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Management lessons learned in supply chain development: the experience of PICS bags in West and Central Africa

INDUSTRY SPEAKS

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Abstract

In order to facilitate the transformation of African agriculture, Africa's smallholders will require more and better access to input markets that deliver context-specific and well adapted innovations. This article summarizes the management lessons learned in developing supply chains for Purdue Improved Crop Storage (PICS) bags in West and Central Africa. PICS bags are hermetic grain storage bags that are leading a revolution in the post-harvest handling of grain on smallholder farmers in Africa. The bags have been very popular with farmers, but the major challenge has been developing supply chains to make those bags available for purchase at the village level. This article: (1) describes the PICS supply chain in West and Central Africa; (2) identifies constraints (i.e. financial, structural, social) that impede the development of the PICS supply chain; and (3) analyzes strategies used by businesses to expand distribution channels and increase bag sales.

Keywords: PICS bags, supply chain development, cowpea, West and Central Africa, input distribution, hermetic storage, storage innovations

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1. Introduction

As smallholder farms in Africa become more market oriented, they will inevitably use more technology, buy more inputs and drive the need to develop better supply chains to supply the technology and related inputs. This article summarizes the management lessons learned in developing the supply chains for Purdue Improved Crop Storage (PICS) bags in West and Central Africa. PICS bags are hermetic grain storage bags that are leading a revolution in the post-harvest handling of grain on smallholder farmers in Africa. In general 20 to 30% of the grain in Africa is lost between harvest and the consumer. With PICS bags farmers and the grain trade can reduce those losses to almost zero. The bags have been very popular with farmers, but the major challenge has been developing supply chains to make those bags available for purchase in rural areas. This article: (1) describes the status of the overall supply chain in countries covered by the PICS1 project including who is manufacturing the PICS bags and why, as well as the organization of the distribution network; (2) identifies constraints (i.e. financial, structural, social) that impede the development of the PICS supply chain; and (3) analyzes strategies used by local businesses (manufacturers, distributors, vendors, etc.) in expanding distribution channels and increasing bag sales.

PICS bags are a simple, low-cost (about US\$ 2-3) triple-layer plastic bag that allows small-scale farmers to protect their harvested grain from insect damage without insecticides (Murdock and Baoua, 2014). The PICS bag consists of an outer layer of ordinary woven polypropylene and two inner liners of high density polyethylene 80 microns thick. Better storage improves household food security and it gives farmers more flexibility in marketing leading to higher incomes. Commercialization of the bags was launched with funding from the Bill and Melinda and Gates Foundation (BMGF) in the PICS1 project from 2007-2014. During this period the technology was disseminated to millions of cowpea farmers in 10 countries in West and Central Africa including Ghana, Nigeria, Burkina Faso, Niger, Senegal, Mali, Benin, Togo, Cameroon and Chad. Subsequently the PICS2 project (2011-2014) showed that the technology could be used to store any dry grain and the PICS3 project (<https://www.picsnetwork.org>) is extending use of hermetic storage in maize growing areas of Nigeria, Burkina Faso and Ghana, and into East Africa in the 2014 to 2019 period. To scale up PICS bag adoption, Purdue University worked with many partners, including local and international non-governmental organizations (NGOs), national agricultural research systems, national extension organizations, farmer-based organizations, women's groups and for-profit businesses (i.e., manufacturers, distributors and agricultural input retailers). The extension effort involved direct contact with millions of farmers in almost 45,000 villages. In developing countries plastic manufacturers produced and local entrepreneurs sold almost five million PICS bags from 2007-2015.

The origin of the PICS technology is in the Bean/Cowpea Collaborative Research Support Program (CRSP) which was funded by the United States Agency for International Development. The Bean/Cowpea CRSP identified cowpea storage as the key constraint to greater productivity in the 1980s. In village meetings farmers had indicated that they could produce more cowpea, but did not because harvest time prices were too low and storage losses were too high. Starting in 1987, Purdue entomology Professor Larry Murdock and colleagues developed a portfolio of non-chemical storage technologies. Adoption surveys showed that the most widely accepted improved storage technology was the triple layer storage bag. Grain coming from the field is commonly infested by low numbers of pest insects whose numbers increase exponentially during postharvest storage. When such grain is sealed in an airtight container, the insects quickly consume the oxygen in the bag, cease feeding and stop reproducing. Depending on the species insects either die or become dormant. In either case they cause no more grain damage. Subsequent research has shown that PICS bags can be used cost-effectively to store any dry grain, reducing storage damage to negligible levels.

The PICS regional adoption studies in 2010 and 2012 showed that about 46% of respondents used some type of hermetic storage and about 44% of the quantity of cowpea stored on farms was in hermetic containers (Moussa *et al.*, 2014). This is substantially more than the 30% of cowpea grain in hermetic storage reported in 2003-2004 survey (Moussa *et al.*, 2011). Given the continued growth in PICS bag sales, the persistent

use of metal drums in some areas and the increased use of plastic jugs, it is likely that cowpea grain stored on farms in the region exceeded the 50% hermetic benchmark in 2013.

In West and Central Africa PICS bags are used by more respondents and for a higher percentage of cowpea than any other hermetic container. Alternative hermetic containers include metal drums, plastic jugs and 'double bags' (i.e. two layer bags, with a single liner of low density polyethylene). PICS adoption surveys show that PICS bags are used by 18% of farmers in the region and for about 20% of cowpea quantity. Some insecticide use still occurs with hermetic containers of all kinds – as a sort of insurance – but insecticide use is down since 2003-2004. When PICS bags are available they are used by women as well as by men. A survey of adult women in randomly selected villages in Burkina Faso, Niger, and Nigeria, has shown that over half of the women use some kind of hermetic storage for their cowpea (Ibro *et al.*, 2014), but PICS bags are the most common hermetic storage in the region. In these surveys about 28% of rural women in these three countries use PICS bags.

PICS has resulted in greater cash income for farmers, new businesses, new jobs, less insecticide exposure, and increased cowpea availability for families, schools and orphanages. Hermetically stored cowpea commands a 10 to 15% premium price in some markets because consumers know it is less likely to be contaminated by insecticide residues. Surveys indicate that most PICS bags are used at least three years before being repurposed for non-hermetic uses. The survey respondents who store in PICS bags gain on average \$ 26.58/bag at sale (Moussa *et al.*, 2014). Given the sales of 1,277,470 PICS bags in the 2010-2012 period, a conservative estimate of the extra cash flow for African farmers and households attributable to PICS is \$ 33,955,153 for the 2012-13 storage year.

From a technology transfer perspective, the PICS project differed from many other agricultural development projects in the sense that from the beginning it treated African farmers as customers, not as charity cases (Sonka *et al.*, 2016). Other than a few bags used in village demonstrations, almost all of the 5 million PICS bags that were manufactured were sold through commercial channels. When PICS started in 2007, the team thought that finding African manufacturers for the bags and implementing demonstrations in thousands of villages would be the major constraints. They quickly learned that African manufacturers were eager to find new products in high demand by their customer base and national extension services and NGOs were quite effective at implementing farmer training programs. The real bottleneck was development of supply chains down to the village level. An early PICS adoption study showed that farmers were reluctant to travel more than about 7 km to buy PICS bags (Moussa *et al.*, 2010). This study identifies how the PICS team attempted to meet the challenge of developing a supply chain that extended to within 7 km of every cowpea farmer in West and Central Africa and the lessons to be learned from that experience.

2. Methods

Given the nature of the PICS experience and the approach used to implement and develop the PICS supply chain, a research case study approach was adopted as the most appropriate analytical framework for the present assessment. This approach drew to some extent from Prahalad's (2004) seminal work exploring strategies to deliver innovative goods and services to economically marginalized, yet vast consumer markets. The research case study approach helps document what is happening based on direct input from stakeholders. It is often used to explore, describe and explain real life experiences where traditional statistical methods may be less appropriate. The case study methodology used in this research draws on social science and business case study methods and is structured along the lines defined by Yin (2003).

This research was carried out in three major phases: pre-field preparation, data collection, and data analysis and reporting. The first phase or pre-field preparation consisted of reviewing the existing literature and project materials (trip reports), interviewing in-country PICS team members, developing the interview guides and other data collection tools and identifying key informants. The second phase of the study consisted of collecting data in the ten PICS1 project countries through key informant interviews with in-country PICS

project staff and supply chain participants including bag manufacturers, vendors (i.e. wholesalers, semi-wholesalers, and retailers), partner NGOs and research institutes, and PICS business consultants. Data collection focused on capturing history and current status of the PICS supply chain in each country; the key factors that influenced private sector actors' willingness to invest in building up the supply chain; the institutional environment that impacted business and marketing strategies; and 'market failures' that needed to be addressed in launching the supply chain. Other information collected was related to factors that hinder the sustainability of the supply chain, and strategies used by the project team at Purdue and partners in expanding the distribution system and in increasing bag sales. The third phase of the study consisted of data analysis and reporting. A more detailed description of the methodology and country-by-country results are available in Coulibaly *et al.* (2012).

3. Results

The PICS project began in 2007 with the launching of activities in Burkina Faso and Niger. The experiences and lessons learned from these countries were used to refine the intervention and management strategies for the next countries. However, the approach remained the same across countries and consisted of three major steps including: (1) the identification of in-country partners including agricultural research institutions and national and international NGOs; (2) the selection of the manufacturer and the national distributors to manufacture and to distribute the PICS bags in the country; and (3) the recruitment of a business consultant to help distributors build up the distribution network and to linkup bags buyers to distributors to allow an efficient distribution of the bags.

In each country, the first year of the PICS1 project was the promotional year used to build up public awareness for the bags. The awareness building consisted of stimulating the demand for the bags through information campaigns using radio advertisements, posters, and village demonstrations. During the awareness building campaigns, the PICS in-country team selected five to six volunteer farmers in each village who were willing to store their cowpea in PICS bags. The volunteers were not allowed to remove the stored cowpea until an agreed date of opening the bags, typically within three to six months. On an agreed date (known as the 'open the bags ceremony') the villagers were assembled to open the stored cowpea. During the promotional year, other farmers who wanted to get bags were able to buy them at a price fixed by negotiation between the PICS project and manufacturers. Year two was characterized by the development of the supply chain and the scaling up of the project. The supply chain actors including bag manufacturers, national distributors, wholesalers, retailers, and volume buyers coordinated the mass production, procurement, and distribution of the bags to end users (e.g. farmers, grains and legume traders, farmers' organizations).

Four groups of constraints were identified across the supply chain: market constraints, logistics constraints, enabling environment, and social constraints. Constraints were prioritized according to their relative impact on one or more actors in the supply chain.

Market constraints

- Poor rainfall observed across countries in 2011 significantly reduced cowpea production and reduced demand for PICS bags. In 2011 the PICS technology was on a path toward adoption in almost all the project countries. A good rainfall in 2011 would have shown the demand for PICS bags since farmers were convinced of the effectiveness of the bags. PICS bags distributors had also projected high demand for that year. The excessive inventory of bags observed with distributors during this research is mainly explained by the poor rainfall. Better weather and crop forecasting by national and regional institutions could have helped improve the PICS bags supply chain management.
- Poor access to better and timely information as well as information sharing among bags distributors was another important constraint affecting the development of the supply chain. The lack of access to timely information for farmers such as where the bags were, and who were the closest distributors influenced the demand for PICS bags. On the vendors' side, poor access to timely information

handicapped profit-maximization and efficient allocation of resources especially the number of bags to procure from the immediate upstream actor in the chain. The direct consequence for the bags distribution was the localized disruption of bag availability, especially with downstream actors during the harvest, as was the case with FASO KABA, a PICS distributor in Mali, and with the regional distributors in Ghana.

- The initial focus of PICS market development on cowpea limited demand because it made the bags a niche product. Given the limited volume of cowpea produced and stored by each household, the number of bags needed per household often is only one or two. Marketing the bags for other grains and legumes from the beginning could have increased sales in early years. PICS2 showed the bags can be used for storing all types of dry grain and subsequent initiatives helped increase demand for the bags.
- The variability and high price of raw materials increased manufacturing costs – A high proportion of the PICS bag cost depends upon petroleum prices. This constraint was mentioned by PICS bag manufacturers in Mali, Ghana and Burkina Faso. Even though the manufacturers strived to keep prices constant to make the bags affordable to resources constrained farmers, this variation in petro-based raw materials prices is a potential threat for the development and sustainability of the chain.
- Low margins at the retail level along with the slow turnover of bag inventory raised risks, increased capital costs and discouraged downstream investments (Figure 1 and 2). Vendors reported that average retail margins were modest, especially given retailers’ inability to take advantage of efficiencies of scale and their high marketing cost they incur per unit sold. Evidence suggests that limited margins, particularly downstream, were influenced by price fixing programs implemented by project partners during the early years of the PICS project. To facilitate widespread adoption of the bags among cash constrained farmers, the retail selling price of the bags was set and advertised on radios and TVs. This reference price was used as a benchmark in subsequent years during trainings in villages and markets. Retailers from isolated areas were harmed because of their high transport costs and disproportionate low share of the revenue. The slow rate of sales and inventory turnover relative to other products increased the risks and costs of capital across the supply chain. Considering the slow turnover of PICS bags, private actors and agro dealers were less inclined to invest their own money in PICS business.

Figure 3 illustrates a rough analysis comparing different interest rates against three illustrative gross margins of PICS bags at the retailer level. A loan amount of 50,000 FCFA (or \$ 103.74) and a 6-month linear repayment period for the procurement of approximately 45 bags at a retail price of \$ 2.28/bag were used as key assumptions for the simulation. The analysis also assumed the financing of loan origination costs. The simulation indicates that at an average gross margin of \$ 0.21/bag, a retailer can only make a profit after full loan repayment at rates roughly 9% and below. All assumptions

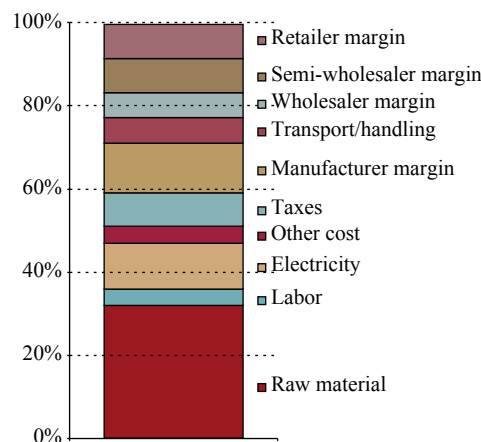


Figure 1. Supply chain cost structure.

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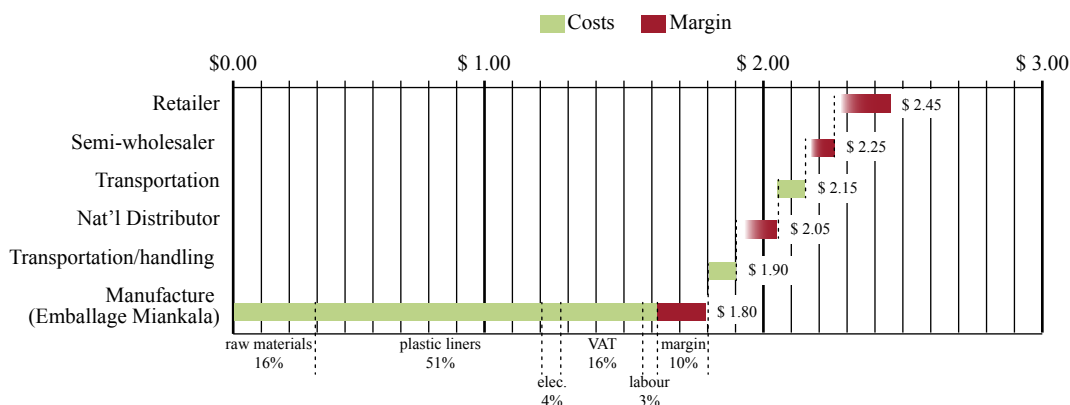


Figure 2. Supply chain margin/cost structure (per 100 kg bag).

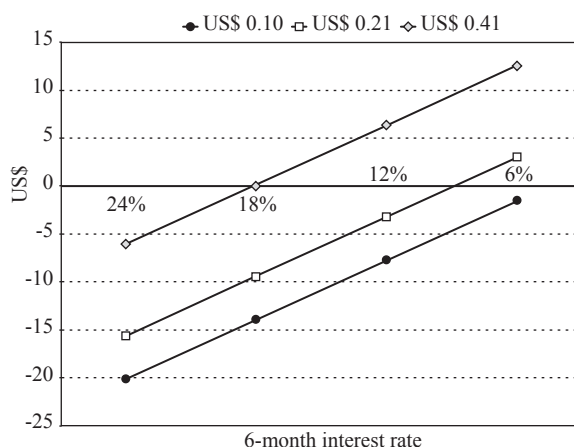


Figure 3. Gross margin vs interest rate (measured in six-month intervals).

being equal, if it were assumed that the retailer were able to turn over the capital once within the first 2 months, then at the average \$ 0.21/bag gross margin the retailer’s ‘break even’ point would be roughly 16%. Given the current status of the supply chain and prevailing borrowing rates, formal credit is not an option for most PICS bag vendors.

- The upstream payment defaults soured relationships with manufacturers and with the PICS project. Failure by some PICS distributors to fully pay manufacturing costs and/or repay loans and advances severely disrupted the growth and development of the supply chain in Burkina Faso, Ghana, Benin, and Togo. In Burkina Faso, the agreement between PICS project and the national distributor ended in 2010 because of the non-reimbursement of financing that the project provided to help him with his first order of PICS bags. Because of this unpaid debt, he was not able to order the bags in 2011 and there was an impasse in Burkina Faso’s PICS market. With increasing demand for the PICS bags and weak supply of official PICS bags in the market, the PICS manufacturer in Burkina Faso, FASOPLAST, decided to produce generic triple bags branded Sosso Boro. These bags were labeled with the FASOPLAST logos and the logo of the Burkinabé national agriculture research institute. The texture of the Sosso Boro inner liner was slightly stiffer than that of the PICS bags, but the thickness was equal (80 microns) to that of the PICS bags. The FASOPLAST bags were sold at a price lower than the PICS bags by \$ 0.10/unit. But FASOPLAST bags sold poorly because many customers noticed the lack of a PICS logo and considered them ‘fake’ bags, which could not be trusted to store cowpea safely. To overcome this situation, a new distributor was identified to sell PICS bags in Burkina Faso in 2011.

- Poorly adapted vendor networks (e.g. grain traders, farmers' based organizations) also hindered the development of the supply chain. This was the case of the farmer's association in Senegal and the Establishment Gansou (ETS Gansou) in Benin. Evidence suggests that the Senegalese farmers' based organization was poorly adapted to an effective and efficient distribution of PICS bags. This was largely because it has a socially-driven organizational mandate that allowed insufficient incentives to vendors. Most of the margins from bag sales were captured by the farmer organization and not by the individual vendors engaged in PICS bag marketing. In Benin the ETS Gansou network was designed to buy grain from aggregators at regional or district levels and supply to urban markets. The flow of products and services was in the opposite direction to that required for PICS bags distribution. In addition, there was a conflict of interest in Benin. ETS Gansou's business model was buying grain cheaply at harvest, storing it and selling it later at a substantially higher price. ETS Gansou was not motivated to sell a product which allowed farmers to store grain on-farm and capture much of that seasonal price change.
- Initial costs of investment in PICS technology vs those of more conventional storage methods discourages uptake among cowpea traders. Most volume cowpea buyers preferred relying on their traditional method of cowpea storage in woven sacks fumigated with pesticides like Phostoxin to control postharvest pests. This is due to what they perceive as comparatively high up-front costs of PICS technology. In addition to this initial investment, the extra labor cost associated with hermetic bagging of the cowpea discouraged trader use of PICS bags. On-farm PICS bags are tied with string or rope. Farmers usually have only a few bags and so time devoted to tying bags is not onerous. Traders often have thousands of bags, are accustomed to quickly sewing bags (usually with treadle sewing machines) and find tying bags to be very labor intensive. PICS bags cannot be sewn because sewing would puncture the liner and it would no longer be air tight.

Logistics constraints

PICS bags vendors reported logistics constraints which caused significant delays in the delivery of PICS bags to different outlets. The delays were often the consequence of a poor organizational and inventory management capacity. PICS experience supports the argument by Kelly *et al.* (2006) that donors should invest in upgrading the legal and market regulatory institutions, transportation and communication infrastructure that support agro dealers and that enable input markets to function. For instance:

- In Niger in 2010, there was a disruption in the supply of the PICS bags because of underestimation of the demand by the vendors. The production of cowpea in 2010 was characterized by an increase in area planted and production. The total demand of PICS bags estimated by the vendors before harvest was evaluated at 100,000 bags with a first order of 50,000 bags delivered at the beginning of harvest, but the second order was delivered very late, almost in December, because of the late payment. The delay in the bags procurement led to a break in the supply of PICS bags from October to the end of November. The delay was explained by the fact that some wholesalers did not pay their cash advance on time. Figure 4 illustrates the complexity of the PICS supply chain for Niger.
- In Cameroon, the local PICS distributor did not have shops or outlets in villages and therefore was unable to efficiently reach farmers and meet the demand for PICS bags in these villages. Field technicians sometimes were forced to take money from farmers and procure the bags for them.
- In Nigeria most of the PICS bags vendors in Nigeria are concentrated in the urban areas because of the poor transportation network to the rural areas. This raised the price of the bags to farmers and restricted availability of PICS bags in the rural areas. For example, the retail price of PICS bags depended on the distance and usually varies between \$ 1.80 and \$ 3.00 in the rural areas. Occasionally the price can go as high as \$ 6 per bag as was the case in the Maigatari area of Jigawa State.
- In Burkina Faso, one challenge was related to the high cost of transport and tax paid to import the bags from Nigeria to Burkina Faso. Because of the high cost of manufacturing in Burkina Faso, the PICS distributor chose to import PICS bags from Nigeria. These bags passed through Niger to enter Burkina Faso. From the Niger border to the warehouse in Ouagadougou, the transportation cost and other fees payment is evaluated at about \$ 20 per bale of 300 bags.

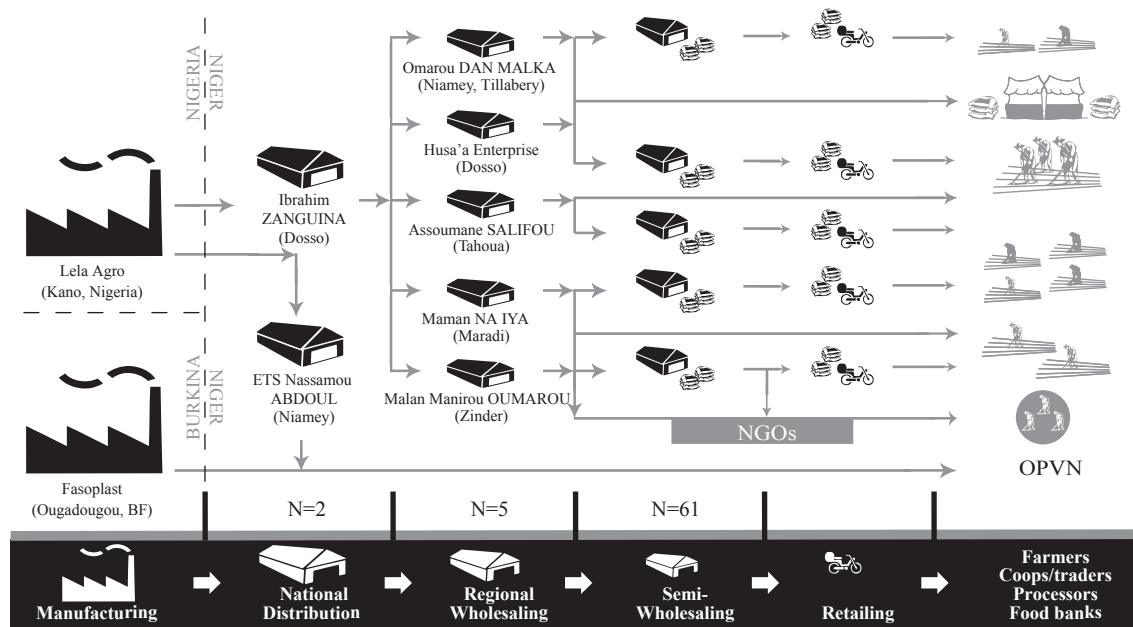


Figure 4. Organizational mapping of the supply chain.

- In Chad in 2011, the order of PICS bags from Nigeria was delayed because of lack of money to pay for the transport. The shipment of 15,000 bags was held at Maiduguri, Nigeria, and did not reach the distributor at Moundou in time for the harvest. Moreover, the 300 bag bales were too big to be handled by Chadian public transportation. To bring the bales at Moundou, the bags were repackaged in bales of 150 bags. This repackaging alone cost \$ 700 and the shipping to Moundou cost about \$ 45 per bale. The national distributor of Chad complained about the high transaction costs which include transport, repackaging, travel negotiate shipping arrangements, and communication fees.
- In Ghana the lack of coordination between the technical, promotional and supply chain actors was a challenge. In Ghana there were cases in which PICS radios and TV messages continued to be broadcast even though there was no bags available in the country. This was especially in 2011 when the national distributor could not order bags locally because of unpaid manufacturing bills from the previous year.

Enabling environment constraints

- In Niger in 2008 and 2009 a government food security program inflated prices at harvest and this discouraged on-farm storage. This program was implemented by the National Food Products Office of Niger (French acronym is OPVN). The stated purpose was to constitute a food reserve to be used during lean periods. OPVN purchased cowpea from producers in every region of Niger. It was purchased at a price of \$ 0.56/kg when the market price was \$ 0.27/kg. This cowpea was stored in the OPVN warehouses. Buyers of these stocks initially targeted were foreign government agencies (i.e. World Food Program) and private domestic buyers. This policy, even though it was popular among producers because it increased their revenues, discouraged farmers from storing cowpea for a higher price in the post-harvest period.
- The weak contract and regulatory enforcement mechanisms also hindered the development of the supply chain. Despite the formal agreement among the national distributors, the manufacturers and the PICS project, not all the bags pre-financed by the PICS project were reimbursed. As noted by Biggs and Shah (2006) input dealers are hampered by underdeveloped financial and insurance markets, weak public institutions for contract law and enforcement, and poor infrastructure. This was the case in Burkina Faso, Ghana, and Benin where the national distributors failed to comply with the terms of the agreements with the PICS project or the manufacturers. In Benin, the consequence was the

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deadlock of the supply chain while in Niger, another national distributor was selected to take over the distribution of the bags. In both cases, the nonpayment resulted in a breakdown in bag supply.

- The relatively high import tariffs/taxes on raw materials along with the price fluctuation of raw materials constituted a challenge faced by the manufacturers of PICS bags. All the manufacturers import raw material from South Africa, Europe or the Middle East. In Mali, the import tariffs at Malian border were estimated at 30% of the free on board cost while in Burkina, they were estimated at 46% of the raw materials cost. In Ghana, on top of the price fluctuation of raw materials the volatility of the exchange rate of Ghana currency (Cedis) in the market was another concern for the Ghanaian manufacturer. These fluctuations and tariffs increase the retail price of the bags.

Social constraints

There were some social constraints and belief systems evoked by the PICS supply chain actors which impeded the development of the supply chain to some extent:

- In Niger for instance, wholesalers mostly used their own financial resources to invest in the PICS business. Few took bank loans because their Muslim religious beliefs discourage paying interest rate.
- In Senegal, social considerations affected the development of the supply chain. Some farmers were reluctant to provide cowpea for the public storage demonstrations because they did not want neighbors to know their cowpea production, or because of perceived differences in social status. In some cases the field technicians were forced to do the storage demonstrations in their household compound with only their family members.

4. Management lessons learned

With the assistance of the BMGF, the PICS1 project pioneered investments across ten countries in West and Central Africa in the development of commercially driven supply chains for its innovative on-farm storage technology. The project tested various strategies designed to encourage investments by manufacturers and local, independent vendors to expand the PICS supply chain. There were a number of successes, yet progress across the PICS landscape was uneven. This study is an effort by the project and its partners to document and learn from the experience. The following is a list of key lessons learned based on a cross-country analysis of the ten case studies. Critical bottlenecks and notable achievements are highlighted along with some recommendations on how best to support the future growth and sustainability of supply chains for PICS bags and other agricultural innovations. Lessons learned include:

1. PICS bags are well adapted to smallholder farmer storage needs – The PICS triple-ply, hermetically sealed storage bags were designed specifically to meet the needs of smallholder farmers for affordable on-farm storage of cowpea. Evidence of strong and growing demand for PICS bags across the region suggests that the technology responds well to farmers' needs, offering them a compelling value proposition. Data also suggest that retail price does not significantly impinge upon the average farmer's willingness to invest his or her limited resources in PICS technology.
2. PICS bags are not as well accepted by large scale traders – The high, up-front cost of PICS technology relative to other conventional, chemical-based storage methods is a significant obstacle, and adoption has been relatively limited. This is especially true among high-volume traders who want to maximize their profits and who view storage expenditures as a sunk cost. Based on a rough comparison of initial costs and not taking into account the storage period, PICS bags are initially 80-90% more expensive per 100 kg of stored cowpea than the fumigation usually used by large scale grain traders. In addition, anecdotal evidence from Northern Nigeria, Benin, and elsewhere suggests that many cowpea traders view PICS technology as a threat to their business model, which includes insecticide sales. Nonetheless, growing health concerns about the use of pesticides for the storage of cowpea could in time increase the demand for untreated, chemical-free cowpea, and thus, the use of PICS technology among cowpea traders.
3. Incremental rollout was a good strategy – The PICS1 project benefited from a progressive rollout over five years (2007-2012) and ten countries. This step-wise expansion became a significant

learning asset and contributed to an ever-expanding knowledge base of best practice over time. As the project's geographical scope expanded into new cowpea producing countries, improvements in the project's design and approach were made based on notable successes and setbacks encountered and associated lessons learned from past experience. This allowed for a gradual refinement and validation of strategies, an evolution that becomes evident when looking at the experience across the entire PICS timeline. Future expansion into new cowpea production areas within the region as elsewhere will no doubt benefit from this existing knowledge base. Yet, market dynamics vary considerably from one place to the next. Any future expansion should thus be preceded by a comprehensive market study to determine potential surplus storage capacity, to identify manufacturers and other supply chain partners, to target major production zones, and to better understand the competitive landscape and market preferences (e.g. consumer, norms/standards), in addition to other information key to planning and strategy development.

4. Risk sharing needed for manufacturers and vendors – Investing in new technologies like PICS bags poses considerable risks for manufacturers, vendors, and other supply chain actors. Strategies are needed to help them address these risks via risk sharing, risk transfer or risk mitigation mechanisms. How to structure and finance the procurement also poses a significant challenge. The project's initial engagement in tripartite arrangements with manufacturers and vendors involved direct financial support for the procurement of PICS bags. This approach carried significant risks for the project. Such risks were beyond the scope of the project to manage effectively and led in some cases to considerable but temporary supply chain disruptions (e.g. Burkina Faso, Niger). Zero-risk or no-risk approaches such as 'guaranteed markets' (e.g. via the direct purchase of demo bags from vendors or use of vouchers) and cost-sharing of promotional activities offer alternative approaches that carry limited risk to the project, but may be effective in incentivizing private sector participation and investments in the supply chain.
5. What type of vendors sells the most PICS bags? – Full-line agro-dealer networks selling a range of complementary inputs such as seeds, fertilizers, and crop protection products can be effective distribution channels to get PICS bags into the hands of rural farmers; however, they are not the only game in town. Evidence suggests that alternatives such as mobile cell phone card vendors and school supply shops can be equally effective in marketing PICS bags. The most crucial qualities are that vendors' business model is appropriately oriented toward the provision of good and/or services rather than toward output markets. For example, the PICS experience in Benin and Nigeria suggests that grain traders' output market orientation and revenue model is in many respects inimical to the activity of marketing PICS bags. Many grain traders see the PICS technology as a direct threat to their business. In Niger and Togo, by contrast, successful vendor networks have piggy-backed on the channel distribution of mobile phone cards and school supplies.
6. Is there a public sector role in the PICS supply chain? – The PICS project worked closely with national research institutes and public extension services in all ten countries. These partnerships were vital to securing necessary local commitment and reaching farmers. Yet, while such institutions can be an effective way to expose farmers to the technology and broaden awareness, they do not constitute a viable long term distribution channel. Extension agents, in particular, are close to farmers and wield considerable influence over farmers' technology adoption and investment decision-making. Thus, the project worked closely in partnership with national extension services in most countries to facilitate local, 'last mile' distribution to farmers in rural areas on a consignment stock basis. However, widespread incidences of non-payment of cash collected from sale of consigned bags presented significant challenges to the supply chain's viability. In some countries, however, agents acting independently from the national extension service and sourcing directly from PICS bag vendors on an ad-hoc basis became effective mobile vendors of PICS bags at the village level. Scope exists to leverage extension agents more broadly as retail sales channels by facilitating direct relationships between individual agents and local PICS bag vendors.
7. Credit is not a key constraint, but low profitability for vendors and risk are – Lack of access to institutional credit does not in itself constitute a binding constraint to supply chain growth. Many vendors active in the PICS supply chain, particularly those operating upstream at the wholesale and

semi-wholesale levels, have banking relationships and are able to meet basic collateral requirements. However, high interest rates, the slow rate of turnover, and risk discourages vendors from using borrowed capital to finance their stocks. An analysis of borrowing costs indicates that at prevailing rates vendors would need to more than double their current sales volume in order to simply meet their loan repayment obligations. General distrust and lack of understanding about how banks work further discourages institutional borrowing, most notably among retailers. In such an environment, identifying ways to more fully leverage informal social capital already established within vendor networks is fundamental to supply chain development. Identifying ways to encourage wholesalers to sell PICS bags more broadly on credit or partial credit and on consignment stock could be explored. Vendor training to increase book-keeping, inventory management, and communications skills is one example.

8. First year reference prices have surprisingly long term effects – Reference price strategies designed to protect buyers and discourage market speculation can significantly dampen investment in the supply chain in subsequent years, especially downstream. In all countries, the project in collaboration with vendor partners identified a price ceiling at which PICS bags would be marketed to farmers the first year. This price was initially communicated to the market via promotional events and advertising. In many cases, these price targets carried over into subsequent years, orienting consumers around a target ‘benchmark’ price. An analysis of how margins are distributed across the supply chain in all ten countries suggests that upstream vendors (e.g. wholesalers, semi-wholesalers) capture (on a proportional basis) the vast majority of available margins, and this pattern is exacerbated under any reference price plan. Retailers have difficulty in securing sufficient margin from the sale of PICS bags to cover their marketing costs and make a reasonable profit from their activities. Facilitating open market price discovery after the first year is preferred. In particular, reference prices should not be part of the project supported advertising and promotional materials in the second and subsequent years.
9. Crop forecasts are key to timely availability of bags – Demand for PICS bags in any given year depends on the harvest, but manufacturers and distributors lack the information and tools to forecast inventory needs. In many cases, distributors waited until after harvest started to order bags. This contributed to delayed delivery of bags, debilitating ruptures in supply, and unsatisfied demand. Miscalculations of demand also led to costly ‘dead stock’ when poor and uneven rainfall in many areas contributed to significant declines in bag demand. The project addressed this challenge in part by facilitating yearly vendor meetings when supply chain actors meet up to discuss challenges and set up a procurement plan for the coming season. In order to strengthen the ability of vendors to procure and stock the right number of bags at the right time, further and deeper investments are needed in procurement and inventory management. Facilitating access among vendor groups to information from weather and crop forecasting agencies and public extension agencies that can help vendors better gauge planting acreages, expected output, and thus, demand for PICS bags is illustrative of such investments.
10. Trademarking the PICS logo was a useful step, but it is no substitute for patent protection – At the suggestion of PICS manufacturers and distributors, the project initiated the process of trademarking the PICS logo in 2009. The trademark provides one tool for the PICS supply chain to discourage substandard bags. Patent protection would have been an even stronger tool, but it was originally not pursued by the university and is no longer an option since the unpatented technology is already out in the public domain. Anecdotal evidence from Burkina Faso suggests that farmers seeing value in the PICS brand as a certification of quality are willing to pay a slightly higher price for PICS-branded bags over competing, lower priced products. Potential scope may now exist to leverage the PICS trademark via innovative licensing arrangements to safeguard PICS quality standards and encourage new investments in PICS bag production and distribution in the region as elsewhere.
11. Project business consultants played a key role which should be gradually shifted to the private sector – Beginning in 2007, the project recruited one or more local consultants in nine of the ten PICS countries to assist with supply chain development efforts. Input from stakeholders indicates that PICS business consultants have made a significant contribution to the project’s success in most countries.

Their role has focused on working with manufacturers and wholesalers to identify new downstream vendors and expand distribution networks, facilitate bag procurement and delivery, and increase bag sales. Given their important role, incremental cost-sharing arrangements with manufacturers and/or wholesalers should be explored to ensure an appropriate and non-disruptive exit strategy for the project and its funding.

To be competitive in today's globalized food markets, smallholder farmers need new and better technologies. Once developed, agriculture innovations need to be mainstreamed into the marketplace to make them available to rural farmers when and where they need them. In addition to reliable and timely delivery, affordability and accessibility are key. Availability in farm communities and access to information on their use are also critical to uptake. In order for innovations to have a positive impact on farmer productivity and income, supply chains must effectively get these tools to the right place, at the right time, in the right quantities, and at the right price. The PICS project provides important agricultural input supply chain development examples which should be the foundation for future improvements in seed, fertilizer, pesticide, and other farm input marketing in Africa.

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