diverse genetic pool for these crops is widely recognized. After the mid-1970s food crisis, research and development practitioners gave considerable attention to the storage conditions that constitutes the Achilles heel of smallholders cropping systems, especially in situations of climatic hazards and food shortage (Greeley, 1982).

The capacity of storing their own seeds is essential for tropical smallholder seed producers. Using seed from their own stores means that farmers 1) can sow varieties that they know best and that correspond to their needs and preferences; 2) can access seeds without having to lay out cash; and 3) have their stored seed always available on time and just nearby. To achieve these goals, seed producers have to deal with a double preventive and curative preoccupation: 1) maintaining quality seeds for upcoming plantings by controlling attacks by insects and pests and maintaining seed ability to germination; 2) safeguarding grains in sufficient quantity to avoid recourse to emergency assistance from outside, when climate condition and seasonal hazards are not favorable.

Storage: A Persisting Critical Step for Seed Producers

In the tropics, regulating their food production and mastering storage conditions are chronic obsessive preoccupation of pre-industrial smallholder seed farmers. Estimates from The World Bank (2011) suggest that as much as 37% of food produced in Sub-Saharan Africa is lost between production and consumption, and 13.5% of the total production in cereals (mays, millet, sorghum) are lost during post-harvesting storage. Along with leguminous plants (cowpeas, beans, peanuts), these cereals are the pillars of the food self-sufficiency policies of these countries. Yearly post-harvesting losses may approximate US$ 4 billion dollars for smallholder farmer local economy. Throughout the African continent, 25%–30% of crop losses are imputable to insect pests during storage (Gueye et al., 2011). Grain losses during storage are not only quantitative; they can adopt different qualitative forms, for example a change in color (e.g., the yellowing of rice), an alteration of smell or taste, a loss of nutritional value (protein or vitamin degradation) a loss of germination capacity of seeds, a loss of quality in the culinary preparation of dishes, and contamination of food by mycotoxins or pathogens. Combined quantitative and qualitative losses impact local market economy, downgrade the market value of local crop production, and impair smallholder farmer food security. They can also worsen the national economy by inducing costly importations of foodstuffs.

Hortus Versus *Ager* Farming Systems: Those Who Store Food Reserves, Those Who Don't

Farmers in the tropics can be roughly subdivided into two major categories. The first category is composed of horticulturalists whose agriculture predominantly consists in the manipulation of perennial plants that reproduce clonally. The majority of these crops are starches that propagate vegetatively. Their cultivation is based on an individualized planting of tubers, corms, suckers, stems and cuttings. In such a system, standing food crops are left in the soil and will be progressively uprooted according to the farmer's need. Horticulturalist systems are primarily located in humid forestlands and require only, if any, short-term storage of harvested food crops prior to their consumption (Dounias et al., 2001).

The second farming system category is based on the cultivation line seeds, predominantly cereals and grain legumes, that are obtained via generative propagation. Seeds are spread or sown in bunches, and those belonging to the same line will grow, develop, fruit and reach final maturation all at the same time. Such synchronized maturity induces an ad hoc unique harvesting of the whole, because these crops cannot be left standing in the soil. Such imposed harvesting over a short period of time implies for seed producers to store their grain production and to progressively stagger consumption (Dounias et al., 2001). This type of farming system predominates in less forested lands and drier ecosystems (savannah, steppes, mountains, sub-arid to arid zones). By contrast to the moderate seasonal fluctuation of humid forestlands climate offering a continuous supply of food resources, the climate outside forests is marked by contrasted seasons and a cyclic succession of abundant versus scarce periods of food availability (Dounias and Ichikawa, 2017). Severe cyclic food shortages can provoke immediate and acute nutritional deficiencies. They incur uncertainty in food supply, a pervasive sentiment of insecurity, and underhanded stress.

Why Plant Domestication Has Made Food Storage so Problematic

The need to store seeds for further cultivation and grains as food reserves is inherent to the adoption of agriculture. But concomitantly, the difficulties to manage seed storage with minimal losses is also inherent to the fact that stored seeds are obtained from domesticated plants. Adoption by early farming societies of a more sedentary lifestyle has considerably enlarged the range of plant species used as food by humans and has been accompanied by constantly enriched food preparation and detoxification technologies.

Wild plants have been interacting with herbivores, especially insects, for several hundred million years. These interactions have led to complex defense approaches against various insect feeding strategies. Insect herbivory induces several internal signals in plants, which respond by producing defense compounds destined to repel or intoxicate insects, and defense proteins that will interfere with their digestion (Beier and Nigg, 1994). Plants also apply morphological features like waxes, trichomes and latices to make the feeding more difficult for the insects (Fürstenberg-Hägg et al., 2014).

Among other effects, plant domestication has caused a reduction of thermostable compounds, like the raphides among Araceae or the heat-denaturable toxic or digestibility reducing proteins among grain legumes (Fraenkel, 1959). Along with the improvement of their agricultural practices and skills, agriculturalist societies were obliged to compose with more complex trade-offs and to find their way between the advantages of plant domestication — increased digestibility of these plants by elimination of the thermostable phytochemicals that they massively secreted in the wild — and their disadvantages — increased sensitivity of crops to drastic environmental conditions and pests attacks, and increased risks by human consumers of contracting foodborne diseases (Todd, 1994). Seed losses due to insects during storage are a direct consequence of the long evolutionary domestication processes that led to reducing plant chemical defenses against herbivory (Johns, 1990).

Diverse Reasons for Storing Seeds

Smallholder seed farmers separately store 1) seed stocks to be planted during the next agricultural season or that will circulate through seed exchange networks (Coomes et al., 2015), and 2) grains that constitute their food reserve. Stocking staple food grain is necessary to overcome erratic times of starvation, but also to take advantage of bumper harvests.

Storage for Seeds

Storing seeds of food plants to preserve planting stocks from one season until the next generally occurs during a short-term storage. Seeds are placed in specific containers that are easily accessible and they are kept in the most smoke-filled part of the homestead. Smoke and ash are efficient short-term parades against termites, weevils, lepidoptera larvae, aphids and caterpillars. Filtered ash is an efficient mechanical barrier against seed foraging and also creates an ambient micro-climate that stabilizes seed germination properties. Protection is generally completed by odoriferous plants that emit volatile and insect-repellent chemical compounds, as well as traps, amulets and other magic protections against rodents and theft (Seignobos, 2005). It is common to observe plants with tapered spines or hooks, corrosive or irritating exudates or urticating hairs, as well as toxic geophytes which are vested with symbolic aggressive values. Sometimes, granaries are associated with coop so that chickens can regulate the proliferation of termites and smallest rodents. In Northern Cameroon, an unusual interspecific collaboration is encouraged through the presence of Gabonese vipers that the farmer will let nesting under the small granaries, baskets and potteries in which seeds are stored. The snake will feed on domestic rodents, and its presence is tolerated for the protection it provides against various kinds of unwished guests. The well-controlled stocking of seeds is rarely a source of stress for the farmers.

Storage for Food Reserve

By contrast to storage for seeds, stocking grains as food reserves is intended to last longer and is a much more serious cause of stress.

Nevertheless, short term food reserves are needed to satisfy consumption immediately after harvesting. These reserves are essentially composed of crop productions that cannot tolerate long-term storage. This mainly includes short-cycle plant varieties which are harvested very early during the cropping rotation. Their grains are generally softer, with a high-water or high-sugar contents that make them non-eligible for long storage. Short cycle crops are most of the time cultivated in gardens adjoining the housing units. Grains that did not dry properly or that were not sufficiently winnowed are considered 'dirt' production with poor market value. They rarely leave the domestic circle and are to be consumed by the household, when not given to livestock.

If short-term storage of lower valued production does not seem to cause stress, medium to long-term storage of food reserves appears more challenging. Pests and environmental conditions outside of the container are relatively under control. Granaries are often raised off the floor on standing stones that favor air circulation underneath and avoid capillary rise of soil humidity. Many of the protections mentioned above for short-term seed storage can also be applied outside of the containers for longer-term food reserves.

By contrast, handling what is happening inside the container is more problematic, because many non-mutually exclusive factors of diverse origins may interact and considerably affect the storage life of food reserves (Justice and Bass, 1978):

- Pre-harvest factors: provenance of seeds, weather during establishment, growth, development, fruiting and maturation of crops;
- Post-harvest factors: principles of grain threshing and separating, winnowing, drying (natural, sun, artificial). Stocking maize cob and unthreshed millet or sorghum rather than just grain significantly increases store losses (Haile, 2006).
- The vigor of the seed population with regard to its structure, composition and genetic heterogeneity — variation among species and among cultivars. The mixing in a single storage container of crop material of diverse genetic origins will induce heterogeneous aptitudes and tolerances to storage conditions;

- The specific properties of the individual seed according to its maturity, size, dormancy (dissipation of dormancy, lifespan), moisture content, and superficial mechanical damages during pre-storage phases;
- Effects of storage environment itself on seed longevity: absolute temperature and its diurnal or seasonal fluctuation; relative humidity; moisture absorption and movement; desiccation and its impact on viability and vigor; vacuum versus respiration and gas circulation inside the container; illumination; storage fungi, bacteria, insects.

Controlling these factors one by one is truly a challenge for farmers. Assessing the synergies between these concomitant factors is nearly impossible.

The stability of the storage environment also depends on the frequency of container openings that is driven by a multitude of situational factors: level of crop yield, volume of short-term and middle term reserves, fluctuating number of consumers within the housing unit, in relation to social mobility, alteration of the household economy, social events like marriage or funerals, assistance to relatives, accidents and other force majeure… Once a container has been opened, its content becomes excessively vulnerable and must be consumed in priority. Controlling ventilation of an underway food reserve requires constant attention and readjusted decisions. The need to alternate openings and closings of the container according to daily weather fluctuations and night-and-day successions eventually turns into an uncertain tightrope walking performance.

Local Knowledge for Mitigating Food Reserve Losses During Storage

In the tropics, an incredible diversity of medicinal plants and plant parts are mobilized by seed farmers with questionable success for stock protection inside the container (Dales, 1996). Whole dried products or preliminary transformed plant materials (powder, ash, oil extract…) are used as desiccant or varnish to line the interior walls of the storage container and to prevent damages from pests. However, contact between food reserves and these medicines may change the smell or taste of the food, or require long soaking of the stored grains prior to their consumption. Rare cases are reported of hermetic enclosure of cereal seeds in an aqueous environment, creating a confined atmosphere rich in carbon dioxide that will kill pathogens and prevent from fermentation for 5–10 years. However, seed farmers have to cope with the absence of proof that their mud silos are truly hermetic, until comes the time to unseal them.

Some protective strategies evoke integrated-biological control methods: for instance, some mountain peoples of Northern Cameroon intentionally encourage the development of the caterpillars of *Corcyra* and *Sitotogra* butterflies inside their containers. Silk produced by the caterpillars is intended to act as a felting that aggregate the seeds until forming a compact operculum that mitigates the penetration of pests.

Food Storage and Stratified Societies

The size, form, location and ownership of seed containers (silos, granaries, attics) depend on kinship, patrimonial/matrimonial rules and other socio-political features that are specific of each ethnic group. By contrast to the near absence of authority in the socio-political systems of tropical forestland horticulturalists, societies whose economy and subsistence depend on the storage of long-term food reserves are predominantly stratified and organized in chiefdoms. Such hierarchized political frameworks, generally combined with a strong gender differentiation, codify the access to food reserve vessels (FAO, 2018).

In Sub-Saharan Africa, there exist a great diversity of chiefdom systems, with chiefs intervening at various levels of the socio-political hierarchy. Chiefs are recognized as masters of crops, masters of the agricultural calendar, and masters of time. They give orders and take decisions that will determine a collective response from the subordinated group. Deciding of the opening of food reserve granaries following a given succession — women granaries are generally opened at first — is probably the most revealing expression of a chief authority (Vincent, 1982). The granaries of a chief will generally be opened only as a last resort, mainly in times of drastic food shortage. Therefore, political power is based on the control of long-term stored food reserves.

In complement of this control by the chief, and in order to compensate the uncertainty affecting their storage conditions, long-term food reserves are embedded with spiritual values and are left under the control of ancestors and supra-natural forces. In Sub-Saharan Africa, granaries hosting multi-annual stored food often officiate as sacrificial altars (Seignobos, 2005).

In bygone times of wars intended to territorial expansion, destroying the food reserves of the enemies has always been a strategic target of the aggressor, and an efficient means to force allegiance from the defeated camp. Local strategies to compensate raiding expeditions included hiding storage underground. However, controlling environment in such hidden granaries was hazardous. More effective defenses consisted in maintaining parklands of planted and fire-resistant trees providing edible fruits and leaves, and para-domesticating wild food resources, especially geophytes, near settlements (Seignobos, 1989).

Recent Trends in Seed Storage

In the early 1990s, the introduction of polypropylene sacks has radically changed cereal storage among smallholder seed producers (Friendship and Compton, 1991). Following the banalization of cemented soils, polypropylene sacks made it possible to store the cereals inside housing units. Compared to jute sacks that provide satisfying ventilation, polypropylene sacks are more efficient against grain borer infestation, and are cheap, solid, convenient for transport and always ready for marketing.

Over the past 4 decades, pesticides, popularized by agro-industrial companies, are more and more in demand by local farmers who use them to treat the bottom and walls of the granaries. Farmers confessed the relative efficacy of their traditional insect repellent plants and they rallied massively the adoption of industrial insecticides. Since the turn of the millennium, food storage in tropical rural areas has been receiving increased attention by development agencies and NGOs that have strongly pushed for an accelerated access to these chemical products at an acceptable cost. Research homing in on the cost-benefits of different storage materials and sizes is sharpening technologies further (Jones and Walsh, 2014). Actions based on a yet experimental and expensive technology investigate new storage possibilities, including hermetic storage sacks (Walsh et al., 2014) or small metal and cement silos. As technically powerful as they are, and although they are carried by laudable development goals, these methods rarely meet with the support of the smallholder farmers, who are reluctant to invest in storage structures that previously cost them nothing. The lack of farmer enthusiasm for these technological substitutions reminds us that a storage container is not just an utilitarian object and an element of architecture; it is also the result of an integrated agrosystem and a sophisticated political framework that shape complex networks of seed access, circulation and sharing.

References

Beier, R.C., Nigg, H.N., 1994. Toxicology of naturally occurring chemicals in food. In: Hui, Y.H., Gorham, J.R., Murrell, K.D., Cliver, D.O. (Eds.), Foodborne Disease Handbook, Diseases Caused by Hazardous Substances, vol. 3. Marcel Dekker, New York, pp. 1–186.

Byrne, K.G., March, J., McGuire, S., Meissner, L., Sperling, L., 2013. The role of evidence in humanitarian assessment: the seed system security assessment and the emergency market mapping and analysis. Disasters 37 (S1), S83–S104.

Coomes, O.T., McGuire, S.J., Garine, E., Caillon, S., McKey, D., Demeulenaere, E., Jarvis, D., Aistara, G., Barnaud, A., Clouvel, P., Emperaire, L., 2015. Farmer seed networks make a limited contribution to agriculture? Four common misconceptions. Food Policy 56, 41–50.

Dales, M.J., 1996. A Review of the Plant Materials Used for Controlling Insect Pests of Stored Products. Natural Resources Institute, Kent.

Dounias, E., Ichikawa, M., 2017. Seasonal bushmeat hunger in the Congo Basin. EcoHealth 14 (3), 575–590.

Dounias, E., Tzerikiantz, F., Carrière, S., McKey, D., Grenand, F., Kocher-Schmid, C., Bahuchet, S., 2001. La diversité des agricultures itinérantes sur brûlis. In: Bahuchet, S. (Ed.), Les peuples des forêts tropicales aujourd'hui. Volume II- Une approche thématique. Avenir des Peuples des Forêts Tropicales, Bruxelles, pp. 65–105.

FAO, 2018. Gender and Food Loss in Sustainable Food Value Chains. A Guiding Note. FAO, Rome.

Fraenkel, G.S., 1959. The raison d'être of secondary plant substances. Science 129, 1466–1470.

Friendship, C.A.R., Compton, J.A.F., 1991. Bag or Bulk? a Decision-making Checklist. Natural Resources Institute, Kent.

Fürstenberg-Hägg, J., Zagrobelny, M., Bak, S., 2014. Plant defense against insect herbivores. Int. J. Mol. Sci. 14 (5), 10242–10297.

Goletti, F., 2003. Current status and future challenges for the postharvest sector in developing countries. Acta Hortic. 628, 41–48.

Greeley, M., 1982. Pinpointing postharvest losses. Ceres 15 (1), 30–37.

Gueye, M.T., Seck, D., Ba, S., Hell, K., Sembène, M., Wathelet, J.P., Lognay, G., 2011. Insecticidal activity of *Boscia senegalensis* (Pers.) Lam ex Poir. on *Caryedon serratus* (Ol.) pest of stored groundnuts. Afr. J. Agric. Res. 6 (30), 6348–6353.

Haile, A., 2006. On-farm studies on sorghum and chickpea in Eritrea. Afr. J. Biotechnol. 5 (17), 1537–1544.

Johns, T., 1990. With Bitter Herbs They Shall Eat it: Chemical Ecology and the Origins of Human Diet and Medicine. University of Arizona Press, Tucson.

Jones, M., Walsh, S., 2014. Seed Storage Brief #3: Economics and Promotion: Insights for Program Design. Catholic Relief Services, Nairobi.

Justice, O.L., Bass, L.N., 1978. Principles and Practices of Seed Storage. United States Development of Agriculture, Washington DC.

McGuire, S., Sperling, L., 2011. Seed systems smallholder farmers use. Food Secur. 8, 179–195.

Meikle, W.G., Markham, R.H., Nansen, C., Holst, N., Degbey, P., Azoma, K., Korie, S., 2002. Pest management in traditional maize stores in west Africa: a farmer's perspective. J. Econ. Entomol. 95 (5), 1079–1088.

Reynolds, P.J., 1974. Experimental iron age storage pits. Proc. Prehist. Soc. 40, 118–131.

Seignobos, C., 1989. Les parades à la razzia dans la zone soudanienne au XIXe siècle, la domestication de la cueillette. In: Eldin, M., Milleville, P. (Eds.), Le risque en agriculture. ORSTOM, Paris, pp. 353–371.

Seignobos, C., 2005. Stratégies de conservation du grain. In: Seignobos, C., Iyébi Manjek, O. (Eds.), Atlas de la province Extrême-Nord Cameroun. IRD Éditions, Marseille, pp. 107–110.

Sigaut, F., 1989. Storage and threshing in preindustrial Europe. Tools Tillage 6 (2), 119–124.

Todd, E.C.D., 1994. Surveillance of foodborne disease. In: Hui, Y.H., Gorham, J.R., Murrell, K.D., Cliver, D.O. (Eds.), Foodborne Disease Handbook, Diseases Caused by Bacteria, vol. 1. Marcel Dekker, New York, pp. 461–536.

Vincent, J.F., 1982. Pouvoir et contrôle du mil : greniers individuels et collectifs chez les montagnards Mofu (Afrique sahélienne). J. d'agriculture traditionnelle de botanique appliquée 29 (3–4), 295–306.

Walsh, S., Baributsa, D., Remington, T., Sperling, L., 2014. Seed Storage Brief #2: Hermetic Seed Storage Technology: Principles, Use, and Economics – a Practitioner's Guide. Catholic Relief Services, Nairobi.

World Bank, 2011. Mission food: The Case of Postharvest Grain Losses in Sub-saharan Africa. Report No. 60371-AFR. The World Bank, Washington DC.