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Market Adoption and Diffusion of Fecal Sludge-based Fertilizer in Developing Countries

CROSS-COUNTRY ANALYSES

Miriam Otoo, Solomie Gebrezgabher, George Danso, Sena Amewu and Iroda Amirova

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The authors

Dr. Miriam Otoo is a senior international researcher and research group leader for Resource Recovery and Reuse based at the headquarters of the International Water Management Institute (IWMI) in Colombo, Sri Lanka. She is a trained agricultural economist, specializing in issues related to the economics of resource recovery and reuse/ circular economy, rural-urban food systems, experimental economics, agricultural markets and productivity in developing countries.

Dr. Solomie Gebrezgabher is an international researcher at IWMI's regional West Africa office in Accra, Ghana. She has an academic background in business economics focusing on issues related to economic and environmental sustainability assessment and business model development in the waste reuse sector in developing countries.

Dr. George K. Danso is a resource economist with the Government of Alberta. His research focuses on the application of economic instruments for achieving efficiency and productivity in water use, safe resource recovery and reuse, regulatory impact analysis, strategic business development and food security, primarily using computable general equilibrium modelling techniques, choice experiments and microsimulation modelling.

Mr. Sena Amewu is a Research officer - Agricultural Economist at the West Africa office of the International Food Policy Research Institute (IFPRI) in Accra, Ghana. He holds an MPhil in Agricultural Economics with research experience in efficiency and productivity analysis of farming systems. Sena was IWMI staff at the time the field research was conducted.

Ms. Iroda Amirova is a PhD student in the Department of Agricultural Policy at the Leibniz Institute of Agricultural Development in Transition Economies, Germany. She holds a MSc degree in agricultural and food economics from the University of Bonn, Germany. Iroda was an intern with IWMI at the time this research study was conducted.

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Front cover photograph: Farmer with a bag of *Fortifer*™ in Kpong Irrigation Scheme, Ghana. *Photo by*: Hamish John Appleby/IWMI.

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ACRONYMS AND ABBREVIATIONS

CV	Contingent Valuation
CVM	Contingent Valuation Method
DFS	Dewatered Fecal Sludge
FAO	Food and Agriculture Organization of the United Nations
FS	Fecal Sludge
GHG	Greenhouse Gas
GHS	Ghanaian cedi
IDRC	International Development Research Centre
INR	Indian rupee
IWMI	International Water Management Institute
LKR	Sri Lankan rupee
MSW	Municipal Solid Waste
NGO	Nongovernmental organization
NPF	Non-pelletized *Fortifer*™
NPK	Nitrogen, Phosphorus and Potassium
PCA	Principal Component Analysis
PF	Pelletized *Fortifer*™
SDG	Sustainable Development Goal
SURE	Seemingly Unrelated Regression Estimation
UGX	Ugandan shilling
USD	United States dollars
VND	Vietnamese dong
WHO	World Health Organization
WTP	Willingness-to-pay

SUMMARY

There are many opportunities to address the dual challenge of waste management and soil nutrient depletion in developing countries via the safe recovery of nutrients from both solid and liquid waste streams for reuse in agriculture. Commercialization of waste-based organic fertilizers such as *Fortifer*™ (fecal sludge-based fertilizer) has the potential to generate significant benefits for developing economies via cost recovery for the sanitation sector and providing affordable alternative agricultural inputs for smallholder farmers. The successful commercialization of *Fortifer*™*,* however, largely depends on future businesses understanding the dynamics and functionings of the markets that they will operate in. To guide future *Fortifer*™ businesses, this report presents a detailed market assessment of a fecal sludge-based fertilizer product – *Fortifer*™, evaluating farmers' perceptions, attitudes and willingness-to-pay (WTP) for the product. Two formulations of the *Fortifer*™ product were considered – pelletized *Fortifer*™ (PF) and non-pelletized *Fortifer*™ (NPF). This report further provides insights into the market demand and outlook as related to the adoption profiles of farmers and adoption rates. This will serve to guide businesses on the types of marketing and pricing strategies to implement in order to facilitate market entry and mitigate the negative effects of competition. This research was conducted in the Greater Accra and Western regions in Ghana; Kampala, Uganda; Bangalore, India; Hanoi, Vietnam; and Kurunegala, Sri Lanka. Furthermore, cross-country analyses were conducted to better understand the effects of market drivers and if possible, capture lessons learned for knowledge sharing.

Farmers' fertilizer purchasing decisions were analyzed to better understand farmers' WTP for agricultural inputs. Price was considered an important factor by farmers on whether to purchase *Fortifer*™ or not across all study areas, except Hanoi. The latter is possibly due to the fact that farmers traditionally face high fertilizer prices (no subsidies), anticipate the expense and so do not view it as a limiting purchasing factor. With most farmers in these countries being smallholders and typically cash-constrained, accessible and suitable financing will be essential to incentivize adoption. A comparison of key product attributes influencing farmers' fertilizer purchasing decisions across Africa and Asia showed that farmers in Hanoi did not score highly in any of the product attributes compared to all other regions. Nutrient content and fertilizer application methods were amongst product attributes, which scored highly across all the study areas, but less so in Hanoi. An important attitude construct that cuts across most of the selected regions is the issue of safety, which captures farmers' perceived concerns about the safety of the product. To this, farmers' attitudes toward fecal sludge-based fertilizer were generally positive in all the study areas, on condition that a relevant authority ((preferably a governmental authority) that can be trusted certifies the product. While farmers in Bangalore and Kurunegala perceived *Fortifer*™ as a substitute for chemical fertilizer and would buy it irrespective of the price offered, farmers in Ghana and Uganda were price sensitive and would only buy *Fortifer*™ if it was cheaper than chemical fertilizer. Additionally, experiential learning as measured by farmers knowing someone who has used the product before and/or if it has been recommended by a trusted source, is critical to whether farmers will purchase the product or not. Future *Fortifer*™ businesses will need to explore strategic partnerships with agricultural ministries and tap into their extension programs to catalyze adoption.

Regression models assessing factors influencing farmers' WTP showed that farmers were less willing to pay for *Fortifer*™ at higher bids, and this was consistent across all the six countries. Statistically significant socio-demographic variables influencing farmers' WTP for *Fortifer*™ included farm size, status of landownership and previous experience using organic fertilizer. The effects of farm size on farmers' WTP differed by product type, in that farmers with larger farm sizes were more willing to pay for PF over NPF. This is expected as the latter requires more labor for application. The effects of the attribute variables were similar and consistent across both the Asian and African countries. Farmers' concerns about product safety and related need

for third-party product certification was confirmed by the regression results. Third-party certification will be especially necessary in the Asian countries where guidelines for fecal sludge use in agriculture are unclear.

Willingness-to-pay estimates for *Fortifer*™ were comparable to the prices of existing compost and artificial fertilizers in all the study areas. In Ghana, the mean WTP estimates for NPF and PF were USD 0.145 kg^{-1} and USD 0.198 kg^{-1}, respectively for the Greater Accra region. The mean WTP for NPF in Western region was 20% higher than the mean WTP for NPF in the Greater Accra region while the reverse was true for PF. Kampala recorded significantly higher prices than either regions in Ghana, with farmers' WTP twice that in Ghana. In the Asian countries, while WTP estimates were fairly similar for Hanoi and Kurunegala, Bangalore estimates were approximately seven times higher. The highest WTP estimates for NPF and PF among these countries were USD 0.73 kg^{-1} and USD 0.52 kg^{-1}, respectively, whilst the lowest WTP estimates were recorded in Hanoi at USD 0.11 kg kg^{-1} and USD 0.13 USD kg^{-1} for NPF and PF, respectively. Generally, across all the countries, farmers were willing to pay more for PF than NPF with the exception of Bangalore and the Western Region in Ghana.

The demand analyses indicated that the Western region of Ghana recorded the highest demand for both NPF and PF at 0.045 million and 0.044 million tons $year^{-1}$, respectively, in spite of the marginally lower adoption rates in comparison to Kampala and the Greater Accra region of Ghana. Demand for NPF and PF in the Western region is about 15 and 24 times higher than that of the Greater Accra region, respectively. Estimated demand in Kampala is significantly lower than any of the other countries, which is not surprising as this is driven by the considerably low fertilizer application rates. Of the Asian study areas, Kurunegala posted the highest demand for both Fortifer products, followed by Hanoi and subsequently Bangalore. The demand for NPF in Kurunegala at 0.6 million tons $year^{-1}$ is nine times and two times more than that recorded for Bangalore and Hanoi, respectively. This is not surprising as the Kurunegala district ranks high in terms of agricultural activities with oil crops, coconut and paddy production dominant in the region. There is a greater demand for NPF as opposed to PF in all of the countries. This is indicative of farmers' greater willingness to adopt a product (a compost-type product) similar to what they currently use. Overall, demand is comparatively lower in the African countries than the Asian countries for both *Fortifer*™ products, which was expected, given the overwhelmingly lower fertilizer application rates in the former. The Western region in Ghana has the highest cultivated area of all the countries but still records demand estimates lower than its Asian counterparts.

Whilst farmers may be keen to adopt a product (NPF) similar to what they currently use, they are more price sensitive to this product as there are comparable substitutes available in the market. In the case of PF, there are no records of its extensive production or that of a similar product in Uganda or Ghana. *Fortifer*™ producers will need to particularly consider this when setting prices. Their decision on whether to implement a penetrative, competitive or premium pricing system is crucial as short-term price changes can significantly affect demand. In the case of Ghana, an increase in the price of NPF by USD 0.05 kg^{-1} will reduce demand by approximately 30%, as is the case in Uganda. For the Asian countries, the elasticity of both the NPF and PF demand curves for Hanoi are approximately the same. This suggests that there is no significant difference in demand with an equal level of price change for both products. However, in the case of Kurunegala, there is a similar trend as in the African countries where the NPF demand curve is more elastic than the PF demand curve. This suggests that farmers will generally be more responsive to price changes for NPF than PF, and an equivalent price change for both NPF and PF will result in a larger change in demand for NPF compared to PF. Thus, whilst a significant potential market exists in Kurunegala, high price sensitivity of farmers may negatively affect demand.

Another important facet of market dynamics considered in this report was the diffusion of *Fortifer*™, assessed using the Bass model. Adoption profiles for *Fortifer*™ indicated that the farmers' coefficient of innovation, p, representative of early adopters, was generally low across all the countries and for both *Fortifer*™ products. For PF, Bangalore recorded the lowest measure for early adopters, while the Western region in Ghana had the highest level of early adopters. As noted earlier, the Western region boasts a strong and extensive agriculture sector, predominantly characterized by large-scale agricultural producers who have more flexibility in terms of financial resources to invest in new technologies. Kampala had the lowest measure among the African regions – which is not surprising given the unusual low fertilizer application rates in Uganda. This result is also mirrored for the case of NPF. For NPF, Kurunegala recorded the lowest measure for early adopters whilst the Greater Accra region had the highest measure. It is interesting to note that in comparing the coefficients for both PF and NPF across all the countries, early adopters had a proclivity for NPF rather than PF with the exception of Kurunegala. This result corroborates the findings from the demand estimations. Whilst the measure of early adoption was generally low, it is interesting to note that on average, farmers from the African countries had a marginally higher measure for early adoption of both PF and NPF than the Asian farmers.

The results confirmed what is traditionally known of developing country farmers, who are typically known as imitators for adoption of agricultural technologies. This is confirmed by the coefficient of imitation, q, (representative of late adopters, i.e. farmers who will adopt a technology, if it is recommended by other farmers or any other trusted source (e.g. extension service agents)) estimates. The values for *q* were the same for both NPF and PF. With the exception of Hanoi, most farmers will most likely adopt *Fortifer*™ if a trusted source can confirm and recommend its quality. This suggests that future *Fortifer*™ businesses will need to invest in strong awareness programs coupled with actual field experiments to increase product recognition and eventual adoption. Strategic partnerships with existing governmental extension programs will be key in view of farmers' reliance on extension agents for technical information and training.

For all the study areas, it was noted that market growth rate in the introduction phase of *Fortifer*™ will be significantly fast. While investments in promotion and awareness programs will be necessary, greater focus should be placed on incentive mechanisms to catalyze farmer adoption. In the African countries, diffusion of *Fortifer*™ products is expected to be faster in Ghana than in Uganda. This is largely driven by the higher measures of early adoption and comparatively higher levels of fertilizer application rates in Ghana. For Uganda, a country with relatively low fertilizer application rates, it is important that *Fortifer*™ businesses focus on the development of new product features and quality improvement to buffer the effects of competitors' innovations. In Asia, diffusion of *Fortifer*™ products will be faster in Bangalore than in Hanoi for both NPF and PF, despite the larger market and higher measures of early adoption in the latter. Greater investments in awareness programs coupled with actual field experiments will be crucial to increase product recognition and eventual adoption, in comparison to Bangalore where farmers are already informally using fecal sludge for agricultural production. This result is also applicable for Kurunegala and Hanoi; however, the comparisons between Bangalore and Kurunegala are inconclusive. Higher percentages of market demand were captured at the period of peak sales in the African countries compared to the Asian countries, suggesting faster market growth rates in the former. This result is indicative of the combined effect of higher innovation and imitation coefficients on market demand and growth. Similar results were noted for PF. Of the African countries, Ghana had the fastest diffusion rate for *Fortifer*™ products, while this was the case for India and Sri Lanka in the Asian countries considered for this study.

1. INTRODUCTION

Opportunities to address the dual challenge of waste management and soil nutrient depletion in many developing countries via the safe recovery of nutrients from both solid and liquid waste streams for reuse in agriculture is high on the global agenda. Large urban cities in Africa and Asia such as Kampala, Uganda, Sekondi-Takoradi, Ghana and Hanoi, Vietnam face the challenge of a growing urban population and a resulting exponential increase in waste generation (Danso et al. 2017). Limited public funds to support waste management infrastructure and services has resulted in significant environmental pollution as most of the generated waste, whether collected or uncollected, is often deposited untreated in open spaces, waterbodies and/or landfills (Kinobe et al. 2015; Matter et al. 2015; Cofie et al. 2010. The long-term effects of these practices include increased human health risk from communities' exposure to untreated waste and generation of significant quantities of greenhouse gas (GHG) emissions in the form of methane, to name a few. This situation is particularly exacerbated for cities characterized by a growing population and rapid urban migration (Sabiiti 2011; Vermeiren et al. 2012; World Bank 2015a, 2015b, 2017; Jagadeesh et al. 2015; Kollikkathara 2009; Loi 2005; Manning 2010).

As evident in the last decade, solid waste generation has doubled and was projected to increase exponentially from 1.3 billion tons a year in 2010 to 2.2 billion tons a year in 2025 (Hoornweg and Bhada-Tata 2012), globally. This increase is mostly attributed to developing countries, where it is driven by a combination of high urbanization rates and economic development. In developing countries, the per capita waste generation rate ranges between 0.4 to 1.1 kilograms (kg) day^{-1}, reaching 2.4 kg day^{-1} in many urban areas, of which on average 50-75% is organic matter (Sabiiti et al. 2014; Kawai and Tasaki 2016). The pattern of inadequate treatment of municipal solid waste translates to other waste streams such as fecal sludge[1] (excreta). For example, an estimated 2.4 billion users of onsite sanitation systems in Sub-Saharan Africa generate fecal sludge that goes untreated resulting in environmental contamination (Rao et al. 2017; Muspratt et al. 2014; Koné 2010). Also important are the health concerns often related to water-borne diseases associated with fecal contamination, which are among the top causes of child mortality in India and Sri Lanka (Hingorani 2011; Bain et al. 2014; Lakshminarayanan and Jayalakshmy 2015). With the increasing challenges of waste management, policy-makers in developing countries have adopted many international principles and approaches such as Agenda 21 and the Sustainable Development Goals (SDGs), but in practice, waste management challenges have not significantly improved (Diener et al. 2014; UNICEF and WHO 2012).

Conversely, municipal solid waste (MSW) and fecal sludge (FS) are huge sources for nutrient recovery (Sabiiti 2011) that have yet to be exploited. The recovery of nutrients from both solid and liquid waste streams is especially important where soils are poor and the availability of alternative inputs is constrained. Many large cities in developing countries boast of large urban arable farm areas (Thebo et al. 2014; Nuwagaba 2003). Uganda is noted as a country with very low fertilizer application rates compared to other countries in the region (Crawford et al. 2005; Bayite-Kasule et al. 2011; EPRC 2011; Pedersen et al. 2012). Average annual fertilizer consumption in Uganda is estimated at around 10,000 to 20,000 tons, which is significantly lower than other comparable African and Asian countries[2] (IFPRI 2008; World Bank 2013). Peri-urban and rural farmers in Uganda face increasingly limited access to fertilizers due to: a) structurally-flawed subsidy programs and b) limited and inefficient distribution networks, resulting in exorbitant market prices; and invariably decreased agricultural productivity. With a foreseeable increasing trend of urban food demand, increasing fertilizer prices and stricter

[1] Fecal sludge consists of human faeces and urine (and flushing water) and has a high concentration of organic matter and nutrients. It is a sludge of variable consistencies collected from onsite sanitation systems, such as latrines, non-sewered public toilets, septic tanks and aqua privies which store blackwater. It has varying concentrations of settleable solids as well as of other, non-fecal matter.

[2] Fertilizer consumption per kg ha^{-1} of arable land are as follows for: a) Vietnam = 373.06, b) Sri Lanka = 160.03, c) India = 157.52, d) Peru = 105.03, e) Ghana = 35.82, f) Uganda = 2.25.

regulations for safeguarding the environment from pollution, initiatives for nutrient recovery from waste will play a key role in the economic development of many urban cities in developing countries and elsewhere.

There is great potential to close the nutrient loop, support a 'circular economy' and cost recovery within the waste sector or even to create viable businesses. The idea of closing the nutrient and water cycles by using municipal organic waste, fecal sludge and wastewater for urban and peri-urban agriculture is nothing new. Not only has it been practiced for generations in many countries either formally or informally, but it has also been proposed and tried on a small scale as a green solution for modern cities (Smit and Nasr 1992; Murray and Buckley 2010; Murray et al. 2011; EAI 2011). Farmers in West Africa and South India, for example, redirect cesspit truck operators to dump the raw collected fecal sludge on their farm fields to obtain the nutrient-rich manure (Otoo and Drechsel 2018; Rao et al. 2016; Cofie et al. 2009). Health authorities however are more concerned about the health issues associated with the use of raw fecal matter in food production but field experiments in Ghana have shown that with sufficient solar drying and crop restrictions, these risks can be minimized (Seidu 2010; Keraita et al. 2014) and this is even possible in situations where there are limited regulations governing the process.

Over a decade of research by the International Water Management Institute (IWMI), the Food and Agriculture Organization of the United Nations (FAO) and the International Development Research Centre (IDRC) shows the use of compost[3] can accrue significant benefits to farmers and also has the potential to reduce public budget allocations to waste management (Otoo and Drechsel 2018; Danso and Drechsel 2014). Additionally, previous studies have shown that composting of municipal solid waste is more beneficial than other existing options such as land filling, incineration or open disposal (Drechsel et al. 2004; Hutton et al. 2009; De Bertoldi et al. 1996; EC 2002). However, very few successful cases have been noted such as Waste Concern in Bangladesh, Balangoda Municipal Compost Plant in Sri Lanka and Zoomlion in Ghana; most initiatives in low- and middle-income countries have been recorded as small scale and seldom viable without significant subsidies. With the limited viability of waste-based nutrient recovery initiatives, compost businesses have been particularly linked to gaps in market information and business planning. Research has shown that farmers' concerns related to low product nutrient content, skin diseases from product use, related labor requirements and general mistrust of information provided on product quality, significantly affect the demand for the compost product (Otoo et al. 2015; Viaene et al. 2015; Danso et al. 2006; Drechsel et al. 2004). In many situations, farmers' willingness-to-pay (WTP) was either too low or farmers preferred existing substitutes for soil inputs such as cow dung, poultry manure or even dried fecal sludge (Evans et al. 2013; Otoo et al. 2012; Cofie et al. 2006; Danso et al. 2006). The use of these alternatives, however, comes with limitations. The cost of transporting fecal sludge from Kampala in Uganda, for example, to peri-urban and rural areas where large-scale farming is more prevalent, is significantly higher compared to other alternatives like chemical fertilizer (Otoo et al. 2015). Additionally, the limited awareness about the value and safety of using fecal sludge for enhancing agricultural productivity is prevalent (NETWAS 2011).

There are opportunities for the pelletization and blending of fecal sludge (FS) and municipal solid waste (MSW) co-compost with rock phosphate, urea/struvite or nitrogen, phosphorus and potassium (NPK) to produce a product with: a) structure improvement (reduced bulkiness while simplifying crop application – pellets) and b) higher nutrient content tailored for specific crops and soils (Annex 1). This will enhance the competitive advantage, marketability and field use (Nikiema et al. 2013, 2014). IWMI has developed such a product called *Fortifer*™, a nitrate-fortified and pelletized fecal sludge and MSW-based co-compost, which addresses the current challenges associated with using 'regular' compost or dried fecal sludge such as bulkiness, low nutrient content and associated health risks (IWMI 2017; Impraim et al. 2014; Nikiema et al. 2013). The main approach is to dry the septage followed by aerobic composting of the dewatered sludge, which sanitizes and reduces its volume. Although fecal sludge can be processed alone, co-composting with another organic waste, such as organic municipal waste is more common, as it improves the composting properties, in particular the carbon-nitrogen ratio and moisture content (Figure A1) (Cofie et al. 2009, 2016). Opportunities to increase the accessibility and usability of value-added fecal sludge products in agriculture include fortification or enrichment of fecal sludge with nutrients such as rock phosphate, struvite/urine or industrial fertilizer to boost their fertilizer value; and pelletizing the composted fecal sludge, resulting in easy-to-handle, safe, high-value products.

The commercialization of such a product in countries such as Ghana, India, Sri Lanka and Uganda, for example, would make an immense contribution to both the sanitation and agriculture sectors. Revenue generation from the sale of the *Fortifer*™ product also provides great opportunities for cost recovery for the sanitation sector (Murray and Buckley 2010), while farmers, on the other hand, have increased access to alternative agricultural inputs at competitive market prices. The successful commercialization of *Fortifer*™, however, requires an accurate estimation of the relative market size for the new product. Even more importantly, the questions of whether demand actually exists and whether end-users

[3] Compost here is defined as a decomposed organic component of municipal solid and liquid (fecal sludge) waste.

are willing to pay for the product need to be explored, as "demand, even among those with limited resources, is not automatic" (Phillips et al. 2003; page 194). In particular, the perceptions of the end-users towards the product and their WTP need to be assessed, especially given mixed reviews of farmers' attitudes concerning excreta use for agricultural production in many developing countries.

In this regard, the objectives of this study are to:

1. Assess farmers' perceptions and attitudes of fecal sludge-based co-compost (*Fortifer*™).
2. Estimate their WTP for fecal sludge-based co-compost (*Fortifer*™).
3. Evaluate the potential market demand and diffusion for fecal sludge-based co-compost (*Fortifer*™).

Many studies have estimated farmers' WTP for compost products but most have been undertaken in developed countries with very few in the developing world (Agyekum et al. 2014; Palatnik et al. 2005; Arene and Mbata 2008; Valerian et al. 2001). In particular, to the best of our knowledge, this is the first comprehensive study that covers several developing countries using an empirical application of a contingent valuation method to assess the market feasibility of a fecal sludge-based fertilizer. The results from this study will provide important demand-side (product-specific attributes) information for future businesses to guide their investment decisions. The findings will not only be of interest to waste management regulators in the selected countries, but also to international donors and sanitation investors who are constantly exploring a holistic approach in generating multiple benefits from waste reuse businesses.

2. EXCRETA-BASED FERTILIZER USE IN DEVELOPING COUNTRY AGRICULTURE

The use of organic nutrients in crop production is not new and different forms such as poultry manure and cow dung, human excreta, slurry from biogas digesters and compost have been used in crop production. Human excreta has been used in crop production for centuries (Drechsel et al. 2010; Pham Duc et al. 2014). However, mineral fertilizer remains the main source of nutrients in agriculture. Although the contribution from organic nutrients is minimal relative to mineral fertilizer, they have high significance considering their effect on soil physico-chemical and biological properties. This minimal contribution is due in part to the lack of production and consumption data as a result of the informal nature of their use in many instances (Roy et al. 2006).

Human excreta is a rich source of NPK, also found in mineral fertilizers, and can therefore be recycled for use in agriculture (Cofie and Adamtey 2009). As a result of the high nutrient value of raw fecal sludge, many farmers in Africa, Asia and Latin America are very eager to use it in crop production because it also offers a cheaper alternative source of nutrients and is much more readily available (Nikiema et al. 2013). The World Health Organization (WHO) has developed guidelines to promote the safe use of human excreta in agriculture, realizing its resource value and nutrient content for crop production (WHO 2006). This has culminated in the recent development of technologies and pre-agricultural use of human excreta such as composting of dried fecal sludge, co-composting with other organic matter and enrichment with inorganic fertilizer (Nikiema et al. 2013, 2014).

Various studies have been conducted to ascertain the suitability and the health risks associated with the use of human excreta as a nutrient source in crop production. Pham Duc et al. (2011, 2014) studied the prevalence of helminth infection among farmers using human excreta as fertilizer in Vietnam. Mackie Jensen et al. (2008) also studied the perceived health risks and benefits among farmers of using human excreta as fertilizer in Vietnam. Lederer et al. (2015) investigated the potential of using recycled human excreta as a nutrient source in agriculture in Uganda. Koné et al. (2007) investigated helminth egg removal and inactivation efficiency using composting of dewatered fecal sludge as a treatment process. Cofie et al. (2010) also investigated farmers' perceptions and cultural attitudes towards the use of human excreta in farming in southern Ghana.

Apart from the health challenges associated with the use of human excreta in farming, which are effectively eradicated through composting (Nikiema et al. 2013; Cofie et al. 2010; Mackie Jensen et al. 2008; Knudsen et al. 2008), there are also socioeconomic and cultural challenges that to a large extent border on the very viability and sustainability of a fecal sludge-based fertilizer business and its acceptability among farmers. Consequently, studies have been conducted in various countries to empirically ascertain and evaluate these conditions. A study by Ali (2004) noted that the failure of most compost projects is due to the lack of attention paid to demand and marketing. A marketing study for compost across four countries; Pakistan, Sri Lanka, India and Bangladesh revealed that identification of market segments and devising good strategies are requirements for successful composting operations (Drescher et al. 2006). In spite of the high cost of inorganic fertilizer, it is quite difficult for farmers to shift to compost because the incremental yield benefits of compost occur in the long term. Rouse et al. (2008) found that the success of the Horizon Lanka, university and community compost projects in Sri Lanka was attributable to effective marketing. A study by Danso et al. (2006) estimated the demand for compost in Ghana and found that government subsidies are necessary to boost both production and use given the abundant availability of cheap poultry manure. A study on marketing of human excreta as a soil ameliorant in Uganda by NETWAS (2011) revealed that re-use of human excreta as a fertilizer in Uganda is a possibility, however a careful selection of target customer segments is a prerequisite for success. A study by Knudsen et al. (2008) evaluated the risk perceptions' and health risks' awareness among Vietnamese farmers using human excreta in agriculture. The farmers prefer composted excreta to fresh, uncomposted human faeces, the latter being described as 'dirty'. In order to identify potential mitigation measures to address negative consumer perceptions and understand the dynamics of the market the new product will be sold in, potential businesses will need to clearly assess the underlying factors of farmers' purchasing decisions and unpack the structural elements that drive market demand.

3. MATERIALS AND METHODS

In this study, a farmer's decision process is modeled using a random utility framework (Danso et al. 2017). We assume that the sociodemographic characteristics of farmers influence their attitudes towards the fecal sludge-based co-compost, *Fortifer*™,[4] and contribute to each farmer's subjective use of the product. Stated preference methods such as contingent valuation and choice-based conjoint analysis have gained immense popularity in eliciting farmers' valuation of new technologies or other farming input products (Burdine et al. 2002; Lusk and Hudson 2004; Kimenju and Groote 2008; Ibro et al. 2009; Gbégbélégbé 2008). These methods elicit WTP from consumers in a hypothetical and less than realistic environment and are based on intended behavior. In this study a contingent valuation questionnaire was applied using a dichotomous choice model to assess farmers' WTP for fecal sludge-based fertilizer. To assess farmers' knowledge, attitudes and perceptions towards fecal sludge-based fertilizer, multivariate data analysis using factor analysis was used. Furthermore, the Bass model was applied to assess the market outlook for fecal sludge-based fertilizer.

3.1 Contingent Valuation Method

In providing estimates for non-market goods and services, stated preference valuation and conjoint analysis are the most dominant approaches (Lusk and Hudson 2004; Kimenju and Groote 2008). Most researchers prefer to use these approaches because of their flexibility in design and the relatively low implementation costs. These methods elicit WTP from farmers in a hypothetical and less than realistic environment and are based on either perceived or intended behavior. Critics argue that these approaches are not incentive-compatible as farmers' prevalent decision-making options are not consistent with their preferences for the good in question (Carson 2000). Thus, it is not too surprising that research has shown that these elicitation techniques have consistently overestimated consumers' WTP measures (Umberger and Feuz 2004; Kimenju and Groote 2008). In spite of this bias, these approaches continue to be used because they provide results that are better than other methods and are relatively cost effective to generate.

The Contingent Valuation Method (CVM) uses a direct stated preference approach to valuing environmental goods or services, in that it asks people through surveys or experiments their WTP for the goods or service. Potential end-users (i.e. respondents) are presented with hypothetical markets where they can express a monetary value of the good or service. The good or service in question might be an introduction of a new good or service or a betterment in certain aspects of the existing good and service. A demand curve can then be traced using the bid values estimated in a contingent valuation (CV) study. There are various methods in use to elicit the bids and each has its advantages and disadvantages. The prominent bidding methods that are generally used include open-ended questions, bidding games, dichotomous choice and double-dichotomous choice. There are several biases in using CV such as starting-point bias, anchoring bias, hypothetical bias, strategic bias and protest bidding. To address these shortcomings, it is recommended that personal interviews be used to conduct surveys and surveys be designed in a 'yes' or 'no' referendum format and respondents be given detailed information on the resource in question. This study therefore used a dichotomous choice model where the respondents' WTP was elicited via personal interviews. The respondents were educated about the *Fortifer*™ product and its different formulations (i.e. either in pellet or powdered form).

The theoretical foundation of the dichotomous choice model lies in the random utility model (Hanemann 1984). In a dichotomous choice model, respondents provide a dichotomous yes/no answer to a question about paying a previously determined amount referred to here as the bid, B_i that varies randomly across farmers. Respondents are presented with hypothetical markets where they can express a monetary value of *Fortifer*™. Farmers' responses are YES if they are willing to pay at least B_i for *Fortifer*™ (i.e. $WTP_i > B_i$). Assuming a linear functional form for the WTP, in a single-bounded dichotomous choice approach, the probability of observing a positive response given the values of the explanatory variables (x_i) is given by:

[4] In this study, fecal sludge-based co-compost refers to the ***Fortifer*™** product, whilst noting that different formulations of the product exist, under consideration for this paper are non-pelletized *Fortifer*™ (NPF) and pelletized *Fortifer*™ (PF).

$$Pr(y_i = 1|x_i) = \Pr(y_i > B_i) \\ = Pr(x_i\beta + e_i > B_i) \tag{1}$$

where y_i is a farmer's WTP, $\hat{\beta}$ is the vector of parameters and e_i is an error term which is assumed to be normally distributed with $e_i \sim N(0, \sigma_2)$. Then we have:

$$Pr(y_i = 1|x_i) = Pr\left(e_i > \frac{B_i - x_i'\beta}{\sigma}\right) \\ \Pr(y_i = 1|x_i) = \Phi\left(x_i'\frac{\beta}{\sigma} - B_i\frac{1}{\sigma}\right) \tag{2}$$

where $\Phi(x)$ is the standard cumulative normal. The estimated parameters $\hat{\beta}$ and the estimated standard deviation $\hat{\sigma}$ can then be used to determine the average WTP of the respondents:

$$E(WTP) = -\frac{\alpha}{\delta} \tag{3}$$

where $\alpha = \beta/\sigma$ and $\delta = -1/\sigma$ are the vector of coefficients associated with the explanatory variables and the coefficient capturing the amount of the bid from the Probit model respectively.

3.2 Factor Analysis

It is hypothesized that farmers' knowledge and attitude towards fecal sludge-based fertilizer will affect their WTP for *Fortifer*™. Thus, a multivariate data analysis using factor analysis was used to assess farmers' knowledge, attitude and perceptions towards a fecal sludge-based fertilizer. Information pertaining to farmers' attitudes toward fecal sludge-based fertilizer consists of many interrelated variables. To reduce the dimensionality of the attitude variables and to create a smaller set of meaningful orthogonal variables, a factor analysis was used (Jolliffe 2002). Factor analysis is used to reorient data and create a few variables (also referred to as factors) which account for as much of the available information as possible. In the factor analysis, p can be expressed as observed random variables, $X=[x_1, x_2, \ldots, x_p]$ can be expressed as linear functions of m ($< p$) and latent factors as $F=[f_1, f_2, \ldots, f_m]$:

$$X_j = \sum_{k=1}^{m} \lambda_{jk} f_k + e_j \tag{4}$$

where λ_{jk}, $j= 1,2, \ldots, p$; $k= 1,2,\ldots,m$ denotes factor loadings and ej, $j= 1,2,\ldots, p$ are error terms or specific factors. The factors obtained have the property that each factor is uncorrelated with all others and thus can be included as explanatory variables in the single-bounded dichotomous choice model.

3.3 Study Area and Sampling Strategy

3.3.1 Description of the study areas

The survey was conducted in the Greater Accra and Western regions of Ghana, Kampala in Uganda, Hanoi in Vietnam, Bangalore in India and Kurunegala in Sri Lanka as depicted in Figure 1. The Greater Accra region is the smallest in terms of land size among the ten regions in Ghana, having a total land area of about 4,450 square kilometers (km sq.) and a bimodal rainfall pattern. The average annual rainfall in the region varies from about 800 millimeters (mm) along the coastal belt to about 1,270 mm in the extreme southwest. The major agricultural activities in the region include crop production (cereals, root and tubers, vegetables and tree crops), livestock, fisheries and alternative livelihoods such as mushroom cultivation, apiculture, rabbit and grass-cutter rearing. The Western region has an approximate land area of about 239,221 km sq. The region is the wettest in the country with a double peak rainfall pattern and an average annual rainfall of 1,600 mm. The vegetation and climate make the region very conducive for agriculture; this coupled with the moderately well-drained, clayey and loamy soil types in the region enables significant plantation agriculture in the region. The region is the largest producer of cocoa, rubber, coconut and oil palm in the country.

At present, Ghana does not produce any inorganic fertilizer although recently a few compost-producing plants operating at a commercial scale have been established. All inorganic fertilizers used in the country are imported by a few private companies, which distribute the fertilizers to registered wholesalers or retailers located in the regional capitals. While there are only few fertilizer importers, there are about 700 retailers of fertilizers spread throughout the country (FAO 2005). In Ghana, despite the fact that the importance of fertilizer is made clear in the National Development Plan, its adoption is still very low (Fuentes et al. 2012). It is estimated that fertilizer application rate is 8 kilograms per hectare (kg ha^{-1}) in Ghana compared to 20 kg ha^{-1} in Sub-Saharan Africa, 99 kg ha^{-1} in Latin America, 109 kg ha^{-1} in South Asia and 149 kg ha^{-1} in East and Southeast Asia (MOFA 2015). The low application rate has been attributed to, among other factors, the high cost of fertilizers. A study by FAO (2005) indicated that the key constraints to fertilizer use in Ghana include insufficient credit to the farmer, high lending rates by banks for the agriculture sector and problems with marketing of agricultural produce. Moreover, distance from the farm gate to the nearest fertilizer dealer is cited as one of the several challenges faced by Ghana in the use of fertilizers (Krausova and Banful 2010). Not only farmers but also agricultural inputs dealers in all the regions have to travel long distances ranging from median distances of less than 50 km in Greater Accra to 152 km in the Western region to access their suppliers (IFDC 2012).

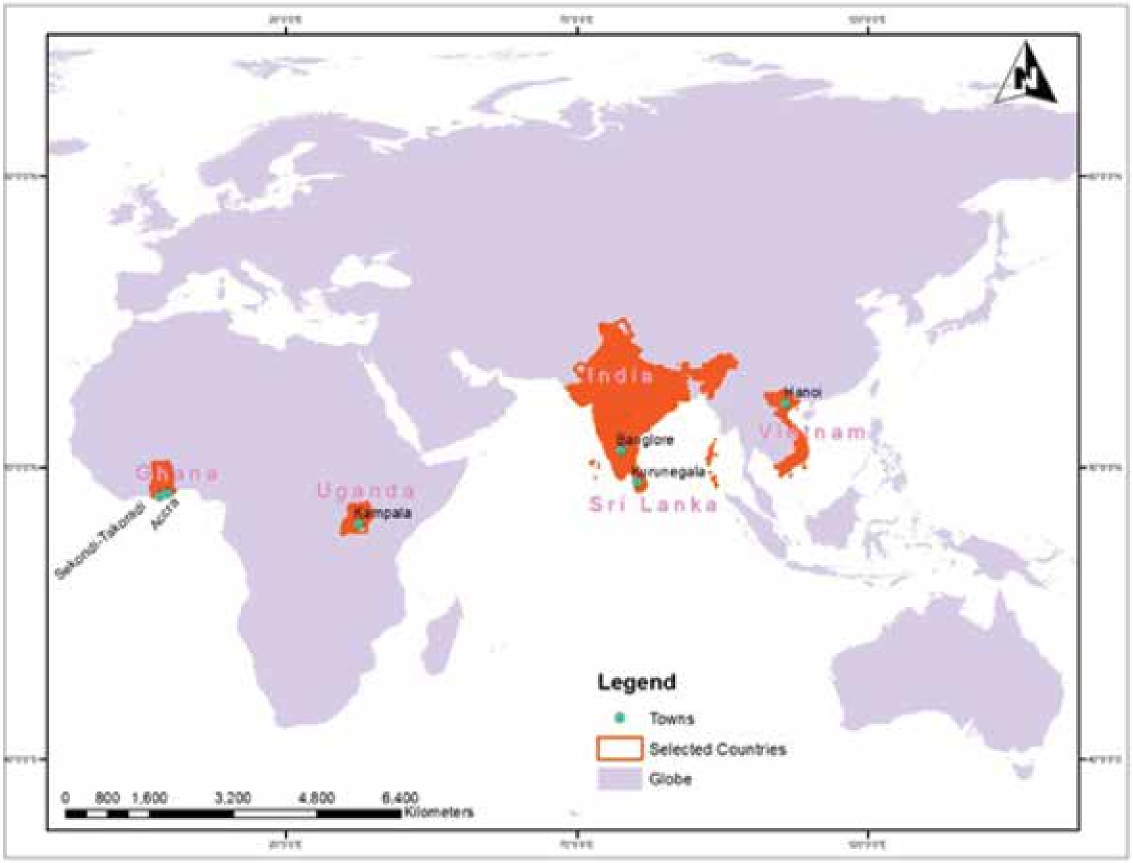
As with Ghana (Greater Accra region), the Ugandan economy is predominantly supported by agriculture and contributes almost 25% to the national gross domestic product. Beyond this, urban agriculture features prominently as part of Kampala's economy and is an important livelihood strategy for the city's urban poor, especially women (Hooton et al. 2007). The city is divided into five divisions, four of which have 25% of their area being peri-urban with agricultural activities. Kampala has a tropical rainforest climate and features two annual wet seasons, making it conducive for agriculture. The total number of agricultural households in the urban and the peri-urban areas of Kampala is estimated at approximately 44,962 (Makita 2009), with an average land holding size ranging from 0.8 to 1.1 ha and hence a total agricultural land of 31,473 ha.

Recent changes in climate patterns have resulted in farmers facing exacerbated challenges with access to basic farming inputs such as water, land and fertilizers. Research suggests that an oligopolistic fertilizer market, plagued by market distortions attributable to ineffective policies, limited infrastructure and a growing organic agriculture sector represents an opportunity for business development in the organic fertilizer subsector (Otoo et al. 2015). The chemical fertilizer supply chain suffers from low market demand due to high prices at the suppliers' end. The chain structure is challenged by inadequate supply, lack of access to market information, limited infrastructure (high transportation cost) and storage (IFDC and Chemonics 2007). Direct import from producers is limited due to capped import volumes and low demand. The chemical fertilizer sector is also a capital-intensive industry. Thus, limited access to financing at a large scale further exacerbates supply-related constraints (IFDC and Chemonics 2007). Low profit margins, an uncertain macro-environment (high exchange rate movements with devaluation of local currency), market distortions (involvement of government and nongovernment organizations [NGOs] in fertilizer distribution to farmers directly or indirectly) and a weak regulatory system that cannot control unlicensed suppliers, as well as domestic and import taxes (changes in government policies) have dis-incentivized the interest of new investors in the fertilizer market (George and Gracious 2005). With increasing and erratic inorganic fertilizer prices and increased organic farming, agricultural producers will become more dependent on organic fertilizer sources as their main nutrient source. Market distortions coupled with the absence of a large-scale government fertilizer program that provides subsidized fertilizer and an inactive private fertilizer sector that can supply fertilizer at competitive prices, represent a great opportunity in the broader fertilizer market for organic (waste-based) fertilizer businesses.

This trend mirrors the case in Vietnam, where the absence of fertilizer price subsidies means that farmers face erratic and significantly high fertilizer prices. Prices are typically subject to international price changes and exchange rate fluctuations of the economy. Accordingly, the Vietnamese fertilizer market has and continues to experience great price volatility. Fertilizer prices have doubled, and in some cases even tripled, over the past year. This creates significant speculation among local producers and farmers about future price hikes, causing a surge in farmer demand. Whilst, producers benefit from input subsidies, fluctuations in fertilizer prices result in significant uncertainties related to production. These trends however represent a great opportunity for waste-based organic fertilizer businesses to take advantage of erratic chemical fertilizer prices and the limited number of actors in the respective market and capture a share of the market. Whilst, peri-urban and urban agriculture is a longstanding feature in Hanoi and its surrounding areas, and an important indicator for fertilizer demand, rapid urban growth is leading to greater competition over land use, such that this practice is being increasingly threatened by conversion to nonagricultural urban uses (Lee et al. 2010). Research suggests that 80% of fresh vegetables, 50% of pork, poultry and freshwater fish, as well as 40% of eggs, originate from urban and peri-urban areas of Hanoi. This region boasts a warm humid subtropical climate with abundant rainfall (Peel et al. 2007), conducive for agricultural production.

This climatic pattern extends also to the Karnataka region (Bangalore, India) and North Western region of Sri Lanka (Kurunegala). Crop production ranks high in both regions in terms of agricultural activities with oil crops, coconut and paddy production dominant in the Kurunegala region. The region of Karnataka boasts 122,470,000 ha of cultivated land (with 157,354 ha in Bangalore), constituting 25.3% of the total geographical area of the state (Government of Karnataka 2017). The 2001 census indicated that farmers and agricultural laborers formed more than half of the workforce of Karnataka (Government of India 2017). The main crops grown are rice, ragi, jowar, maize, and pulses (tur and gram), oilseeds and a number of cash crops. Karnataka is the largest producer of coarse cereals, coffee, raw silk and tomatoes among the states in India (FAO 2017; Government of India 2017). Horticultural crops are grown over an area of 16,300 km² and the annual production is about 9.58 million tons, with the generated income constituting over 40% of all income from agriculture. Contrary to the cases of Vietnam and the two African countries, there are large-scale government chemical fertilizer programs that provide subsidized fertilizer to farmers and a moderately active private fertilizer sector that supplies fertilizer at competitive prices in India and Sri Lanka. The fertilizer industry is however similarly plagued with market distortions related to limited product differentiation, distribution inefficiencies in the supply chain, information flow and foreign exchange rate fluctuations. Overall, the selected regions for this study boast a conducive climate for agriculture, which along with market distortions in the chemical fertilizer sector preliminarily translate into a great industry opportunity for a burgeoning organic waste-based) fertilizer industry.

FIGURE 1. SELECTED STUDY AREAS.



3.3.2 Sampling strategy

Prior to conducting the market experiments, a scoping study was conducted in each of the cities to make a preliminary determination of the key potential customer segments for the *Fortifer*™ product. As a potential substitute for chemical fertilizer, *Fortifer*™ is viewed as a key agricultural input and smallholder farmers were noted as the main prospective customer segment. Subsequently, a survey was conducted to assess farmers' attitudes and WTP for *Fortifer*™ in six cities in five countries, representing two continents – Africa and Asia. The surveys were conducted in Greater Accra and Sekondi-Takoradi of the Western region in Ghana, Bangalore in India, Kampala in Uganda, Kurunegala in Sri Lanka and Hanoi in Vietnam. The CV surveys were conducted in 2015 in all the selected locations. Respondents for the study were sampled from farming households in several districts, representative of urban, peri-urban and rural parts of the city region.

In Kampala, for example, the respondents were sampled from farming households in five districts (Table 1) representative of: a) urban Kampala (i.e. Kampala city, central division) and b) peri-urban Kampala (i.e. Luwelo, Mukono, Mpigi and Wakiso divisions). The targeted sample size of 300 farmers was proportionally distributed across each district based on the land use (i.e. residential land vs. agricultural land) distribution per district. Respondents from each district for the study were randomly sampled from farming households with and without compost-use experience in the different divisions. Twenty-five respondents provided a protest response and refused to respond to the surveys. Therefore, a total of 275 farmers fully completed the survey, with valid observations for the analysis. In Ghana, for the Greater Accra region, 226 farmers were interviewed in six districts while in the Western region, four districts were sampled and a total of 235 respondents were interviewed. The districts were Accra, Tema and Ashaiman municipalities, Shai Osu-Doku, Ada East and Ga East districts in Greater Accra and Nzema East Ahanta West, Mpohor and Bia East in the Western region. For each district, at least two communities were selected. The Ashaiman irrigation site was deliberately selected in Ashaiman metropolis as it is the main site for agricultural activity in the district. Similarly, Tema, Klaggon and Community 11 and 12 were selected, as agricultural activities are mainly concentrated in these communities.

A similar sampling approach was implemented in the Asian cities and the data are presented in Table 1. In addition to the responses to CVM experiment questions, data were collected on the respondents' socioeconomic characteristics, farmers' fertilizer-use characteristics, farmers' fertilizer purchasing behavior including their knowledge, perceptions, attitudes and experience in using different compost products, among other factors. These data served as the explanatory variables in investigating the heterogeneity in the farmers' preferences for fecal sludge-based co-compost.

TABLE 1. SAMPLING STRATEGY FOR SELECTED CITIES.

AFRICA						ASIA					
GREATER ACCRA REGION (N=226)		WESTERN REGION (N=235)		KAMPALA (N=275)		BANGALORE (N=80)		HANOI (N=296)		KURUNEGALA (N=267)	
Accra	14	Nzema East	55	Kampala	112	Urban	30	Gia Lam	154	Ibbagamuwa	14
Tema	44	Ahanta West	75	Luwelo	39	Peri-urban	50	Me Linh	98	Riddigama	24
Ashaiman	61	Mpohor	40	Mukono	54			Thanh Tri	25	Malawapitiya	21
Shai Osu-Doku	27	Bia East	65	Mpigi	65			Thoung Tin	19	Wariyapola	32
Ada East	47			Wakiso	5					P. Nuwara	45
Ga East	33									Bingiriya	22
										Pannala	24
										Polpitigama	49
										Kuliyapitiya	30
										Kurunegala city	6

3.4 Implementation of the CVM – Experimental Design

Prior to the implementation of the market experiments, pilot surveys were conducted to explore the type of farming activities in and around the selected study areas. Samples of the *Fortifer*™ product were introduced to the farmers during the pilot surveys to get an insight into their willingness to use and pay for the product. In each selected survey site, informal discussions were conducted with a group of farmers to determine the starting bid levels to be used during the actual survey. Before the actual surveys, enumerators underwent a one-day training focusing on the execution of the market experiment, technicalities of the questionnaire and characteristics of the *Fortifer*™ product for which the WTP values were to be elicited. This ensured that the enumerators were knowledgeable about the product and would be able to adequately address any questions that the farmers might raise regarding the product during the actual survey. Two different types of formulations of the *Fortifer*™ product were used in the market experiments: a) a pelletized co-compost and b) non-pelletized co-compost. To elicit the farmers' WTP for the *Fortifer*™ products, they were randomly assigned different bid levels to control for the effect of extraneous variables on the dependent variable.

The study used a single-bounded dichotomous choice model to estimate the WTP for both the pelletized and non-pelletized *Fortifer*™ (NPF) product. The farmers were thus initially provided with a bid; when this was accepted, they were then given a higher bid for which their acceptance or rejection was evaluated. In the instance when the initial bid was rejected, the farmers were given a lower bid and their acceptance or rejection of the bid were also evaluated. The CV experiment was designed on the basis of 'low bids', 'medium bids' and 'high bids' for both types of the *Fortifer*™ product. Using the throw of a die, the farmers were randomly assigned to these three categories – when the die showed a 1 or 4, the participant was assigned a 'low bid'; when the die showed a 2 or 5 the participant was assigned a 'medium bid' and when the die showed a 3 or 6 the participant was assigned a 'high bid'. Table 2 shows the different bids assigned to the farmers. The different bids were determined based on consultation with local partners in each of the countries and based on a scoping market study. The ranges of price levels were chosen to reflect the low-end and high-end prices that were observed in the actual fertilizer markets in the different cities. For example, the levels of prices chosen ranged from USD 0.12 kg^{-1} to USD 0.54 kg^{-1} in Kampala, Uganda. Thus if a randomly selected respondent was assigned a low bid for NPF, the respondent was initially given a bid of USD 0.15 If they accepted this bid level, they were subsequently presented with a higher bid of USD 0.19, which they accepted or not. Table 2 shows that on average the population of participants was fairly evenly assigned to the different bid levels in the selected cities – with the exception of Kampala where the majority was assigned the low-level bid. It is important to note that the bids were presented to the respondents in local currencies in the different cities but for uniformity and ease of comparison of the results, the bids are presented here in United States dollars (USD).

TABLE 2. DESIGN OF THE CONTINGENT VALUATION EXPERIMENT (BIDS IN USD KG^{-1}).[a]

Country	City	Bid design	Pelletized Fortifer (PF)				Non-pelletized Fortifer (NPF)			
			Initial bid	*Higher bid*	*Lower bid*	*% of respondents facing the bid*	*Initial bid*	*Higher bid*	*Lower bid*	*% of respondents facing the bid*
Ghana	Greater Accra region	Low bid	0.15	0.17	0.13	45	0.09	0.12	0.07	44
		Medium bid	0.17	0.20	0.15	32	0.12	0.14	0.09	32
		High bid	0.20	0.21	0.17	23	0.14	0.16	0.12	24
	Western region	Low bid	0.15	0.17	0.13	47	0.09	0.12	0.07	43
		Medium bid	0.17	0.20	0.15	28	0.12	0.14	0.09	29
		High bid	0.20	0.21	0.17	25	0.14	0.16	0.12	28
Uganda	Kampala	Low bid	0.29	0.31	0.25	50	0.15	0.19	0.12	40
		Medium bid	0.37	0.39	0.31	25	0.23	0.25	0.21	35
		High bid	0.46	0.54	0.39	25	0.27	0.31	0.25	25
India	Bangalore	Low bid	0.57	0.82	0.49	36	0.33	0.57	0.25	38
		Medium bid	0.82	1.07	0.74	34	0.57	0.74	0.49	30
		High bid	1.07	1.23	0.98	30	0.74	0.90	0.66	32
Vietnam	Hanoi	Low bid	0.12	0.17	0.10	45	0.10	0.12	0.07	41
		Medium bid	0.17	0.19	0.14	25	0.14	0.17	0.12	27
		High bid	0.21	0.24	0.19	30	0.19	0.21	0.17	32
Sri Lanka	Kurunegala	Low bid	0.15	0.18	0.13	28	0.08	0.12	0.05	22
		Medium bid	0.18	0.21	0.14	32	0.13	0.14	0.12	35
		High bid	0.21	0.23	0.18	40	0.15	0.17	0.14	43

Notes: [a] Conversion rates used for the bids are: GHS = Ghanaian cedi (USD 1.00 = GHS 3.04), UGX = Ugandan shilling (USD 1.00 = UGX 2,599.78), INR = Indian rupee (USD 1.00 = INR 61.03), VND = Vietnamese dong (USD 1.00 = VND 21,148) and LKR = Sri Lankan rupee (USD 1.00 = LKR 130.56). All currency values are for 2015. Source: World Bank Database.

4. RESULTS AND DISCUSSION

4.1 Sociodemographic Characteristics of the Respondents

Table 3 presents the sociodemographic statistics of the respondents from the selected study areas. This information will be useful for the subsequent sections, particularly in estimating the WTP measures and the influence of these variables on the mean WTP. The survey results showed that the sampled farmers were disproportionately male across all the cities, although comparatively fewer in Kampala and the Western region of Ghana. Most farmers were within the age bracket of 38–51 years, which corroborates the finding that the productive age group in developing countries (14–59 years) is the age group that provides labor to the agriculture sector (World Bank 2016; ILO 2016). The average ages of the sampled farmers in the African and Asian cities were 45 and 48 years, respectively. The level of education of the farmers was noted to be moderately evenly distributed across the three categories of: a) no education, b) primary education and c) secondary education in the African cities. In the Asian cities, with the exception of Bangalore, a disproportionate percentage of the farmers had a secondary education in comparison to the other educational levels. The relatively high literacy level of the farmers suggested that the farmers had the basic education to perform activities such as reading and understanding the instructions on labels and fertilizer application methods – which may be an implicit factor that influences their willingness to adopt/use the *Fortifer*™ product.

Most of the respondents belonged to medium- and large-sized households, ranging between three and seven members. This result may be indicative of the use of family labor for agricultural activities. This assertion is also supported, particularly in the African cities, by the fact that a significant percentage of the farmers do not engage in off-farm employment. A similar trend was observed in Asia, although the percentages were relatively proportionally distributed across on- and off-farm employment in Bangalore and Hanoi. The number of years that the farmers had been engaged in agricultural activities varied significantly across the different countries from as low as one year to 40 years, with an average of 25 years of farming experience. The highest percentage of farmers belonging to a farmers' association occurred in the Western region in Ghana. This is not surprising as this region is a main agricultural belt in the country. Additionally, whilst urban and peri-urban agricultural is prominent in the selected cities – the farmers tend to be nomadic due to increasing urban development and thus typically have a lower incentive to engage in farmers' associations, especially if this comes at a cost. Farmers in the study areas were predominately small scale with an average land size ranging from 0.83 to 7.92 acres, although the latter is more representative for the Western region farmers in Ghana. This significant variation also translates to the income earned, ranging from USD 849 to approximately USD 5,062 – with the highest earners in Hanoi. It is important to note that the large standard deviations may well be attributable to the fact that farmers are typically unwilling to reveal their incomes and thus the stated income levels may be biased downwards. Although, traditionally noted to be nomadic farmers, most of the respondents in all the cities owned their land.

With the exception of Kampala and Bangalore, a dominant percentage of the farmers used chemical fertilizers. The case of Kampala is attributed to several distortions in the fertilizer market, including: a) an uncertain macro-environment, characterized by high exchange rate movements with a devaluation of local currency; b) high domestic and import taxes; c) a weak regulatory system that cannot control unlicensed suppliers; and d) limited established distribution networks. As expected, organic fertilizer use was higher among farmers in Kampala and Bangalore, although on average 50% of the farmers in the other locations used organic fertilizer.

TABLE 3. SOCIODEMOGRAPHIC STATISTICS OF RESPONDENTS.

		AFRICA			ASIA		
VARIABLES	**DESCRIPTION**	**GREATER ACCRA REGION (N=226)**	**WESTERN REGION (N=235)**	**KAMPALA (N=275)**	**BANGALORE (N=80)**	**HANOI (N=296)**	**KURUNEGALA (N=267)**
Age	Average age of respondents (years)	50 (11.84)	48 (12.8)	38 (14.33)	45 12.56)	49 (11.03)	51 (11.86)
Gender	Gender category (%) 1 = Male, 0 = Female	1 = 74% 0 = 26%	1 = 66% 0 = 34%	1 = 56% 0 = 44%	1 = 72% 0 = 28%	1 = 93% 0 = 7%	1 = 79% 0 = 21%
Education	Educational level (%) 1= None, 2= Primary, 3= Secondary, 4= Tertiary	1 = 20% 2 = 39% 3 = 29% 4 = 12%	1 = 32% 2 = 22% 3 = 37% 4 = 9%	1 = 12% 2 = 44% 3 = 37% 4 = 7%	1 = 20% 2 = 13% 3 = 25% 4 = 42%	1 = 0% 2 = 11% 3 = 88% 4 = 1%	1 = 37% 2 = 18% 3 = 74% 4 = 8%
Hhmember	Household size as measured by number of members in household	5.86 (2.65)	7 (2.9)	5.0 (2.78)	4.9 (2.34)	2.9 (1.43)	4.01 (1.45)
Farm_exp	Farming experience as measured in years	22.77 (11.30)	24 (12.5)	12.76 (13.06)	27.5 (10.92)	ND	23.74 (14.23)
FBOM	Member of farmer's association (%) 1= Yes, 0= No	1 = 28% 0 = 72%	1 = 43% 0 = 67%	1 = 14% 2 = 86%	1 = ND 0 = 76%	ND	ND
Offarm_work	Farmer's engagement in off-farm work (%) 1= Yes, 0 = No	1 = 13% 0 = 87%	1 = 14% 0 = 86%	1 = 34% 0 = 66%	1 = 41% 0 = 59%	1 = 41% 0 = 59%	1 = 29% 0 = 71%
Farmsize	Size of farm as measured in acres	4.48 (4.9)	7.92 (11.9)	1.20 (1.09)	1.93 (1.69)	0.83 (1.13)	5.18 (4.51)
Landownership	Farmers' status of landownership (%): 1 = Owns land, 0 = Otherwise	1 = 44% 0 = 56%	1 = 69% 0 = 31%	1 = 95% 0 = 5%	1 = 93% 2 = 7%	ND	1 = 93% 0 = 7%
Dom_fert	Dominant fertilizer used by farmer (%): 1= Inorganic 0= Organic/other	1 = 82% 0 = 18%	1 = 87% 0 = 13%	1 = 14% 0 = 86%	1 = 30% 0 = 70%	1 = 58% 0 = 42%	1 = 67% 0 = 33%
Use_org_fert	Use of organic fertilizer (%): 1 = Yes, 0 = No	1 = 55% 0 = 45%	1 = 39% 0 = 61%	1 = 86% 0 = 14%	1 = 70% 0 =30%	1 = 45% 0 = 55%	1 = 46% 0 = 54%
Farmincome	Average annual farm income (USD)	890.46 (1,109.81)	1,055.59 (1,519.40)	700.11 (651.32)	ND	5,061.94 (4,842.07)	1,938.43 (1,927.51)

Note: Standard deviations are in brackets.
ND = No data available.

4.2 Farmers' Fertilizer Use Patterns and Purchasing Behavior

Table 4 presents a breakdown of the different types of fertilizer types that the surveyed farmers used. As previously noted, chemical fertilizer was the dominant fertilizer product used by the farmers in all the cities with the exception of Kampala – where there is a greater reliance on organic materials. This result was not surprising as distortions in the chemical fertilizer market have constrained farmers' access. An uncertain macro-environment, characterized by high exchange rate movements with a devaluation of local currency, high domestic and import taxes, market distortions created by the involvement of the government and NGOs in fertilizer distribution to farmers directly or indirectly, and a weak regulatory system that cannot control unlicensed suppliers, has significantly disincentivized the interest of new investors in the chemical fertilizer market. Furthermore, direct import from producers is limited due to capped import volumes. Inadequate access to financing at a large scale, lack of access to market information, limited infrastructure (related high transportation costs) and storage, and a limited established distribution network have further exacerbated the supply-related constraints for a capital-intensive fertilizer industry (IFDC and Chemonics 2007). Moreover, there is neither a large-scale government fertilizer program that provides subsidized chemical fertilizer to farmers nor an active private fertilizer sector that supplies fertilizers at competitive prices. These supply-limiting factors have eventually driven down demand and farmers have resorted to alternative soil nutrient inputs.

TABLE 4. FARMERS USING DIFFERENT TYPES OF SOIL INPUTS (VALUES IN PERCENTAGES).

Types of soil inputs	Greater Accra region (N=226)	Western region (N=235)	Kampala (N=275)	Bangalore (N=80)	Hanoi (N=296)	Kurunegala (N=267)
Inorganic fertilizer	84	94	14	79	100	76
Poultry manure	11	4	26	ND		2
Cow dung	5	1	31	29		1
MSW-based compost	0	1	17	20	75[a]	3
Farm residues	0	0	5.3	4		18

Note: [a] The overall percentage of respondents using different kinds of organic fertilizers.

The use of poultry manure for agricultural activities was quite predominant in Ghana until recently (Boateng et al. 2006). Despite farmers' increasing demand for poultry manure, its availability is increasingly diminishing given the declining state of the country's poultry industry, which is attributable to lax import policies. Bangalorean farmers are also noted to be large users of organic fertilizers, although this was not observed in Hanoi (Table 5).

TABLE 5. AVERAGE ANNUAL QUANTITY OF FERTILIZER TYPE USED FOR AGRICULTURAL ACTIVITIES (KG ACRE^{-1}).[a]

Types of soil inputs	Greater Accra region (N=226)	Western region (N=235)	Kampala (N=275)	Bangalore (N=80)	Hanoi (N=296)	Kurunegala (N=267)
Inorganic fertilizer	246 (249)	104 (28)	8 (4.7)	537.4 (374.4)	667.8 (433.5)	513.0 (413.9)
Poultry manure	1040 (601)	1016 (698)	144.6 (111.4)	ND		934.5 (567.9)
Cow dung	ND	ND	263.8 (258.05)	822.5 (564.2)	847.5 (413.4)[b]	790.85 (663.3)
MSW-based compost	326 (131)	230 (171)	138.3 (120.8)	491.5 (408.9)		482.0 (457.2)
Farm residues	0	0	ND	ND		689.5 (541.2)

Note: [a] Standard deviations are in brackets.
[b] Average quantity of different kinds of organic fertilizer.

4.3 Factors Influencing Farmers' Fertilizer Purchasing Decisions

The survey included statements related to a set of fertilizer attributes that were likely to have an influence on farmers' choice of fertilizers. To determine the most important factors that influence farmers' choices, farmers were asked to rate various product attributes. These product attributes were rated based on their level of importance prior to purchasing fertilizer using a Likert scale. Product attributes were then ranked for their level of importance based on the number of farmers giving high scores (4-5) to each attribute (Table 6).

Farmers in both regions of Ghana rated a suitable credit offer as the most important product attribute in making their fertilizer-purchasing decisions. While price was ranked as the second most important product attribute in the Western region, a convenient location to buy the product was rated as the second-most important attribute in Greater Accra. Nutrient content and fertilizer application methods were also amongst the product attributes, which scored high in both regions. Other product attributes which farmers considered before purchasing fertilizer were organic matter, volume to apply and a label showing product certification by relevant authorities such as the Ministry of Food and Agriculture. The importance of brand and packaging ranked as the least important attributes in both regions. Moreover, whether the product was locally made or imported was not considered as an important product attribute determining farmers' fertilizer purchase decisions. In contrast, farmers in Kampala considered whether someone they knew had used it as the most important aspect when making a fertilizer purchase decision. Fertilizer application method, organic matter, water-holding capacity and volume to apply were also considered as important product attributes. Unlike surveyed farmers in Ghana, farmers in Kampala did not consider a suitable credit offer and price as the most important attributes when making purchase decisions. While farmers in Ghana were indifferent to the safety of a product, farmers in Kampala rated safety as an important product attribute when making purchase decisions.

Farmers in Bangalore, Hanoi and Kurunegala considered different product attributes when making fertilizer purchase decisions. While farmers in Bangalore and Kurunegala rated product quality as measured by nutrient content and safety as the most important product attributes respectively, farmers in Hanoi made their fertilizer purchase decisions based on whether someone they knew had used it. In addition to nutrient content and safety, farmers in Bangalore and Kurunegala rated price and organic matter as important product attributes when making purchase decisions. Water-holding capacity and volume of fertilizer to apply were also rated as important product attributes by Kurunegala farmers.

Comparison of key important product attributes influencing fertilizer purchase decisions across Africa and Asia showed that farmers in Hanoi did not particularly give a high score to any of the product attributes compared to all other regions. While price was given a moderate to high score in all of the regions, farmers in Hanoi rated price as the least important product attribute. While farmers in Ghana rated a suitable credit offer as very important in their purchase decisions they were indifferent to the safety of the product; in contrast farmers in other regions, with the exception of Hanoi, were indifferent to credit offers but rated safety as an important product attribute.

TABLE 6. FACTORS INFLUENCING FARMERS' FERTILIZER PURCHASING DECISIONS.

	Respondents' assessment of questions (Average of a 5-level Likert scale ranking)					
	Greater Accra (N=226)	Western region (N=235)	Kampala (N=275)	Bangalore (N=48)	Hanoi (N=296)	Kurunegala (N=267)
Assessment questions	Mean of surveyed respondents	Mean of surveyed respondents	Mean of surveyed respondents	Mean of surveyed respondents	Mean of surveyed respondents	Mean of surveyed respondents
Price	4.09	4.36	3.65	4.67	1.91	4.06
Nutrient content	4.12	3.99	3.66	4.83	3.22	4.17
Organic matter	3.87	3.88	4.16	4.12	2.07	4.04
Water-holding capacity	3.57	3.61	4.15	3.64	2.52	4.04
Safety	3.19	3.26	4.07	4.42	2.18	4.34
Packaging	2.62	2.67	3.17	3.60	2.26	3.53
Certification label	3.64	3.70	3.43	3.31	2.42	ND
Brand name	2.28	2.37	3.22	3.62	2.46	3.51
Suitable credit offer	4.28	4.47	3.31	3.57	2.21	3.74
Convenient location to buy	4.22	4.20	4.01	3.11	2.49	3.85
Volumes to apply	3.84	3.89	4.15	3.09	2.33	4.16
Fertilizer application	4.11	4.01	4.26	3.11	3.07	3.37
Recommended by trusted source	3.93	4.00	3.94	3.04	3.03	3.69
Know someone who has used it	3.25	3.34	4.27	3.06	3.26	ND
Product is locally made	1.63	1.42	3.83	ND	2.19	3.69
Product is imported	1.63	1.41	3.40	ND	3.12	ND

Note: ND = No data available.

4.4 Farmers' Attitudes toward Fecal Sludge-based Fertilizer – Results of Factor Analysis

The farmers were asked a series of questions aimed at assessing their knowledge, attitudes and perceptions regarding fecal sludge-based fertilizers. This information was collected to investigate the effect of farmers' attitudes on their WTP for *Fortifer*™. To investigate the underlying structure of the attitude variables, we conducted a factor analysis. This section presents the results of the factor analysis for the selected regions.

4.4.1 Factor analysis results for Ghana

Table 7 presents the factor loadings of attitude variables (in bold) on the extracted factors after varimax orthogonal rotation. The factor analysis of attitude variables in Greater Accra resulted in four factors while three factors were identified in the Western region. Each of the factors had an eigenvalue greater than 1. The first three factors were similar in both regions, but in a different order, indicating that their relative importance differed. The total variance accounted for was 67% in Greater Accra and 51% in the Western region. Cronbach's alpha coefficients were computed to examine the internal consistency of each factor. Values were moderate to high (0.62-0.89), indicating that the attitude variables loading on each of the factors measured the same underlying construct. The first factor termed '*positive attribute*' had high loadings on questions related to the potential benefits of *Fortifer*™ in both regions. This factor captured the tendency of farmers to accept *Fortifer*™ based on its perceived potential benefits such as its potential to enhance agricultural productivity, nutrient availability to crops and enhance long-term soil fertility including its contribution to improving sanitation and environmental sustainability. However, in the Western region, while perceived potential benefits of *Fortifer*™ had positive factor loadings on '*positive attribute*', the variables related to farmers' concerns about religious and cultural beliefs against using fecal sludge-based fertilizers had negative factor loadings (-0.71 and -0.76). This indicated that when a farmer believes that it is religiously and culturally unacceptable to use a fertilizer made from fecal sludge, the farmers' tendency to consider the benefits of using fecal sludge-based fertilizer is reduced. The second factor called '*certification-trust*' is linked to certification of *Fortifer*™ by relevant authorities. This factor captures farmers' tendency to buy the product based on approval by relevant and trusted authorities. The third factor in both regions called '*price sensitive*' had high loadings on statements related to perceived price and cost of handling of *Fortifer*™ compared to alternative fertilizers such as chemical and other organic fertilizer found in the market. This factor captures farmers' tendency to buy *Fortifer*™ if it is cheaper than alternative fertilizer products and that it is easier to transport and handle compared to other organic fertilizers. The variable related to offering fecal sludge-based fertilizer at the same price as chemical fertilizer had a negative factor loading in both regions (-0.84 in Greater Accra and -0.76 in Western region), indicating that while farmers believed that *Fortifer*™ is easier to handle and transport, they would not buy it at the same price as chemical fertilizers. The fourth factor in Greater Accra called '*safety-cultural issues*' had high loadings on statements that reflected farmer concerns on safety, including cultural and religious beliefs against using fecal sludge-based fertilizers.

TABLE 7. FARMERS' ATTITUDES TOWARDS *FORTIFER*™ – RESULTS FROM GREATER ACCRA AND THE WESTERN REGION.

Perception statements	Greater Accra – factor loadings				Western region – factor loadings		
	Positive attribute (Factor 1)	*Certification-trust* (Factor 2)	*Price sensitive* (Factor 3)	*Safety-cultural issues* (Factor 4)	*Certification-trust* (Factor 1)	*Positive attribute* (Factor 2)	*Price sensitive* (Factor 3)
Compost/pellet derived from fecal sludge should be certified by relevant authorities	-0.096	**0.839**	0.165	-0.185	**0.882**	0.018	-0.039
If *Fortifer*™ is certified by the relevant authorities, it can be trusted	-0.102	**0.836**	0.117	0.055	**0.853**	-0.073	0.052
I am aware of the advantages/disadvantages of using compost/pellets derived from fecal sludge	0.215	**0.547**	-0.155	0.081	**0.712**	0.186	-0.053
I do not have any reservation in accepting and using fertilizer pellets derived from fecal sludge	0.339	**0.691**	-0.055	-0.032	**0.811**	0.084	0.021
Fortifer™ has potential to enhance agricultural productivity	**0.693**	0.325	0.019	0.088	0.396	**0.522**	-0.090
Fortifer™ can be a good replacement for chemical fertilizers	**0.698**	0.400	0.193	0.093	0.465	0.472	0.187
Using *Fortifer*™ can be economically more attractive for my farm than inorganic fertilizers	**0.779**	0.192	-0.016	0.196	0.225	**0.561**	0.191
The nutrients in *Fortifer*™ could easily be available to crops	**0.879**	-0.005	-0.031	0.088	0.273	**0.641**	0.026
I believe that *Fortifer*™ enhances long-term soil fertility	**0.876**	-0.082	0.184	0.063	0.132	0.471	0.321
Fortifer is easier to transport and handle than other organic fertilizers	0.229	-0.236	**0.765**	0.180	-0.073	0.198	0.331
I would buy *Fortifer*™ if it was sold at the same price as chemical fertilizer	0.348	-0.132	**-0.848**	0.138	0.095	-0.048	**-0.763**
I would buy *Fortifer*™ if it was cheaper than chemical fertilizer	0.2177	0.263	**0.792**	-0.295	0.127	-0.020	**0.882**
I would use *Fortifer*™ as it contributes to improvement of sanitation	**0.879**	-0.060	-0.067	-0.082	0.037	**0.605**	-0.060
I would use *Fortifer*™ as it contributes to reduction of environmental degradation	**0.630**	-0.074	0.443	-0.086	-0.104	0.184	0.375
Using pellets derived from fecal sludge is not safe to use	0.032	-0.008	-0.056	**0.877**	-0.104	-0.278	-0.469
Regardless of price, I try to avoid buying fertilizer pellets derived from fecal sludge	-0.049	0.048	-0.325	**0.620**	0.059	0.053	**-0.840**
I have a religious belief against the use of a fertilizer made from fecal sludge	0.226	-0.056	0.145	**0.724**	0.121	**-0.717**	0.019

(Continued)

TABLE 7. FARMERS' ATTITUDES TOWARDS *FORTIFER*™ – RESULTS FROM GREATER ACCRA AND THE WESTERN REGION. *(CONTINUED)*

Perception statements	Greater Accra – factor loadings				Western region – factor loadings		
	Positive attribute (Factor 1)	Certification-trust (Factor 2)	Price sensitive (Factor 3)	Safety-cultural issues (Factor 4)	Certification-trust (Factor 1)	Positive attribute (Factor 2)	Price sensitive (Factor 3)
It is culturally unacceptable to use a fertilizer made from fecal sludge	0.026	0.055	0.236	0.660	0.06	-0.761	0.050
Eigen value	4.79	2.66	2.37	2.43	4.08	2.81	2.19
Variance explained (%)	26	15	13	13	19	17	16
Cronbach alpha coefficient	0.89	0.75	0.74	0.62	0.73	0.86	0.81

4.4.2 Factor analysis results for Uganda

Three factors were identified in Kampala (Table 8). The first factor, *certification-trust*, had high loadings on variables related to certification of *Fortifer*™ by relevant authorities. This factor captures farmers' tendency to trust and buy the product based on approval by relevant and trusted authorities. This is also in line with farmers' attitudes towards certification of the product in Ghana. Thus, farmers in the selected regions of Ghana and Uganda perceived that product quality is guaranteed if certified by relevant authorities. In addition to certification, this factor had high loading on statements related to the perceived price of *Fortifer*™ compared to chemical fertilizer indicating that farmers tend to buy *Fortifer*™ if it is cheaper than chemical fertilizer. The second factor, *safety issues*, had high loadings on variables reflecting farmers' awareness of the advantages and disadvantages of fecal sludge-derived fertilizer and their concerns on safety aspects. This is also in line with results obtained in Ghana whereas factor four captured farmers' concerns on safety. The third factor, *positive attributes*, captured farmers' perceived advantage of fecal sludge-based fertilizer including their preference of the pellet over non-pellet form.

TABLE 8. FARMERS' ATTITUDES TOWARDS *FORTIFER*™ – RESULTS FROM KAMPALA.

	Factor loadings		
Perception statements	*Certification-trust* (Factor 1)	*Safety issues* (Factor 2)	*Positive attributes* (Factor 3)
Compost or pellets derived from fecal sludge should be certified by relevant authorities	**0.786**	-0.0744	0.133
If *Fortifer*™ is certified by the relevant authorities, it can be trusted	**0.500**	-0.179	0.123
I am aware of the advantages and disadvantages of using compost or pellets derived from fecal sludge	0.220	**0.581**	-0.518
I do not have any reservation about accepting and using fertilizer pellets derived from fecal sludge	**0.664**	0.0327	-0.056
I would buy *Fortifer*™ if it was sold at the same price as chemical fertilizer	0.399	-0.302	-0.070
I would buy *Fortifer*™ if it was cheaper than chemical fertilizer	**0.600**	-0.500	0.109
I would use *Fortifer*™ as it contributes to improvement of sanitation	**0.703**	0.060	-0.037
I would use *Fortifer*™ as it contributes to reduction of environmental degradation	0.230	-0.065	**0.839**
Using pellets derived from fecal sludge is not safe	-0.068	**0.762**	-0.066
Regardless of price, I try to avoid buying fertilizer pellets derived from fecal sludge	-0.167	**0.759**	0.144
I would prefer the pellet form over the powder form	-0.002	0.056	**0.805**
Eigen value	3.91	1.78	1.45
Variance explained (%)	26	19	14
Cronbach alpha coefficient	0.81	0.62	0.65

4.4.3 Factor analysis results for India and Sri Lanka

The farmers responded to fewer knowledge and attitude variables in India and Sri Lanka compared to those used in Ghana and Uganda. Table 9 presents the factor analysis results for Bangalore and Kurunegala. Three factors were identified in both cities. The total variance accounted for was 73% in Bangalore and 58% in Kurunegala. The first factor, *substitute*, had high loadings on variables related to the perceived price of *Fortifer*™ compared to chemical fertilizers. Likewise, the second factor in Kurunegala, *certification-substitute*, had high loadings on variables related to certification of the product by relevant authorities and to variables related to the perceived price of fecal sludge-based fertilizer. Both factors captured farmers' tendency to buy *Fortifer*™ irrespective of the price offered. Thus, farmers in Bangalore and Kurunegala perceived that *Fortifer*™ can substitute for chemical fertilizer. This is contrary to what was observed in Ghana and Uganda where farmers were price-sensitive and would only buy the product if it was cheaper than chemical fertilizer. The second factor in Bangalore, *certification-trust*, had high loadings on variables related to certification of the fertilizer product by relevant authorities and farmers' awareness of the advantages and disadvantages of fertilizers derived from fecal sludge.

TABLE 9. FARMERS' ATTITUDES TOWARDS *FORTIFER*™ – RESULTS FROM BANGALORE AND KURUNEGALA.

	Factor loadings – Bangalore			Factor loadings – Kurunegala		
Perception statements	*Substitute* (Factor 1)	*Certification-trust* (Factor 2)	*Safety Issue* (Factor 3)	*Positive* attribute (Factor 1)	*Certification-* substitute (Factor 2)	*Awareness* (Factor 3)
Compost or pellets derived from fecal sludge should be certified by relevant authorities	0.180	0.793	-0.199	0.051	0.741	0.340
If *Fortifer*™ is certified by the relevant authorities, it can be trusted	0.148	0.123	-0.328			
I am aware of the advantages and disadvantages of using compost or pellets derived from fecal sludge	-0.112	**0.924**	0.117	-0.231	0.035	**0.773**
I do not have any reservation about accepting and using fertilizer pellets derived from fecal sludge	0.505	**0.794**	-0.169	0.200	0.055	**0.747**
I would buy *Fortifer*™ if it was sold at the same price as chemical fertilizer	**0.850**	0.003	-0.259	0.251	**0.622**	-0.229
I would buy *Fortifer*™ if it was cheaper than chemical fertilizer	**0.947**	0.027	0.103	0.175	**0.743**	0.202
I would use *Fortifer*™ as it contributes to improvement of sanitation	**0.866**	0.127	0.224	**0.856**	0.069	0.015
I would use *Fortifer*™ as it contributes to reduction of environmental degradation				**0.779**	0.123	-0.028
I would use *Fortifer*™ as it improves the quality of the soil of my land				**0.725**	0.223	-0.081
Using pellets derived from fecal sludge is not safe	0.196	0.410	**0.607**			
Regardless of price, I try to avoid buying fertilizer pellets derived from fecal sludge	**-0.118**	**-0.234**	**0.852**			
Eigen value	4.15	1.95	1.43	2.77	1.34	1.06
Variance explained (%)	30	27	16	26	18	14
Cronbach alpha coefficient	0.90	0.81	0.42	0.69	0.53	0.29

The third factor, *safety issues*, had high loadings on variables reflecting farmers' concerns about safety aspects. However, the Cronbach alpha is low (0.42) indicating that the attitude variables loading on the safety factor do not measure the same underlying construct. Looking at the factors extracted from Kurunegala, the first factor, *positive attribute*, had high loadings on variables related to the perceived advantage of fecal sludge-derived fertilizers for improving sanitation and the environment. The third factor, *awareness*, captured farmers' knowledge of the advantages and disadvantages of fecal sludge-derived fertilizers and their acceptance without any reservation. However, the Cronbach alpha is low (0.29) indicating that the attitude variables loading on this factor does not measure the same underlying construct.

4.4.4 Factor analysis results for Vietnam

The perception statements used in the Hanoi surveys differed slightly because of the context and there was a need to adapt the questionnaires accordingly to ensure proper comprehension by the farmers. Three factors were identified in Hanoi (Table 10). The first factor, *certification-trust,* had high loadings on variables related to the use of a standardized production process and certified labelling of the *Fortifer*™ product by relevant authorities. Additionally, this factor had high loadings on statements related to confirmation of product quality by extension agents and other farmers who had used and tested the product. The second factor, *safety issues*, had high loadings on variables reflecting farmers' awareness of use of waste-derived (MSW and/or fecal sludge) fertilizer and their concerns on safety aspects. This result mirrors farmers' concerns on safety in Bangalore, Ghana and Uganda. The third factor, *substitute*, had high loadings on variables related to the perceived price of *Fortifer*™ compared to chemical fertilizers. This factor captured farmers' willingness to buy *Fortifer*™ in view of the price offered. Whilst the farmers in Bangalore and Kurunegala perceived that *Fortifer*™ can substitute for chemical fertilizer and will purchase it regardless of the price, this is contrary to what was observed in Vietnam where farmers are price-sensitive and would only buy the product if it was cheaper than chemical fertilizer.

TABLE 10. FARMERS' ATTITUDES TOWARDS *FORTIFER*™ – RESULTS FROM HANOI.

	Factor loadings		
Perception statements	*Certification-trust* (Factor 1)	*Safety issues* (Factor 2)	*Substitute* (Factor 3)
I would buy the product if there was proof that it is not made from municipal waste	0.211	**0.802**	-0.327
I would buy if there was proof that the product is not made from fecal sludge	0.115	**0.817**	-0.358
I would buy the product if it was produced through a standardized industrial production procedure	**0.606**	0.575	0.134
I would buy if the product was clearly labelled	**0.819**	0.385	-0.023
If Fortifer is certified by the relevant authorities, it can be trusted	**0.856**	0.294	-0.030
I would buy *Fortifer*™ if its effects were verified/confirmed by a local agricultural extension model	**0.892**	0.025	-0.126
I would buy *Fortifer*™ if specialized staff at my district/commune recommended me to use it	**0.702**	0.197	-0.325
I would buy *Fortifer*™ if fellow farmers have tested that it works	**0.715**	0.161	-0.212
I would buy *Fortifer*™ if it was 20% cheaper than the current most expensive NPK fertilizer	-0.053	-0.241	**0.877**
Price does not matter as long as it is good quality	-0.188	-0.309	**0.660**
I would buy *Fortifer*™ if I can purchase it on credit	0.431	**0.754**	0.088
I would buy *Fortifer*™ if there are sellers in my commune	0.631	0.553	-0.027
Eigen value	6.27	2.19	1.23
Variance explained (%)	33	23	19
Cronbach alpha coefficient	0.71	0.83	0.77

Looking at the overall result from each country, sampled farmers in all the selected regions perceived that if *Fortifer*™ is certified by relevant authorities, it can be trusted. Another important attitude construct that cuts across most of the selected regions is the safety issue which captures farmers' perceived concerns about the safety of the product. While sampled farmers in Bangalore and Kurunegala perceived that *Fortifer*™ can substitute for chemical fertilizer and would buy it irrespective of the price offered, farmers in Ghana and Uganda were price sensitive and would only buy *Fortifer*™ if it was cheaper than chemical fertilizer. Once the factors were identified, indices were created for each factor by calculating the factor scores for each farmer in the sample. The factor scores were then used as one of the explanatory variables in the dichotomous choice model to assess consumers' WTP for *Fortifer*™ (see subsequent section 5.5.1).

4.5 Factors Influencing Farmers' WTP for Fecal Sludge-based Fertilizer (*Fortifer*™)

4.5.1 Regression model results

We used a Probit regression model to estimate equation 2. Table 11 depicts the variables used in the econometric analysis. The log-likelihood ratio test was used to select the appropriate model for the analysis. A Principal Component Analysis (PCA) was used to determine the questions that provided a better assessment for farmers' purchasing decisions and perceptions about *Fortifer*™. The PCA showed that factors such as product certification, price and safety concerns of the product were the relevant questions to assess farmers' purchasing decisions. Also, the PCA revealed that the ability to use the product if certification was done by a relevant authority, product use without any reservations, certification by a trusted authority and benefits to the environment were better determinants of farmers' perceptions for a pelletized and certified *Fortifer*™ product.

Separate regression models were run for two formulation types of *Fortifer*™ – NPF and PF (Table 12). As noted earlier, the *Fortifer*™ product was developed to address challenges associated with using 'regular' compost or dried fecal sludge such as bulkiness, low nutrient content and associated health risks. Thus, it was important to not only assess farmers' WTP for the general *Fortifer*™ product (fecal sludge-based fertilizer) but also the specific product attributes. Reduced product bulkiness implies a more concentrated product with reduced volume, lower transportation costs and related lower labor costs. Farmers may thus be incentivized to pay a marginally higher price for pelletized over non-pelletized compost.

A set of common explanatory variables was used to explain farmers' WTP for the two products, which enabled comparison of results between the two models as well as comparison of results across regions and countries. In addition to the sociodemographic characteristics of the farmer and the random amount the farmer was asked to pay (Bid1), other explanatory variables included attitude variables obtained from the factor analysis. Attitudes of farmers are not necessarily independent of their sociodemographic characteristics, i.e. the differences in the attitudes of farmers are likely to be related to their sociodemographic characteristics. This poses an endogeneity problem as attitudes are partly determined by sociodemographic characteristics of farmers. To overcome the endogeneity problem, the factors obtained were first regressed on the sociodemographic characteristics of farmers as a system of linear equations by using seemingly unrelated regression estimation (SURE). Results of the SURE model indicated that the models were not significant and that the attitude variables were not endogenous for all the countries. Thus, the attitude variables were considered as exogenous explanatory variables.

TABLE 11. DEFINITIONS OF VARIABLES USED IN THE ECONOMETRIC ANALYSIS.

Variables	Description
Bid1	Amount of bid proposed to the farmer in USD kg^{-1}
Age	Age of the farmer in years
Education	Farmer's education in years
Hhmember	Size of farmer's household, as measured by the number of the members in the household (variable use as a proxy to measure household labor)
Farm_exp	Farmer's experience in years
Farmsize	Size of the farm in acres
Farmincome	Average annual income of the farmer in USD
FBOM	Member of farmers' association; dummy variable, 1 if member and 0 if not
Use_org_fert	Farmer's current use of organic fertilizer; dummy variable, 1 if farmer currently uses organic fertilizer and 0 if not
Offarm_work	Farmer engages in off-farm employment; dummy variable, 1 if yes and 0 if not
Landownership	Farmers' landownership (current land holding) variable; dummy variable, 1 if farmer owns land and 0 if not; 0 here defined as either renter, squatter, owns the land but untitled
Positive-attribute	Index measuring the factor score for the farmer's perceived benefits[a] of *Fortifer*™
Certification-trust	Index measuring the factor score for the farmer's willingness to buy *Fortifer*™ if certified by a trusted entity
Price-sensitive	Index measuring the factor score of the farmer's perceived price and cost of handling of *Fortifer*™ as compared to alternative fertilizers such as chemical fertilizer (farmer's willingness to buy *Fortifer*™ if competitively priced with its substitutes)
Safety-culture	Index measuring the factor score of the farmer's concerns on safety, particularly as related to cultural and religious beliefs
Safety issues	Index measuring the factor score of the farmer's concerns on safety as related to the farmer's awareness of the advantages and disadvantages of fecal sludge-based fertilizer and associated safety concerns
Substitute	Index measuring the factor score of the farmer's perceived price of *Fortifer*™ compared to chemical fertilizers
Certification-substitute	Index measuring the factor score of the farmer's willingness to buy *Fortifer*™ if certified by a trusted entity and perceived price of *Fortifer*™ compared to chemical fertilizers
Product awareness	Index measuring the factor score of the farmers' knowledge of the advantages and disadvantages of fecal sludge-derived fertilizers and their acceptance without any reservation

Note: [a] Perceived benefits here relate to the potential of *Fortifer*™ to enhance agricultural productivity, nutrient availability to crops, long-term soil fertility including its contribution to improving sanitation and environmental sustainability.

Results for Ghana: Tables 12 and 13 present the Probit model results for the WTP equations for NPF and PF in Greater Accra and the Western region respectively. In Greater Accra, the Bid1 variable was statistically significant in both models; as the bid went up the probability of a positive answer went down. Thus, the higher the amount requested to pay, the lower the probability a farmer would be willing to pay for NPF and PF. Furthermore, it implied that the farmers were more likely to choose different formulations of *Fortifer*™ if it was less expensive than other inorganic or organic fertilizers. Examining the results of the sociodemographic characteristics of respondents, some of the sociodemographic characteristics which had a statistically significant effect on farmers' WTP for NPF did not have a significant effect on the probability of farmers' WTP for PF and vice versa. While the educational level of the farmer had a negative and significant effect on the likelihood of farmers' WTP for NPF, it had no statistically significant effect on farmers' WTP for PF indicating that farmers with higher level of education were less likely to be willing to pay for NPF.

In contrast to the results for the Greater Accra region, in the Western region the Bid1 variable was not statistically significant in both models indicating that price did not have a significant effect on farmers' WTP for different formulations of *Fortifer*™. For the sociodemographic characteristics of the respondents, the variable *farm_exp,* which represents the farmers' farming experience, had a negative and statistically significant effect on farmers' WTP for PF however, the same variable did not have a statistically significant effect on farmers' WTP for NPF indicating that as farmers' farming experience increases, farmer's likelihood of paying for PF reduces. Thus, young farmers with less years of farming experience are more likely to pay for PF in the Western region.

We expected farmers' characteristics to have a significant effect on farmer's WTP for *Fortifer*™. This was confirmed by the fact that farm characteristics such as farm income, farmers' previous use of any organic fertilizer and having off-farm work and land titles all had a statistically significant effect on the likelihood of a farmer's WTP for at least one *Fortifer*™ formulation in Greater Accra. While farm size and whether a farmer

TABLE 12. PROBIT ESTIMATES – WTP FOR NPF AND PF IN THE GREATER ACCRA REGION.

Variable	**NPF**		**PF**	
	Coefficient	*Z-value*	*Coefficient*	*Z-value*
Bid1	-0.090	-2.18**	-0.077	-1.95*
Farm_exp	0.005	0.45	-0.003	-0.04
Education	-0.245	-1.95**	-0.053	-0.46
Farmsize	-0.003	-0.13	-0.004	-0.20
Farmincome	0.0003	0.88	0.0001	2.76**
FBOM	0.212	0.85	-0.055	-0.24
Use_org_fert	-0.517	-2.07**	-0.309	-1.36*
Offarm_work	0.821	2.05**	0.611	1.76*
Landownership	-0.078	-0.18	0.007	0.98
Positive-attribute	0.071	0.49	0.015	0.89
Certification-trust	0.049	0.48	-0.038	-0.40
Price-sensitive	-0.269	-2.12**	-0.047	-0.41
Safety-culture	-0.275	-1.81*	0.016	0.16
Constant	2.762	3.08**	1.731	1.57*
Log likelihood	-83.19		-97.96	
LR Chi^2	26.68		28.11	
Prob > Chi^2	0.001		0.020	
Pseudo R^2	0.14		0.15	
Number of observations	160		158	

Notes: *Significant at the 0.10 level.
**Significant at the 0.05 level.

is a member of a farmers' association did not have a statistically significant effect on farmers' WTP for both *Fortifer*™ formulations, farm income had a positive and significant effect on farmers' WTP for PF. This indicates that farmers with higher income are more likely to be willing to pay for PF, implying that wealthier farmers have more flexibility in allocating funds and are more willing to invest in new agricultural inputs to further improve yield. Farmers who previously used any form of organic fertilizers such as compost or animal dung are less likely to be willing to pay for any of the *Fortifer*™ formulations. This might be because organic fertilizers, such as composts, are available informally at a lower price and animal dung is sourced at a lower price in Ghana, thus making *Fortifer*™ less attractive for those who rely on other organic fertilizers.

Having off-farm work had a positive and significant effect on farmers' WTP for both *Fortifer*™ formulations, indicating that farmers who had off-farm work were more likely to be willing to pay for the two *Fortifer*™ formulations. Furthermore, we expected that farmers who owned the land they cultivated would be more likely to be willing to invest in agricultural inputs to ensure that long-term soil quality is preserved.

However, our results showed that landownership did not have a statistically significant effect on farmers' WTP for any of the *Fortifer*™ formulations. Of the attribute variables, farmers' perceived price and cost of handling of *Fortifer*™ compared to alternative fertilizers such as chemical fertilizer (*price-sensitive*) and safety concerns driven by cultural and religious beliefs (*safety-culture*) were noted to negatively influence their WTP for the *Fortifer*™ product, particularly NPF.

Similarly, in the Western region farm characteristics such as farm size, farm income, landownership and farmers' previous use of any organic fertilizer all had statistically significant effects on the likelihood of farmers' WTP for at least one *Fortifer*™ formulation. Farm size had a positive and statistically significant effect on farmers' WTP for both *Fortifer*™ formulations, however farm size did not have a statistically significant effect on farmers' WTP in the Greater Accra region. This indicated that in the Western region, farmers with larger farm sizes will be more willing to pay for *Fortifer*™ products.

TABLE 13. PROBIT ESTIMATES – WTP FOR NPF AND PF IN THE WESTERN REGION.

Variable	NPF		PF	
	Coefficient	*Z-value*	*Coefficient*	*Z-value*
Bid1	-0.029	-0.59	0.036	0.81
Farm_exp	-0.001	-0.53	-0.003	-1.87**
Education	0.144	0.95	-0.160	-1.21
Farmsize	0.061	1.41*	0.042	1.79*
Farmincome	0.002	2.37**	-0.001	-1.18
Landownership	-0.132	-0.43	-0.404	-1.54*
Use_org_fert	-0.277	-0.96	-0.560	-2.15**
Offarm_work	-0.436	-1.21	-0.380	-1.21
Certification_trust	-0.232	-1.56*	0.153	1.08
Positive_attribute	-0.044	-0.27	0.089	0.52
Price_sensitive	0.149	1.06	-0.006	-0.05
Constant	-0.319	-0.34	0.258	0.22
Log likelihood	-60.57		-75.22	
LR Chi^2	24.19		21.34	
Prob > Chi^2	0.010		0.030	
Pseudo R^2	0.17		0.13	
Number of observations	124		124	

Notes: *Significant at the 0.10 level.
**Significant at the 0.05 level.

While farm income had a positive and significant effect on farmers' WTP for NPF, it was weakly significant at the 20% critical level in the case of PF indicating that farmers with higher income were more likely to be willing to pay for NPF. This was in contrast to the results obtained in Greater Accra where farmers with higher income were more likely to pay for PF. Farmers who previously used any form of organic fertilizers such as compost or animal dung were less likely to be willing to pay for any of the *Fortifer*™ formulations. Similar results were obtained in the Greater Accra region.

Model results pertaining to attitude variables revealed that in Greater Accra, the parameters for *price-sensitive* and *safety-culture* were significant at 5 and 10% critical levels respectively for NPF. *Price-sensitive* and *safety-culture* both had a negative effect on the probability of farmers' WTP for NPF. The attitude variable *price-sensitive* captures farmers' tendency to buy *Fortifer*™ if it is cheaper than chemical fertilizer and easier to transport and handle compared to other organic fertilizers while the *safety-culture* variable captures farmers' concerns on safety, including cultural and religious beliefs against using fecal sludge-based fertilizers. A negative and significant effect of these attitude variables indicated that farmers who believed that *Fortifer*™ should be priced lower than other inorganic fertilizer as well as farmers who had concerns about the safety of the product were less likely to pay for NPF. In contrast, attitude variables did not have a significant impact on farmers' willingness to pay for PF.

In the Western region, the attitude variable, *certification-trust* had a negative and statistically significant effect on farmers' WTP for NPF but was weakly significant at the 20% critical level and had a positive effect in the case of PF. This indicated that farmers expressing concerns about product certification are less likely to pay for NPF but are more likely to pay for PF in the Western region. Other attitude variables did not have a significant impact on farmers' WTP for both *Fortifer*™ products.

Results for Uganda: The results of the Probit models for Kampala are presented in Table 14. The FBOM (farmer's membership in the farmers' association) variable was omitted from the regression models due to the limited variation in the data points. Only two farmers were noted to belong to a farmers' association. For both regression models, the Bid1 variable is negative and statistically significant as expected, indicating that price increases will reduce the probability of a farmer buying either NPF or PF. Of the sociodemographic variables, the farmers' experience in agricultural production and level of farm income are statistically significant. In the case of NPF, the more experienced the farmer is, the less likely she/he is to invest in NPF. Whilst this result is contrary to what was expected – as more experienced farmers are likely to be more familiar with the benefits of organic fertilizer use–this result may suggest that 'older' farmers are less willing to invest in inputs with delayed/ longer-term benefit accrual. Similar to the case in the Greater Accra region, farmers earning higher incomes are more willing to purchase *Fortifer*™ products, although more so for PF than NPF. Farmers engaging in off-farm work were noted in both Kampala and the Greater Accra region to be willing to pay for PF. This may be indicative of budget flexibility that the farmers have from additional income earned from off-farm employment.

It was hypothesized that farmers with a smaller household size would be more willing to use PF given its attributes of reduced labor requirements in comparison to NPF. The *Hhmember* variable was used as a proxy to measure labor availability for agricultural production. Although the negative coefficient supports the notion of labor savings for PF use, it is statistically insignificant. Subsequently excluding it from the regression model had very marginal (insignificant) effects on the fit of the model. Landownership plays an important role in farmers' purchasing decisions of agricultural inputs. We note from the results that farmers who own the land they farm on are more willing to invest in *Fortifer*™ than those who are either renters, squatters or own untitled land. This corroborates the findings in both regions in Ghana. Farmers with previous experience in using other organic fertilizers such as compost, animal manure (*use_org_fert*) are more willing to buy *Fortifer*™ products, which is in contrast to the findings in Ghana. This may be suggestive of the lower product quality available to farmers, but as indicative in Table 4, organic fertilizer use is more prevalent in Uganda than in Ghana.

Two of the three attribute variables were statistically significant for both NPF and PF. Farmers who have safety concerns (reservations) with *Fortifer*™ use are less willing to pay for the product as indicated by the negative coefficient. This result is supported by farmers' willingness to buy a formulation of *Fortifer*™ if a trusted governmental authority certifies the product – indicative of their need of safety assurance.

TABLE 14. PROBIT ESTIMATES – WTP FOR NPF AND PF IN KAMPALA.

Variable	NPF		PF	
	Coefficient	*Z-value*	*Coefficient*	*Z-value*
Bid1	-4.548	-2.58***	-4.037	-3.31***
Farm_exp	-0.011	-1.78*	0.008	1.27
Education	0.018	0.80	0.013	0.61
Hhmember	0.026	0.80	-0.020	-0.71
Farmsize	0.058	0.76	0.117	0.18
Farmincome	0.00007	0.75	0.0003	1.93**
Use_org_fert	0.439	1.71*	0.106	0.678
Offarm_work	-0.092	-0.42	0.356	1.75*
Landownership	0.351	1.98*	0.407	1.95*
Safety issues	-0.428	-4.45***	-0.202	-2.34***
Certification_trust	0.198	2.24***	0.149	1.70*
Positive_attribute	-0.146	-1.30	-0.083	-0.80
Constant	1.557	2.80***	0.902	1.64*
Log Likelihood	-127.808		-155.741	
LR Chi^2	53.61		41.14	
Prob > Chi^2	0.0001		0.0001	
Pseudo R^2	0.173		0.117	
Number of observations	258		258	

Notes: *Significant at the 0.10 level.
**Significant at the 0.05 level.
***Significant at the 0.01 level.

Overall, the results from the African countries indicated that farmers' willingness to buy *Fortifer*™ decreases with increasing prices as expected. The effects of the socioeconomic variables related to the farmers' agricultural production experience, farm income, landownership and off-farm work on the farmers' WTP for *Fortifer*™ were similar across the three cities. Higher farmer income and landownership positively influenced their investment decision for *Fortifer*™ as did off-farm work. Surprisingly, contrasting results were noted for the variable capturing the effect of farmers' previous use of organic fertilizer on their WTP. Product certification is a crucial factor that influences farmers' purchasing decisions of any *Fortifer*™ product. This result indicated that there is a strong need for relevant governmental authorities in these countries to provide adequate product safety and quality control.

Results for India: Bangalorean farmers were less willing to pay for *Fortifer*™ at higher prices as indicated by the negative coefficient for the Bid1 variable (Table 15). Of the socioeconomic variables, farmers' experience in agricultural production was the only statistically significant variable. It showed that the more experienced the farmer is, the less likely she/he will invest in PF, similar to the findings in Uganda and Ghana. Whilst this result is contrary to what was expected – as more experienced farmers are likely to be more familiar with the benefits of organic fertilizer use–this result may suggest that 'older' farmers are less willing to invest in inputs with delayed benefit accrual. Prior use of organic fertilizer positively influences farmers' WTP for both NPF and PF. The income effects of off-farm work on farmers' purchasing decisions of *Fortifer*™ can be ambiguous in that with the additional income, they may be willing to invest more in agricultural inputs. However, the option of alternative employment, especially if wages are higher, may deter farmers from making incremental investments in agriculture. It was noted among Bangalorean farmers that the latter is true and this may be indicative of increased urban development that threatens peri-urban and urban agriculture. Landownership is a critical factor influencing farmers' purchasing decisions of *Fortifer*™. Similar to the African cases, farmers that rent, squat or own untitled land are less willing to invest in *Fortifer*™. This may suggest that they view buying *Fortifer*™ as an investment for which they may not recoup a return in the 'very' short term. Of the attribute variables, certification and perception of product safety significantly influenced farmers' WTP for the *Fortifer*™ product. Whilst, the coefficient on the *substitute* variable was positive and indicated that farmers were more willing to buy *Fortifer*™ if it was sold at the same or a lower price than chemical fertilizer, it was not statistically significant.

TABLE 15. PROBIT ESTIMATES – WTP FOR NPF AND PF IN BANGALORE.

Variable	NPF		PF	
	Coefficient	*Z-value*	*Coefficient*	*Z-value*
Bid1	-4.308	-2.80***	-5.487	-3.16***
Hhmember	-0.036	-0.23	0.217	1.09
Education	-0.066	-1.07	0.058	0.88
Farm_exp	0.0158	0.42	-0.102	-2.04**
Farmincome	-0.002	-0.54	0.0025	0.45
FBOM	-0.184	-0.23	0.221	0.30
Use_org_fert	0.458	1.96*	1.419	1.69*
Offarm_work	-2.371	-2.32***	0.576	0.82
Landownership	0.997	2.06**	0.792	2.92***
Substitute	0.367	0.99	0.294	0.70
Certification_trust	1.668	3.15***	0.219	0.68
Safety_issues	-0.841	-2.09**	-0.905	-2.52***
Constant	3.586	1.69*	1.758	0.7
Log likelihood	-14.43		-15.171	
LR Chi^2	45.33		38.40	
Prob > Chi^2	0.001		0.001	
Pseudo R^2	0.611		0.559	
Number of observations	54		54	

Notes: *Significant at the 0.10 level.
**Significant at the 0.05 level.
***Significant at the 0.01 level.

Results for Vietnam: Data were not available for the off-farm work, landownership and FBOM variables, and so were not included in the regression models for Hanoi. Additionally, age of the farmer was used as a proxy to measure the farmers' experience in agricultural production given limited data on the number of years the farmers were engaged in farming activities. As expected, the Bid1 variable was negative and statistically significant – suggesting higher farmers' WTP for *Fortifer*™ in view of lower prices (Table 16). Farmers with higher levels of education were noted to be less willing to pay for NPF, similar to the case in Ghana. This result may be because older farmers were less willing to adopt new agricultural technologies and were inherently less educated. An interesting result was that farmers with larger farm size were less willing to pay for NPF whilst the opposite was true for PF. This confirmed our hypothesis that farmers will adopt PF based on the inherent labor-saving characteristic of the product. Although farmers predominantly use inorganic fertilizer as opposed to organic fertilizer, the regression model suggests that farmers who have greater experience using organic fertilizer are more likely to pay for *Fortifer*™, in particular PF.

In terms of the attribute variables, the negative and statistically significant coefficient on the *substitute* variable suggested that farmers would be more willing to pay for *Fortifer*™ if its price was lower than or equal to that of chemical fertilizer. Product certification by a trusted governmental entity was additionally noted to be an important factor in farmers' purchasing decisions of *Fortifer*™ as in Bangalore. Farmers had no reservations about using either NPF or PF as long as it was proven safe and of high quality. The sign and significance of the *safety_issues* variable, which measures the farmers' concerns on safety related to use of a fecal sludge-based fertilizer, provided further evidence to support this result.

TABLE 16. PROBIT ESTIMATES – WTP FOR NPF AND PF IN HANOI.

Variable	**NPF**		**PF**	
	Coefficient	*Z-value*	*Coefficient*	*Z-value*
Bid1	-2.082	-2.34***	-2.284	-3.67***
Farm_exp	0.003	0.43	-0.005	-0.96
Education	-0.036	-2.18***	-0.003	-0.24
Farmsize	-0.343	-2.28***	0.175	1.95*
Farmincome	0.000002	0.58	-0.0000007	-0.76
Use_org_fert	-0.159	-0.94	0.415	3.14***
Substitute	-0.277	-3.61***	-0.074	-2.06**
Certification-trust	0.081	1.95*	0.042	1.97*
Safety_issues	-0.284	-4.12***	0.031	0.62
Constant	1.199	2.65***	-0.074	-0.25
Log likelihood	-232.02		-521.56	
LR Chi^2	43.80		33.12	
Prob > Chi^2	0.0001		0.0001	
Pseudo R^2	0.386		0.308	
Number of observations	260		260	

Notes: *Significant at the 0.10 level.
**Significant at the 0.05 level.
***Significant at the 0.01 level.

Results for Sri Lanka: The results for the regression model for Kurunegala showed that farmers would be less willing to pay for *Fortifer*™ at higher bids (Table 17). Assessing the effects of the socioeconomic variables showed that education had an ambiguous effect on farmers' WTP for *Fortifer*™. Whilst this variable was generally insignificant for PF across the other cities, it was negative and statistically significant in Kurunegala. Higher levels of education can suggest a greater understanding of the benefits from *Fortifer*™ use and thus these farmers were more willing to use the product, although this was specific to PF. Farm size was an important variable affecting farmers' WTP for *Fortifer*™ – farmers with larger farms had a lower WTP for NPF than those with smaller-sized farms. This confirmed our hypothesis that farmers consider the labor-saving characteristics of agricultural inputs (in this case, fertilizers) in their purchasing decisions. Higher farmer income positively influences farmers' WTP – suggesting that wealthier farmers have more flexibility in allocating financial resources and are more willing to invest in new agricultural inputs to further improve yield.

All the attribute variables were statistically significant in the case of PF. Beyond the imperative need for a certified *Fortifer*™ product to incentivize farmers' WTP for the product, farmers' perceived benefits positively influenced their WTP. Additionally, the farmers in Hanoi were noted to be more willing to pay for *Fortifer*™ if they were knowledgeable about the advantages and disadvantages of using fecal sludge-based fertilizers and accepted its use without any reservation.

TABLE 17. PROBIT ESTIMATES – WTP FOR NPF AND PF IN KURUNEGALA.

Variable	NPF		PF	
	Coefficient	*Z-value*	*Coefficient*	*Z-value*
Bid1	-17.915	-6.07***	-6.983	-1.98**
Hhmember	0.055	2.90	0.017	0.30
Farm_exp	-0.006	-0.98	-0.006	-0.96
Education	0.018	0.59	0.065	2.18***
Farmsize	-0.004	-1.95*	-0.003	-0.74
Farmincome	0.00002	1.93*	0.00002	1.98*
Use_org_fert	0.115	0.58	-0.050	-0.28
Landownership	-0.325	-0.86	0.052	0.17
Positive-attribute	-0.067	-0.75	0.075	2.12**
Certification-substitute	0.096	2.13**	0.028	2.33***
Awareness	0.119	1.32	0.173	2.15***
Constant	3.093	4.49***	0.440	0.53
Log likelihood	-134.08		-174.20	
LR Chi^2	52.62		20.90	
Prob > Chi^2	0.0001		0.034	
Pseudo R^2	0.164		0.156	
Number of observations	267		267	

Notes: *Significant at the 0.10 level.
**Significant at the 0.05 level.
***Significant at the 0.01 level.

In summary, results for the Asian countries indicated that increases in price will decrease farmers' WTP for both *Fortifer*™ products. Farm size was an equally important indicator for farmers' purchasing decisions, particularly for NPF – as farmers were less likely to be willing to pay for NPF if they had large farm sizes. This is indicative of the incremental labor requirements for NPF (representative of additional production costs) which farmers take into account when deciding on the type of fertilizers they will use. Farmers' income generally did not influence their WTP for *Fortifer*™, with the exception of Kurunegala where wealthier farmers were more likely to purchase PF. The effects of landownership on farmers' WTP was evident only in the case of Bangalore, as was farmers' previous experience in using organic fertilizer. The latter result however extends also to Hanoi. Important determinants of farmers' WTP for NPF and PF were the attribute variables. In both cases, product certification by a trusted governmental body was imperative to incentivize farmers' purchase of *Fortifer*™. This result is supported by the fact that farmers' concerns on safety associated with the use of *Fortifer*™ negatively affects their likelihood of purchasing the product. Price of competitive products significantly influences farmers' adoption behavior as noted by the negative and significant coefficient of the *substitute* variable, although specific to Hanoi. Cheaper substitute products will result in a lower demand for *Fortifer*™.

In comparing the results of the Asian and African countries, the regression models showed that farmers were less willing to pay for *Fortifer*™ at higher bids, and this was consistent across all the six countries (Annexes 2 and 3). Assessing the effects of the socioeconomic variables showed that education had an ambiguous effect on farmers' WTP for *Fortifer*™. Farm size, status of landownership and previous experience using organic fertilizer also significantly influenced a farmer's purchasing decision on *Fortifer*™. Most farmers in the study countries, with the exception of the Greater Accra region and Hanoi, owned the land that they farmed. It is thus expected that farmers from Kampala, Bangalore and Kurunegala, all things being equal, will be more willing to pay and use *Fortifer*™. The effects of farm size on farmers' WTP differed by product type, in that farmers with larger farm sizes were more willing to pay for PF over NPF, as the latter requires more labor for application. The effects of the attribute variables were similar and consistent across both the Asian and African countries. In particular, farmers' concerns about product safety and related need for certification were key factors influencing their decision when purchasing *Fortifer*™. Third-party product certification is necessary, especially in the Asian countries where guidelines for fecal sludge use in agriculture are unclear.

4.5.2 Farmers' marginal WTP

Marginal effects results – Ghana and Uganda: Table 18 presents the estimated marginal effects of the explanatory variables on the likelihood of farmers' WTP for *Fortifer*™ products in the Greater Accra and Western regions, and Kampala. As expected, in Greater Accra, the bid variable had a negative and statistically significant marginal effect. The higher the amount the farmer was requested to pay, the lower the probability that a farmer would be willing to pay for *Fortifer*™. Thus, if the bid amount rose by USD 1.00, the probability of the farmer paying for NPF and PF decreased by 0.027. The impact of increasing the price on farmers' WTP was similar for both *Fortifer*™ products. In contrast, in the Western region, the bid amount had no statistically significant marginal effect on the likelihood of farmer's WTP for both *Fortifer*™ products. The case of Kampala was similar to that of the Greater Accra region where there was a negative marginal effect of the bid on farmers' WTP for *Fortifer*™. A USD 1.00 increase in the bid amount reduced the probability of a farmers' WTP by 1.445 and 1.573 for NPF and PF, respectively. This reflects a significant reduction in demand from price changes that producers need to pay particular attention to.

The effect of the farmers' sociodemographic characteristics showed that the education variable had a negative and statistically significant marginal effect on NPF in the Greater Accra region while education of farmer did not have a statistically significant marginal effect on farmer's WTP for both products in the Western region and Kampala. However, the variable *farm_exp* had a negative and statistically significant marginal effect on farmers' WTP for PF and NPF in the Western region and Kampala, respectively. Thus, an increase in one level of education decreased the probability of WTP by 0.072 for NPF in Greater Accra region and an increase in the number of years of farming by one year decreased the probability of WTP by 0.001 for PF in the Western region and 0.003 for NPF in Kampala.

The effect of farm characteristics showed that off-farm work and previous use of organic fertilizer had statistically significant marginal effects on farmers' WTP for both products in Greater Accra while farm income had a statistically significant marginal effect on farmers' WTP for PF only. Similarly, farm characteristics such as farm size, farm income, land title and previous use of organic fertilizer had statistically significant marginal effects on farmers' WTP for at least one *Fortifer*™ product in the Western region and Kampala. The fact that a farmer used organic fertilizer decreased the probability he/she would be willing to pay for NPF and PF by 0.152 and 0.109 respectively in the Greater Accra region while it decreased the probability of farmer's WTP for PF by 0.194 in the Western region. In Kampala, previous experience with organic fertilizer increased the probability of farmers' WTP for *Fortifer*™ by 0.152 for NPF, with no marginal effects for PF. Moreover, farmers who had off-farm work were more likely to pay for PF only in Kampala, and both NPF and PF in the Greater Accra region while off-farm work did not have a statistically significant marginal effect on farmers' WTP for both products in the Western region. Farm income had a positive and statistically significant marginal effect on farmers' WTP for PF in Greater Accra and Kampala while it had a positive and statistically significant marginal effect on farmers' WTP for NPF in the Western region. An increase in farm income by USD 1.00 increased farmers' likelihood to pay for PF by 0.0003 and 0.0001 in Greater Accra and Kampala, respectively. In the Western region, an increase in farm income by USD 1.00 had a greater marginal effect of 0.001 for NPF. Farm size had a significant and positive marginal effect on farmers' WTP for both products only in the Western region. An increase in farm size by 1 acre increased farmer's likelihood to pay for NPF and PF by 0.199 and 0.015 respectively. Land titles did not have a statistically significant marginal effect on farmers' WTP for both products in Greater Accra while it had a significant and positive marginal effect on farmers' WTP for both products in Kampala. It was noted that when farmers own the land they cultivate, the probability of their WTP for both NPF and PF increases by 0.124 and 0.154, respectively.

TABLE 18. MARGINAL EFFECTS FOR WTP EQUATIONS FOR NPF AND PF IN THE GREATER ACCRA AND WESTERN REGIONS, GHANA AND KAMPALA, UGANDA.

Variables	Greater Accra region		Western region		Kampala	
	NPF	*PF*	*NPF*	*PF*	*NPF*	*PF*
	Coefficient	Coefficient	Coefficient	Coefficient	Coefficient	Coefficient
Bid1	-0.023**	-0.022*	-0.009	0.013	-1.445***	-1.573***
Hhmember	-	-	-	-	0.008	-0.008
Education	-0.076**	-0.038	0.047	-0.055	0.006	0.005
Farm_exp	-	-	-0.003	-0.001**	-0.003*	0.003
Farmsize	-	-	0.199*	0.015*	-0.019	0.005
Farmincome	0.000	0.0002**	0.001**	-0.002	0.00002	0.0001**
Use_org_fert	-0.148**	-0.143**	-0.091	-0.194**	0.152*	0.041
Offarm_work	0.243**	0.248**	-0.142	-0.132	-0.029	0.136*
Landownership	-0.014	0.002	-0.043	-0.140*	0.124*	0.154*
Price_sensitive	-0.077**	-0.019	0.048	-0.002	-	-
Safety_culture	-0.059*	0.009	-	-	-	-
Certification_trust	-	-	-0.076*	0.053	0.063***	0.058*
Positive_attribute	-	-	-0.014	0.031	-0.046	-0.032
Safety_issues	-	-	-	-	-0.136***	-0.079***

Notes: *Significant at the 0.10 level.
**Significant at the 0.05 level.
***Significant at the 0.01 level.

The marginal effects also showed that a higher score in the attitude variables, price-sensitive and safety-cultural issues, decreased the likelihood of consumers' WTP for NPF in Greater Accra. When the score in the attitude variables *price-sensitive* and *safety_cultural issues* increased by 1 unit, the probability of WTP for NPF decreased by 0.077 and 0.059 respectively. In the Western region, only one attitude variable – *certification_trust* – had a negative and statistically significant marginal effect on farmers' WTP for NPF indicating that an increase by one unit in the score of the attitude variable *certification_trust* decreases the probability of WTP for NPF by 0.076. Thus, while at least one attitude variable had a statistically significant marginal effect on NPF in both regions, none of the attitude variables had statistically significant marginal effects on farmers' WTP for PF in both regions. In the case of Kampala, a unit increase in the score of the *certification_trust* variable increased the probability of WTP for both NPF and PF by 6.3% and 5.8%, respectively. On the other hand, perceived product safety concerns decreased demand. A unit score increase in the *safety_issues* variable decreased the likelihood of a farmer's WTP for NPF and PF by 14% and 8%, respectively. The *positive_attitude* variable however had no marginal effect on the probability of WTP for either products.

Marginal effects results – India, Vietnam and Sri Lanka: Table 19 presents the estimated marginal effects of the explanatory variables on the likelihood of farmers' WTP for *Fortifer*™ products in Bangalore, Hanoi and Kurunegala. As expected, in all three countries, the bid variable had a negative and statistically significant marginal effect. The higher the price a farmer had to pay, the lower the probability that they would be willing to pay for *Fortifer*™*.* A USD 1.00 increase in the bid amount offered decreased the probability of the farmer paying for NPF by 160%, 30% and 594% in Bangalore, Hanoi and Kurunegala, respectively. Likewise, for PF, a USD 1.00 increase in price reduced demand by 139%, 89% and 277% in the three cities. This result suggests a very elastic demand curve, particularly for Kurunegala.

The effect of the sociodemographic characteristics of the farmers showed that the education variable had an ambiguous effect on *Fortifer*™ products across the countries. Whilst a negative effect was observed in Hanoi, a 1-level increase in the education level of a farmer increased the probability of WTP by 3% for PF in Kurunegala. No marginal effects for this variable were observed in Bangalore. The variable *farm_exp* had a negative and statistically significant marginal effect on farmers' WTP for PF in Bangalore. Thus, an increase in the number of years of farming by one year decreased the probability of WTP by 2.6% for PF in Bangalore.

The effect of farm characteristics showed that farm income, off-farm work, previous use of organic fertilizer, farm size and status of landownership had statistically significant marginal effects on farmers' WTP for at least one *Fortifer*™ product in the three countries. Farm income had a positive and statistically significant marginal effect on farmers' WTP only in Kurunegala and for PF. An increase in farm income by USD 1.00 increased farmers' likelihood to pay for PF by 0.000007. In the Western region, an increase in farm income by USD 1.00 had a greater marginal effect of 0.001 for NPF. Interestingly, farmers who had off-farm work were less likely to pay for NPF in Bangalore. The income effects of off-farm work on farmers' purchasing decision of *Fortifer*™ can be ambiguous in that with the additional income, they may be willing to invest more in agricultural inputs. However, in the case of Bangalore, the option of alternative employment, especially if wages are higher, may deter farmers from making incremental investments in agriculture.

The fact that a farmer used organic fertilizer increased the probability that she/he would be willing to pay for NPF and PF by 18% and 34%, respectively in Bangalore, while it increased the probability of farmers' WTP for PF by 16% in Hanoi. However, no marginal effects were observed for either *Fortifer*™ product in Kurunegala. Farm size had a significantly negative marginal effect on farmers' WTP for NPF and a positive marginal effect for PF in Hanoi and Kurunegala. An increase in farm size by 1 acre decreased a farmer's likelihood to pay for NPF by 5% and 0.1% in Hanoi and Kurunegala, respectively. On the other hand, a 1-acre increase in farm size increased the probability of farmers' WTP by 7% and 0.1% in Hanoi and Kurunegala, respectively. Status of landownership had an effect on farmers' purchasing decisions in Bangalore. Farmers who owned the land they cultivated were willing to pay for the *Fortifer*™ product, irrespective of the formulation. Landowning farmers were 38% and 16% more likely to be willing to pay for NPF and PF, respectively. No marginal effects for this variable were observed in either Hanoi or Kurunegala. The *Hhmember* variable, capturing the effects of free or inexpensive labor availability, had no marginal effects on demand in any of the countries.

The marginal effects also showed that a higher score in the attitude variables, *certification_trust* and *positive_attitude*, increased the likelihood of consumers' WTP for at least one of the *Fortifer*™ products in all three countries. A unit increase in the score of the *certification_trust* variable increased the probability of farmers' WTP for NPF by 65%, 2% and 3% in Bangalore, Hanoi and Kurunegala, respectively. The marginal effects of the *positive_attitude* variable were only observed for PF in Kurunegala.

On the other hand, farmers' concerns on safety issues associated with *Fortifer*™ use had a negative and statistically significant marginal effect on their WTP for both NPF and PF, indicating that a one-unit increase in the score of the variable *safety_issues* would decrease the probability of WTP for NPF and PF by 33% and 23%, respectively in Bangalore. A 4% decrease was similarly observed for NPF in Hanoi.

TABLE 19. MARGINAL EFFECTS FOR WTP EQUATIONS FOR NPF AND PF IN BANGALORE, HANOI AND KURUNEGALA.

	Bangalore		**Hanoi**		**Kurunegala**	
Variables	*NPF*	*PF*	*NPF*	*PF*	*NPF*	PF
	Coefficient	Coefficient	Coefficient	Coefficient	Coefficient	Coefficient
Bid1	-1.678***	-1.390***	-0.296***	-0.886***	-5.949***	-2.772**
Hhmember	-0.014	0.551	-	-	-0.018	0.007
Education	-0.026	0.015	-0.005***	-0.001	0.006	0.026***
Farm_exp	0.006	-0.026*	0.001	-0.002	-0.002	-0.002
Farmsize	-	-	-0.049***	0.068*	-0.0013*	0.001
Farmincome	-0.0008	0.0006	0.0000002	0.0000002	0.000004	0.000007*
FBOM	-0.072	0.059	-	-	-	-
Use_org_fert	0.177*	0.341*	-0.024	0.157***	0.037	-0.030
Offarm_work	-0.742***	0.163	-	-	-	-
Landownership	0.380*	0.155*	-	-	-0.096	0.021
Substitute	0.143	0.074	-0.039***	-0.029*	-	-
Awareness	-	-	-	-	0.039*	-0.069***
Certification_trust	0.650***	0.056	0.016*	0.020*	-	-
Certification_substitute	-	-	-	-	0.032**	0.010***
Positive_attribute	-	-	-	-	-0.022	0.030**
Safety_issues	-0.327***	-0.229**	-0.040***	0.012	-	-

Notes: *Significant at the 0.10 level.
**Significant at the 0.05 level.
***Significant at the 0.01 level.

4.5.3 Farmers' WTP estimates

Based on the regression estimates, WTP estimates and respective confidence intervals based on the Krinsky and Robb method were computed for testing the null hypothesis that WTP>=0. The WTP estimates for NPF and PF were determined using the mean values of the explanatory variables. The mean WTP for the two *Fortifer*™ products are presented in Table 20 for all the countries. The mean WTP estimates are statistically different from zero for all the countries, implying that farmers were receptive to the *Fortifer*™ products.

For Ghana, the mean WTP estimates for NPF and PF were USD 0.145 kg^{-1} and USD 0.198 kg^{-1}, respectively for the Greater Accra region. The mean WTP for NPF in Western region was 20% higher than the mean WTP for NPF in the Greater Accra region while the reverse was true for PF, i.e. farmers in Greater Accra were willing to pay 20% higher than their counterparts in the Western region. The standard measurement for fertilizers in Ghana was mostly in 50-kg bags, thus the mean WTP for NPF in standard packaging was USD 7.11 for the 50-kg bag while the mean WTP for PF was USD 9.91 for the 50-kg bag in the Greater Accra region. These figures were comparable to the existing prices for compost and artificial fertilizers such as NPK in the country. Kampala had significantly higher prices than either regions in Ghana, with farmers' WTP recorded as 2 times and 2.3 times those in the Western and Greater Accra regions, respectively.

In the Asian countries, while WTP estimates were fairly similar for Hanoi and Kurunegala, Bangalore estimates were almost seven times higher. The highest WTP estimates for NPF and PF among these countries were USD 0.73 kg^{-1} and USD 0.52 kg^{-1}, respectively, whilst the lowest WTP estimates were recorded in Hanoi at USD 0.11 kg^{-1} and USD 0.13 USD kg^{-1} for NPF and PF, respectively. Generally, across all the countries, farmers were willing to pay more for PF than NPF with the exception of Bangalore and the Western Region. The noted WTP estimates for the Asian countries as with the African countries were comparable to the existing market prices for inorganic fertilizers.

4.6 Demand Estimation and Market Diffusion of Fecal Sludge-based Fertilizer

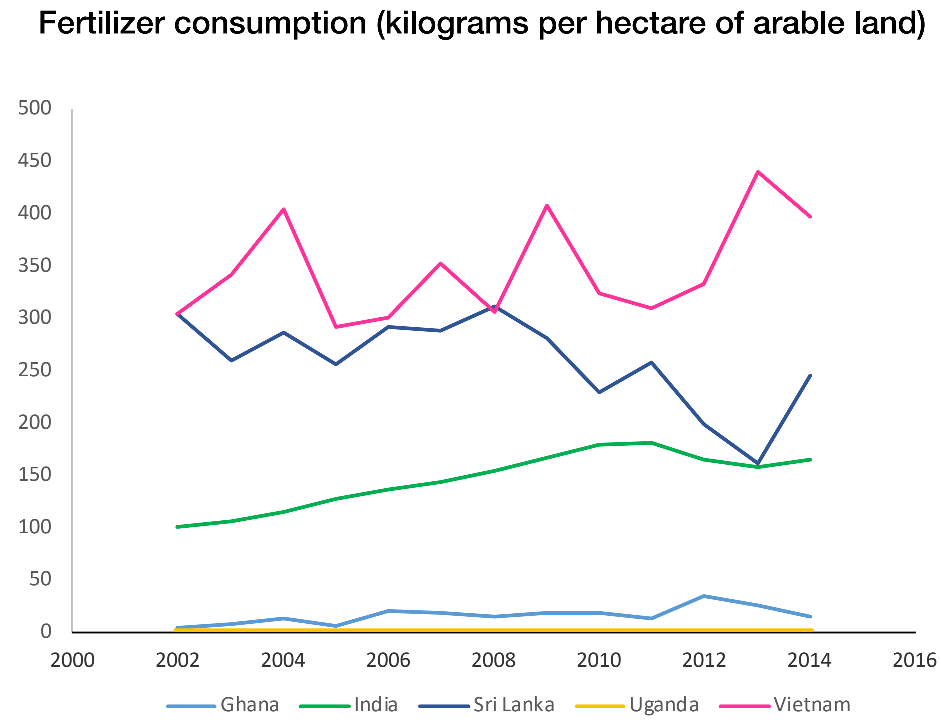
4.6.1 Estimated market demand for Fortifer™

Understanding the potential market for *Fortifer*™ extends beyond estimating the WTP measures and the factors that affect them but also requires having a clear overview of the potential quantity demanded in view of other market effects (e.g. competition). Fertilizer consumption rates across the study areas showed a big disparity between the African and Asian countries. Uganda and Ghana recorded very low levels of fertilizer application rates at an average of 2 kg ha^{-1} and 25 kg ha^{-1}, respectively (Figure 2). Particularly for Uganda, this has been attributed to a fertilizer industry plagued by market distortions which are subsequently exacerbated by ineffective policies and limited infrastructure. With neither a large-scale government fertilizer program that provides subsidized fertilizer to farmers nor an active private fertilizer sector that supplies fertilizer at competitive prices, farmers face erratic fertilizer prices amidst the limited number of actors in the fertilizer market. Whilst these market distortions and barriers are limiting factors in the chemical fertilizer sector, they represent an opportunity for business development in the organic fertilizer subsector and businesses such as those for *Fortifer*™ production. Low fertilizer application rates in Ghana have been attributed to, among other factors, the high cost of fertilizers. Key constraints to fertilizer use in Ghana include insufficient credit to the farmer, high lending rates by banks for the agriculture sector and problems with marketing of agricultural produce.

TABLE 20. WTP ESTIMATES FOR NPF AND PF FOR ALL COUNTRIES.

Study areas	**NPF**		**PF**	
	Mean WTP	*95% confidence interval*	*Mean WTP*	*95% confidence interval*
Greater Accra region	0.145 USD kg^{-1}	(0.06, 0.23)	0.198 USD kg^{-1}	(0.06, 0.34)
Western region	0.173 USD kg^{-1}	(0.10, 0.45)	0.166 USD kg^{-1}	(0.12, 0.21)
Kampala	0.34 USD kg^{-1}	(0.27, 0.67)	0.41 USD kg^{-1}	(0.37, 0.50)
Bangalore	0.73 USD kg^{-1}	(0.58, 0.99)	0.52 USD kg^{-1}	(0.36, 0.63)
Hanoi	0.11 USD kg^{-1}	(0.05, 0.28)	0.13 USD kg^{-1}	(0.01, 0.18)
Kurunegala	0.15 USD kg^{-1}	(0.14, 0.17)	0.16 (USD kg^{-1}	(0.07, 0.20)

FIGURE 2. FERTILIZER CONSUMPTION IN THE COUNTRIES STUDIED.



Source: Authors.

In the Asian countries, on the other hand, there were comparatively higher levels of fertilizer application rates – with Hanoi recording the highest at 370 kg ha^{-1}, followed by Kurunegala at 216 kg ha^{-1} and Bangalore at 165 kg ha^{-1}. Despite high levels of fertilizer consumption in Vietnam, there are fertilizer price subsidies, which means that farmers face erratic and significantly high fertilizer prices. Prices are typically subject to international price changes and exchange rate fluctuations. Contrary to the case of Vietnam and the two African countries, there were large-scale government chemical fertilizer programs that provide subsidized fertilizer to farmers and a moderately active private fertilizer sector that supplied fertilizer at competitive prices in India and Sri Lanka. The fertilizer industry is however in the same way plagued with market distortions related to limited product differentiation, distribution inefficiencies in the supply chain, poor information flow and foreign exchange rate fluctuations.

Based on data for the aforesaid fertilizer consumption and estimated adoption rates (Table 21), we estimated the potential demand for *Fortifer*™ in the study areas. As *Fortifer*™ is a novel product, adoption rates were estimated based on the percentage of respondents who answered yes to the 1st bid and either yes or no to the 2nd bid. We acknowledge that considering a more conservative measure would be to use the percentage of respondents who answered yes to the 1st bid and yes to the 2nd bid (i.e. 1st bid = Yes, 2nd bid = Yes). This however creates an upward bias in the corresponding WTP measure. It is not surprising that adoption rates were higher for NPF than PF because the farmers were familiar with compost-type products and in Ghana, India and Sri Lanka, there is significant informal use of fecal sludge in agriculture. The highest adoption rates were in Hanoi and Kurunegala and, surprisingly, Kampala. Interestingly, the range for adoption rates for PF was quite narrow considering all the countries – suggesting that whilst the farmers may overwhelmingly adopt NPF, they are a bit more reserved in their investment in PF. Bangalorean farmers generally had the lowest adoption rates for both *Fortifer*™ products.

Chemical fertilizer application rates were used as a basis for the calculation of the application rates of *Fortifer*™. Average chemical fertilizer applications were obtained via secondary data sources and *Fortifer*™ application rates were estimated at five times this estimate as *Fortifer*™ is considered to be a close competitive substitute product. It is important to note that the consideration of transportation costs to farmers for accessing *Fortifer*™ may reduce the estimated market demand and invariably the estimated economic return to producers. In this study, we assumed that the farmers will purchase the product from their current fertilizer outlets and will not incur any additional transportation costs when purchasing *Fortifer*™. This may not necessarily be true, especially in Ghana where the distance from the farm-gate to the nearest fertilizer dealer is one of the key challenges farmers face when trying to access fertilizer inputs (Krausova and Banful 2010).

TABLE 21. VARIABLES USED IN THE DEMAND ESTIMATION OF *FORTIFER*™.

	Greater Accra region	Western region	Kampala	Bangalore	Hanoi	Kurunegala
Cultivated area (ha)	35,083	672,000	130,000[a]	157,354[b]	216,400	872,068[c]
Average chemical fertilizer application rate (kg ha^{-1})[d]	25.27	25.27	1.91	165.1	369.8	215.9
Estimated Fortifer application rate (kg ha^{-1})	126.35	126.35	9.55	825.5	1849	1079.5
Adoption rate (%) – PF	41.4	51.61	57.25	33.33	58.33	47.19
Adoption rate (%) – NPF	68.26	53.33	71.37	55.56	90.42	71.16

Notes: Adoption rates were estimated based on the percentage of respondents who answered yes to the 1st bid and either yes or no to the 2nd bid.
[a] The estimated acreage includes notable surrounding agricultural districts (i.e. Luwelo, Mpigi, Mukono and Wakiso in addition to Kampala).
[b] Estimated acreage for urban and rural Bangalore.
[c] Estimated acreage for Kurunegala province (i.e. 656,664 ha for Kurunegala district and 215,404 ha for Puttalam district).
[d] Estimate based on average from 2011–2014. Source: https://data.worldbank.org/indicator/AG.CON.FERT.ZS

Of the African study areas, the Western region records the highest demand for both NPF and PF at 0.045 million and 0.044 million tons year^{-1}, respectively, in spite of the marginally lower adoption rates in comparison to Kampala and the Greater Accra region (Table 22). Demand for NPF and PF in the Western region is about 15 times and 24 times that of the Greater Accra region, respectively. Estimated demand in Kampala is significantly lower than any of the other countries, which is not surprising as this is driven by the considerably low fertilizer application rates. It is important to note that notable surrounding agricultural districts were considered in the market-size estimation, i.e. Luwelo, Mpigi, Mukono and Wakiso in addition to Kampala. Of the Asian study areas, Kurunegala posts the highest demand for both *Fortifer*™ products, followed by Hanoi and subsequently Bangalore. The demand for NPF in Kurunegala at 0.6 million tons year^{-1} is nine times and two times more than that recorded for Bangalore and Hanoi, respectively. This is not surprising as the Kurunegala district ranks high in terms of agricultural activities with oil crops, coconut and paddy production dominant in the region. Demand estimates for Hanoi are based on consideration of agricultural land for the whole province. The latter, coupled with high fertilizer application rates and adoption rates contribute to the recorded high demand estimate.

There is a greater demand for NPF as opposed to PF in all of the countries. As previously noted, farmers are more willing to adopt a product similar to what they are familiar with (a compost-type product). Overall, demand is comparatively lower in the African countries than the Asian countries for both *Fortifer*™ products, which was expected, given the overwhelmingly lower fertilizer application rates in the former. The Western region in Ghana has the highest cultivated area of all the countries but still records demand estimates lower than its Asian counterparts.

TABLE 22. ESTIMATED MARKET DEMAND FOR *FORTIFER*™ (TONS YEAR^{-1}). [a]

Study areas	NPF	PF
Greater Accra region	3,026	1,835
Western region	45,281	43,820
Kampala	886	711
Bangalore	72,222	43,255
Hanoi	361,712	233,392
Kurunegala	670,275	444,245

Note: [a] The estimate market demand is calculated as a product of the cultivated area, estimated *Fortifer*™ application rate (tons ha^{-1}) and the estimated adoption rate.

Beyond estimating the demand for the *Fortifer*™ products, it is important that future businesses have an idea of farmers' responsiveness to price changes. Whilst this is captured in the regression models to some extent, the use of the demand curve allows us to better illustrate price ranges where demand is most sensitive. A negatively sloped demand curve can be drawn from the cumulative probability distribution of the bids offered to the farmers for both *Fortifer*™ products. Figure 3 (a–f) shows the plot of the percentage of respondents who gave a positive response to 1st bids offered for both NPF and PF.

As with any linear demand curve, at higher price points the demand curves are more elastic and more inelastic at lower price points for all the countries. In the case of the demand curves for the African countries, we can assess and compare the level of demand elasticity between NPF and PF based on the inclines of the demand curves. This is based on the notion that for two intersecting demand curves, price elasticity at any given price point will be greater for the flatter demand curve than the relatively steeper demand curve. At the point of intersection, the demand curves have an identical price and quantity. Based on this, the demand curves for NPF are generally more elastic than the demand curves for PF for all three countries. As noted from the demand estimates in Table 22, whilst farmers may be keen to adopt a product (NPF) similar to one that they are familiar with (a compost-type product), they are more price responsive as often there are comparable substitutes available in the market. In the case of PF, there are no recorded cases of its extensive production or that of a similar product in Uganda or Ghana. *Fortifer*™ producers will need to particularly consider this when setting prices. Their decision on whether to implement a penetrative, competitive or premium pricing system is crucial as short-term price changes can significantly affect demand. In the case of Ghana, an increase in the price of NPF by USD 0.05 kg^{-1} will reduce demand by approximately 30% and this is also the case in Uganda.

In considering the demand curves for the Asian countries, the elasticity of both NPF and PF curves for Hanoi are approximately the same (overlapping demand curves). This suggests that there is no significant difference in demand with an equal level of price change for both products. However, in the case of Kurunegala, there is a similar trend as that in the African countries where the NPF demand curve is more elastic than the PF demand curve. This suggests that farmers will generally be more responsive to price changes for NPF than PF, and an equivalent price change for both NPF and PF will result in a larger change in demand for NPF compared to PF. As an example, for a USD 0.05 kg^{-1} price change, demand decreases by 30% for NPF whilst that for PF decreases by 20%. Thus, whilst a significant potential market exists in Kurunegala, high price sensitivity of farmers may negatively affect demand.

FIGURE 3. FARMERS' RESPONSIVENESS TO PRICE CHANGES (FARMERS' DEMAND CURVE FOR PF AND NPF).

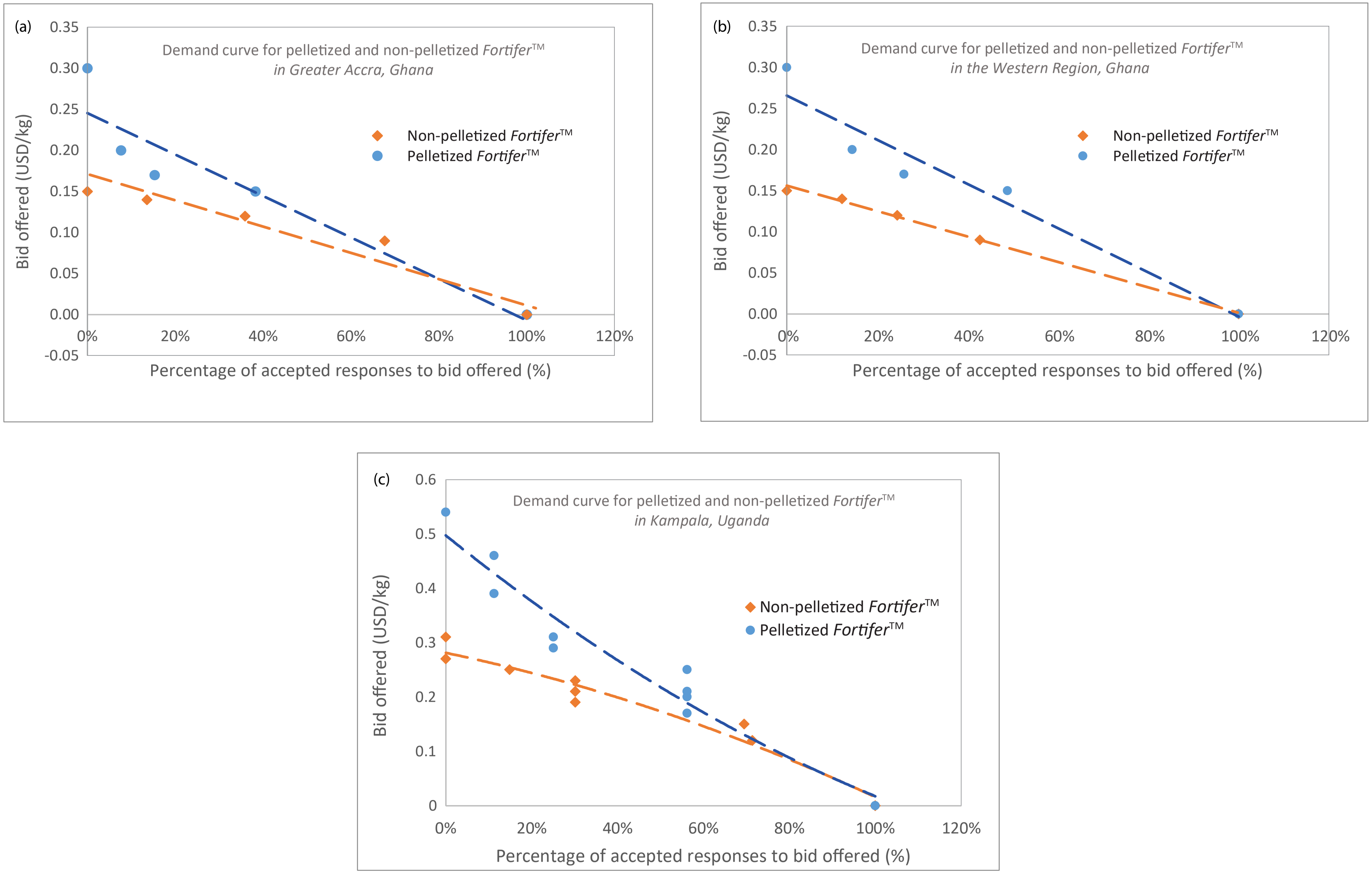
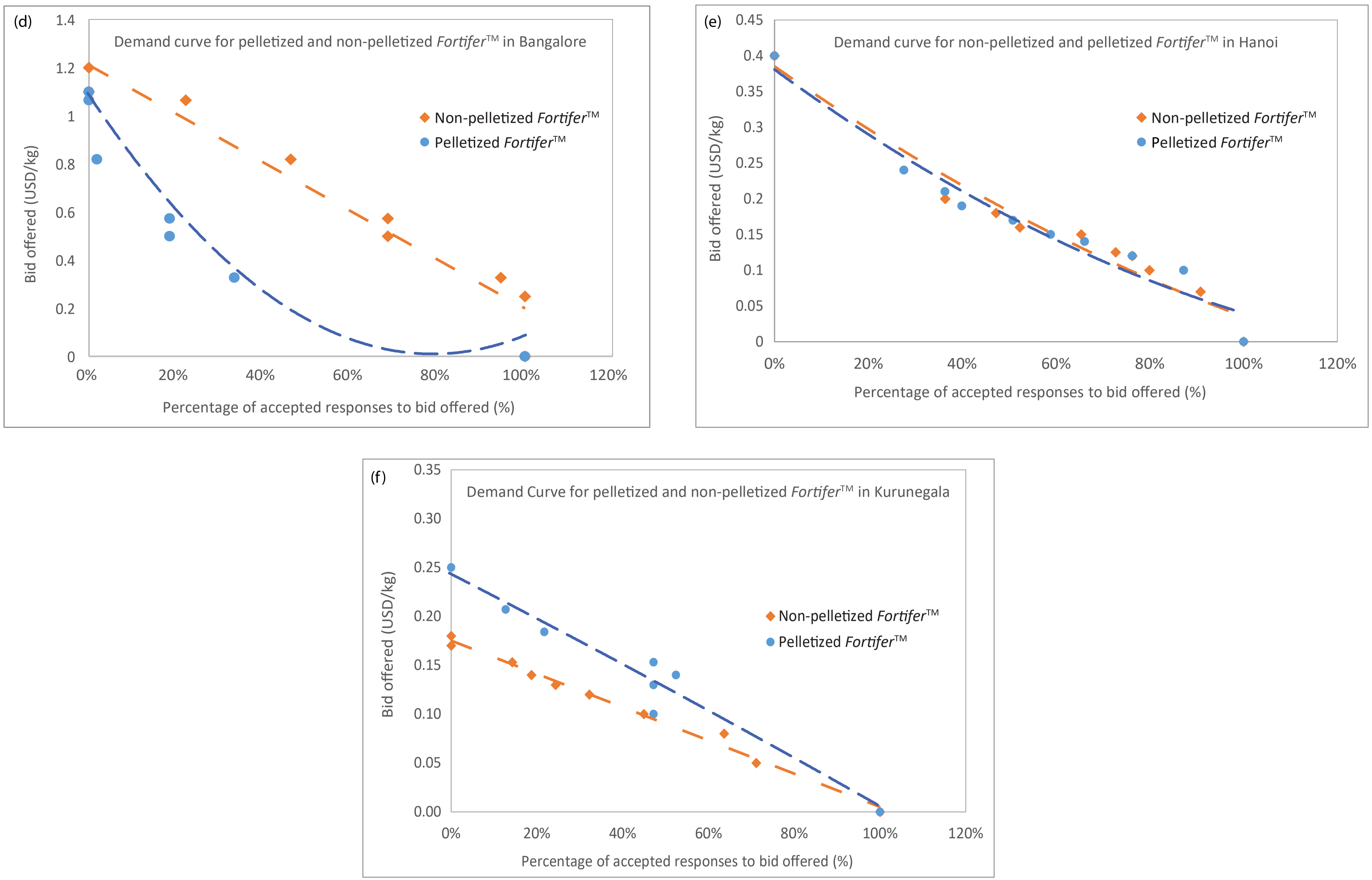


FIGURE 3. FARMERS' RESPONSIVENESS TO PRICE CHANGES (FARMERS' DEMAND CURVE FOR PF AND NPF). (CONTINUED)



4.6.2 Market diffusion of Fortifer™ – an adopter's perspective

A comprehensive overview of market elements for the successful commercialization of a product requires understanding the rate of diffusion of the product (i.e. market demand growth of the product over time). The evaluation of the market outlook will aid potential *Fortifer*™ businesses in business planning. This is important, as investment toward an uncertain future can be difficult and risky; market-forecasting tools have been developed to alleviate the risk and to obtain more accurate and reliable information (Proctor 2000). As *Fortifer*™ is a fairly novel product in the fertilizer market, there are no existing time series data to develop a standard demand equation for a market trend analysis.

The Bass model was used for the market outlook assessment of *Fortifer*™ in this study. This model has been used extensively in marketing for dynamic forecasts of market demand for new products against the background of intense rivalry between products or brands and is used to describe consumers' behavior in relation to their loyalty towards the product (Bass 1969; Satoh 2001). The Bass model allows one to forecast the rate of diffusion of the *Fortifer*™ product (future product behavior), whilst accounting for external factors such as market competition. This represents important demand-side information that can guide investors' decisions on the envisioned stages of their businesses' life cycles. This is important because it is well known that adopters of agricultural technologies, particularly in developing countries, are often characterized as laggards (late adopters/imitators) rather than innovators (introduction) or early adopters (growth). In this regard, it is important for future *Fortifer*™ businesses to know the adoption profile of potential customers (farmers) and assess the effects on market demand.

The Bass model is a mixed model capturing both innovative and imitative effects – i.e. the influence that early-adopting consumers and late-adopting consumers have on market demand. The Bass model is an *S* curve model that contains two values ('*p*' and '*q*'), one that represents a value for the degree of innovation – *p* (sales influenced by desire for novel products – early adopters) by consumers and another for the degree of imitation – *q* (sales influenced by word-of-mouth – late adopters) (Bass 1969); and is defined as:

$$\frac{f(t)}{1-F(t)} = p + \frac{q}{M}[A(t)] \tag{5}$$

The density function of time to adoption is given by *f(t)* and the cumulative fraction of adopters (i.e. demand) at time *t* is given by *F(t)*. The coefficients of innovation and imitation are defined by *p* and *q*, respectively. *A(t)* is defined as the cumulative adoption at period, *t*. This basic premise states that the conditional probability of adoption at time *t* (the percentage of the population that will adopt or buy a product at time *t*) is increasing in the fraction of the population that has already adopted. Therefore, part of the adoption influence depends on imitation or 'learning' and part of it does not. The parameter *q* reflects that influence and the parameter *p* reflects an influence that is independent of previous adoption (Mahajan et al. 1990). *M* defines the potential market (the ultimate number of adopters) for the product in question.

In application, the major interest is in the coefficients of imitation and innovation (*p* and *q*) – which characterize the adoption profile of potential consumers and the timing of the peak in adoption, and the potential market size (M) of the *Fortifer*™ market. The optimal time that sales of a product will peak (i.e. the time where most of the market share for the product considered is captured [5]) is given by:

$$\frac{\ln\left(\frac{q}{p}\right)}{p+q} \tag{6}$$

Jeuland (1994) found that the average value of p is often quite small – 0.01 or less, while *q* is rarely greater than 0.5 and rarely less than 0.3. Lawrence and Lawton (1981) found that the value of *p* + *q* lies between 0.3 and 0.7. These estimates, however, consider multiple sectors, which may not be reflective of the agricultural input market. This is because the diffusion rate (i.e. adoption and imitation) of new products or technologies is known to be particularly low in the agriculture sector in developing countries (Otoo 2011; Kasirye 2013; Simtowe et al. 2016). In the case of fertilizer use, strong loyalty of farmers (low switching behavior) for chemical fertilizers in the absence of strong alternative products in the market may affect the rate of adoption of *Fortifer*™.

In the absence of existing data for *p* and *q* for *Fortifer*™, other organic fertilizer products or similar substitute products, this study estimated the coefficients based on the findings of Sulthan et al. (1990). The coefficient of innovation, *p*, representative of early adopters, was estimated as the percentage of respondents that was willing to buy the fecal sludge co-compost product, specifically those that provided a positive response to both the 1st and 2nd bid offers. We used a more conservative measure given the traditionally low diffusion rates of new technologies among agricultural producers in developing countries. The coefficient of imitation, *q*, representative of late adopters, was estimated based on the population of respondents who stated that they would purchase *Fortifer*™ products if they were recommended by other farmers or any other trusted source (e.g. extension service agents). They are representative of possible imitators in the sample population. Using a five-level Likert scale[6], respondents – a) who agreed (level 4) and b) strongly agreed

[5] This is based on the assumption that the business operates as a monopolist (no existing competition) and captures the largest share of the organic (waste-based) fertilizer market. Whilst this may be uncharacteristic of developing countries, especially given the high level of product imitation in the agricultural input market, this assumption holds if it is assumed that the organic fertilizer business has a contractual agreement with the city municipality (sanitation service provider) that gives them sole access to the key waste input (fecal sludge). This agreement/ partnership gives the business a competitive advantage in the production of the Fortifer product.

[6] The Likert scale was defined as consent to the statement: level 1 = strongly disagree, 2 = disagree, 3 = neutral, 4 = agree, 5 = strongly agree.

(level 5) with the statement were considered to be imitators and the representative percentage of the population estimated accordingly. The *S* curve was estimated based on estimating the sales (adoption) at time, *t* given as:

$$S(t+1) = p * M + (q-p) * Q(t) - \left(\frac{q}{M}\right) * Q(t)^2 \qquad (7)$$

where *M* is defined as the potential market (the ultimate number of adopters) for *Fortifer*™ and is estimated in Table 22. *Q(t)* is cumulative sales of *Fortifer*™ at time, *t*.

Farmers' adoption profiles for *Fortifer*™**:** As expected the coefficient of innovation, *p*, representative of early adopters, was generally low across all the countries and for both *Fortifer*™ products (Table 23). For PF, Bangalore recorded the lowest measure for early adopters, while the Western region in Ghana had the highest level of early adopters. As noted earlier, the Western region boasts a strong and extensive agriculture sector, predominantly characterized by large-scale agricultural producers who have more flexibility in terms of financial resources to invest in new technologies. Additionally, Kampala has the lowest measure among the African regions – which is not surprising given the unusual low fertilizer application rates in Uganda. This result is also mirrored for the case of NPF. For NPF, Kurunegala recorded the lowest measure for early adopters whilst the Greater Accra region had the highest measure. It is interesting to note that in comparing the coefficients for both PF and NPF across all the countries, early adopters had a proclivity for NPF rather than PF with the exception of Kurunegala. This result corroborates the findings from the demand estimations. Whilst the measure of early adoption was generally low, it is interesting to note that on average, farmers from the African countries had a marginally higher measure for early adoption of both PF and NPF than the Asian farmers.

For the coefficient of imitation, *q*, representative of late adopters (i.e. farmers that will purchase if it is recommended by other farmers or any other trusted source (e.g. extension service agents), the results confirmed what is traditionally known of developing countries, where farmers are typically known as imitators for adoption of agricultural technologies. The values for *q* were the same for both NPF and PF as single data points were considered for each farmer's response. Hanoi farmers had the lowest measure for imitated-based adoption whilst the Greater Accra region recorded the highest level among all the regions. Kampala had the lowest measure for the African regions considered although only marginally lower. With the exception of Hanoi, most farmers will most likely adopt *Fortifer*™ if it is recommended by a trusted source/someone who has used it and confirmed high quality. This suggests that *Fortifer*™ producers will need to invest in strong awareness programs coupled with actual field experiments to increase product recognition and eventual adoption. Strategic partnerships with existing governmental extension programs will be key for *Fortifer*™ businesses in view of farmers' reliance on extension agents for technical information and training, particularly in developing countries.

TABLE 23. ADOPTION PROFILES OF FARMERS FOR *FORTIFER*™.[a]

	PF			NPF		
Study areas	*Coefficient of innovation,* p	*Coefficient of imitation,* q	*Potential market,* M	*Coefficient of innovation,* P	*Coefficient of imitation,* q	*Potential market,* M
Greater Accra region	0.217	0.891	1,835	0.438	0.891	3,026
Western region	0.298	0.821	43,820	0.321	0.821	45,281
Kampala	0.183	0.760	711	0.220	0.760	866
Bangalore	0.110	0.884	43,255	0.259	0.884	72,222
Hanoi	0.194	0.320	233,392	0.332	0.320	361,712
Kurunegala	0.205	0.620	444,245	0.150	0.620	670,725

Note: [a] *p* – estimated as % of respondents willing to buy fecal sludge co-compost, i.e. respondents who provided a positive response to both the 1st and 2nd bid offers; *q* – estimated as % of respondents who stated that they would purchase *Fortifer*™ products if they were recommended by other farmers or any other trusted source, i.e. respondents who agreed and strongly agreed with the related statement; *M* – estimated as in Table 22; and measured in tons year^{-1}.

4.6.3 Effects of farmer adoption profiles on market demand – African countries

Greater Accra region, Ghana: As observed in Figure 4a, sales (adoption) for NPF in the first half of the first year were negative, suggesting the need for *Fortifer*™ producers to account for storage costs in their financial statements. This was also the case for PF (Figure 4b). Both *Fortifer*™ products showed an exponential growth very early on in the growth phase and took 2.5 and 4.5 years to reach peak sales for NPF and PF, respectively. The shorter peak period for NPF compared to PF was mainly attributable to the higher measure of early adopters ($p = 0.438 > 0.217$), but also farmers' greater willingness to adopt a product similar to that with which they were familiar. In the case of PF, if necessary, businesses can adjust their production capacity and other financial requirements in order to target a higher average peak volume at the estimated average peak time. To achieve a comparatively higher and steady growth, businesses can adopt new strategies to reach new customer segments, new marketing and distribution strategies. Additionally, regular customer testing and evaluation will be useful to further tailor product features, in particular for *Fortifer*™, such as nutrient ratio requirements and pelletization to consumer preferences.

The market for NPF and PF can be captured in approximately 4.5 and 7 years, respectively. The difference in the length of adoption time is based on the relative difference in early adoption measures. At this stage, sales grow at slower rates and finally stabilize, essentially the *S-curve* will flatten out. *Fortifer*™ businesses will maximize profit and recover all the cost of operation and development. The main goal in this phase for businesses is to maximize production capacity. Prices can be increased or matched with competitors' prices. Whilst the cost of research and development (R&D) will be lower at this stage, experiments for the development of new product features are important to buffer the potential decrease in demand in the declining stage (as observed in the latter quarter of year 4). Product promotion will still be necessary to avoid possible brand switching. Competition for market share will be particularly stiff in this stage and strategic pricing, quality adjustment and promotional and awareness programs will be necessary to maintain current customers but also to reach additional customer segments. This will also be applicable to PF.

Western region, Ghana: In contrast to the Greater Accra region, sales (adoption) for NPF in the first year were positive in the Western region (Figure 4c). This is not surprising given the greater demand in the latter market but also the comparatively high measure of early adoption rates. The market peaked in year 3, which was slightly earlier than that of Greater Accra. The PF market not only peaked a little later than the NPF market in the Western region (Figure 4d), which was indicative of farmers' proclivity for a product similar to that with which they were familiar, but also sales in year 1 were negative as in Greater Accra region.

At the peak, businesses would have captured 68% and 69% of the NPF and PF markets, respectively; suggesting that *Fortifer*™ businesses need to invest more in incentive mechanisms that encourages farmers' adoption. Imperfect farmers' knowledge of human waste-based organic fertilizers may attributable for this trend in the introduction stage. Strong awareness programs coupled with actual field experiments will increase product recognition and shorten this phase. Credit-based sales with growers may be a good option to explore in order to establish farmer relationships and ensure demand. This strategy is increasingly been adopted by chemical fertilizer suppliers in Ghana. However, this implies that the cost of R&D (sunk cost) and negotiations may be higher and lead to lower profit overall at business start-up. The marginal difference in the time period in which markets for both products are fully captured is similarly attributable to the differences in the innovation coefficient. In comparing the two regions in Ghana, even with larger markets for both NPF and PF, market growth rates were marginally faster in the Western region compared to the Greater Accra region. The organic fertilizer market is still in a nascent stage in Ghana and there is ample opportunity for new compost and *Fortifer*™ businesses to enter the market. It is important to note that although chemical fertilizer businesses have the largest share in the industry, market distortions inherent in their supply chain mitigates the effects of their market power of which *Fortifer*™ businesses can take advantage. However, especially in the Western region where agricultural production is extensive and thus a greater number of fertilizer businesses exists, effective pricing strategies will be crucial to ease market entry for *Fortifer*™ businesses. Given farmers' price sensitivity, *Fortifer*™ businesses will need to implement a penetrative or competitive pricing strategy to mitigate competition effects.

Kampala, Uganda: The trends observed in Kampala were similar to those in the Western region; negative demand for PF in the first year, although not for NPF (Figures 4e and 4f). Both *Fortifer*™ products showed an exponential growth very early on in the growth phase and took 3.5 and 4.5 years to reach peak sales for NPF and PF, respectively. For NPF, approximately 67% of market demand could be captured in the first year. On the other hand, it took about four times the number of years to achieve the same for PF. At the peak, businesses would have captured 79% and 60% of the NPF and PF markets, respectively. The relatively slower market growth rates for both products were mainly attributable to the assumed and conservative lower diffusion coefficients due the traditional nature of low adoptability by Ugandan farmers and their current level of knowledge and use of human waste-based organic fertilizers. Product growth sales and even eventually demand can be increased via the adoption of innovative marketing and pricing strategies and strongly positioning the product in the market at the introduction stage. Market growth stagnates at approximately years six and eight for NPF and PF, respectively. For a country with relatively low fertilizer application rates, it is important that *Fortifer*™ businesses focus on the development of new product features and quality improvement to buffer the effects of competitors' innovations (i.e. loss of consumer interest in products and a switch to new competitive products). Additionally, prices will need to be set lower to attract and possibly maintain more price-sensitive consumers.

In comparing the adoption (sales or cumulative sales) graphs for the three African countries for NPF, the Western region reached its peak sales the fastest, followed by Kampala and subsequently the Greater Accra region (Annex 4). This is also the case for PF in the Western region. On the other hand, the Greater Accra region reached its peak incremental sales faster than Kampala for PF. For NPF, 79%, 66% and 62% of the market demand was reached at the period of peak sales in the Greater Accra region, Kampala and Western region, respectively. This result is reflected in the time period in which the market was fully captured – 4.5, 6 and 5 years for the Greater Accra region, Western region and Kampala, respectively, indicative that Greater Accra has a faster market growth rate. On the other hand, for PF, 69%, 63% and 60% of the market demand was reached at the period of peak sales in the Western region, Kampala and Greater Accra region, respectively. Corroborating this result are the time periods in which the product markets were fully captured. For all three countries, there were limited to no incremental sales after years 6 and 8 for NPF and PF, respectively. In summary, the diffusion of *Fortifer*™ products will be faster in Ghana than in Uganda despite the larger market in the former, largely driven by the higher measures of early adoption and comparatively higher levels of fertilizer application rates in Ghana.

4.6.4 Effects of farmer adoption profiles on market demand – Asian countries

Bangalore, India: Sales (adoption) of NPF in the first year were positive in Bangalore (Karnataka region) (Figure 5a). This is not surprising given the comparatively high measure of early adoption rates in comparison to Kurunegala. The market peaked in 3.25 years and thereafter was fully captured a little after year 5. At the peak sales period, 69% of the market demand was captured although it is worth noting that a significant proportion of this occurred in the year 2. Adoption of PF, although at a slow rate, in contrast to the African countries, was positive in the first year (Figure 5b). The PF market, as with the other African countries, peaked much later than the NPF market in Bangalore (in 5.5 years), which is indicative of farmers' proclivity for a product similar to that with which they are familiar. At peak sales, however, similar to PF, 69% of the market demand would have been reached. The introduction of *Fortifer*™ products can be facilitated when the competitive products are at the current chemical fertilizer stage of maturity. However, subsidies for the latter sector mean that effective pricing strategies (penetrative pricing) will be crucial to ease market entry. Additionally, strong awareness programs coupled with actual field experiments will increase product recognition and eventual adoption. By the eighth year there were no incremental sales for the product and market growth stagnated. Given the slower growth rate for PF, innovative marketing and incentive mechanisms related to product pricing would be essential in strongly positioning the product in the market and maintaining a strong customer base.

Hanoi, Vietnam: Similar to Bangalore, sales were positive for NPF in the first year (Figure 5c). This observation is marginally mirrored by the case of PF, although negative sales were only observed for about one-quarter of the first year (Figure 5d). Both *Fortifer*™ products showed an exponential growth very early on in the growth phase (although faster for NPF) and took 3 and 4.5 years to reach peak sales for NPF and PF, respectively. For NPF, approximately 55% of market demand was captured when peak sales were reached, while it took five years for PF in comparison to three years for NPF. As corroborated by the innovation coefficients (given the same imitation coefficient), adoption of NPF will be significantly faster than PF in Hanoi. At the peak, businesses would have captured about 53% of the PF market, suggesting that most market growth occurs in the introduction stage of the product's life cycle. Similar to Bangalore, innovative pricing strategies (credit-based sales or penetrative pricing) and strong awareness programs coupled with actual field experiments will be needed to increase product recognition and eventual adoption. This implies that the cost of R&D (sunk cost) and negotiations will be higher and lead to lower profit overall at business start-up. It was observed that it took 10.5 years to fully reach the PF market, in comparison to 6.5 years for NPF. The longer life cycle of the PF product, means that *Fortifer*™ businesses will not only need to invest in product promotion to reach additional customer segments and maintain customer bases, but also conduct regular customer testing and evaluation to further tailor product features such as nutrient ratio requirements to consumer preferences.

Kurunegala, Sri Lanka: As with Bangalore and Hanoi, sales for NPF in the first year were positive in contrast with PF, which were negative (Figure 5e and 5f). This is not surprising given the greater demand in the former market but also the comparatively higher measure of an early adoption rate. The market for NPF peaked in year 4, which was slightly later than the other two Asian countries. The PF market peaked marginally later than the NPF market (4.5 years), which was indicative of farmers' preference for products similar to those with which they were familiar. The marginal difference in the time period in which markets for both products were fully captured can be attributable again to the differences in the innovation coefficient. At the peak, businesses would have captured 60% and 68% of the NPF and PF markets, respectively. This suggests that, as with Bangalore and Hanoi, most market growth of both NPF and PF occurs during the introductory phase of the products' life cycle.

FIGURE 4. FARMERS' ADOPTION CURVES FOR NPF AND PF IN AFRICAN COUNTRIES.

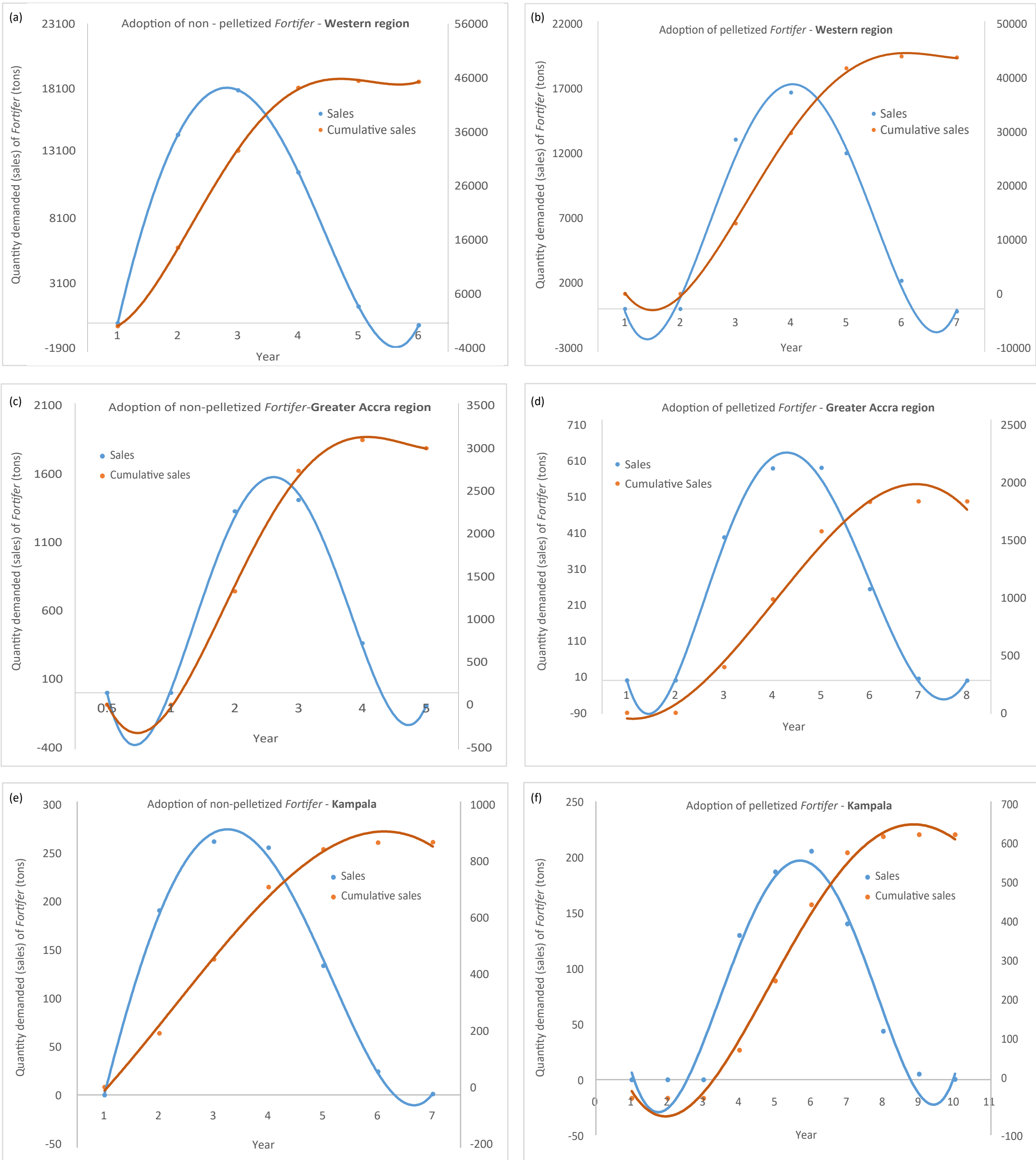
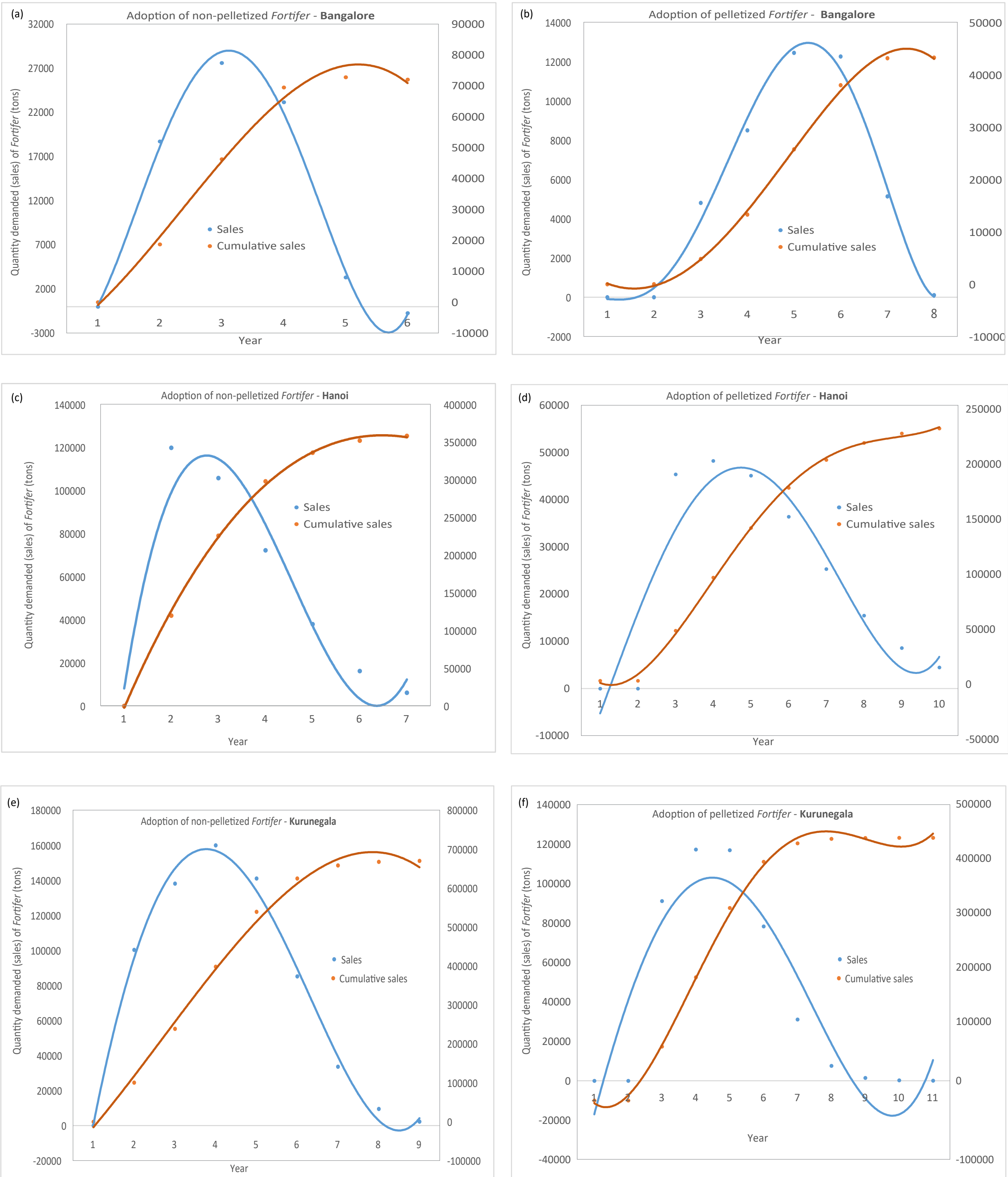


FIGURE 5. ADOPTION CURVES FOR NPF AND PF IN ASIAN COUNTRIES.



Typically, producers increase prices or match their competitors' price when they are in or close to transitioning to the growth phase. With a significant portion of the market for PF already captured in the introductory phase, producers of PF can adopt this pricing strategy. This however cannot be the case of NPF as the share of the market captured is lower and farmers are more price-sensitive (more elastic demand) than they are to PF. Maintaining a penetrative or competitive pricing strategy even in the growth phase would serve producers better in reaching new customer segments and maintaining their customer base. Product promotion will still be necessary to avoid possible brand switching.

In comparing either adoption (sales or cumulative sales) graphs for the three Asian countries for NPF, Hanoi reached its peak sales the fastest, followed by Bangalore and subsequently Kurunegala (Annex 5). This result is corroborated by the respective innovation coefficients. On the other hand, for PF, Kurunegala reached its peak sales faster than either Hanoi or Bangalore. For NPF, 55%, 60% and 69% of the market demand was reached at the period of peak sales in Hanoi, Kurunegala and Bangalore, respectively. This finding suggests that in Hanoi, where limited farmers' knowledge and use of human waste-based organic fertilizers may cause low adoption rates in the introduction stage, greater investments in awareness programs coupled with actual field experiments will be needed to increase product recognition and eventual adoption, in comparison to Bangalore where farmers are already using fecal sludge for agricultural production. This result is also reflected in the time period in which the market is fully captured – 5, 6.5 and 8.5 years for Bangalore, Hanoi and Kurunegala, respectively, indicative that Bangalore will have a faster market growth rate for NPF. Similarly, for PF, 53%, 68% and 69% of the market demand was reached at the period of peak sales in Hanoi, Kurunegala and Bangalore, respectively. Whilst the market growth for PF for Bangalore and Kurunegala was faster than that of Hanoi, the differences between Bangalore and Kurunegala were inconclusive. For all three countries, there were limited to no incremental sales after year 8.5 and 10 for NPF and PF, respectively. In summary, the diffusion of *Fortifer*™ products will be faster in Bangalore than in Hanoi for both NPF and PF, despite the larger market and higher measures of early adoption in the latter. This result was also applicable for Kurunegala and Hanoi, however the comparisons between Bangalore and Kurunegala were inconclusive.

For all the countries under consideration, market growth rate in the introduction phase of the product life cycle was significantly fast. In this regard, while investments in promotion and awareness programs will be necessary, focus should be placed on incentive mechanisms to capture new customer segments and maintain the current customer base. In comparing the results of African countries to the Asian countries for NPF, on average, higher percentages of market demand were reached at the period of peak sales in the African countries as opposed to the Asian countries. This result translates to faster market growth rates observed in Africa compared to Asia, suggesting a significant combined effect of the higher innovation and imitation coefficients on market demand and growth. Similar results were noted for PF. It is important to note that although the difference in average percentages of market demand reached at the period of peak sales was marginal, the difference observed for the market growth rate was substantial. This result is reflected in the time period in which the market was fully captured – 6, 7 and 8 years for the Western region, Greater Accra region and Kampala, respectively; and 7.5, 8 and 9 years for Kurunegala, Bangalore and Hanoi, respectively. Of the African countries, Ghana had the fastest diffusion rate for *Fortifer*™ products, while this was the case for India and Sri Lanka in the Asian countries considered for this study.

5. CONCLUSIONS

There are numerous opportunities to address the dual challenge of waste management and soil nutrient depletion in many developing countries via the safe recovery of nutrients from both solid and liquid waste streams for reuse in agriculture. Commercialization of waste-based organic fertilizer such as *Fortifer*™ has the potential to generate significant benefits for developing economies via cost recovery for the sanitation sector and comparatively affordable alternative agricultural inputs for smallholder farmers. The successful commercialization of *Fortifer*™*,* however, largely depends on businesses' understanding the dynamics and functionings of the markets that they operate in. To guide potential investors in *Fortifer*™ businesses, this report presents a detailed market assessment of the product – highlighting farmers' perceptions and attitudes towards *Fortifer*™*,* and their WTP. The report further provides insights into the market demand and diffusion of the product as related to the adoption profiles of farmers and adoption rates. This serves to inform businesses on the types of marketing and pricing strategies to implement in order to facilitate market entry and mitigate the effects of competition. The analyses were conducted in the Greater Accra region and Western region in Ghana; Kampala, Uganda; Bangalore, India; Hanoi, Vietnam; and Kurunegala, Sri Lanka. Furthermore, cross-country comparison analyses were conducted to better understand the effects of noted market drivers and if possible, lessons learned for knowledge sharing.

We analyzed farmers' fertilizer purchasing decisions as it is hypothesized that they influence their WTP for agricultural inputs. Credit-based transactions were noted as an important purchasing decision factor by farmers in both regions of Ghana but less so in Kampala and the study areas in Asia. It is well known that most farmers in Ghana are smallholders and typically cash-constrained and so accessible and suitable financing is essential to incentivize adoption. Therefore, it was not surprising that the price of the product was noted as an equally important factor considered by farmers in the input-purchasing decisions across all study areas. A comparison of key product attributes influencing farmers' fertilizer purchasing decisions across Africa and Asia showed that farmers in Hanoi did not score highly in any of the product attributes compared to all other regions. While price is given a moderate to high score in all of the regions, farmers in Hanoi rated price as the least important product attribute. The latter is possibly because farmers traditionally face high fertilizer prices (no subsidies), anticipate the expense and so do not view it as a limiting purchasing factor. Nutrient content and fertilizer application methods were also amongst product attributes, which scored highly across all the study areas, but less so in Hanoi. Experiential learning as measured by farmers knowing someone who has used the product before and/or if it has been recommended by a trusted source, is critical to whether farmers will purchase a product or not. Future *Fortifer*™ businesses need to explore strategic partnerships with agricultural ministries and tap into their extension programs to catalyze adoption.

Analysis of farmers' perceptions about *Fortifer*™ in all the study areas, suggested that adoption will only occur if *Fortifer*™ is certified by trusted third-party entities (preferably a governmental authority). Another important attitude construct that cuts across most of the selected regions is the 'safety issue' which captures farmers' perceived concerns about the safety of the product. While farmers in Bangalore and Kurunegala perceived *Fortifer*™ as a substitute for chemical fertilizer and would buy it irrespective of its price; farmers in Ghana and Uganda were more price-sensitive and would only purchase *Fortifer*™ if it were comparatively cheaper than chemical fertilizer.

Regression analysis results provided further support of the factor analysis results above. In comparing the results of the Asian and African countries, the regression models showed that farmers were less willing to pay for *Fortifer*™ at higher bids, and this was consistent across all the six countries. Assessing the effects of the socioeconomic variables showed that education had an ambiguous effect on farmers' WTP for *Fortifer*™*.* Farm size, status of landownership and previous experience using organic fertilizer significantly influenced a farmer's purchasing decision of *Fortifer*™*.* Most farmers in the study countries, with the exception of the Greater Accra region and Hanoi owned the land that they farmed on. It is thus expected that farmers from Kampala, Bangalore and Kurunegala, all things being equal, will be more willing to pay for and use *Fortifer*™*.* The effects of farm size on farmers' WTP differed by product type, in that, farmers with larger farm sizes were more willing to pay for PF over NPF, as the latter requires more labor for application. The effects of the attribute variables were similar and consistent across both the Asian and African countries. In particular, farmers' concerns about product safety and the related need for certification were key factors influencing their decision when purchasing *Fortifer*™*.* Third-party product certification will be necessary especially in the Asian countries where guidelines for fecal sludge use in agriculture are unclear.

Beyond understanding the factors that drive farmers' purchasing decisions for *Fortifer*™*,* farmers' WTP and demand were estimated. Generally, across all the study areas, farmers were willing to pay more for PF than NPF with the exception of Bangalore and the Western region in Ghana. The noted WTP estimates for the Asian countries as with the African countries were comparable to the existing market prices for inorganic fertilizers. Farmers' WTP for both *Fortifer* products were comparatively similar with the exception of Bangalore and Kampala, which recorded significantly higher values. Mean WTP estimates for NPF and PF were USD 0.145 kg^{-1} and USD 0.198 kg^{-1}, respectively for the Greater Accra region, Ghana whilst those for NPF in the Western region were 20% higher. However, the reverse was true for PF, i.e. farmers in Greater Accra were willing to pay 20% higher than those in the Western region. Kampala noted significantly higher prices than either regions in Ghana. In the Asian study areas, while WTP estimates were similar for Hanoi and Kurunegala, Bangalore estimates were almost seven times higher. The highest WTP estimates for NPF and PF among these countries were USD 0.73 kg^{-1} and USD 0.52 kg^{-1}, respectively whilst the lowest WTP estimates were recorded in Hanoi at USD 0.11 kg^{-1} and USD 0.13 kg^{-1} for NPF and PF, respectively.

Demand for both *Fortifer* products was relatively substantial. Of the African study areas, the Western region recorded the highest demand for both NPF and PF at 0.045 million and 0.044 million tons $year^{-1}$, respectively, in spite of the marginally lower adoption rates in comparison to Kampala and the Greater Accra region (Table 22). Demand for NPF and PF in the Western region was about 15 and 24 times that of the Greater Accra region, respectively. Estimated demand in Kampala was significantly lower than any of the other countries, which is not surprising as this was driven by the considerably low fertilizer application rates. It is important to note that notable surrounding agricultural districts were considered in the market size estimation, i.e. Luwelo, Mpigi, Mukono and Wakiso in addition to Kampala. Of the Asian study areas, Kurunegala posted the highest demand for both *Fortifer* products, followed by Hanoi and subsequently Bangalore. The demand for NPF in Kurunegala at 0.6 million tons $year^{-1}$ was nine and two times more than that recorded for Bangalore and Hanoi, respectively. This is not surprising as Kurunegala district ranks high in terms of agricultural activities with oil crops, coconut and paddy production dominant in the region. Demand estimates for Hanoi were based on consideration of agricultural land for the whole province. The latter, coupled with high fertilizer application rates and adoption rates contributed to the recorded high demand estimate. A greater demand was observed for NPF than PF in all the countries. As previously noted, farmers are more willing to adopt a product similar to what they are familiar with. It is important to note that the demand estimates may not be comparable across the study areas given different geographical scales. With that in mind, generally, it was noted that demand was comparatively lower in the African countries for both *Fortifer* products, which was expected, given their overwhelmingly lower fertilizer application rates. The Western region in Ghana had the highest cultivated area of all the countries but still recorded demand estimates lower than its Asian counterparts.

Another important facet of market dynamics considered in this report is the diffusion of *Fortifer.* For all the study areas, it is noted that market growth rate in the introduction phase of *Fortifer* will be significantly fast. In this regard, while investments in promotion and awareness programs will be necessary, greater focus should be placed on incentive mechanisms to catalyze farmer adoption. In the African study areas, diffusion of *Fortifer* products is expected to be faster in Ghana than in Uganda despite the larger market demand in the former. This is largely driven by the higher measures of early adoption and comparatively higher levels of fertilizer application rates in Ghana. For Uganda, a country with relatively low fertilizer application rates, it is important that *Fortifer* businesses focus on the development of new product features and quality improvement to buffer the effects of competitors' innovations (i.e. loss of consumer interest in products and switch to new competitive products). Additionally, prices will need to be set lower to attract and possibly maintain more price-sensitive consumers. A comparison of adoption rates for the Asian study areas indicated that diffusion of *Fortifer* products would be faster in Bangalore than in Hanoi for both NPF and PF, despite the larger market and higher measures of early adoption in the latter. This finding suggests that in Hanoi, limited farmers' knowledge and use of human waste-based organic fertilizers may cause low adoption rates in the introduction stage. Greater investments in awareness programs coupled with actual field experiments will be crucial to increase product recognition and eventual adoption, in comparison to Bangalore where farmers are already using fecal sludge for agricultural production. This result is also applicable for Kurunegala and Hanoi; however, the comparisons between Bangalore and Kurunegala are inconclusive.

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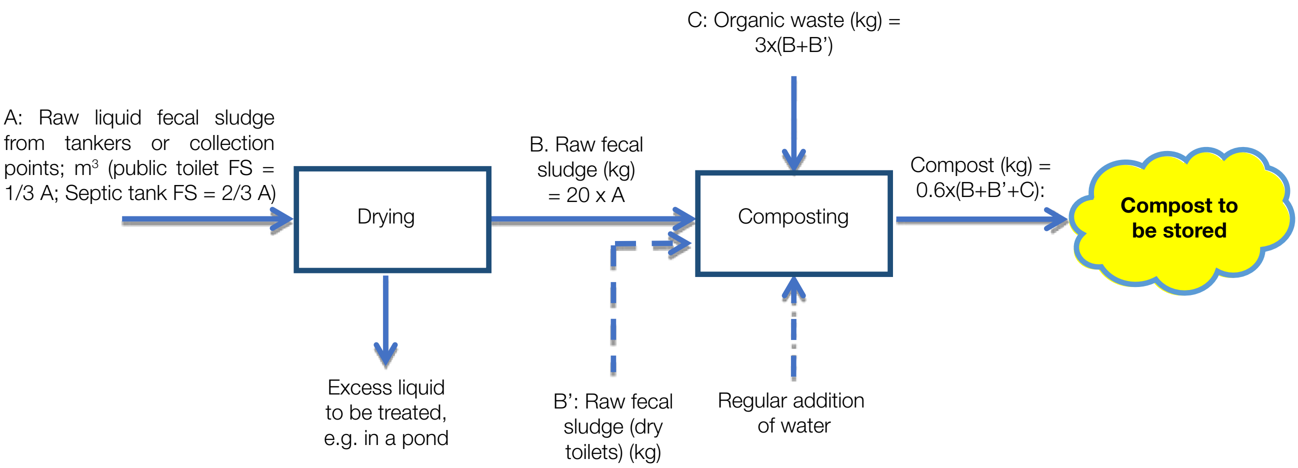
ANNEXES

ANNEX 1. FORTIFER DEVELOPMENT

Figures A1 and A2 present the technical processes for the production of *Fortifer*™ (a nitrate-fortified and pelletized fecal sludge and MSW co-compost): a) composting and b) pelletization, respectively. Human excreta collected as fecal sludge from on-site sanitation systems is dried using drying beds. The drying process lasts between 7 to 20 days depending on climatic conditions and the quantity of the waste material. Dewatered fecal sludge (DFS) is generated at a rate of 10-25 kg m^{-3} of the fecal sludge mixture (the ratio of public toilet sludge to household fecal sludge being 1:2), which is then composted. Raw fecal sludge from dry toilets and organic waste are added to the DFS and composted together. The composting process lasts for a period of 2 to 2.5 months for DFS, 3 to 3.5 months for a co-compost with market waste and DFS (mass ratio being 3:1) or 4 to 4.5 months for a co-compost with sawdust (mass ratio being 3:1).

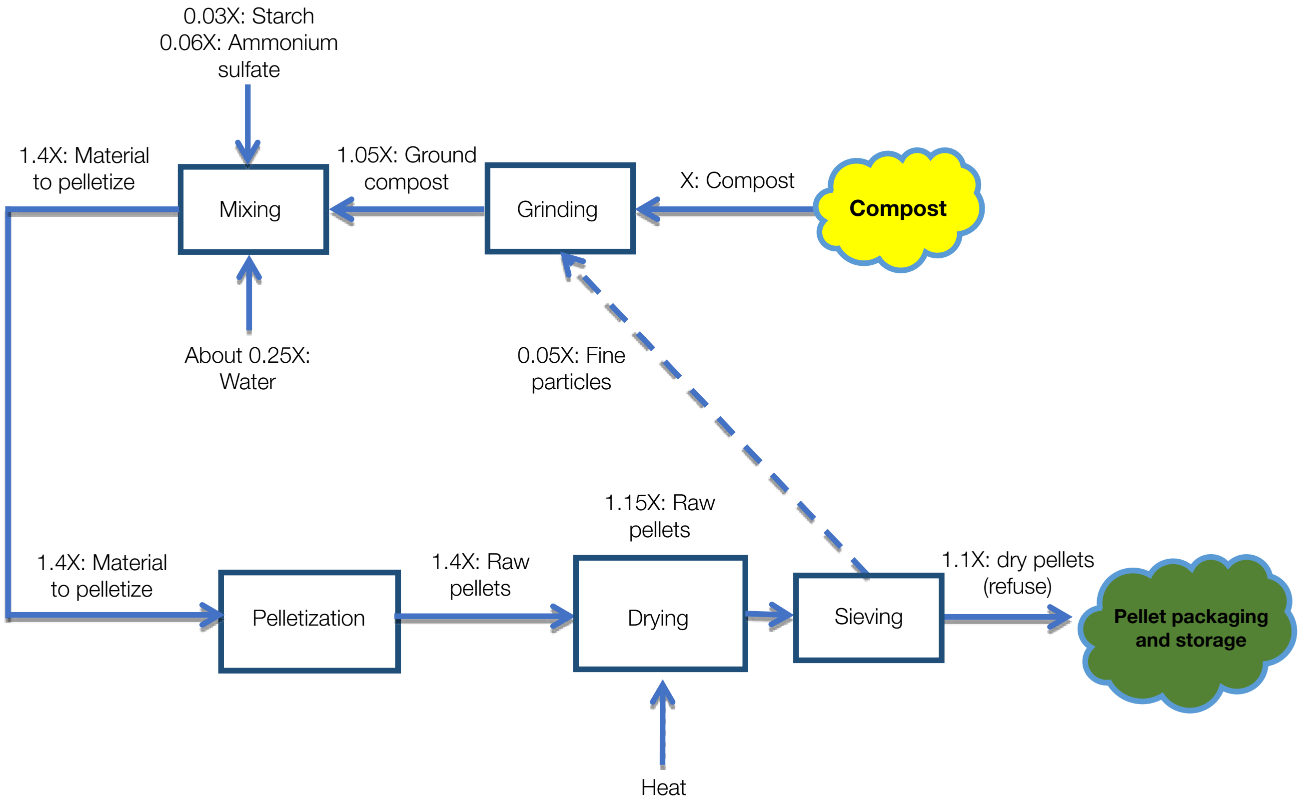
FIGURE A1. COMPOST PRODUCTION FROM FECAL SLUDGE.



Souce: Nikiema et al. 2014

The matured compost is then ground to a specific consistency. The ground compost is then mixed with starch, ammonium sulfate and water in ratios of 1: 0.03; 1: 0.06 and 1: 0.25, respectively. The resulting nitrate-fortified substance is then pelletized using a pelletizer. The raw pellets are then dried, sieved and packaged. Any remnants/fine particles resulting from the sieving process are added back into the process at the initial grinding stage. The pelletization step requires less than a day for pellet formation and 3 to 7 days for drying of pellets (depending on the drying method and climatic conditions, especially if solar energy is used.

FIGURE A2. FORTIFICATION AND PELLETIZATION PROCESS OF COMPOST.



Souce: Nikiema et al. 2014

ANNEX 2. PROBIT REGRESSION RESULTS FOR WTP FOR NPF ACROSS ALL COUNTRIES

	Africa			Asia		
	Greater Accra, Ghana	Western region, Ghana	Kampala, Uganda	Bangalore, India	Hanoi, Vietnam	Kurunegala, Sri Lanka
Variables	*Coefficient*	*Coefficient*	*Coefficient*	*Coefficient*	*Coefficient*	*Coefficient*
Bid1	-0.090**	-0.029	-4.548***	-4.308***	-2.082***	-17.915***
Hhmember	-	-	0.026	-0.036	-	0.055
Farm_exp	0.005	-0.001	-0.011*	0.0158	0.003	-0.006
Education	-0.245**	0.144	0.018	-0.066	-0.036***	0.018
Farmsize	-0.003	0.061*	0.058	-	-0.343***	-0.004*
Farmincome	0.0003	0.002**	0.00007	-0.002	0.000002	0.00002
Landownership	-0.078	-0.132	0.351*	0.997**	-	-0.325
FBOM	0.212	-0.132	-	-0.184	-	-
Use_org_fert	-0.517**	-0.277	0.439*	0.458*	-0.159	0.115
Offarm_work	0.821**	-0.436	-0.092	-2.371***	-	-
Certification_trust	0.049	-0.232*	0.198**	1.668***	0.081*	-
Positive_attribute	-0.006	-0.044	-0.146	-	-	-0.067
Price_sensitive	-0.269**	0.149	-	-	-	-
Safety-culture	-0.275*	0.026	-	-	-	-
Safety issues	-	-	-0.428***	-0.841**	-0.284***	-
Substitute	-	-	-	0.367	-0.277***	-
Certification-substitute	-	-	-	-	-	0.096**
Awareness	-	-	-	-	-	0.119
Constant	2.762**	-0.319	1.557***	3.586*	1.199***	3.093***
Log likelihood	-83.19	-60.57	-127.808	-14.43	-232.02	-134.08
LR Chi^2	26.68	24.19	53.61	45.33	43.80	52.62
Prob > Chi^2	0.001	0.010	0.0001	0.001	0.0001	0.0001
Pseudo R^2	0.14	0.17	0.173	0.611	0.386	0.164
Number of observations	160	124	258	54	260	267

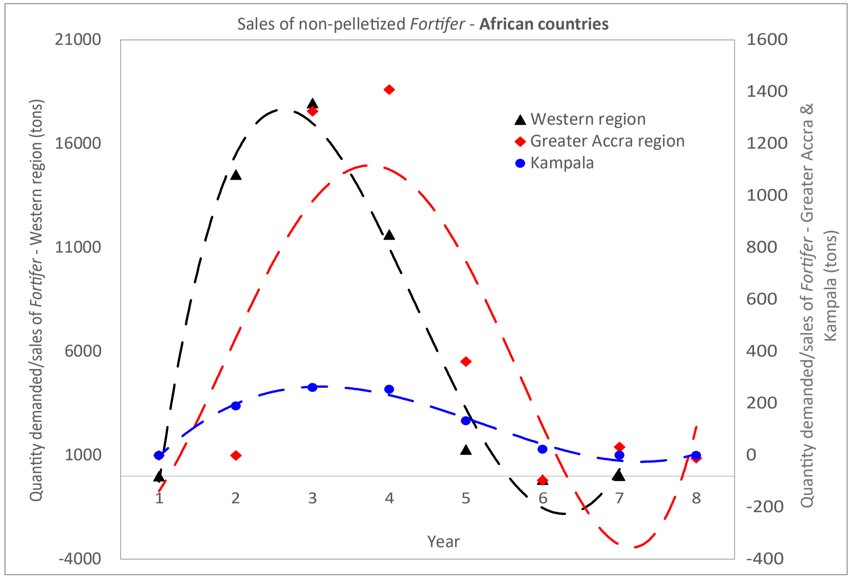
*Significant at the 0.10 level.
**Significant at the 0.05 level.
***Significant at the 0.01 level.

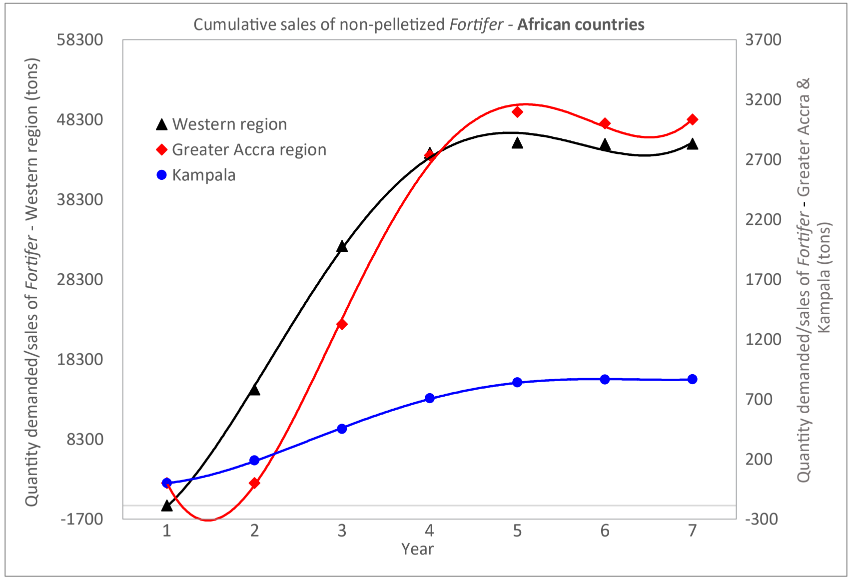
ANNEX 3. PROBIT REGRESSION RESULTS FOR WTP FOR PF ACROSS ALL COUNTRIES

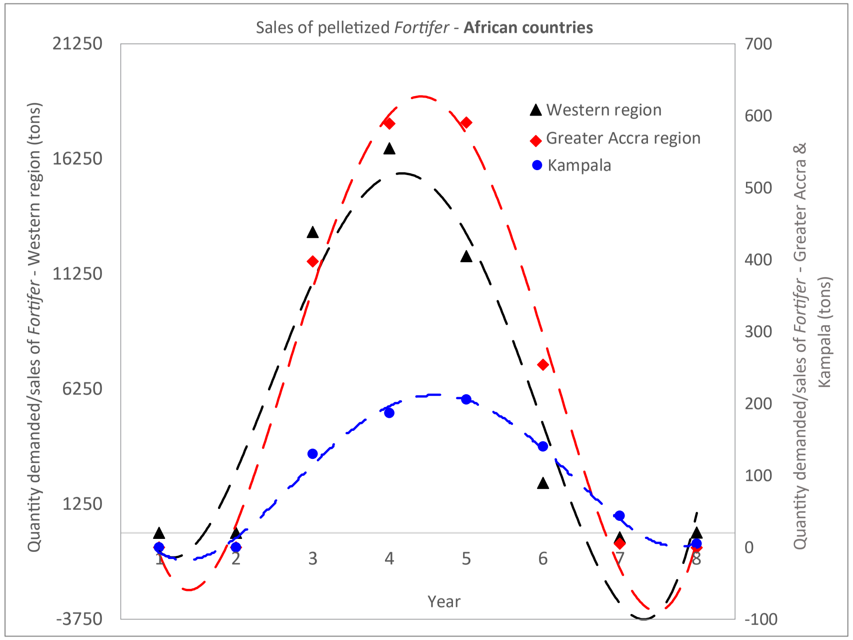
	Africa			Asia		
	Greater Accra, Ghana	Western region, Ghana	Kampala, Uganda	Bangalore, India	Hanoi, Vietnam	Kurunegala Sri Lanka
Variables	*Coefficient*	*Coefficient*	*Coefficient*	*Coefficient*	*Coefficient*	*Coefficient*
Bid1	-0.077*	0.036	-4.037***	-5.487***	-2.284***	-6.983**
Hhmember	-	-	-0.020	0.217	-	0.017
Farm_exp	0.003	-0.003**	0.008	-0.102**	-0.005	-0.006
Education	-0.053	-0.160	0.013	0.058	-0.003	0.065***
Farmsize	0.004	0.042*	0.117	-	0.175*	-0.003
Farmincome	0.0001**	-0.001	0.0003**	0.0025	-0.0000007	0.00002*
FBOM	-0.055	-	-	0.221	-	-
Landownership	0.007	-0.404*	0.407*	0.792***	-	0.052
Use_org_fert	-0.309*	-0.560**	0.106	1.419*	0.415***	-0.050
Offarm_work	0.611**	-0.380	0.356*	0.576	-	-
Certification_trust	-0.038	0.153	0.149*	0.219	0.042*	-
Positive_attribute	0.015	0.089	-0.083	-	-	0.075**
Price_sensitive	-0.047	-0.006	-	-	-	-
Safety-culture	0.016	-	-	-	-	-
Safety issues	-	-	-0.202***	-0.905***	0.031	-
Substitute	-	-	-	0.294	-0.074**	-
Certification-substitute	-	-	-	-	-	0.028***
Awareness	-	-	-	-	-	-0.173***
Constant	1.731*	0.258	0.902*	1.758	-0.074	0.440
Log likelihood	-97.96	-75.22	-155.741	-15.171	-521.56	-174.20
LR Chi^2	28.11	21.34	41.14	38.40	33.12	20.90
Prob > Chi^2	0.02	0.030	0.0001	0.001	0.0001	0.034
Pseudo R^2	0.15	0.13	0.117	0.559	0.308	0.156
No. of observations	158	124	258	54	260	267

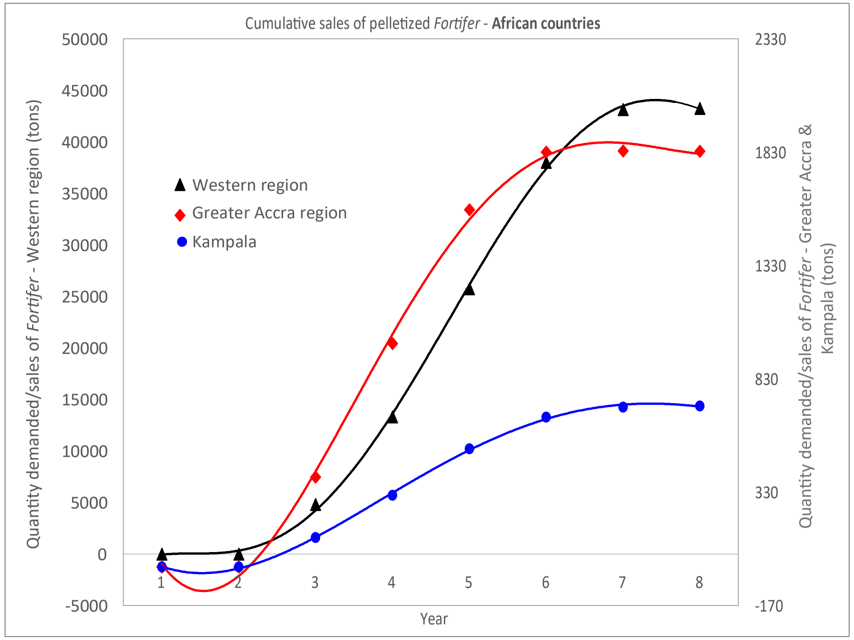
*Significant at the 0.10 level.
**Significant at the 0.05 level.
***Significant at the 0.01 level.

ANNEX 4. SALES AND CUMULATIVE SALES CURVES FOR NPF AND PF – COMPARISON FOR AFRICAN COUNTRIES

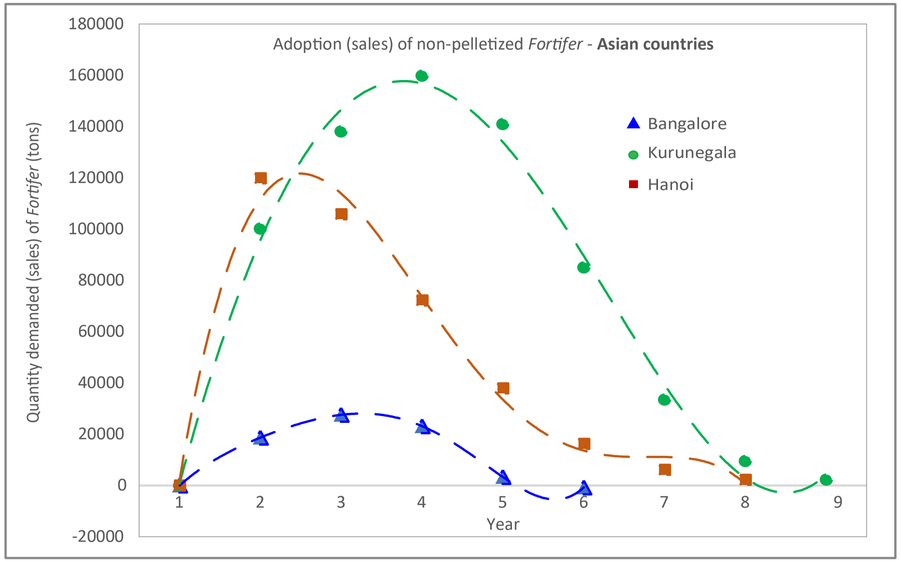


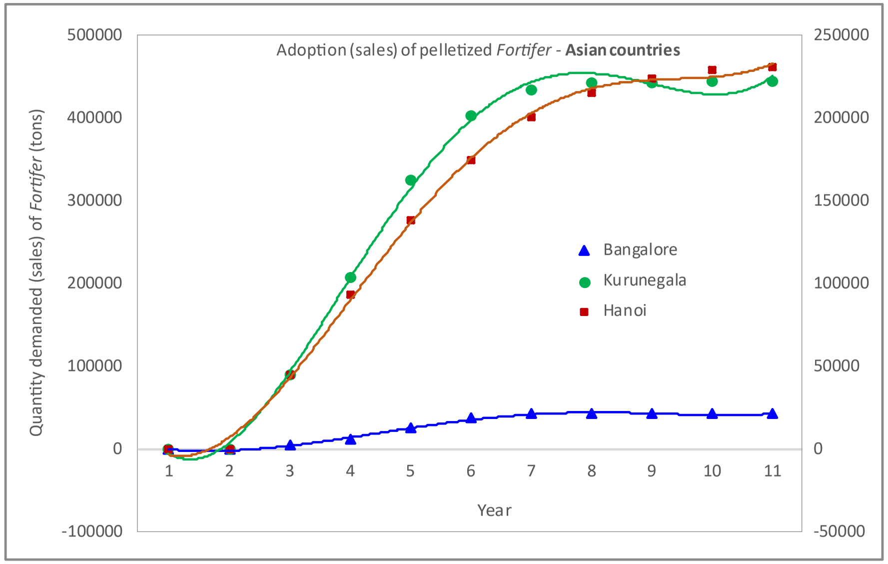


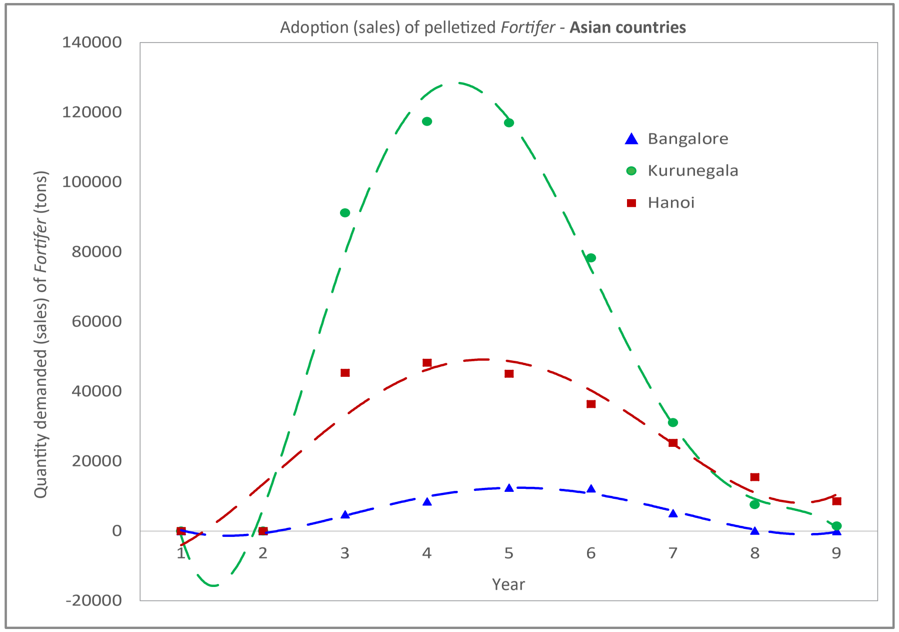


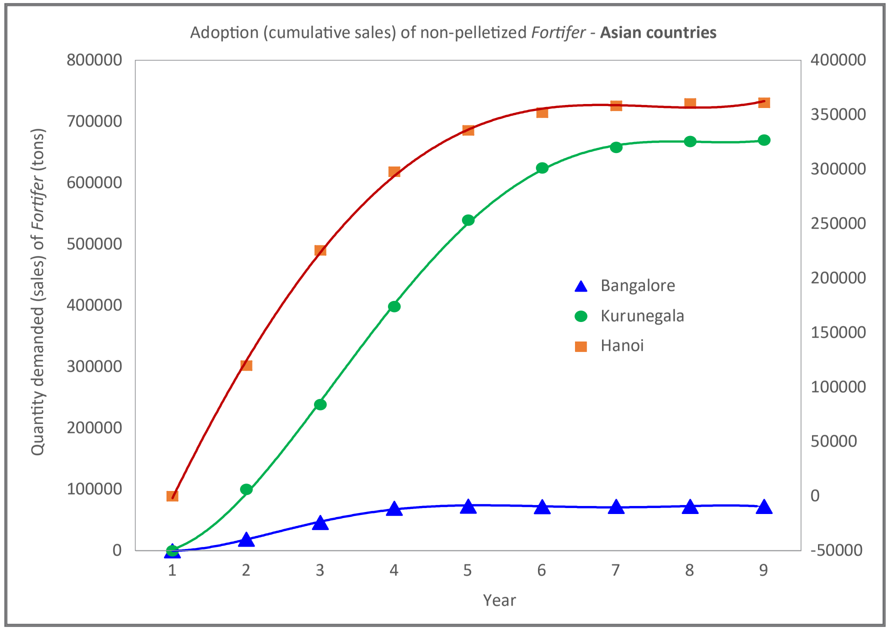


ANNEX 5. SALES AND CUMULATIVE SALES CURVES FOR NPF AND PF – COMPARISON OF ASIAN COUNTRIES









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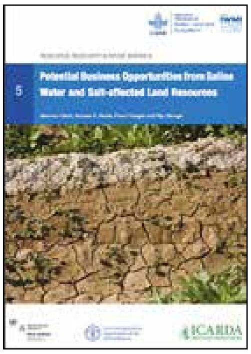

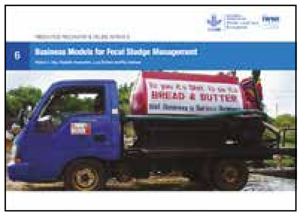

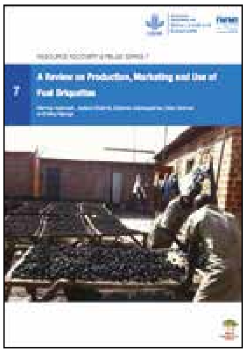

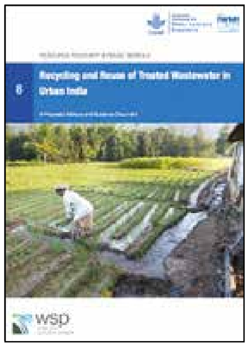

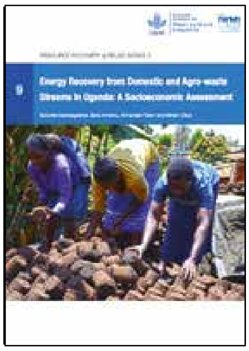

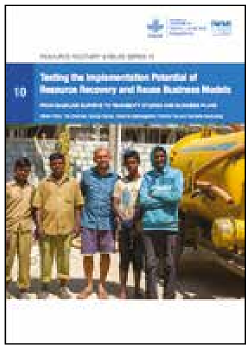

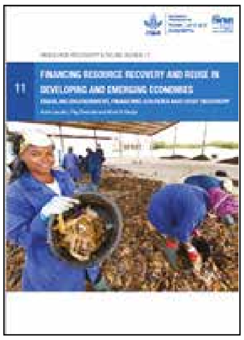

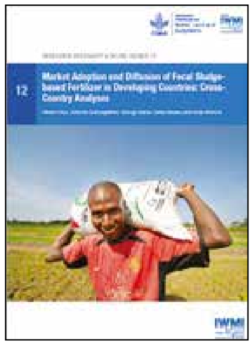

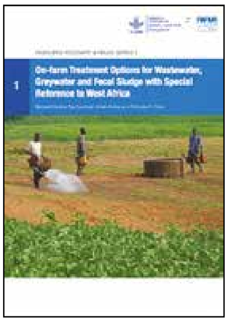

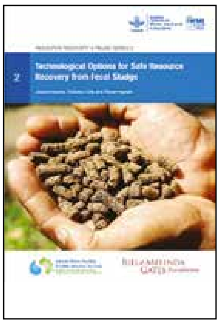

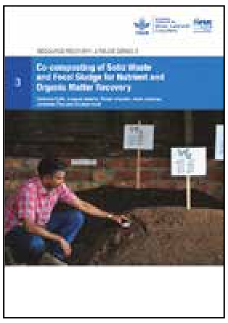

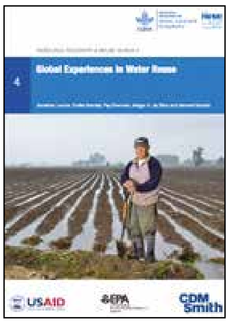

RESEARCH PROGRAM ON Water, Land and Ecosystems

LED BY: IWMI International Water Management Institute

Photo: Desire JP Lompo.

CGIAR Research Program on Water, Land and Ecosystems

The **CGIAR Research Program on Water, Land and Ecosystems (WLE)** is a global research-for-development program connecting partners to deliver sustainable agriculture solutions that enhance our natural resources – and the lives of people that rely on them. WLE brings together 11 CGIAR centers, the Food and Agriculture Organization of the United Nations (FAO), the RUAF Foundation, and national, regional and international partners to deliver solutions that change agriculture from a driver of environmental degradation to part of the solution. WLE is led by the International Water Management Institute (IWMI) and partners as part of CGIAR, a global research partnership for a food-secure future.

Resource Recovery and Reuse (RRR) is a subprogram of WLE dedicated to applied research on the safe recovery of water, nutrients and energy from domestic and agro-industrial waste streams. This subprogram aims to create impact through different lines of action research, including (i) developing and testing scalable RRR business models, (ii) assessing and mitigating risks from RRR for public health and the environment, (iii) supporting public and private entities with innovative approaches for the safe reuse of wastewater and organic waste, and (iv) improving rural-urban linkages and resource allocations while minimizing the negative urban footprint on the peri-urban environment. This subprogram works closely with the World Health Organization (WHO), Food and Agriculture Organization of the United Nations (FAO), United Nations Environment Programme (UNEP), United Nations University (UNU), and many national and international partners across the globe. The RRR series of documents present summaries and reviews of the subprogram's research and resulting application guidelines, targeting development experts and others in the research for development continuum.

CGIAR Research Program on Water, Land and Ecosystems (WLE)
International Water Management Institute (IWMI)
127 Sunil Mawatha, Pelawatta
Battaramulla, Sri Lanka
Email: wle@cgiar.org
Website: wle.cgiar.org
Thrive Blog: wle.cgiar.org/thrive

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