sustainability

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Informal *Commercial* Seed Systems: Leave, Suppress or Support Them?

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Abstract: Smallholder farmers require seed systems that can meet diverse functions: move a range of planting material; spread specialty varieties (climate-resilient or nutrient-dense varieties); reach last-mile areas; and perform in high-stress contexts. Acknowledging that smallholders use both formal and informal systems, this article focuses on the latter and on a component largely unexamined to date: informal *commercial* seed systems (ICSSs). Four evidence-based cases show how ICCSs contribute to varied seed system functions. In Tanzania, traders have moved multiple modern bean varieties countrywide and within just a few years. In the remote Ugandan north, traders have commercialized the sale of sweetpotato vines (produced off-season) to those lacking their own critical marshlands. In Bolivia, traders routinely sell native and modern varieties of seed tubers to farmers, along with their commerce in ware potatoes. In central Mali, a cluster of villages produces and sells pearl millet seed that is specially adapted to extreme drought conditions. All four cases share key characteristics: they distinguish seed vs. grain, serve local, regional, and international customers, and, perhaps most importantly, are sustained without subsidy or project support. As ICSSs meet farmers' demands for seed that is not supplied by other actors, a question remains as to whether ICSSs should be left alone, leveraged, or improved further. Recognizing possible legal and operational challenges, this article suggests that ICSSs first be studied in-depth—characterizing their variations, locales, and system functions—so that future debates on possible support can be grounded in concrete evidence of ICSSs' strengths, weaknesses, and unique benefits.

Keywords: informal commercial seed; traders; last-mile delivery; variety turnover; seed security; resilience; climate stress; smallholder farmers

Citation: Sperling, L.; Almekinders, C.J.M. Informal *Commercial* Seed Systems: Leave, Suppress or Support Them?. *Sustainability* **2023**, *15*, 14008. https://doi.org/10.3390/su151814008

Academic Editor: Michael S. Carolan

Received: 8 July 2023
Revised: 28 August 2023
Accepted: 8 September 2023
Published: 21 September 2023

1. Introduction

Catalyzing effective seed systems has long been a focus of both development and humanitarian practitioners as good seed (new varieties and quality seed) is a core input that boosts smallholder farming systems. For development entrepreneurs, seed can be a lucrative business; for example, in Africa alone, which is the focus of this piece, the formal sector African seed market reached USD 1.9 billion in 2019 ([1], citing Agribusiness Research and Analysis, June 2021). For humanitarians, giving smallholder farmers access to good seed can spur quick recovery gains as well as be cost-effective; for example, 1 kg of sorghum seed aid may produce 100 kg of food [2]. Recent figures from the USAID Bureau of Humanitarian Assistance for FY2021 showed that seed-related assistance occupied 65% of their emergency agricultural requests, resulting in aid amounting to USD 234.7 million (S. Walsh, USAID seed security officer, *pers. communication, October, 2022*).

In reference to smallholder farmers in particular, the functions of seed system support are increasingly diverse. In addition to just moving high-quality, well-performing seed, seed system interventions may variously aim to (1) move climate-resilient varieties, even in stressed regions; (2) diffuse nutrient-dense varieties, including to the malnourished;

(3) deliver new varieties faster (also referred to as 'fast tracking' or speeding up 'variety turnover'); (4) reach last-mile areas and populations, which are those that are geographically or economically marginal; and (5) maintain performance in high-stress contexts.

While smallholder farmers themselves generally rely on different types of seed systems, sometimes even for the same crop, seed system developers to date, regardless of the driver for the seed system intervention, have put near-sole focus on strengthening formal seed sector functioning; in other words, they have focused on bolstering government and formal private sector seed-linked entities. Investments have routinely homed in on activities such as scaling up formal public sector production of early-generation seed [3] and supporting large, medium, and/or small private sector businesses to perform further multiplications [4,5]. The origins of this formal seed sector cognitive model derive from seed business successes focused particularly on hybrid maize and vegetable seed and largely operating in stable, more productive farming areas. In routine practice, this same formal sector business model has also been used as the base blueprint for seed system development for other crops, across geographies, and even to respond to diverse seed system functions.

The second main type of seed system, the informal type, is the focus of this piece. The informal sector has been given much less visibility in research and development planning even though the informal sector supplies 70 to 90% of the seed smallholder farmers in Africa currently use [1,6,7]. Note that the 'informal' seed sector has also been variously labeled as 'traditional', 'local', and 'farmer-managed' (e.g., [8]) even though it often is not any of these. The sector is dynamic [9], extends across regions and geographies [10,11], and frequently widens beyond farmer-managed processes to engage sets of higher-level commercial market actors, including networks of traders and their associated supply chains [10,12–14]. This piece seeks to put a spotlight on the commercial component of the informal seed sector with the objective of supporting our argument that this important functional component in informal seed systems merits more study. This piece draws from seed system cases for diverse crops (common bean, sweetpotato, pearl millet, and potato crops) and regions (Tanzania, Uganda, Mali, and Bolivia), and is grounded in extensive descriptions from the academic and gray literature, as well as direct accounts from field experts involved. These concrete field cases show that informal commercial seed systems (ICSSs) have potential to contribute to the full diverse set of seed system functions: moving specialty varieties (climate-resilient or nutrient-dense varieties) quickly, widely, and even to last-mile and stressed areas. The current contributions of this informal commercial sector also suggest that it likely merits more support, in ways that may challenge seed system practitioners to move toward more creative thinking and action.

2. Informal Commercial Seed Systems as Component of Informal Seed Sector

The informal seed sector encompasses several components: (1) seed/planting material from farmers' own production (harvest, selection, storage); (2) seed obtained through farmers' social networks (such as relatives, neighbors, or friends); and (3) seed selected from local markets (as distinct from formal seed-specific markets such as agro-dealers) (note that, from here on, the authors use the term 'seed' to include a range of planting material). Farmers' own seed management practices for many crops have been described in detail, especially by practitioners aiming to document and improve seed quality [15–17]. Likewise, seed acquisition through social networks has been well described in its varied forms: direct farmer-to-farmer seed sharing, reliance on community seed banks, and even diffusion/sharing via local nodal farmers. All of these methods imply some sort of relational connection and 'within community' sharing (e.g., [9,18–22]).

In contrast, farmers' sourcing of seed from local markets has been given less scholarly or practical attention, and even its recognition as a component of the informal seed sector is relatively new. Select research has given insight into aspects of both the demand and supply sides of local seed markets, such as, for example, the practices farmers might use in selecting seed from local open markets or kiosks [23,24] and the practices traders might

use to manage and anticipate market seed supply. Strong quantitative evidence has also highlighted the importance of local market seed to smallholder farmers' seed security. In one of the largest data sets published to date on smallholder seed sourcing, 51% of the seed farmers were sowing was accessed from local markets [7]. Analysis of local seed markets has partly been obscured due to misplaced stereotypes. First, sowing materials selected from markets are sometimes reduced to being 'just grain'. Second, informal sector specialists may prefer to emphasize that farmers mainly save seed and are thus self-sufficient, rather than recognize that off-farm sources for seed—like local markets—are routinely used.

This piece aims to shed light on informal sector functioning with particular emphasis on informal commercial seed systems (ICSSs). A recent report from AfricaSeeds, a key policy organization formerly tied to the African Union, recognizes the existence of informal commercial seed systems [1]. AfricaSeeds identifies two types of ICSSs: 'Unregulated Commercial Seed Entities' and 'Commercial Farmer-Managed Seed Systems'. Both these ICSS types are charted as central components of the informal seed sector structure within AfricaSeeds' organizational diagrams and also feature prominently in their decade-long proposed action plan for 2022–2031 [1]. This official recognition is an important start for spurring more research into how ICSSs function and for identifying entry points to leverage and enhance their operations. In the next section, we explore four cases of ICCS functioning. The four cases are quite different from each other and suggest that the informal commercial seed sector contains significant variations and may require a broad conceptual framing to unravel the scope of organizational types, possible functions, and roles in meeting the range of seed system functions.

3. Informal Commercial Seed Systems: Four Cases

These four field cases are first presented as vignettes. They have been selected from the few cases we know that cover different crops and contexts and that have been documented (that is, they are relatively well researched and there is formally published material on them, although the number of publications is limited), and all of these cases have been reported as highly successful as well as ongoing. We draw from the literature, our own experiences, and our interviews with key researchers. The short descriptions are then followed by an analysis of some of the ICSS case commonalities and differences. The cases are quite diverse; they are drawn from four countries with contrasting agroecological and market settings, and involve four different crop types: a legume (common bean), a root (sweetpotato), a tuber (potato), and a cereal (pearl millet). The first three cases (from Tanzania, Uganda, and Bolivia) center on what AfricaSeeds labels as 'Commercial Unregulated Commercial Entities' (a partial misnomer). The last (Mali) is a 'farmer-managed commercial seed system' case.

Vignette #1: Tanzania—The Informal Commercial Seed System for the Common Bean (Sources: [25]; N. Templer, pers. communication, April 2023).

Tanzania is the top common bean producer in Africa, producing 1.2 million MT/year, and the yellow bean is among its major bean types. Yellow bean production has been skyrocketing, reaching 340,000 ha in 2018. As little was known about the seed supply fueling this growth, survey research in 2019 traced major production, distribution, and sale hubs in 12 different regions countrywide. The research traced the yellow bean trade backwards, starting with known procurement sources and then linking those back to sites of production. In total, 298 (predominantly) grain traders and 64 (locally known) seed traders were interviewed (including wholesalers, exporters, aggregators, and retailers).

The results revealed that this extensive yellow bean business, which produces 42,000 MT annually just among those interviewed, was 100% fueled by informal seed. Traders at all scales reported no direct ties to the research sector or to private seed companies, and none had accessed either certified or quality declared seed. All traders interviewed sold bean grain and informal seed; it was not one business or the other, but both. While grain sales predominated, informal seed proved an important moneymaker, representing between

15 and 40% of trader business in non-sowing and sowing periods, respectively. Grain vs. seed price differences varied by variety, grading (especially cleanliness), and seasonality, with margins as high as +50% reported. Clear signals suggested that the customers of the traders were looking for seed (planting material): they asked for seed directly, or inquired about the geographic source of the material, storage conditions, etc. Traders, for their part, anticipated local seed supply, inter alia, by buying from specific growers ('good seed producers'), sourcing from regions with parallel adaptation, keeping varieties pure, and keeping freshly harvested stocks apart. Traders managed the seed as a potential planting material, as seed (vs. just grain) gave monetary payoffs.

The informal nature of the seed trade did not mean that it was static, traditional, or closed. Surprisingly, DNA analyses showed that over 60% of the sampled yellow beans (N = 461) derived from modern yellow bean varieties, with the predominant variety identified having been released in 2018, just several seasons prior to the survey. This indicates that modern variety diffusion has proved to be fast and geographically wide, although the exact channels by which the new varieties entered the informal system remain to be traced.

Vignette #2: Uganda—Informal Commercial Seed (Vine) Supply for Sweetpotato (Sources: [26]; R. Gibson, pers. communication, March 2023).

Sweetpotato vines are not easy to come by in Gulu District, northern Uganda. The long dry season, lasting from December to mid-March, causes the sweetpotato crop to desiccate, and most farmers lack vines to plant at the start of the rainy season in April. A small group of farmers with access to land in swampy marsh areas serves as the backbone of sweetpotato planting material in the area. They are able to plant in the lowlands in December, harvest and sell roots generated from the crop from April to June (when few other fresh foodstuffs are available), and also sell the very valuable vines as planting material to the many people who lack swamp-land access.

Research conducted from 2013 to 2015 revealed some of the details of this informal private sweetpotato seed (vine) enterprise. Farmer–multipliers, growing less than/equal to 0.3 ha of mainly landraces in the dry season, sold roots as well as vines to varied clients, such as local farmers and town sellers, and, more rarely, directly to local markets and sometimes NGOs. Sale distances varied with the type of customer. The sales of vines to farmers by local multipliers were mostly to customers within a 10 km radius. Sales by town sellers could be distinguished at two destinations: one 0–5 km away for local customers and another between 20 and 200 km away. Many of the latter sales were to Kitgum and Pader, districts in northern Uganda, but they also occurred in many other directions, including to South Sudan. Sales to NGOs were commonly to customers located 10–100 km away. Thus, while the informal commercial seed system was clearly providing an essential service to local Gulu District smallholders, it also reached across international borders.

The prices along the informal seed channels in Gulu were largely consistent with costs, supply, and demand. The cheapest option for farmers was to cut and buy vines on a multiplier's farm. The vines were most expensive when harvested, packed, and sold by vine multipliers in local markets or similarly preordered and ready to be taken away from a multiplier's farm. The prices also fluctuated significantly depending on the client, locale, and period in the year. For instance, local multipliers sold at prices between UGX 270 and 420 in 2013.

The scale also varied. Local multipliers were selling about 30 small bundles (a total of about 1500 cuttings) to smallholders, who were mostly their neighbors. The town sellers were mostly selling about 20 small bundles (meaning that, again, the final customers were mostly likely to have been smallholders), often locally but sometimes in neighboring districts and even across country borders.

The quality standards within this sweetpotato ICSS case were governed by 'informal' regulations such as the need to maintain a good reputation. The system was not 'unregulated': it was governed by the needs and wants of customers and feedback from users. Proof of quality standards was whether farmers and other customers came back for more.

Vignette #3: Bolivia—Informal Selection and Commercialization of Seed Potato by Traders

(Sources: [12,27,28]; G. Thiele, pers. communication, May 2023).

Domesticated in the Andes, potato is one of the main food crops in Bolivia, with both native and improved potato varieties commonly grown by predominantly smallholder farmers. This vignette focuses on the Cochabamba Department in Bolivia. The potato system in Cochabamba is differentiated into three subsystems: those of the Papa Imilla (based principally on commercial native potato varieties), the Papa Holandesa (based on improved varieties such as Alpha and Desiree), and the Papa Nativa (less commercial and highly diverse native varieties). The public potato program in Bolivia is relatively small and focuses on improved and native commercial varieties. The availability of certified seed from government and commercial programs is limited and usually restricted to the Desiree and Waycha varieties. Despite multiple donor-supported initiatives for the Bolivian potato seed programs in the last decade, the majority of the farmers in Bolivia still rely on the informal potato seed system for their new varieties and to renew their seed stock.

Traders of both commercial native and improved potato varieties are the key actors that link farmers with the larger urban retail markets in Cochabamba and even across the border to Peru when market price-and-demand signals are favorable. These traders, mostly women, aggregate potatoes by buying from farmers, then transport the produce to other markets and sell to retailers. These traders are also key actors in the supply of seed potatoes. Most farmers sell their harvests to these traders, either at their farm-gate, at a local market, or at the location where the trader has her depository. Farmers usually bring unsorted bulk or a partly sorted harvest in large bags of 80–100 kg. By further sorting out the tubers from the bulk harvest, the team of people working for the trader separates the harvest into different ware potato sizes (primera, segunda, tercera) and seed sizes (cuarta or 'chili murmu': 30–50 mm). The seed tubers are explicitly treated and commercialized as seed; sprouting and size are two characteristics that distinguish the seed tubers from ware potato. The trader stores her seed in their depositories in conditions that, ideally, allow light sprouts to develop. Sprouts on the tubers signal to the buyer that the seed is ready to be planted.

Farmer customers travel to the depositories of the traders and markets to purchase seed tubers from the traders. It is not rare for farmers to 'buy back' seed from the traders to whom they sold their potato harvests. There are also farmers from the lower eastern highlands in the region of Santa Cruz who travel to places like Cochabamba to look for these traders to purchase seed potato from the repositories (locally known as 'garajes'). In higher areas of Santa Cruz (<2000 m), potato is an important cash crop and farmers predominantly plant the improved potato varieties of the 'Hollandesa' type. It is rarely possible to save harvested tubers to use as seed in the next planting season because of the high temperatures; therefore, farmers have to purchase seed for every planting.

Many of these marketed tubers that are commercialized by traders have been produced in fields at higher altitudes which tend to experience lower virus pressure and therefore produce better quality seed, including seed of commercial native varieties. The quality of the potato seed being traded in the markets or depositories is not indicated through labels or other written information. Rather, the social relations (often involving kinship ties) and trust among seed traders, potato-producing farmers, and seed-purchasing farmers play pivotal roles in shoring up quality. Intermediary traders are also known for being providers of loans for inputs, to be paid back at harvest. Hence, despite some limitations, this farmer–trader-based ICSS in Bolivia is relatively successful at meeting farmers' needs for acceptable seed of their principal varieties across different agroecologies and altitudes.

Vignette #4: Mali—Pearl Millet: The Informal Commercial Seed Supply from Specialized Villages

(Sources: [29,30]; H. Guindo and E Weltzien, pers. communication, April 2023).

Northern Mali (Douentza District) has experienced ongoing conflicts since 2012 and is characterized by frequent droughts. Farmers in this Sahelian zone face some of the harshest

conditions for crop production, even in normal times: rainfall of 200 to 400 mm/year, temperatures rising to 50 °C, and very poor, sandy soils. Pearl millet dominates agricultural production and farmers prefer to grow their own highly adapted varieties. Seed security in this stressed region translates to finding the right crop, high-quality seed, a highly specialized set of varieties, and having enough seed available.

The challenges of seed security are formidable in many climate-stressed (and conflict-stressed) zones, but are even more so in this northern zone of Mali. Fortunately, a cluster of villages–Tabi, Tega, and Toupere—has a good reputation for both the quality and quantity of its pearl millet seed. In terms of quality, these villages produce a much-sought early-maturing pearl millet variety (yielding in 65 days) that is so prized that the 'Mil de Tabi' has gained a reputation nationally, as well as being locally and regionally renowned. Not only is the local variety highly adapted and high-performing, but the seed itself is carefully managed—in initial selection, in the field, and postharvest. In terms of quantity, the three villages are able to produce (and store) large quantities of seed and grain every year (possibly due to water run-offs from nearby rocky outcrops). A survey in the drought year 2006 showed that the villages had some 10 MT of pearl millet seed in their stores, at a time when many local people not only lacked seed but were buying grain from afar—from 'Segou' or 'Koutiala'—just to eat. Therefore, having local seed in times of great difficulty is one important aspect of this success story.

These farmer-managed seed entities have been involved in various transactions. Research accounts suggest that seed has long been given free within close social networks (to relatives and neighbors), but that seed transactions have been billed highly to outsiders. Prices in the most recent sowing season (2022) reached 1000 CFA/kg as compared with CFA 450–500 for grain.

In a novel development, farmers in the village cluster formed a successful seed cooperative just a few years ago. Most of their clients are smallholder farmers themselves and come from a range of nearby villages; these locals bought about 7 MT of 'Mil de Tabi' seed this last 2022 season. That said, while most of the seed is sold within the immediate region, some has been vended even as far as Burkina Faso and the Malian city of Segou (600 km away). Also, as insecurity has been rising, the clientele has expanded, especially to humanitarian relief agencies. Agencies such as the Red Cross/Red Crescent have procured 'Mil de Tabi' at the request of Malian farmer-aid recipients. In fact, the village-based cooperative sold 41 MT in relief seed in 2018 alone. It is important to note that, at this time of writing, many regions of Mali are experiencing conflict-related insecurity, with government, private sector, and even occasionally relief-aid seed delivery ruptures. In the face of multiple breakdowns, this farmer-managed seed has become even more critical for helping to fill in key seed security gaps.

This ICSS case is thus one that focuses on farmer-managed commercial seed of a local variety. It has shown considerable dynamism, moving from an informal base geared to smallholder farmer clients to adding more formal links, including setting up a cooperative and expanding to also serve institutional clients, such as relief seed NGOs. Also, as insecurity rises and many seed providers withdraw from seed production and delivery activity, these northern Malian seed villages have continued to function and even expand operations.

3.1. Some Essential Commonalities among ICSSs

On the basis of these brief descriptions, the four ICSS cases seem quite different. However, a first synthesis also suggests some important similarities. All four cases are **rooted in informal systems:** they are based on seed production that has existed locally in a given region and they have emerged from the work of local informal system actors. They also all represent **commercial** undertakings: planting material is sold and entities work to make a profit. There are **different prices for seed and grain/ware** and, in the case of sweetpotato, even different products (roots vs. vines). Some of the prices are even more tailored. For the common bean, the variety and degree of grading translate to

different prices. For sweetpotato, the distances for transport and type of customer result in tailored prices. Furthermore, the cases are situated in select local regions, but they serve on **wider geographic scales** than their own locality, including across national borders. The commercialization of seed is **not subsidized** in these cases (either to the producer or to the client). And the cases are **not dependent on project cycles**; that is, they are not driven by, nor are they specifically tied to outside governmental or development programs. These ICSS cases may serve some such programs, but their operations are not financed 'externally' by development initiatives. In the Mali case, a cooperative was recently developed with outside support, but only after years of village engagement in seed production and seed transactions independently. Finally, these ICSS cases render **seed available on a recurring basis**. The cases are also all ongoing as of this writing (there are no historical data available on their starting points). Table 1 summarizes these details. The cluster of features for these ICSSs suggests that the seed-linked work has attributes that lend the activities to being sustainable and to directly serving smallholder farmers, among others.

Table 1. Informal commercial seed system cases: selected features.

Case	Commercial	Seed/Grain Price Differences?	Geographic Scale	Subsidy		Linked to Project Cycles?	Ongoing
				To Supplier	To Client		
Tanzania Common bean	Yes	Yes	Country-wide and international	No	No	No	Yes
Uganda Sweetpotato	Yes	Yes	Region-specific and international	No	No	No	Yes
Bolivia Potato	Yes	Yes *	Mosty regional	No	No	No	Yes
Mali Pearl millet	Mixed: Part yes Part no **	Yes	Region-specific and international	No	No	No	Yes

(*) Because the small tuber is not valued as ware potato, the price per bag is usually lower than that of bags with larger potato tubers. However, once the tuber has sprouted, the price can increase considerably, with a peak toward planting time. (**) Some of this work in Mali is noncommercial, and involves giving and sharing seed in a region where social networks can be strong.

3.2. Select Differences among ICSSs

Despite some commonalities, this first exploration of the four ICSS cases yielded a first set of important differences that merit highlighting.

Actors. The first three of the ICSS cases involve central actors that extend well beyond the core of local farmers, while the fourth is strongly farmer-based. Note that these actors are not exclusively seed producers or seed entrepreneurs. Rather, they tend to focus on seed as one part of multiple enterprises, next to selling the grain, roots, and tubers for consumption. In addition, some sellers work more seasonally in response to farmers' sowing schedules.

- The Tanzania bean case centers squarely on traders at varied scales. These include mainly grain traders who also occasionally sell informal seed as well as local traders who specialize in the local seed trade seasonally. Wholesalers, aggregators, collectors, and retailers are all cited as partners in this Tanzanian ICSS, which moves local seed as well as modern varieties very widely.
- The Uganda case of sweetpotato vine commercialization starts with specialist vine multipliers but also quickly encompasses a network of multiple business entrepreneurs. As concretely described: '*Our study in northern Uganda has not revealed a specifically farmer seed system, but instead a more diverse system comprised of specialist multipliers (some acting also as aggregators), traders, transporters and sellers. Some of these actors had not evolved from farmers; most town sellers. . .had market stalls at which they sold fruit and vegetables off-season*' ([31], p. 606).
- In the potato case, the traders involved with seed are almost exclusively wholesalers or 'mayoristas', as they are called (in differentiation from retailers). They may also

have farms, but their main business is commercializing ware (food) potato. Many have a depository in an urban area of Cochabamba. The tuber size that is fit for seed is actually not as highly valued as the ware potato size and thus the seed and ware potato businesses are very complementary. Financially speaking, it is not clear how important the seed trade is for these traders as compared with the ware potato business.

- The Mali case—localized to three specific villages known for their high quality and quantity of pearl millet seed—is the only one of the four commercial cases that seems truly farmer-centered. The villages are self-organized, with farmers managing processes from local variety management to seed multiplication to end sales, with quality defined by locally demanded standards. That said, there has been evolution. In 2014, the farmers in each of the three villages formed an official cooperative (government-registered; 'Kayi Tourou Djerou' from Tabi, 'Toou Guessou Boroum' from Toupere, and 'Kasgou Djerou' from Tega). They also formed a seed coordination committee among them, so that they could better organize the sale of seed and improve the management of the seed production and marketing processes. The cooperatives now own specialized seed stores, separate from the family grain stores, and sell their seed in labeled packages of different sizes, and with seed treatment to improve stand establishment. They conduct germination tests before packaging seed for sale on their own, or with support from national seed services in case a certificate is required.

Again, referring back to the recently labeled AfricaSeeds classifications (AfricaSeeds, 2022), these four cases encompass both of the two informal commercial types: the 'Commercial farmer-managed system' and what are called 'Unregulated seed enterprises'. As shown in several of the cases above, the ICSSs are not unregulated; they are, rather, governed by local standards of what keen customers deem as acceptable seed and planting material. Also, the pricing and trust in relations are subject to locally accepted norms and values.

Seed system functions. These cases seem to be geared toward quite different functions which partly mirror the diverse needs increasingly desired in the broader seed system field (see Introduction).

- The Tanzanian ICSS case seems to function as an unusual conduit for moving new, modern varieties. This ICSS spurs variety access (and turnover) for a range of local and modern bean varieties and moves the varieties quickly to smallholders within and across multiple regions of Tanzania, as well as across borders (e.g., to Kenya and Uganda).
- The Uganda sweetpotato case involves producing vine planting material that is intrinsically hard to multiply and keep viable from the harvest to the next planting season. Local producers who have access to plots with more humid conditions are able to keep their crop going in the dry season and aim to serve smallholder client needs, specifically in the immediate 'last-mile' region. The town sellers in Gulu form a niche of suppliers who sell vines to clients farther away and who are not able to carry over vines from harvest to planting due to extended hot and dry conditions.
- In the Bolivia case, the demand for seed potato in Bolivia has two drivers: the difficulty of storing seed potatoes in the lower areas around Santa Cruz and seed degeneration in the rest of the potato-producing area. The first makes farmers purchase each season. The second leads to farmers restocking periodically, i.e., after a variable number of years. The traders are often referred to as sources of seed that is from higher-area production fields, suggesting low disease pressure conditions and relatively clean and healthy seed.
- The Mali seed villages produce a highly specialized variety with high intravarietal diversity, specifically adapted for a region that endures high climatic stress (frequent, severe droughts and high temperatures) as well as periods of civil unrest and conflict. The villages serve routine seed as well as emergency client needs and, in this way, serve as a supplier for the relief-to-development continuum in a relatively remote region.

Note that for both the Ugandan and Malian cases, the ICSSs serve as important seed security systems in their respective areas; for the given crops (sweetpotato and pearl millet), there are not many alternative planting material sources.

Links with formal seed sector: sources for germplasm. The four cases also document quite different relationships with the formal research sector. Until recently (the exception being the Mali case), none seemed to have any links to the formal seed sector (e.g., certified or QDS seed), and their relationships with formal variety and breeding groups appear to be variable.

- The Tanzania ICSS case has clearly involved moving modern as well as local varieties. DNA analysis identified several distinct clusters of modern varieties being diffused from the Tanzanian research system with the predominant common bean types labeled as Selian 13, Uyole 13, and Nyole (in addition to released varieties from Burundi, Uganda, and the Democratic Republic of the Congo). The speed of diffusion seems remarkable as the predominant type, Selian 13, had only been released one year before the research survey was effected. Also, the extent of modern variety presence, 60% of the full sample, is unusually high.
- For Uganda, the vines being sold in the ICSS come from local varieties, and these sellers have no access to modern germplasm. That said, in the Gulu zone, in parallel, there are a series of NGOs that have organized selected multipliers to produce vines of modern varieties (specifically orange-fleshed sweetpotato; OFSP) for larger farms and for contract buyers (NGOs and local government projects). As noted in Rachkara et al. [26], p. 606: '*Different scales of private enterprise serve different purposes, informal systems distribute planting material to smallholders and larger multipliers and commercial companies to larger farmers. Only together can they claim to 'work everywhere and for everyone*'.'
- In Bolivia, not many new potato varieties have successfully entered the system lately. The potato traders essentially grade the common ware potatoes for seed. This suggests that they do not necessarily play a role in the initial phase of the introduction and diffusion of new varieties. Their function may be more one of providing relatively healthy and fresh seed of the right physiological age.
- The Mali case centers on very local germplasm. Links to the more formal sector currently focus on select seed quality issues (e.g., seed treatment) rather than on novel germplasm concerns. Note that these farmers have deliberately refrained from introgressing other pearl millet germplasm into their variety, so as to maintain its unique characteristics. They have possibly intensified the mass selection activities for their commercial seed production. However, researchers have used the Tabi variety as the basis for a breeding program in Niger. This variety was identified as being biofortified, and tolerant to a common insect pest, the pearl millet head miner. This variety underwent one cycle of recurrent selection for Striga resistance and was recently registered in the Niger variety catalog as ICRITABI (E. Weltzien, pers. communication, May 2023).

4. Discussion

4.1. Reflection on Importance of ICSSs

This piece has presented four distinct cases centering on informal commercial seed systems (ICSSs). The snapshots suggest the variability among ICSSs, but also their potential importance in serving varied seed system functions and customers. Other ICSSs have been noted in the literature, e.g., for cassava and yam in Nigeria (Pircher et al., 2018; Stuart et al., 2021), for cassava in SE Asia [10], and for local maize in Kenya [32], but their functioning has not yet been systematically studied and documented. These cases, however, (a) demonstrate that the phenomenon of ICSSs exists; and (b) suggest that ICSSs may be more widespread than their relative invisibility in policy and development practice would signal. Ironically, all the cited seed businesses (individuals and groups) are recognized as quite successful ones locally and regionally but have not appeared on the official seed system radar or, at least, have not appeared there until recently (viz. 1).

It might be important to note that ICSSs seem to have emerged and evolved through demand. They are performing several crucial roles and filling key seed security gaps: (1) the ICSSs provide plant material for crops with which the formal sector has little advantage, e.g., self-pollinating and diverse open-pollinating varieties, and vegetatively propagated crops; (2) the ICSSs serve geographic regions and clients that are underserved (or not served at all) by formal government seed sectors or private seed companies; (3) several of the ICSSs seem to be able to operate in volatile, unstable environments (even war-torn environments) which may prove inhospitable to more official formal vendors; and lastly, (4) the ICSSs are usually not limited in the type of germplasm, meaning they can provide modern germplasm but also quite specialized local germplasm, e.g., the pearl millet in the Mali case, from which larger enterprises might refrain.

With all of these features of ICSSs, the wide geographic ranges and speed with which they move new and highly adapted materials bear emphasis. Other entities, including formal and private sector organizations, can move well-performing varieties (whether modern or preferred local), but the speed and breadth at which ICSSs can promote varietal turnover are remarkable (e.g., in the Tanzania case). This apparent ICSS function might prove especially useful in the face of fast-developing threats and those that warrant more continually revolving germplasm or even crop types (e.g., acute or repeated disasters, or more gradual climate changes). For those interested in strengthening seed systems for smallholders (including the more vulnerable), the challenge is then to decide what posture to adopt toward ICSSs. Should one just 'leave these systems alone'? They are already serving important functions—and sustainably. Should one 'formalize them', so they become more visible and can attract the benefits of formal support? These authors would advocate neither extreme view. Ignoring them (i.e., leaving them alone) would lead to a set of real missed opportunities, that is, opportunities to leverage them further in positive ways that could influence places, people, and crop types that are neglected or underserved by the formal seed system actors. Strictly formalizing them would most likely kill them (due to unrealistic rules and/or standards) and could bring their key functions in the supply of planting material to a halt. Furthermore, formalizing these ICSSs in contexts in which systematic enforcement of the rules and standards is unlikely may only add to ad hoc and selective and possibly counter-productive authority interventions. These authors recognize the distinct value of ICSSs and suggest rather that policy and on-the-ground development specialists aim to provide ICSSs with room to maneuver. This requires the identification of opportunities to enhance their actions, legally and practically, and strategize on ways to leverage them further. Note that ICSSs might also need to expand, evolve, and progress in ways that may not be predicted.

Before this piece looks to future opportunities (next section), the authors frame all actions with a caveat: there are realistic constraints. That traders can move planting materials fast and far serves as a strength but can also form a threat. For some crops, seed and planting material act as conduits for spreading disease; moving seed and planting material quickly and widely may also move diseases quickly and widely. Hence, 'negative' as well as positive innovations may travel with seed [31,33]. Alleviating actions may have to be programmed along with facilitating ones.

4.2. Steps for Greater Understanding and Possible Support of ICSSs

Moving forward to possibly support ICSSs involves some preliminary steps. Stereotypes about informal seed (i.e., being scorned as just grain) might need to be explicitly addressed and countered by providing empirical evidence. Informal seed, though not certified, is often the better option because it is more accessible and better adapted in many cases than seed from the formal system, if the latter is available at all, which is especially true for self-pollinating and diverse open-pollinating varieties and vegetatively propagated crops. Also, in the informal system, not all seed is saved or freely shared (another common stereotype), and the informal system might best be understood as including a large commercial (buying) component. Then, as a further preliminary step, ICSSs need to be better

characterized and understood in multiple contexts. What are the variations in ICSSs? And under what conditions and with which crop types does each ICSS type typically thrive? What are the values and functions they offer in the eyes of their customers? Are some more suitable than others for supporting and expanding ICSSs? And, of course, when should these systems not be leveraged?

The secondary steps are, then, forward-looking ones. There will be challenges to leveraging successful ICSS functions and also to identifying possible entry points to strengthen ICSSs in novel ways. As a start, areas of possible support include the three following:

Links to performing varieties. Creating more deliberate ties between ICSSs and formal breeding programs could spur traders to pick up well-performing and farmer-preferred varieties more quickly, whether modern or highly preferred local. This can result in diffusing (selling) a greater range of varieties, which could have positive effects on farming system stability. Research experiments have been undertaken in which traders review pre-released varieties with special attention paid to their food processing traits [34]. Raising traders' awareness of and access to new varieties more systematically could result in even quicker variety introductions if demanded by farmers. Among other actions, key actors in ICSSs could (a) review variety trials in the prerelease phase; (b) be invited to participate in key seed platforms; (c) be targeted with new variety information (digital as well as printed); and even (d) be directly tied to high-quality seed supplies to help bulk up emerging varieties. It is noteworthy to emphasize that traders are key in creating variety and seed demand pull.

Seed storage support. Supporting traders to improve their storage practices may result in clear gains fairly easily. Postharvest storage loss has been extensively documented and varies greatly across crops and countries. For instance, data compiled by the Africa Postharvest Loss Information System (APHLIS) for nine crops showed postharvest losses in 2021 varying from 2.2% (for oats in Ethiopia) to 18% (for maize in six separate countries) [35]. Storage losses specifically for seed have been less explicitly monitored, but farmers in Kivu, Democratic Republic of the Congo reported seed-weight losses of 35 to 50% for maize and 15 to 31.5% for beans across three sites [36]. As grain and seed are very tightly allied in informal systems, local seed losses are routinely likely to reach grain loss estimates, if not be more elevated, given that local seed has to be graded and selected very carefully.

Smallholder farmers are often targeted by NGOs and development projects to share information on and access to improved storage techniques [37,38]. Storage support to traders has been less extensive (e.g., 11 of 121 cereal storage cases reviewed in [39]), and targeted support to seed-linked traders is virtually undocumented. Given the importance of ICSSs, storage support could take varied forms: giving honed technical advice, promoting improved storage methods and devices (e.g., hermetic bags), and even giving incentives for improved storage facilities [24].

Seed quality support. Perhaps the most challenging area for supporting and then leveraging ICSSs revolves around seed quality. Introducing new varieties and improving seed storage are directly linked to enhancing quality. However, for formally certified seed proponents, the crux of ICSSs might be the variability in seed quality per se for attributes like vigor, germination, and pathogen-free material. Homing in further, farmers themselves can sometimes compensate for low germination by planting at higher densities or even resowing when needed. It is the pathogen threat, i.e., the risk of spreading pathogens, that looms large in ICSSs and requires more creative thinking. Thinking of out-of-the-box solutions might be needed. For vegetatively propagated crops, for instance, this might include virus-testing kits that allow rapid tests for in situ testing [40]. It is quite possible that select seed traders themselves will embrace such opportunities as it should be clear that the sustainability of ICSS activities depends on customer satisfaction.

In all of these discussions on quality, it is important to underline that formal systems themselves are not perfect and also that ICSSs have comparative advantages. Formal systems are also plagued by instances of certified seed that is no longer viable and that may be 'fake'. Formal systems also frequently make the wrong variety available to farmers

and make seed available well after the planting periods, pointing to two features in which ICSSs tend to excel: variety quality and 'on time' provision.

Note that supporting ICSSs implies not just exploring and expanding technical options and novel organizational links but also navigating uneven legal (seed legislation) spaces. A review by FAO of seed policies and trends [41] showed that farmers' seed systems (i.e., informal) were explicitly recognized in the seed legislation of 40 percent of the countries studied, that is, 94 countries and 2 regional organizations. The seed laws of the remaining 60 percent were silent on this matter. That said, there were very different postures on the specific issue of seed sales. *'Some countries exempted, for example, seed sales among farmers from their seed legislation. Other countries only exempted non-commercial seed exchanges or barter arrangements from their seed laws. Some countries exempted informal seed sales; others regulated them.' (22, point 67).* A fuller analysis was recommended. Minimally, as a strong starting point, ICSS work could leverage activity by improving grain production and supply as a first conduit to enhancing local seed.

5. Conclusions

The four cases discussed in this piece present very different examples of informal commercial seed systems (ICSSs) that developed and largely function without donor-financed project support. They function in conditions that are agroecologically and socioeconomically marginal and for crops for which formal seed systems are not well equipped or cannot make sufficient profit. Assuming ICSSs have comparative advantages in making seed systems function better, it seems to be forward thinking to better understand the roles they play, how they can contribute to making seed systems more resilient in the face of climate change, nutritional challenges, or other security challenges, and how they can be strengthened in practical ways. There are options to explore for supporting ICSSs—to improve variety turnover, storage, and even seed quality—but these systems will need to be given more practical and legal consideration to provide them with the needed space to evolve and expand so as to spur more effective seed system functioning.

Author Contributions: Conceptualization, L.S.; methodology, L.S. and C.J.M.A.; software, none; validation, L.S. and C.J.M.A.; formal analysis, L.S. and C.J.M.A.; investigation, L.S. and C.J.M.A.; resources, none; data curation, L.S. and C.J.M.A.; writing—review and editing, L.S. and C.J.M.A.; supervision, L.S.; project administration, L.S.; funding acquisition, none. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Informed Consent Statement: Informed consent was obtained from all seed system specialists mentioned in the study.

Data Availability Statement: Data supporting reported results can be found in the literature used and in the personal communications as indicated in the body of the text.

Acknowledgments: A good number of seed system specialists commented on this draft, with all of them also sharing detailed information on specific ICSS field cases. For technical comments, we sincerely thank (in alphabetical order) Richard Gibson, Hamidou Guindo, Shawn McGuire, Paul Rachkara, Noel Templer, Graham Thiele, and Eva Weltzien. We are additionally grateful to the Mali case experts, Eva Weltzien and Hamidou Guindo, for sharing updated, unpublished (and exciting) information.

Conflicts of Interest: The authors declare no conflict of interest. The views expressed are solely those of the authors.

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