Agricultural technology commercialisation: stakeholders, business models, and abiotic stressors – Part 1

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Abstract: A wide range of innovative technologies have emerged to facilitate the creation, expansion, and streamlining of food value chains (FVCs) in developing countries. These technologies target agricultural production, processing, storage, marketing, distribution, and consumption. Technology has the potential to bolster food security and make FVCs more efficient. Commercialisation of technologies requires sound business strategies for products to sustain. A typology of business models is presented to assist entrepreneurs in integrating their technologies into FVCs. The impacts of abiotic stressors like access to capital, supply chain resiliency, and ownership dynamics are discussed to help entrepreneurs develop strategies for their own agricultural ventures.

Keywords: food value chains; FVCs; technology; commercialisation; stressor; entrepreneurship.

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1 Introduction

Growth in the world population has increased demand for food and threatened global food security, which is characterised by the accessibility, usability, and availability of food. An array of other factors, including the worldwide expansion and changing dietary preferences of the middle class, urbanisation, diminishing natural resources, food price volatility, and inefficient labour and land use have exacerbated the problem (World Health Organization, 2012). Despite these challenges, the Food and Agriculture Organization (FAO, 1996) of the United Nations ascertains that our planet has the capacity to sustain the expanding population. This requires the optimisation of land use productivity in terms of labour, crop yield, water conservation, and waste reduction (OECD-FAO, 2011).

Global food security needs are currently being addressed through agricultural policies that focus on promoting more sustainable farming practices, reducing food waste and losses – one of the foremost impediments to food security – and fostering greater commercial and technical innovation in agricultural systems. Approximately one-third of the world's food produced for human consumption (1.3 billion tons) is wasted by consumers or lost along the supply chain each year (Gustavsson et al., 2011). In developing countries, nearly 40% of food losses occur after harvest and are caused by premature harvesting, unsafe handling and processing, a lack of processing capabilities, or poor storage facilities (Ibid). Sub-Saharan Africa alone suffers from almost $4 billion of post-harvest grain losses every year. If effective processing and storage technologies could be utilised to prevent these losses, the saved food would have the potential to feed 48 million people (World Bank, 2011).

Improving land use productivity and reducing food waste can be accelerated by the adoption and use of agricultural technologies that improve the processes comprising food value chains (FVCs). These processes can be divided into the following phases: agricultural production, processing, storage, marketing, distribution, and consumption. There are 3.7 billion people in the world today that earn US$8 a day or less, 70% of who depend on agricultural activities for their livelihoods (World Economic Forum, 2009). Successfully tapping into the smallholder market with affordable technologies fosters the growth and sustainability of FVCs. Numerous businesses, non-profit organisations, and academic programmes have emerged to develop innovative technologies that both improve the livelihoods of farmers and promote food security. Yet these entities face enormous obstacles as they attempt to put their products in the hands of people who need them most (Contractor and Lorange, 2002). These challenges can be financial, socio-cultural, environmental, or political in nature. They manifest in different forms depending on the geographic and cultural context of the customer base. One way to overcome these challenges is for technology entrepreneurs to develop, pilot, and refine business models until they identify a series of successful strategies for commercialisation that are resilient, sustainable, and scalable in particular regions and nations.

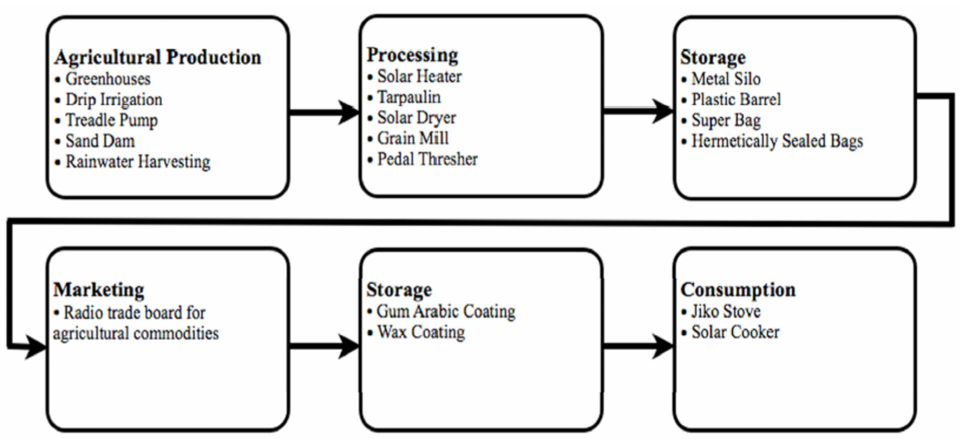
A typology of business models for the commercialisation of agricultural products and services can help entrepreneurs identify potential partners, develop business strategies, and consider different methods of market insertion and growth (Copley et al., 2013). In this article, the viability of each model is assessed based on its resilience in a FVC. Before an entrepreneur chooses a business model, he or she must conduct the due diligence to determine which model is most likely to succeed. These business models can also be combined or pursued in parallel to best suit the needs of the entrepreneur. Each of the models discussed in this paper is uniquely suited to accommodate different stressors within a FVC. Stressors are defined as elements of pressure that act upon a FVC, either reinforcing or mitigating value along the chain. Some examples include socio-economic issues, stakeholder relationships, and environmental impacts. Evaluating these models relative to strengths, weaknesses, opportunities, and threats in response to a series of stressors will inform the entrepreneur's decision making process and devise sustainable business models that strengthen FVCs and improve livelihoods.

2 FVC technologies

2.1 Agricultural production

There are many technologies that can improve the timing, quality, and yield of agricultural goods including greenhouses, drip irrigation systems, treadle pumps, sand dams, and rainwater harvesting systems (RHSs). For example, low-cost greenhouses allow farmers to control the temperature, light, and harvest cycle of plants and enable them to grow crops year-round (Pack and Mehta, 2012). When paired with drip irrigation systems, greenhouses can reduce farmers' water consumption by more than 30% (Shock, 2006). Treadle pumps, RHSs, and sand dams also assist in securing water for crop cultivation. This is particularly important in semi-arid and arid climates where food scarcity is especially acute and a successful crop depends on economising water. RHSs and sand dams also assist in securing more water for crop cultivation. While RHSs collect water from roofs, roads, and temporary water sources to store for future use, sand dams collect water by extracting it from dams built across seasonal river beds (Excellent Development, 2012). All of these technologies help farmers optimise their production to meet consumer demand for agricultural products.

Figure 1 Simplified FVC with examples of relevant technologies



2.2 Processing

Processing occurs when raw agricultural materials are altered into new, more valuable states (International Assessment of Agricultural Knowledge, 2009). Post-harvest processing technologies reduce the risk of food spoilage by extending the shelf life of products. Applying heat, replacing natural raw ingredients of food, and using aseptic packaging are all methods of increasing shelf stability. This increase in value allows farmers to extract higher rates from their customers (World Bank, 2011).

Solar dryers, grain mills, pedal threshers, small-scale rice drying, tarpaulins, and solar heaters are all examples of processing technologies. Solar dryers are a fast, safe way to trap heat from the sun and evaporate the water inside of food (Gregoire, 1984). Tarpaulins made of polyester or polyethylene are used to dry maize and other goods on the ground or hanging from a rope (Nandudu, 2011). Solar heaters for grain made from plastic or corrugated galvanised iron are held down to the ground with rocks, allowing their hot micro-climate to reduce moisture; this process mitigates both mold growth and insect infestation (World Bank, 2011). Processing can increase shelf life, reduce post-harvest waste, improve nutrition density, increase fibre and phenol antioxidant content, and reduce the volume and weight of the food (Vinson et al., 2005).

2.3 Storage

Storage of agricultural products is essential after processing. Technologies that enhance food storage protect food from pests and moisture and provide a means of safe preservation for long periods of time. Insect pests and grain pathogens are responsible for ruining 20%–30% of grain if kept in traditional storage granaries made from dung, sticks, or mud (Tafera et al., 2011). These technologies include hermetically sealed bags, super bags, plastic drums, and metal silos. For smaller storage solutions, hermetically sealed bags are triple-layered to protect against insects. Larger super bags made of polythene material act as liners inside of traditional woven grain storage bags (World Bank, 2011). Super bags can be designed to hold up to three tons of grain with a gas barrier that restricts oxygen and water vapour from entering. Plastic drums can also be used as granaries. These storage methods significantly improve grain shelf life by providing protection from pests and moisture (Ibid). Metal silos can also help farmers protect their grains from pests and reduce post-harvest waste as well as provide local employment opportunities, since they can be constructed by artisans using locally available materials and well-known construction methods.

2.4 Marketing

Food marketing is the process that connects agricultural goods to consumers. It encompasses a variety of tasks integral to successful FVCs, such as making investment decisions, utilising institutions, managing resource flows, and engaging in physical and business activities (Jaffee and Gordon, 1993). Technologies that enhance food availability and consumer education serve to improve logistics for farmers, vendors, and consumers, leading to more efficient FVCs. Marketing technologies must provide suppliers with information to help them market their goods more strategically. The use of mobile technology has immense potential to provide educational opportunities in rural regions of underdeveloped countries. For example, cell phones have been used to provide real-time conditions regarding weather, soil, pests, and diseases for smallholder farmers in rural India (Patel et al., 2010). In Kenya, the Kenya Agricultural Commodities Exchange (KACE) provides farmers with market price information to help them decide where and when to sell their crops. KACE provides this information via radio, phone, and resource centre, helping to minimise transaction costs between all agricultural stakeholders (Mukhebi et al., 2007).

2.5 Distribution

Distribution in FVCs consists of physically getting agricultural products to the consumer. Technologies that aid this process can reduce food waste and facilitate transport, providing increased access to agricultural products for consumers. For example, cold chains are the ways in which temperature-sensitive food gets from the producer to the consumer so that it does not perish in the process (Rodrigue et al., 2006). There are various technologies that keep food refrigerated such as gel packs, dry ice, quilts, reefers, and eutectic plates. Reefers are refrigerated shipping containers used to carry food between countries (Ibid). Other methods of preventing food waste during transportation are wax coatings on produce, polyethylene packing, and applying gum Arabic to fruits to prevent oxygen and carbon dioxide from causing it to age. The coating is edible, water soluble, eco-friendly, and can be made from acacia trees (Ali et al., 2010).

Distribution strategies that support local sourcing of produce can drastically reduce reliance on imports, allowing communities to save money and boost local agro-businesses (World Economic Forum, 2009). Further, when companies partner to distribute bundles of products from many different suppliers, distribution costs are minimised. Cereal banks are local community warehouses where farmers bring their grain immediately after harvest and are paid for their contributions. Then when grain is scarce in the community, it is sold from the warehouse at below-market prices (World Bank, 2011). This shortens the distance that people have to travel to purchase grains, and makes grains affordable when external prices are high.

2.6 Consumption

Consumers have a direct influence on supply and demand in a market, which affects the actions of other key players in the FVC, even though they do not directly partake in the FVC processes (Hawkes and Ruel, 2011). Certain technologies and marketing strategies have been created to assist in more nutritious and healthy food consumption (World Economic Forum, 2009). Solar cookers, fireless cookers, ceramic stoves, and biogas digesters are technologies that provide the consumer with a safer cooking environment while decreasing fuel costs. Solar cookers are stoves designed to trap heat from the sun with reflectors using metal sheets (Cuce and Cuce, 2013). They enable people to cook without wood or charcoal, saving forests from logging and providing safety to women who have to walk long distances to find firewood for cooking. Fireless cookers are low-cost devices that are used as a secondary form of cooking. They can be used for food preparation or to keep food warm for extended periods of time, with the potential to reduce waste and alleviate smoke (Okello, 2009). Ceramic Jiko stoves are another technology that aid in food consumption. These stoves are portable, more eco-friendly than open-fire cooking, and can reduce fuel expenditures for a family by 18% over a five-year period (Vaccari et al., 2012). Farmers who have significant amounts of animal waste can utilise anaerobic digestion to produce natural gas for cooking. Low-cost biogas digesters eliminate the need for charcoal, leading to a substantial reduction in environmental and health impacts from cooking (Mehta and Mehta, 2011).

3 Challenges to technology commercialisation

Even though a variety of technologies have been developed to improve each phase of a FVC, many of these technologies have failed to reach the target customer segments. Traditional dissemination methods such as donating technologies to developing countries have not been consistently successful since donors often overlook how the technology will fit into the specific social, political, geographic, economic, and cultural context of its users (Polak, 2008). If the technology's design is inappropriate for the context and the product fails to create value for the user, the user will not continue to utilise or promote the product within his or her social network, especially when the user feels no sense of ownership over the donated product. Additionally, the user will not invest adequate time, labour, or money in maintaining the product and it will ultimately be abandoned (Conley and Udry, 2003).

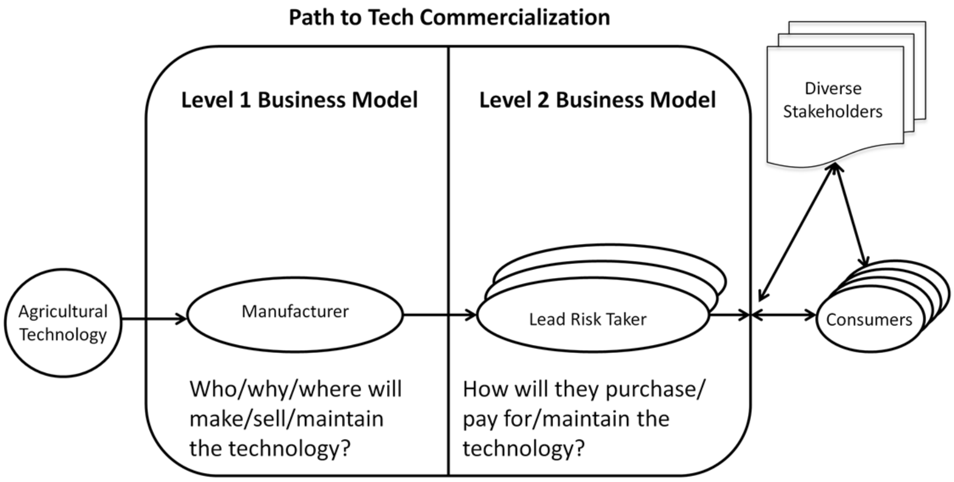
Commercialisation has proven to be a more successful method for technology dissemination because of the sense of ownership that stakeholders have in the technologies they purchase (Polak, 2008; USAID, 2011). If the user identifies a clear business model for generating profit from the outset and the technology yields successful results, the user will want to capitalise on its economic value and continue operating and maintaining the technology. Nonetheless, commercialisation still has its own unique challenges that can impede and disrupt nascent technology ventures. Many ventures do not wish to invest the time and capital into designing, researching, validating, and manufacturing products to meet consumer demand in a developing country context (London and Hart, 2004). These ventures may also doubt whether their standard business models will be profitable in an environment where uncertain economic conditions, weak governance, and poor infrastructure pose significant risk to fledgling businesses (World Economic Forum, 2009; USAID, 2011).

Several stressors along the FVC can impact the success of commercialising technologies. It is vital to address these stressors when developing a business strategy, as most occur outside of the realm of the manufacturing facility. For instance, poor economic circumstances in rural areas lower the profit that a farmer can receive from value addition. Agro-ecological heterogeneity also may require regional design changes for certain products (Jack, 2011). Implementation of a disruptive technology could be met with cultural resistance that can best be addressed with localised manufacturing, partnerships with community groups, and sufficient marketing. For example, fireless cookers that were introduced to western Kenyans were met with resistance due to the high cost of their insulating material and poor contextual marketing. When a workshop was conducted where women were able to bring their own designs and use local staple foods for demonstration purposes, the stigma against this product was greatly reduced (Okello, 2009). In essence, product design, implementation strategy development, and steady-state business strategy development must be undertaken in a concurrent and integrated fashion.

4 Business models for technology commercialisation

Typically, an entrepreneur will enter a new market by manufacturing a product and selling it at a higher cost to reap a profit. During this process, he will efficiently and effectively manage cash flow, engage in marketing activities, and provide after-sales support and maintenance. This process is fairly linear for low-cost products that can be easily purchased and owned by individuals or businesses. The entrepreneur will develop a business model for this enterprise to function effectively and profitably. However, several of the technologies discussed in this paper are too expensive for smallholders to buy outright in an independent fashion. For example, a solar dryer manufacturer hoping to expand sales to rural areas will find difficulty reaching customers who can afford to purchase their product without a financing plan. For the technology to reach the intended customers, a second-level business strategy must be developed. This model must, from the customer's perspective, explicitly delineate how they will buy, profit from, and sustain the product. It must also explain how capital costs will be recovered, and how profits or losses will be shared amongst partners. The two-level business model conceptualisation addresses this need for detailed business models of collective ownership (Mehta and Mehta, 2011). Collective ownership models might be employed for the entire lifecycle of the product or only initially, as one individual may acquire all equity overtime. The second-level business model may also address other stressors that impact the success of commercialisation, such as providing capital, supply chain consistency, or finding new markets and sales channels.

Figure 2 Two-level business plan



The two-level business plan is founded on the premise that equity from and between all stakeholders in a venture will yield the most successful results (Ibid). It prevents social tensions from arising and affecting the use of the product, while promoting pride and ownership over the product and increasing the likelihood of its maintenance. If the entrepreneur cannot propose a practical level two business plan, he might not be successful in engaging his customers and increasing his sales and profits. For example, an entrepreneur who develops an innovative solar dryer and wishes to enter a new market must first establish local manufacturing operations or establish a partnership for manufacturing, assembling, or importing the product. The entrepreneur (and manufacturer) will develop a business model that delineates how the product would be manufactured, distributed, and sold, how revenues would be utilised, how costs would be minimised, and how customer relations would be maintained from awareness to after-sales support services. These activities would constitute the level one business plan for the venture. Osterwalder and Pigneur's business model canvas provides a compelling framework for developing this business model.

Next the manufacturer would consult with diverse entities to determine how the solar food dryers could reach their target consumers. The consumers might lack access to capital to purchase the solar dryers, lack market linkages for dried food products, or have difficulties sourcing high-quality produce for drying. The manufacturer must develop and validate business models that demonstrate how diverse entities can collaborate to reap benefits from the solar dryer. These business models must be developed from the consumer's perspective with clearly articulated flows of money, value, and agricultural products – raw and processed. For example, one model could involve marketing agencies purchasing large numbers of solar dryers and leasing them to farmers in rural areas to dry their produce on site. Another model might revolve around financing agencies providing low-interest loans to farmers to purchase solar food dryers with a marketing agency partnership guaranteeing the purchase of processed (dried) food products. A third model might involve a farmer's cooperative purchasing several solar dryers and renting them to members at a low-cost. The manufacturer must analyse these different multi-stakeholder models in the backdrop of the contextual realities. These consumer-centric concept-of-operations are referred to as the level two business models.

Level two business models are extremely varied because they depend on the unique characteristics of the manufacturer's product as well as the established modes of generating revenues and providing services. The manufacturer can choose to establish business relationships with a wide array of actors including agro-enterprises, community centres, cooperatives, marketing agencies, micro-loan institutions, local governments, NGOs, informal lending systems. These institutions act as the initial customer and help the manufacturer to access the end-user consumers. Typically one institution will act as the lead risk taker with others playing supporting roles in the value chain. Each of these partners has its own specific motivations and desired outcomes for its engagement in the venture. These motivations and expectations must be clearly articulated and validated to make the venture successful. If the manufacturer is not able to demonstrate how these multi-stakeholder systems would work, the business venture is unlikely to be successful.

The manufacturer must consider the impact of relevant abiotic stressors on the business model. An example provided by many farmers in Kenya is the Amiran Farmer's kit. This kit includes the installation, training, and continued agro-technical support for an 8' × 15' greenhouse. By providing training and extended support, Amiran alleviates several stressors related to a farmer's ability to maintain and optimise a product. Amiran has partnered with the Kenyan government to showcase these kits at farm shows and vocational institutions to boost marketing and enhance reputation of its product. However, this kit is cost prohibitive to smallholder farmers with limited income. Amiran does not directly provide any method of financing, which has limited their customer base. However, they have developed partnerships with financing agencies to facilitate access to capital.

A manufacturer should consider how consumers will access capital in order to broaden its potential market share. The strategy of the manufacturer must also be dependent upon the characteristics of each individual product. More mobile products can be shared or rented. Complex products may require customer training or a separate entity to operate. Supply chain resiliency is another stressor that greatly affects the commercialisation of a technology. Seasonal goods must be treated differently than those that grow year-round. Weather can greatly disrupt road conditions and halt less developed supply chains. The regional availability of the value-added market is also important to consider. These value-added goods may even need to be sold in entirely different markets from the original goods, potentially by leveraging export markets.

This paper presents a typology of level two business models that would enable the integration of agricultural technologies into FVCs. A case study of how each business model could apply to a hypothetical solar dryer manufacturing enterprise is discussed.

We describe how certain abiotic stressors impact the viability of the business models and implicate the manufacturer, customers, end-users, and other supporting entities. This typology will help inform entrepreneurs on possible strategies for creating economically sustainable and socially equitable technology-based ventures in developing countries. The overarching goal is to develop win-win propositions for all stakeholders connected to FVCs in a manner that optimises the FVC and makes it more sustainable and equitable.

Table 1 Commercialisation stressors by stakeholder

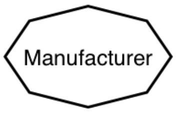
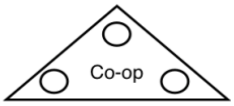
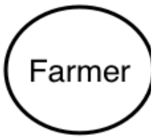
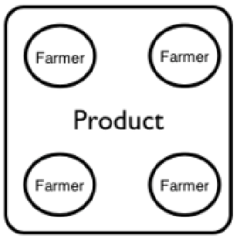
Stressors on manufacturer	*Stressors on risk takers*	*Stressors on customers*	*Stressors on diverse stakeholders*
• Product characteristics a Complexity b Durability c Mobility d Popularity e Contextual appropriateness • Product marketing • Product scaling • Product supply chain resiliency	• Trust and social capital • Supply chain resiliency of goods • Product marketing • Product scaling	• Access to capital • Collective ownership • Trust and social capital • Supply chain resiliency of goods	• Trust and social capital • Rural-urban migration • Environmental impact

Data regarding these stressors was refined over three years of developing and commercialising various agricultural technologies in East Africa. From May through July 2012, primary data was collected from detailed interviews with over 100 stakeholders (including farmers, vendors, and traders) from various regions of Kenya. Their concerns regarding a FVC were organised using social-technical-economic-environmental-political (STEEP) criteria. A model was constructed of the FVC with feedback loops utilising a systems thinking approach in order to better understand the relationship between the listed concerns and how they impact each stakeholder (Meadows, 2008). This system was then evaluated for each level two business model, where commercialisation stressors were identified.

5 A guide to the typology

The following typology is comprised of business models that demonstrate how a manufacturer can best collaborate with different actors to install, sustain, and scale a technology-based venture. The typology proposes a series of strategies designed to maximise the success of a venture and then classifies these strategies based on the most prominent actors in the model. This serves to provide some clarity and structure to the vast number of diverse strategies that can be employed to commercialise agricultural technologies. These models can be combined in various ways to yield richer and more equitable multi-stakeholder models. As a reference, the manufacturer is the originator of the technology and is the entity trying to develop level two models that can be sustained by the marketplace. The manufacturer seeks customers to purchase its products, and then must work with these customers to find consumers who are the ultimate users of the products. While the business models may generically refer to the end-user of the technology as a ‘farmer’, the end-user could be engaged in any other role – value addition, distribution, storage, depending on the nature of the technology product in question.

Table 2 Relevant stakeholders

Stakeholder	*Symbols*	*Explanation*
Manufacturer/ technology firm		The manufacturer’s role is to build products for profit, create partnerships, and form business relationships with entities that will help to sell its product and maximise product demand.
Agricultural venture		The agricultural venture adds value to agricultural products and monetises them by generating revenues as an agriculture-based enterprise.
Cooperative		The cooperative pools resources and invests in new technologies to improve the lives and livelihoods of its members.
Farmers		The farmers identify markets to sell their goods and use value-addition products to enhance their profits.
Informal group		An informal group joins farmers together to achieve a common purpose (with no legal obligation and minimal start-up costs).
Marketing agency		A marketing agency sources products, identifies optimal markets, minimises transportation and storage costs, and generates revenue through commission.
Financing agency		A financing agency provides loans for upfront product costs and makes money from the interest.
Partner company		A partner company works with the manufacturer to establish a for-profit enterprise.
Training/ vocational institution		A training/vocational institution provides training to individuals interested in acquiring specific vocational or agricultural skills.

In other words, let us assume that a company comes across an innovative solar food dryer technology. This technology may have been licensed by a larger organisation, developed by an educational institution, imported from a different market, or designed and manufactured internally. This company is now the manufacturer trying to develop different level two business strategies for the various stakeholders to convey the potential of their solar food dryers. This typology is a reference for the solar food dryer company in its quest to enter the marketplace or expand their share. These scenarios are not supposed to be replicated by manufacturers since every operating context is diverse and necessitates an independent and comprehensive analysis. At the same time, the scenarios provide a pliable medium for the manufacturer to bring back diverse considerations into its own venture. To further explain what types of entities are involved in these models, this section will briefly define the actors included in the business models and describe their motivations and goals for developing a technology enterprise.

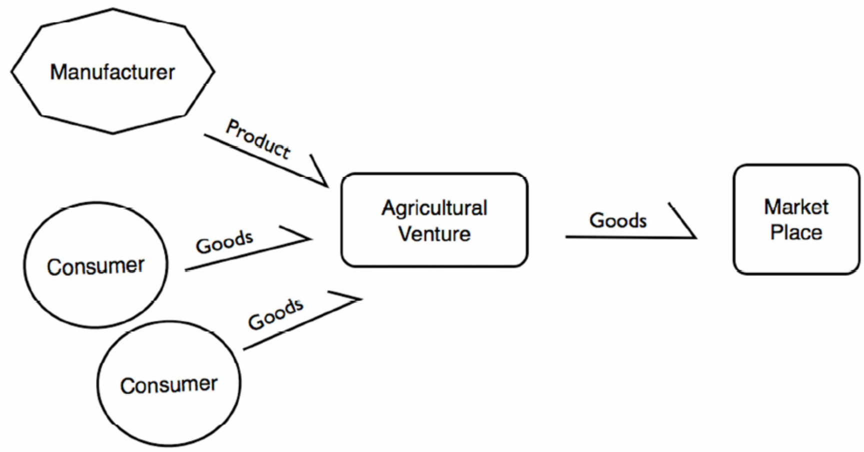
Table 3 Other potential stakeholders

Stakeholder	*Explanation*
Community centre	A community centre provides goods or services to improve the standard of living in a specific community.
Local government	The local government generates revenues, establishes food security, and increases employment for a community.
Micro-loan institution	A micro-loan institution provides loans and makes money from interest.
National government	The national government generates revenues, establishes food security, and increases employment for a country.
Non-governmental organisation (NGO)	An NGO provides goods or services to advance a specific cause, minimises costs, maximises the impact of a product, and typically has a subjective mission to create a specific social impact.
Rotating savings and credit cooperative (ROSCA)	A ROSCA is an informal structure to help people access capital periodically.

6 Agricultural venture model

- the manufacturer sells the product(s) to the agricultural venture
- the agricultural venture uses the product(s) in its business operations that relate to the FVC
- the agricultural venture typically buys goods from farmers, adds value and sells it in the market place
- this model requires an agricultural venture with enough capital to purchase the product(s) and directly market its processed foods.

Figure 3 Agricultural venture model diagram



6.1 Example

An agricultural venture purchases 50 solar dryers from the manufacturer. It also purchases vehicles to transport raw goods from farms to the company's factory/warehouse and ultimately to the market. Once it contracts enough suppliers of fresh produce, it begins drying the goods to sell in the market. As it refines its business operations, it can scale up by contracting more suppliers and purchasing more solar dryers from the manufacturer. The agricultural venture has its own (easy access to) capital and the manufacturer does not need to pro-actively work with the manufacturer to make the level two business model work.

6.2 Access to capital

This is the most basic model of technology commercialisation because it involves the manufacturer selling a product outright to an agricultural venture that will then use the product in its operations. In contrast to the rest of the models, this model is focused on ventures that have the capital outlay to directly invest in the manufacturer's technology. Since agricultural ventures usually engage in processing-related activities, they might also purchase goods from local farmers and then sell it in the market place. The agricultural venture therefore manages quality control, marketing, shipping of goods, etc. The agricultural venture is constantly looking for goods so that it can process and sell them. Therefore, it might be inclined to incentivise farmers to supply year-round. This model works well with products that require high capital costs but have large profit margins compared to the raw goods. For example, mango juice is significantly more profitable than mangos sold on the open market. However, the capital costs of industrial juice-making machinery are high and quality control is a must. A cold chain might be necessary and hence a centralised manufacturing facility would be most appropriate. An independent venture with sound financial backing would be able to alleviate several stressors while creating value for the mango farmers as well. It is fairly common to find such high-capital organisations to be completely or partially owned by the government.

6.3 Supply chain resiliency of goods

This model is also suitable for products that add value by improving distribution networks. Transporters can struggle with heavy rains, leaving them trapped at a farm for long periods of time, delaying their shipments and causing significant losses. For example, mangoes have a very short shelf-life and mango juice requires cold-storage transport. A stronger supply chain network organised by an independent entity could utilise bulk transportation, supply chain management, and dedicated marketing to decrease price volatility due to road conditions and increase access to optimal suppliers.

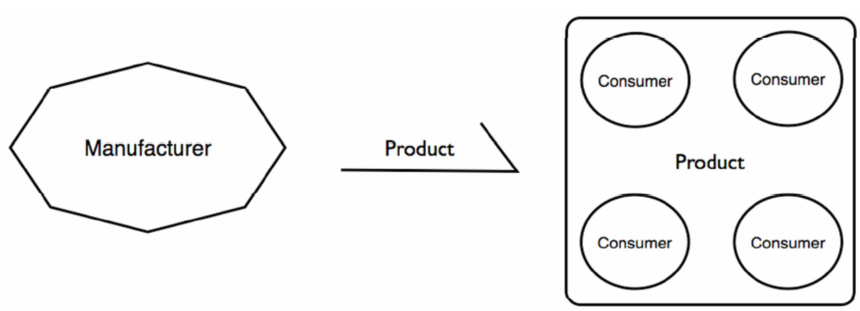
6.4 Product characteristics (complexity)

This model is a good choice for products that may be too complex for individual stakeholders to operate without significant training. The agricultural venture would be able to afford dedicated and trained staff for maintenance of the product, reducing the need for the manufacturer to train individual users. An example might be a large-size sunflower-seed oil electrical generator, which is a complex device that involves significant maintenance. An agricultural venture would have the capital and on-site support to ensure that this electrical generator is functional at all times.

7 Informal group model

- The manufacturer sells the product(s) to an informal group of farmers.
- Farmers share the product(s) equitably based on the amount of capital they have invested in the product(s).
- One individual in the group will be in charge of routine maintenance. Others will compensate for that labour by giving the individual additional use of the product. This job can rotate among the group so that every farmer has the opportunity to fulfil this role.
- Farmers can use the product(s) to complete their FVC activities and earn profits.

Figure 4 Informal group model diagram



7.1 Example

Four farmers who have lived in the same community for years decide to collectively purchase a single solar dryer. They equally share the initial cost of the solar dryer and take turns using it throughout the harvest seasons. Although these farmers were willing to invest in a solar dryer together, they find it difficult to share the dryer during certain seasons of the year when many crops are harvested and need to be dried at the same time. They also have trouble deciding who will fix the solar dryer when it breaks, especially if multiple parties are to blame for the damage. The lack of an effective coordination and maintenance plan for the solar dryer leads to social tension within the group. With the additional revenue generated from the solar dryer, the farmers might consider purchasing more solar dryers to facilitate sharing and prevent strains on their relationships.

7.2 Collective ownership/product characteristics (mobility, complexity)

In areas where different stakeholders live and work very closely to one another, it is natural for groups to self-organise in support of one another and their ventures. They will often share best practices, market information and even tools or machinery to facilitate their work. A farming tool, like a scythe or new plough technology, would be much easier to share than an infrastructure product like a greenhouse or drip irrigation system. The geographical distance between partners at the agricultural production phase may make sharing difficult, especially under adverse weather conditions or high-demand periods.

7.3 Trust and social capital

When these groups are created, they there are typically no legal entities or contracts that dictate how they must cooperate with one another. An operating structure evolves from the social dynamic of the group to promote mutual gain for all members. At the same time, the fact that no legal agreement binds the group together enables a member to take advantage of the group with no legal repercussions. It is very important that members trust one another before they start an informal joint venture. This model would be well-suited for products related to distribution as long as transporters operate in the same markets. This would allow them to frequently interact with each other to make collective decisions regarding maintenance and sharing details. For example, transporters can take turns using reefers, a cold-storage technology, to transport quickly perishable goods (Rodrigue et al., 2006). When they return to the market they will be accountable to the other members of their group. Problems could arise since these partners are direct competitors. The trust between members must contend with their competitive nature. This is an important note for the manufacturer, as social issues that arise from the implementation of a product have the potential to create a permanent negative stigma. For example, interviews with over 100 consumers have indicated an overwhelmingly negative attitude towards greenhouse tomatoes, with claims that they have significantly reduced quality and short shelf lives. These characteristics are applicable only to one of the earlier seed varieties used in greenhouses. While new varieties are being used that alleviate these concerns, the stigma associated with these tomatoes will be much more difficult to remove.

A manufacturer may have an easier time marketing a product to a small informal group of retailers. Retailers typically have strong relationships with each other, are often in the same location, and sell similar products. This would allow them to share a value-added storage product with ease. Interviews with over 60 retailers in several markets in Kenya have shown that wastage at the market is the most important factor in turning a profit. This waste can be caused by a lack of demand, volatile prices, or produce quality. A manufacturer selling low-cost storage units could seek out a small group of produce retailers who would be willing to pool resources to purchase the product. Since they work in close proximity and typically have strong social relationships, they would be more easily able to share until their increased profits allow them to purchase individual units. This low-cost, easy to share solution would allow the manufacturer to access a dense and socially-connected client base. Product success among a small group of retailers could very quickly lead to utilisation by entire markets.

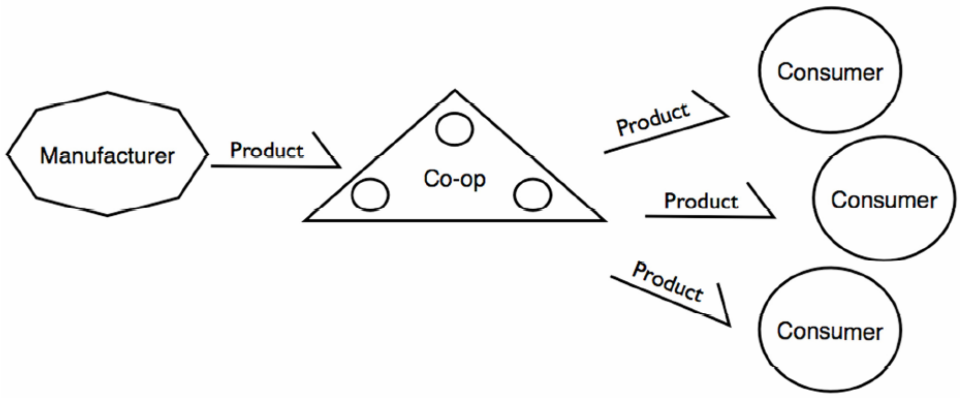
7.4 Value-added market availability

Despite an informal group's interest in purchasing agricultural technologies, a manufacturer would find it more difficult marketing their product to this audience as opposed to a more structured organisation. Informal groups will likely begin using a product as a result of successful branding and word-of-mouth marketing, requiring the benefits of the product to be well-known and sufficiently advertised. This model will work best if the primary innovation of the product is cost-savings of a previously successful product, allowing smaller stakeholders access to a market they previously could not afford to participate in. This model would also be suitable for virtual products that may relate more to marketing than physical changes to the product. An example would be a smartphone application that provides agricultural information and real-time pricing to farmers and helps them increase profits. The web developer could sell this application on a per-phone basis. As farmers begin to rely on this information, they will be more inclined to purchase personal access to garner competitive advantage by having this information always available.

8 Cooperative model

- The manufacturer sells the product(s) to the cooperative.
- Farmers rent the product(s) for a certain number of days. The cooperative charges its members a low rental fee to use the product(s), whereas it charges non-members a higher rental fee.
- The cooperative pays for routine maintenance on the product(s) out of its own budget. Farmers are charged a penalty for damage due to negligence.
- The farmers are solely responsible for all profits and losses associated with their use of the product(s).

Figure 5 Cooperative model diagram



8.1 Example

Farmers affiliated with a cooperative grow tomatoes for the local market. The cooperative purchases 50 solar dryers from the manufacturer. Since the cooperative purchased a bulk order of solar dryers, it was given a ten percent discount off their total cost. The farmers then use the cooperative's dryers to dry tomatoes for personal consumption or sale at the local market. Farmers that are part of the cooperative can rent and use these solar dyers at a discounted rate (or for free) while other farmers who are not part of the cooperative may use the solar dryers at a higher price. These rental fees supplement the cooperative's membership dues, providing it with funds to maintain the current solar dryers, invest in future solar dryers, or purchase new technologies that complement the solar dryers.

8.2 Collective ownership

Similar to the informal lending model, the cooperative model shows how a group can work together to collectively own and manage a product. Yet those in the cooperative differ from the informal group because the members of the cooperative work within an official framework that ensures equitable asset-sharing. Unlike the informal group model, which evolved from social ties, the cooperative is equipped with formal mechanisms that prevent members from monopolising or abusing group assets. So while members of an informal group might be able to borrow an asset for longer than they have requested at no additional cost, members in a cooperative will have to adhere to the cooperative's rules if they wish to reap its collective benefits. While rules are formalised, the relationships between members are much less developed than in the informal group model, which could intensify social dynamic issues. This could manifest if the product has limited time spans of profitability. For example, a solar dryer for tomatoes may only be profitable for a few months each year. Tensions are more likely to arise when sharing the dryer if the members are not socially accountable, as they would be in the informal group model.

8.3 Trust and social capital

The formation of the cooperative provides a formal organisation that has potential for marketing value-addition. These cooperatives are able to build trust with consumers that could allow them to streamline their supply chain and build a more resilient network (Mehta et al., 2011). Products do not need to be mobile, since they will typically stay in one location that all members can access. An example of this business model is a tea cooperative that shares drying and grinding machinery between tea growers. The machinery remains at a central location, with the growers bringing their tea to be processed. In this scenario, members typically also use the cooperative to market as a single entity. In products that are shared but not mobile, it is imperative that an individual is designated to take primary care of the product. A greenhouse, for example, requires daily maintenance. A single day of neglect could lead to destructive pest infestations. Issues may arise if the caretaker is not properly chosen or must relinquish duties.

8.4 Access to capital

Since cooperatives have more structure and a larger number of members, they have more capital for purchasing existing products and investing in new products. The manufacturer would benefit from keeping a close business relationship with similar cooperatives. Also, if these cooperatives have confidence in the manufacturer's products they would be likely to invest in any new lines of technologies the manufacturer would bring to market.

8.5 Supply chain resiliency of goods

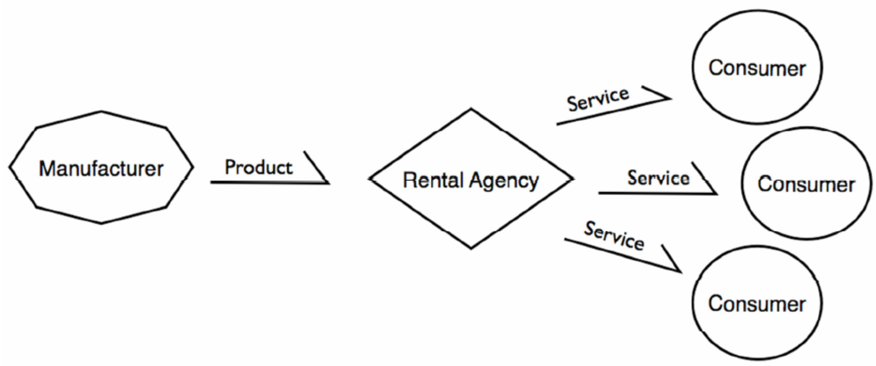
While the larger, formalised nature of this model allows for greater leveraging of resources for marketing and sharing, cooperatives must adhere to certain structures and have group consensus on new ventures. As a result, working with this entity from the manufacturer's perspective can be slow and painstaking. Delays also have the potential to affect the use of the product, complicating sales in volatile markets. A grain storage facility, for example, may be more difficult to access than with a more informal model. This risks impacting the speed and reliability of the value chain, especially in response to sudden events such as weather conditions or changes in government regulation. The manufacturer should assess the probability of this risk based on the characteristics of its product before proceeding with this model.

9 Rental agency model

- The manufacturer sells the product(s) to the rental agency.
- The rental agency rents the product(s) to customers who pay to take the product(s) to their properties for a pre-determined length of time.
- The rental agency may be able to charge a fee to deliver and pick up the product(s).
- The rental agency may hold customers financially accountable if damages occur while in their possession.

- Over time the rental agency can reinvest profits and grow their business. This will provide more farmers with access to the product(s).

Figure 6 Rental agency model diagram



9.1 Example

A rental agency purchases ten solar dryers from the manufacturer. Farmers pay daily rent for the solar dryers to the agency. The rental agency offers its customers incentives so that if they rent two or more solar dryers at a time, they will receive a discount and have their pick-up and delivery fees waived. Farmers realise that using a solar dryer to increase the value of their goods would increase their profit potential and provide greater revenue stability. The word begins to spread among other farmers, and then the rental agency experiences a higher demand for their service. The rental agency begins to charge a higher price for renting the solar dryers, generating more profits for the company. It can reinvest these profits into purchasing more solar dryers, thus growing the venture and increasing its economic gains. The rental agency also has the option to allow farmers to use the product at a specific venue where they can dry their foods for a usage fee. By keeping the products in one location, the agency reduces its transportation costs and can keep its usage fees lower for the customer.

9.2 Product marketing/product scaling

As the rental agency generates its profits from a small number of products, it can reinvest those profits and continue to scale-up operations. This model is different from the informal group and cooperative models in the sense that it works to expand its customer base, rather than concentrating on a constrained subset of customers. While the manufacturer maintains a healthy relationship it could continue to sell new or upgraded products to the rental agency.

9.3 Product characteristics (mobility)

For processing-based value-addition, products that are best for the rental agency model have some similar characteristics to those for the informal group model. The manufacturer should consider the size and mobility of its product when considering this model. If a product is not mobile, the rental agency could offer a usage fee to each customer. This would work well for products or services with inconsistent demand, like a laboratory that provides soil quality testing. Farmers, suspecting soil problems are resulting in decreased yields, would pay to have their soil analysed using high-tech equipment and trained agricultural professionals. With more mobile products, offering delivery and pick-up services for a fee would allow the rental agency to generate additional revenue and further incentivise product use. This will also provide farmers with limited transportation options the ability to access bulkier products. Therefore, the manufacturer should consider finding a rental agency with access to a vehicle. Farming tools that require maintenance could be easily rented, such as a hay baler. Since hay baling is a periodic form of work, a manufacturer would have much more success in a market where farmers could rent products for small periods of time every few months.

9.4 Product characteristics (durability)/environmental impact

Since the immediate owner will not use the equipment, asset protection will be a primary concern. Typical users will not care for the rental agency's property as they would care for their own. For this reason the manufacturer should make sure that any products sold to the rental agency are extremely durable and can be repaired easily with interchangeable parts made available by the manufacturer. Product durability is also important in the global context of combating climate change. Products and services need to be made more ecologically efficient to foster a more sustainable world. Ecologically efficient designs are those that satisfy human needs, reduce ecological impacts, and reduce resource intensity throughout the life-cycle in line with the Earth's estimated carrying capacity (WBCSD, 2000). This model allows the manufacturer to sell products that may have high manufacturing costs but also have short, repetitive use periods and long product lifetimes. This reduces material intensity and increases material productivity, two key eco-efficiencies defined by the WBCSD. By following eco-efficient design criteria, the manufacturer will reduce risk, cut costs, improve reputation, and fuel growth (Corporate Eco-forum and The Nature Conservancy, 2012).

9.5 Value-added market availability

Similar to the agricultural venture model, value-added marketing can be partially conducted by the rental agency, allowing for quicker inception of the product. The rental agency has the option to differentiate their payment options. They can receive cash, processed goods, or both as payment from their customers. Consumers that do not have the cash can still rent the products for a percentage of their earnings; however, they will only seek to rent a product if they also have access to these value-added markets. For example, a manufacturer could provide a new method for cold-storage transportation for flower growers. Farmers would not be able to afford to purchase transportation themselves, but may lose bargaining power if they rely on their customers for transport. A separate agency that would provide cold-storage transportation to markets they identify in return for a percentage of the shipped flowers could allow farmers better access to markets and larger profit margins.

9.6 Supply chain resiliency of goods

This model is also more adaptable to changes in supply than the previous models, and can handle more seasonal goods, since products do not need to be shared amongst stakeholders. If the manufacturer's product is intended for seasonal produce, however, it may want to consider products to augment revenues in the off-season. The manufacturer must also be knowledgeable regarding potential seasonal demand changes of its product to ensure that the rental agency is properly stocked.

10 Conclusions

The business models in this typology serve as a guide for entrepreneurs working to establish sustainable, lucrative, and scalable strategies for disseminating agricultural technologies in developing countries. Manufacturers can choose aspects from any model based on which stressors they may find most important to address. These stressors are not comprehensive; the manufacturer must consider all potential impacts of each business model based specifically on the characteristics of the product and the target market. Additionally, many of these base-of-the-pyramid ventures benefit from the inclusion and integration of multiple unconventional partners, such as governments, NGOs, and international educational institutions. The models that have been provided focus on direct relationships between the manufacturer and customers. Other models can be generated that focus on different aspects of the dissemination of agricultural technologies; financing agreements, institutional partnerships, and the localised manufacturing are some examples of such models. An upcoming paper utilises the same model methodology to explore those other aspects.

References

Ali, A., Maqbool, M., Ramachandran, S. and Alderson, P.G. (2010) 'Gum Arabic as a novel edible coating for enhancing shelf-life and improving postharvest quality of tomato (Solanum lycopersicum L.) fruit', *Postharvest Biology and Technology*, October, Vol. 58, No. 1, pp.42–47.

Conley, T.G. and Udry, C.R. (2003) 'Learning about a new technology: pineapple in Ghana', *The American Economic Review*, Vol. 100, No. 1, pp.35–69.

Contractor, F.J. and Lorange, P. (2002) *Cooperative Strategies in International Business: Joint Ventures and Technology Partnerships Between Firms*, Elsevier Science, Oxford, UK.

Copley, A., Eckard, C., DeReus, A. and Mehta, K. (2013) 'Business strategies for agricultural technology commercialization', *NCIIA Annual Meeting*, March.

Corporate Eco-forum and The Nature Conservancy (2012) *The New Business Imperative: Valuing Natural Capita*l, Design and Digital Publishing.

Cuce, E. and Cuce, P.M. (2013) 'A comprehensive review on solar cookers', *Applied Energy*, February, Vol. 102, pp.1399–1421.

Epstein, T.S. (2001) 'Development – there is another way: a rural–urban partnership development paradigm', *World Development*, August, Vol. 29, No. 8, pp.1443–1454.

Excellent Development (2012) *Pioneers of Sand Dams* [online] http://www.excellentdevelopment.com/articles/people-amp-communities/what-are-sand-dams (accessed 30 May 2012).

Food and Agriculture Organization (1996) *Rome Declaration on World Food Security and World Food Summit Plan of Action* [online] http://www.fao.org/docrep/003/w3613e/w3613e00.htm (accessed 29 July 2012).

Gregoire, R.G. (1984) *Understanding Solar Food Dryers*, Volunteers in Technical Assistance, Arlington, VA.

Gustavsson, J. et al. (2011) *Global Food Losses and Food Waste: Extent Causes and Prevention*, FAO, Rome.

Hawkes, C. and Ruel, M.T. (2011) *Value Chains for Nutrition*, International Food Policy Research Institute, New Delhi, India.

International Assessment of Agricultural Knowledge, S.a.T.f.D. (2009) *Agriculture at a Crossroads*, IAASTD, Washington DC.

Jack, B.K. (2011) *Constraints on the Adoption of Agricultural Technologies in Developing Countries*, White paper, Agricultural Technology Adoption Initiative, J-PAL (MIT) and CEGA, UC Berkeley.

Jaffee, S. and Gordon, P. (1993) *Exporting High Value Food Commodities: Success Stories from Developing Countries*, No. 198, World Bank Publications, Washington, DC.

London, T. and Hart, S.L. (2004) 'Reinventing strategies for emerging markets: beyond the transnational model', *Journal of International Business Studies*, August, Vol. 35, No. 5, pp.350–370.

Meadows, D.H. (2008) *Thinking in Systems: A Primer. White River Junction*, Chelsea Green Publishing Company, VT.

Mehta, C. and Mehta, K. (2011) 'A design-space and business-strategy exploration tool for infrastructure-based ventures in developing communities', *International Journal for Service Learning in Engineering*, Vol. 6, No. 2, pp.30–57.

Mehta, K., Maretzki, A. and Semali, L. (2011) 'Trust, cell phones, social networks and agricultural entrepreneurship in east Africa: a dynamic interdependence', *African Journal of Food, Agricultural, Nutrition, and Development*, Vol. 11, No. 6, pp.5373–5388.

Mukhebi, A. et al. (2007) 'Linking farmers to markets through modern information and communication technologies in Kenya', *AAAE Ghana Conference*, August, Vol. 23.

Murray, W.E. (2001) 'The second wave of globalisation and agrarian change in the Pacific Islands', *Journal of Rural Studies*, April, Vol. 17, No. 2, pp.135–148.

Nandudu, P. (2011) *Uganda: Handy Farm Tools – the Tarpaulin Is Multipurpose* [online] http://allafrica.com/stories/201109281166.html (accessed 25 May 2012).

OECD-FAO (2011) *Agricultural Outlook 2011–2012*, OECD Publishing.

Okello, V. (2009) 'Engaging communities in alleviating smoke – what the real experts tell you', *Boiling Point. A Practitioner's Journal on Household Energy, Stoves, and Poverty Reduction*, No. 57, pp.12–13.

Pack, M. and Mehta, K. (2012) *Design of Affordable Greenhouses for East Africa*, Seattle, Washington.

Patel, N. et al. (2010) *Avaaj Otalo – A Field Study of an Interactive Voice Forum for Small Farmers in Rural India*, pp.733–742, ACM, New York.

Polak, P. (2008) *Out of Poverty: What Works When Traditional Approaches Fail*, Berrett-Koehler, San Francisco.

Rodrigue, J-P., Comtois, C. and Slack, B. (2006) *The Geography of Transport Systems*, Routledge, New York, NY.

Shock, C. (2006) *Drip Irrigation: An Introduction* [online] http://ir.library.oregonstate.edu/xmlui/bitstream/handle/1957/20206/em8782-e.pdf?sequence=1 (accessed August 2012).

Tafera, T. et al. (2011) 'The metal silo: an effective grain storage technology for reducing postharvest insect and pathogen losses in maize while improving smallholder farmers' food security in developing countries', *Crop Protection*, March, Vol. 30, No. 3, pp.240–245.

USAID (2011) *USAID & ATAI Evidence Summit on Agricultural Technology Adoption and Food Security in Africa*, Washington, DC.

Vaccari, M., Vitali, F. and Mazzù, A. (2012) 'Improved cookstove as an appropriate technology for the Logone Valley (Chad – Cameroon): analysis of fuel and cost savings', *Renewable Energy*, November, Vol. 47, pp.45–54.

Vinson, J.A. et al. (2005) 'Dried fruits: excellent in vitro and in vivo antioxidants', *Journal of the American College of Nutrition*, February, Vol. 24, No. 1, pp.44–50.

WBCSD (2000) *Eco-efficiency: Creating More Value with Less Impact*, World Business Council for Sustainable Development, Geneva.

World Bank (2011) *Missing Food: The Case of Postharvest Grain Losses in Sub-Saharan Africa*, The World Bank, Washington, DC.

World Economic Forum (2009) *The Next Billions: Business Strategies to Enhance Food Value Chains and Empower the Poor*, World Economic Forum, Geneva.

World Health Organization (2012) *Food Security* [online] http://www.who.int/trade/glossary/story028/en/ (accessed 11 September 2012).