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TESTING TOOLS FOR ASSESSING SYSTEMIC CHANGE: NETWORK ANALYSIS

**THE SOBA PROJECT AND SIERRA LEONE'S VEGETABLE MARKET
SYSTEM**

LEO REPORT #42
Leveraging Economic
Opportunities

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ACRONYMS

| | |
|-------|---|
| DfID | United Kingdom's Department for International Development |
| EVD | Ebola Virus Disease |
| MSA | MarketShare Associates |
| LEO | Leveraging Economic Opportunities |
| SOBA | Sierra Leone Opportunities for Business Action |
| SLL | Sierra Leone Leones |
| USAID | United States Agency for International Development |

EXECUTIVE SUMMARY

Network analysis is a tool for mapping relationships between actors in a system, and has therefore recently gained interest by the market development community as a way to understand system dynamics and design more effective, targeted interventions.

In late 2015, a researcher from MarketShare Associates with the [Leveraging Economic Opportunities \(LEO\)](#)¹ activity conducted a network analysis of traders within the vegetable market system in Sierra Leone, to evaluate network analysis as a technique for describing market system dynamics, evaluating systemic change over time, and identifying potential leverage points for intervention by market systems programs. The DfID-funded Sierra Leone Opportunities for Business Action (SOBA) program, which hosted the analysis and provided data collection and analytical support, intended to use that information for partner selection, performance monitoring, indicator design, and impact measurements over time.

The research yielded several useful observations about Sierra Leone’s vegetable market system:

- We found a large number of centrally located actors that were positioned to act as bottlenecks as well as potential leverage points.
- We also found a highly localized non-trade communication network that offered significant opportunities for inserting valuable information and other resources into the market system.
- We found a high degree of gendered homophily among trade and non-trade communication partners – in other words, female social and communication networks significantly influence female trader business practices and performance.
- We observed that the vegetable system is highly fragmented, with multiple overlapping network fragments that spanned large sections of the country, but showed little or no trade linkages with one another. We uncovered at least three large networks that had almost no interaction with each other, but significant geographic overlap. This finding in turn led the research team to question whether a “lead-firm” approach used by many market systems programs would have been sufficient in this context. At the least, SOBA would need to find centrally-placed traders, or lead firms, in each distinct network, in order to foster widespread change across the national market system.

There is growing recognition among market systems development practitioners of the need to capture the deeper changes that are occurring in the systems in which they work. LEO has been investigating practical ways to measure indications of systemic change; this started with a literature review and synthesis of efforts to evaluate systemic change for inclusive market development. The synthesis paper identified the growing interest among practitioners to measure indications of systemic change, but also the lack of well-recognized tools and frameworks for doing so.

To support this, LEO explored the utility of four tools – **Standard Measurement Tools, Outcome Harvesting, SenseMaker, and Social Network Analysis**, conducting trials of each on field-based projects. Full reports from those tool trials are available at www.microlinks.org/leo, along with a synthesis report.

¹ For more information on LEO, visit www.microlinks.org/leo.

- Using a combination of network analysis and qualitative follow-up, we also explored the social embeddedness of vegetable trade, discovering widespread practices of input and credit provision between actors in the system.

A basic parametric analysis of the observed network – our research explored one fragment and detected several others – yielded a list of actors that would provide useful leverage points for SOBA, although the fragmented nature of the national market system meant that other leverage points would need to be identified in the other fragments – requiring additional research. In addition, randomly selecting actors from across the parametric ranking of the network would also be useful for identifying sentinel points (individuals, not to be confused with sentinel indicators) SOBA could use to evaluate the spread of new information and trading practices across the network.

Lastly, this research also attempted to evaluate the utility of network analysis for the market systems practitioner community more broadly, seeking to gain insight into market system dynamics given the ability of network analysis to finely parse relationships between agents in a system². We found that the tool is extremely powerful toward this end. However, at the same time, it is also time- and cost-intensive. Moreover, we found that focusing on trade relationships (i.e., actual transactions), alone, yielded a partial and potentially misleading portrait of relationships in a given system. In a real-world socio-economic system of hundreds (at least) of interacting agents, it is also impossible to verify the degree to which a network analysis is complete, or even fairly representative of the actual trade network (which is ultimately indescribable). It would be a waste of time to do a series of network analyses in the hopes of comparing them, because one would not know how comparable they are to each other.

Instead, looking at three layers of the market system, simultaneously, yielded the most insight:

1. Commerce (transactions) between traders;
2. Social organization around market information among traders; and
3. Collaborative institutions among competing and non-competing actors in the market system.

The first two were explored directly through the network analysis; the third was addressed through qualitative, key informant interviews with traders identified through the network analysis.

In order for it to be widely applicable by market systems programs, we would need to develop a “network-light” approach. Such an approach would keep the insight into social institutions developed by snowballing through trade relationships, while stopping short of the exhausting and potentially cost-ineffective parsing of trade relationships characteristic of a “full” network analysis.

² In all, LEO evaluated the utility of four tools, doing field trials of three. A synthesis report is available at www.microlinks.org/leo.

I. INTRODUCTION

This report is organized as follows: following this introduction, Section II provides background context on the vegetable market in Sierra Leone. Section III then explores the methodology of network analysis, including key metrics used to analyze the observed network and limitations of the study's findings. Section IV presents the report's main findings, starting with a review of data about respondents and moving into the network analysis, then including qualitative data we gathered through key informant interviews. The report ends with a series of conclusions, summarizing the findings and making recommendations for SOBA's programming in Section V. Section VI contains reflections and recommendations for other market systems programs that may be considering using network analysis in their work.

A. SOBA

Sierra Leone Opportunities for Business Action (SOBA), funded by the UK's Department for International Development (DfID) and implemented by Adam Smith International, is a market systems development program that aims to reduce poverty in Sierra Leone. To do this, SOBA provides targeted technical and financial investment in business practice innovations that grow businesses and improve farmer and small-scale entrepreneur performance and market position concurrently. Since 2013, SOBA has made investments within the agriculture, light manufacturing and renewable energy sectors in Sierra Leone.

SOBA's agriculture sector interventions broadly target the food trade system, focusing on practice and performance shifts at firm level that enable improved performance and growth for businesses and farmers alike. SOBA's work in the vegetable market system to date includes the following:

- Improved agricultural input distribution through expanded networks, integrated advisory services and a growing range of high-quality inputs and advisory services.
- Efficient commodity and produce sourcing for food processors and traders through preferred supplier programs, better aligned performance incentives, guaranteed purchase and expanded trade networks.
- Improved outgrower practices that offer value-added investment to farmers (like seeds, advisory services, storage, and credit) that expand production and result in meaningful income improvements concurrently.

B. LEO

The USAID-funded Leveraging Economic Opportunities (LEO) project is designed to support the capacity of donor staff and market systems development projects to design and implement evidence-based programs that facilitate inclusive market systems development. LEO's core research questions are the following:

- How does one define and recognize significant, enduring, pro-poor change in market-systems resulting from the activities of development agencies? What are the defining features of these kinds of intermediate outcomes?
- How can we identify early changes that reflect progress in a market systems facilitation project, before systemic changes and final project goals have had enough time to occur?
- What practical methods and tools can we use to monitor systemic change and early change?
- How can these results provide feedback to improve the management of facilitation activities?

LEO's effort to answer these questions includes the identification and testing of methods that can capture whether and how systemic change is occurring, including network mapping, SenseMaker, outcome harvesting

and standard measurement tools. It is hoped that these trials will enable missions and implementing partners to understand whether the programming they are funding is leading towards expected results when still early in an activity's lifecycle, and to capture evidence that systemic changes are occurring. This research was conducted under the LEO project managed by ACDI/VOCA, with the research designed and carried out by MarketShare Associates.

C. LEO AND SOBA COLLABORATION TO TRIAL NETWORK ANALYSIS

SOBA and LEO collaborated to trial network analysis to further SOBA's understanding of vegetable trade dynamics, to identify leverage points for follow-on interventions, and to identify sentinel points for potentially observing early indications of systemic change. The network analysis was expected to provide a picture of information flow and firm-level response that would be critical for program targeting, partner selection, performance monitoring, indicator design, and both baseline and follow-on impact measurements.

MarketShare Associates led the design, analysis and write-up of findings. SOBA team members were heavily involved in the trial design and results analysis. The SOBA team also directly carried out survey testing and data collection.

II. CONTEXT

Sierra Leone's vegetable market has experienced huge changes over the last few years. Prior to the Ebola Virus Disease (EVD) outbreak and simultaneous collapse of the iron ore industry, vegetable trade was a high-growth economic opportunity. Thanks to a stronger national focus on local procurement and a steady and growing demand for vegetables, fueled by the mining and hospitality industries, local vegetable production and resale was on the rise.

However, restrictions on movement and trade imposed as quarantine measures to stave off the spread of EVD during the 2014 outbreak resulted in the sector's near collapse. These included:

- Severe restrictions on travel and movement. Major vegetable production areas are located far from key and core markets. Restrictions on mobility nearly halted all trade and produce movement from farms to consumers.
- Bans on periodic markets and trade activity. Local sales also restricted.
- Bans on large gatherings. Weddings and other celebrations, a premier catering opportunity where "high end" vegetables were often part of the meal, were limited to small groups only, largely shuttering catering operations.

The impact of significantly reduced vegetable resale carried over to the ag-inputs industry. Vegetable seeds and other inputs are typically higher margin products for ag-input distributors. The loss of several vegetable seasons combined with bad credit practices and poor repayments hit the already anemic ag-inputs industry; the start of 2016 saw two of the more established ag-input distributors fold.

The EVD outbreak ended in late 2015 and with it the quarantine measures that were so damaging to the vegetable sector. Though the iron ore and hospitality industries have not fully rebounded, growing demand from a new set of foreign mining and construction companies and renascent hotel, restaurant, and resale businesses as well as the return to relative normalcy for Sierra Leoneans has seen demand for local vegetables growing again.

SOBA targeted the vegetable sector at the onset of the program because it offers opportunities for significant pro-poor growth. More than 70,000 farmers – mostly women – are engaged in vegetable production. The “exotic” vegetable varieties are also grown as cash crops, rather than food crops, and are an important source of income.

SOBA’s investments in the vegetable sector, just underway when the Ebola outbreak began to rise, primarily focused in the ag-inputs and services sectors. Here, the program continues to improve national-level distributor performance, to expand upcountry distribution networks, to grow product and service ranges and suppliers, to integrate advisory services and to link in digital technology for inventory and customer management as well as marketing and information campaigns.

SOBA’s vegetable trade investments, including efficient sourcing and supply management, expanded wholesale marketing, and integrated packaging and storage, are burgeoning.

III. METHODOLOGY

Network analysis is an analytical method used to visualize and analyze actors (or agents) in a system and the relationships between them. It can depict many types of formal and informal networks, including firms linked in a market system, households linked through kinship or social ties, and collaborating groups or associations. A network map can show the number and characteristics of agents and the structure of relationships between them. Those linkages can describe a variety of flows, including products, payments, business services, credit, information, and technology diffusion. One can use the information in a network map (or graph) to deduce the influence of specific agents, the redundancy built into structural patterns, and other network features.

Another strength of network analysis – its ability to reveal social relationships that influence economic decisions – emerged through the investigation. The heavy influence of social networks on “embedded” economic networks, which is a reference to the view that economic behavior takes place within a social context, has been observed in a variety of studies examining job search, price setting and the diffusion of innovation,³ and features significantly in this network analysis.

Compared to a value chain analysis, a network analysis is a profoundly detailed investigation of the social and economic webs that surround the path of a commodity from raw material to consumption.⁴ Where a value chain analysis would show one box, labeled “Traders,” sandwiched between “farmers” and “processors” or “supermarkets,” a network analysis offers a detailed map of hundreds of traders of varying capacities and preferences, with distinct upstream and downstream links. Moreover, network analysis is not limited to describing commercial transactions. Using the same tool, analysts can incorporate information about trader membership in social groups, which has implications for their access to basic services like finance and information. In sum, network analysis offers a granular and contextually rich way to understand trade relationships.

³ Granovetter, Mark, “The Impact of Social Structure on Economic Outcomes,” *Journal of Economic Perspectives* – Vol 19, No 1 – Winter 2005.

⁴ Hidalgo, Cesar, “Why Information Grows: The Evolution of Order, from Atoms to Economics”, Basic Books, New York, 2015. Hidalgo argues that economic development is, at least partly, a process whereby individuals develop unique capacities and roles within a network structure, allowing the network to accomplish tasks that would not be possible for any individual or directly managed group to achieve.

SUMMARY OF FIELDWORK

The SOBA project intended to use network analysis to map trade, information flows, and supporting service sector response originating from a major vegetable producing area that trades into neighboring Freetown. The survey was a forced-choice questionnaire (see Annex 1) developed and refined over two rounds of field-testing with approximately 75 trial surveys. It asked respondents about their own businesses, their trading partners, and their non-trade communication partners (people in the sub-sector with whom they exchanged vegetable-trade-related information, but did not transact). Field trials were conducted in the Lungi area of Port Loko district. Once the tool was finalized, we completed 153 valid surveys in Port Loko, Kambia, Bombali, Koinadugu, Western Urban and Western Rural Districts.

For sampling, we mostly followed a snowball strategy, tracing trade relationships from respondents (egos, in network parlance) to their reported trading partners (alters), then interviewed the alters to identify their trading partners, and so on. In some circumstances, such as in Makeni Town, Bombali District, we snowballed for respondents and covered traders in other visible markets, such as the fresh vegetable corner at the town center. Our aim with purposive sampling was to crawl from retailers to wholesalers and regional distributors, thereby discovering the larger network of vegetable trade.

Four enumerators administered the surveys using Android-based tablets, uploading the data to the ONA data platform for aggregation, under the supervision of SOBA staff. An MSA consultant reviewed the data daily to control quality and identify alters for future surveys. An additional consultant supported data analysis and formatting prior to uploading survey results to the network software.

To conduct the network analysis with the data, we used [Cytoscape](#)⁵, an open-source network analytical software package that provides visualization functionality as well as a variety of analytical tools. We added a centrality plug-in to the basic Cytoscape package to be able to use a variety of centrality measures, some of which are detailed below.

In addition to surveys, we also conducted 29 qualitative interviews with traders and farmers. The qualitative interviews provided additional contextual data that proved to be useful for understanding the significance of the network data.

In all, this activity took about three months of work for the MSA consultant, including about six weeks of work for SOBA staff. Quantitative data collection took place over four weeks, with two additional weeks for qualitative surveys.

NETWORK PARAMETERS

SOBA was interested in finding two types of individuals within the vegetable trade network:

- Centrally placed traders who may have a higher than average influence on trade and information flows;
- Sentinel figures, located at distinct scale levels within the trade network, who could give the program an idea of the scale at which it had successfully influenced behaviors.

⁵ For more information on Cytoscape, visit www.cytoscape.org.

To identify the first category of traders (centrally located individuals), the analysis examined and compared four *centrality measures*. Centrality measures describe a node's placement within the context of its peers, giving indications of its potential influence within a network. The four centrality measures used were:

- 1) **Degree centrality** – ranks nodes by the number of connections each one maintains with other nodes. A node with six connections will be ranked higher than a node with two connections, for example.
- 2) **Closeness centrality** – ranks nodes by the sum of paths (or numbers of connections) to all other nodes. It tends to identify those nodes that are located toward the center of an observed network, but does not necessarily indicate that highly ranked nodes are thereby pivotal to exchange between other nodes in the network.
- 3) **Eigenvector centrality** – ranks nodes by the connectedness (degree) of their neighbors. A high eigenvector score indicates that a node is connected to more high-degree nodes than average.
- 4) **Betweenness centrality** – ranks nodes by the degree to which a given node lies on the shortest path between any pair of other nodes. Betweenness probably comes closest to acting as a proxy for influence in a trade network. However, it is highly sensitive to missing data (as discussed below).

To find the second category of traders (sentinel figures), a simpler visual analysis of the network would suffice to identify traders at different tiers of the network.

LIMITATIONS TO THE ANALYSIS

A number of issues limit the conclusions one should justifiably draw from observation of the larger trade network graph. As discussed in detail below, these include missing data and the scant research into appropriate implications that can be drawn from network analysis.

The most immediate limitation owes to *missing data*. It was clear to us that traders only listed a fraction of their total trading partners when surveyed, but it was unclear exactly how much data we were missing. In other words, we could not determine the degree to which our observation of the network was representative of the whole network. This is a common problem in network analysis of real-world systems – researchers commonly assume that respondents tend to list their most significant connections and then move forward with a data analysis.

Smith and Moody examined the sensitivity of various graph parameters to missing information and found that betweenness scores are the least reliable, while degree (number of connections) and homophily (similarity between connecting nodes) measures are robust to missing data.⁶ Closeness centrality and eigenvalues lie between them. As a result of this review, the research team decided to focus on degree centrality, but would nevertheless run the other centrality analyses to compare the findings of each measure.

Fragmentation, or the presence of small, disconnected clusters, is also reasonably robust to missing data, under the assumption that if no links show up between clusters in a network, it is likely that any undiscovered links are less likely to be reported because they are weak. Narrowing down to the network of relationships only between two egos (i.e., in the SOBA case, only those relationships reported between the 153 nodes surveyed, excluding all 'alters' referenced by 'egos' but never surveyed) helps to improve the validity of all scores, because one can justifiably assume that reported trade connections are those considered by all egos to be the most significant, and eliminating alters removes a significant number of dead-end connections that would

⁶ Smith, Jeffrey A.; Moody, James. "Structural Effects of Network Sampling Coverage I: Nodes Missing at Random." *Soc Networks*. 2013; 35 (4).

skew centrality measures. The order of analysis in Section 4b is thus to examine centrality rankings in the ego/ego network, then extrapolate those findings out to the larger ego/alter network.

However, a potentially more significant limitation owes to the *lack of research into network structures that are more or less indicative of a healthy market system*. In other words, while there are many robust measures for network features, there is not yet much research into the implications such metrics have for social and economic networks and how to interpret the resulting data. There are dozens of ways to analyze network structures, but few of them offer insight into whether or not agents can control trade flows, for example. One can use centrality measures for the latter, but what is the use of, say, quantifying the network diameter or the degree distribution? What does that actually say about the performance of agents within the network, or the network's ability to reward quality, or allow for informal credit to flow between agents?

Even with centrality measures, researchers can use eigenvector centrality and degree centrality to identify prominent nodes, but we found that follow-up, qualitative analysis (such as conducting key informant interviews) is required to understand the node's potential to affect change in the market system. The qualitative follow-up interviews add an institutional dimension to the analysis that makes it easier to compare the position of one node to those of other nodes in the network. In other words, the graph from surveys must be contextualized with qualitative interviews – the network data alone was not as useful as the network data combined with qualitative information. Our research achieved contextualization through comparing the trade graph to social graphs, combined with targeted qualitative follow-up interviews that discussed perceptions of trust, embedded services, and recourse to other trade partners, among other issues.

Lastly, it would have been *impossible, if not a waste of time, to try to map out the whole market system*. With thousands of actors and relationships, not to mention seasonal differences, it is too complex to be completely mapped. This research stopped far short of interviewing every possible trader. However, it did manage to capture significant portions of the vegetable market. Moreover, the piece of the market mapped out illuminates institutions and opportunities that are likely to pertain to the wider market system, as we discuss below.

IV. FINDINGS

A. STYLIZED FACTS ABOUT THE TRADER RESPONDENT POPULATION

After testing the tool, the evaluation team carried out 153 valid surveys, providing information on 474 trade relationships and 144 non-trade communication relationships (e.g. sharing price or other market information) among 497 distinct actors in the vegetable trade system. The following is a description of salient features of the surveyed population, as background to the ensuing network analysis.

Of the 153 respondents, 33 (22 percent) were men and 120 (78 percent) were women. The median and mean ages of respondents were both 40 years. Both men and women traded primarily in exotic and local vegetables⁷,

⁷ There are two kinds of vegetables grown in Sierra Leone. 1) "local traditional" varieties, including hot chili pepper, garden eggs, sweet potatoes, okra, and cassava and potato leaves. 2) high value "exotic" varieties, including tomatoes, onions, eggplants, sweet peppers cabbages, carrots, lettuce, spring onions, green beans, cauliflower, radish, cucumbers, parsley, and potatoes.

as illustrated in Table 1. Nearly half of all respondents also traded in seeds, and almost 30 percent traded in agro-chemicals and fertilizer.

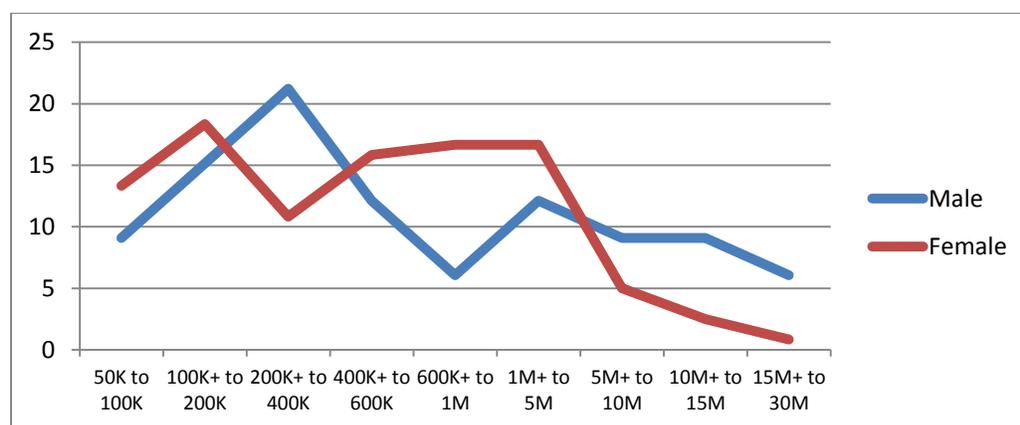
| Table 1: Items Traded | Total sample | Male | Female |
|------------------------------|---------------------|-------------|---------------|
| Exotic vegetables | 90% | 82% | 92% |
| Local vegetables | 77% | 70% | 79% |
| Seeds | 45% | 48% | 44% |
| Agro-chemicals & fertilizers | 28% | 27% | 28% |
| Other | 6% | 15% | 3% |
| Total (number) | 153 | 33 | 120 |

Trader involvement in seeds and fertilizer is discussed in depth below – anticipating that discussion, it is common for traders to forward seeds, fertilizer and food (mainly rice) to farming households at the start of a season in order to secure a portion of that farmers’ harvest. Some of the most significant findings of this analysis are that there is a huge volume of resources moving upstream and downstream in the vegetable system (with delayed cash settlement), strong competition among traders to lock up supply, and lengthy durations of relationships between actors.

To give some insight into the sizes of trader business, Table 2 below shows the mean and median figures for reported average daily revenue, in Sierra Leone Leones (SLL).⁸ A few large male and female traders skewed mean figures upward, with a small number of very large male-led trading businesses predominating. However, as Chart 1 shows,⁹ more than 20 percent of the men surveyed managed businesses with average daily revenue below the median amount, so it would be a mistake to imagine that men only managed high-value trading businesses. On the contrary, many women had much higher volume businesses than a large proportion of the male respondents.

| Table 2: Average Daily Revenue (SLL) | Total sample | Male | Female |
|---|---------------------|-------------|---------------|
| <i>Mean</i> | 2,189,673 | 4,260,000 | 1,620,333 |
| <i>Median</i> | 500,000 | 500,000 | 500,000 |
| Count | 153 | 33 | 120 |

Chart 1: Average Daily Revenue as a Percentage of Male/Female Respondents



⁸ As of the completion of field research in October 2015, 1 USD = 4,198 SLL

⁹ For clarity, Chart 1 compares the percentage of each sub-population (female and male) reporting average daily revenue in each of the buckets in the X axis. So, more than 20 percent of male respondents reported average daily revenue of between SLL 200,000 and SLL 400,000.

At the same time, larger vegetable traders were also more diversified with regard to their dependency on vegetable trade, as seen in Table 3. A few significantly more diverse actors drove the mean well below the median figure. The picture that comes out of the data at this point is of a few very large, diversified actors (both male and female, though men were larger outliers) and a long tail of small trader operations, predominantly female-led, that rely on vegetable trade for four fifths of their business income.

| Table 3: Veg Trade as % of Total Reve- | Total sample | Male | Female |
|---|---------------------|-------------|---------------|
| <i>Mean</i> | 72.5% | 73.3% | 72.3% |
| <i>Median</i> | 80.0% | 80.0% | 80.0% |
| Count | 153 | 33 | 120 |

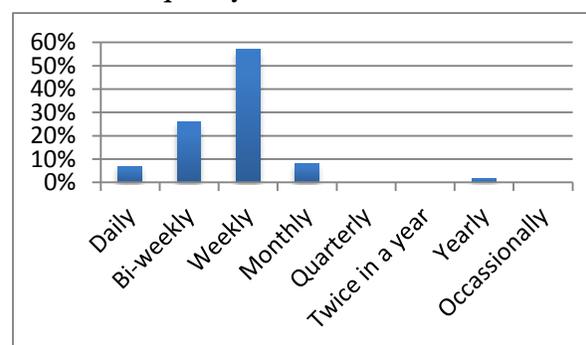
In addition, women tended to spend much more of their time each week selling vegetables, both on average and as a median score. Table 4 shows the amount of time men and women devoted to vegetable trade, with women on average trading vegetables nearly six days per week and men averaging fewer than four.

| Table 4: Number of Days Trading/Wk | Total sample | Male | Female |
|---|---------------------|-------------|---------------|
| <i>Mean</i> | 5.18 | 3.73 | 5.58 |
| <i>Median</i> | 6.00 | 4.00 | 6.00 |
| Count | 153 | 33 | 120 |

Lastly, shifting focus to trade relationships reported by survey respondents, the majority of trade took place on a weekly basis, with most other reported frequency occurring either daily or twice per week (see Chart 2). This helps to give a picture of the turnover of trade in the vegetable system.

Given the high perishability of vegetables combined with prevailing poor storage practices, it is surprising that 57 percent of transactions between traders would occur only weekly – one might guess that high spoilage would demand more frequent trade interactions. It seems possible that the predominance of weekly interactions could be caused by the general lack of liquidity in the trade system (discussed in detail below), although it is difficult to know what frequency of trade would be ideal.

Chart 2: Frequency of Trade



As for the direction of reported trade relationships, Table 5 shows the percentage of trade relationships reported as “buying from,” “selling to,” or “both.” It is interesting to note that the survey team found nearly as

| Table 5: Direction of reported relation- | % of trade |
|---|-------------------|
| Buying from | 46% |
| Selling to | 38% |
| Both buying and selling | 16% |
| Total trade relationships | 474 |

many “selling to” relationships (38 percent) as “buying from” (46 percent). This is partly a function of the fact that we attempted to follow supply lines up from retailers to larger suppliers. But it is also partly a function of the density of trade networks – in Port Loko, for example, we noticed a dense network of trade relationships between women who acted mostly as retailers, with the same vegetables changing hands in a small area several times. This, again, might have to do with the perishability of the products in question. In qualitative follow-up interviews, retailers reported selling a portion of their stock to a neighboring retailer if they felt that market demand would not exhaust their current supply before a portion of it spoiled.

B. NETWORK ANALYSIS

This sub-section provides a discussion of network analysis and qualitative follow-up findings. The 153 surveys yielded a network population of 497 individuals and 474 trade relationships. Where the previous sub-section examined characteristics of the respondents themselves (egos), this sub-section details findings from examining the trade relationships they reported (egos with alters and egos with egos).

CENTRALITY PARAMETERS

By observing the trade network graphs and running basic centrality analyses, we could identify a large number of centrally located agents in the vegetable trade network. Before discussing the combined trade and social network analysis, we will discuss the findings from the trade network analysis, alone, using the centrality measures explained in the methodology section.

The order of analysis was first to analyze the largest fragment of the ego/ego network along the four centrality parameters (degree, closeness, eigenvector and betweenness). We considered the most highly ranked nodes from each measure, evaluating their placement within the largest fragment of the wider ego/alter network, so that we could determine the use and relevance of each centrality measure. Once one or more of the four metrics was considered useful, we would then run that analysis for the entire ego/ego network (not only the largest fragment) and extrapolate to the larger network to develop a list of pivotal actors.

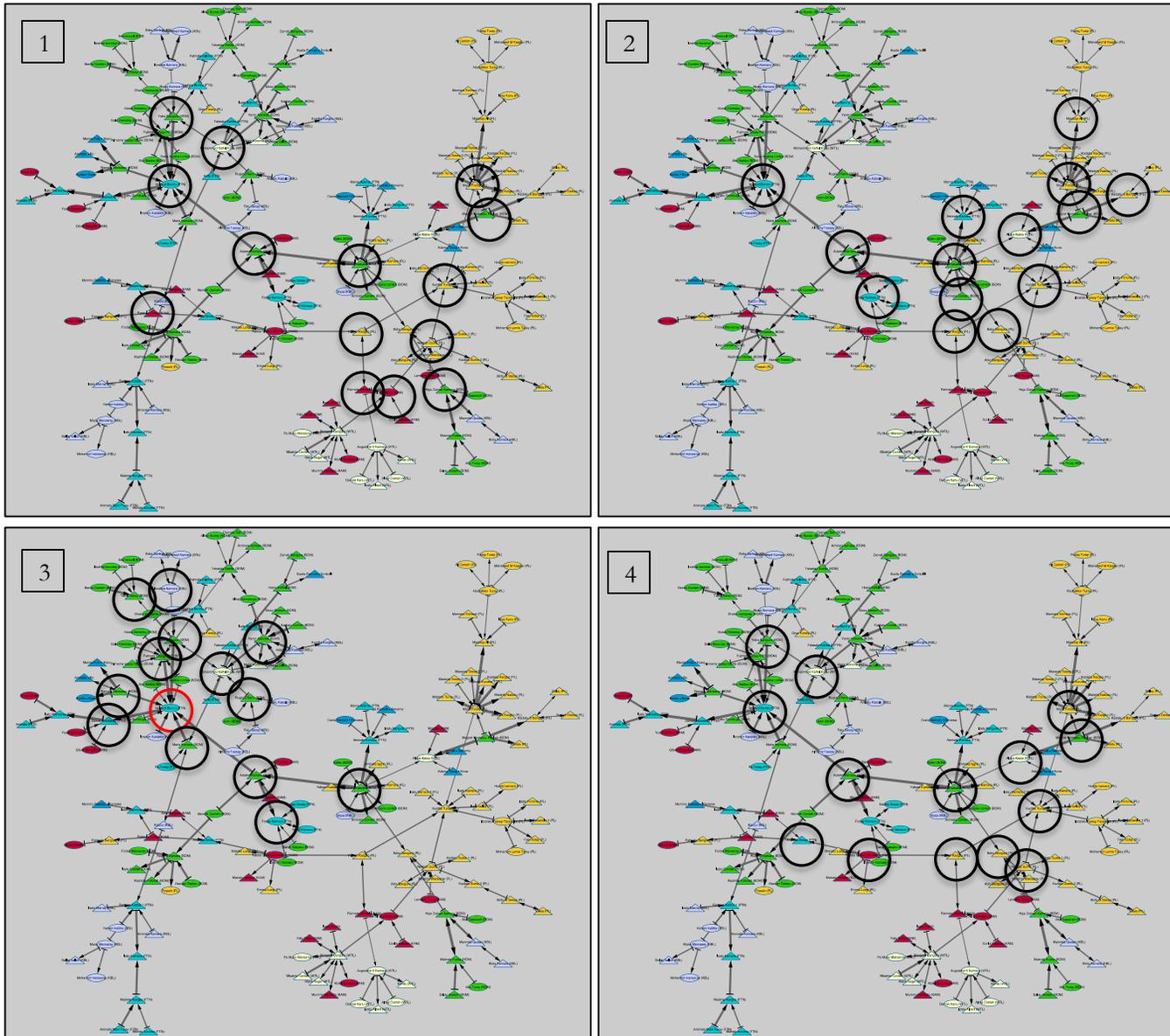
Centrality measures give information about a node's position within a network, relative to other nodes. Analyzed collectively, these give an indication of potential influence within a network. In sum, the four measures are:

- 1) **Degree centrality** – presents the number of connections one person has (a 'popularity' proxy), giving an indication of the degree to which an individual is connected directly to other individuals.
- 2) **Closeness centrality** – situates a person topographically in the network, giving an indication of the degree to which an individual lies near the center point of an observed network.
- 3) **Eigenvector centrality** – gives an indication of the connectedness of the other relationships in one's network. It looks at the connections of an individual's connections (like degree centrality, but one connection away).
- 4) **Betweenness centrality** – gives an indication of one's influence within a trade network, by examining the degree to which individuals have to move through you to reach other individuals

In Chart 3 (see next page) one can see the top 14 individuals in the largest component of the ego/alter network, indicated by a black circle, as ranked by the four centrality measures. We ranked only the top 14 traders because the first metric, degree centrality, gave us 14 traders with three or more connections (or degrees) and a much larger number with only two connections – stopping at 15 or 20 connections would thus have been more arbitrary than stopping at 14. We then analyzed the largest fragment of the ego/ego network to rank the top 14 traders by the three additional metrics, and then extrapolated back to the larger ego/alter network, identifying the top 14 traders for each metric in the largest component of the ego/alter network.

Chart 3 shows four graphs of the same ego/ego set of individuals, one graph for each centrality measure. The different colors in the nodes represent traders from different regions in Sierra Leone. The lines indicate trade between those traders. The graph does not map to geography – they are produced by a graphing function that spreads out the network map to make relationships easily observable. The length of lines is not meaningful.

Chart 3: Comparison of centrality measures: (1) Degree, (2) Closeness, (3) Eigenvector, (4) Betweenness



Based on Smith and Moody’s research (as discussed in the Methodology section), we focused on degree centrality for to generate a list of centrally placed actors, but we ran the other centrality analyses for comparison purposes. **Degree centrality (1)** is the most straightforward measure, requiring only that analysts sum the reported connections of all surveyed actors – degree centrality is simply a measure of the number of connections a given trader is reported to have. In our case, with obviously missing data, degree centrality becomes at least partly an indication of the number of times a given trader is mentioned by other traders – a sort of popularity measure, in other words. As seen in Chart 3’s Graph 1, degree centrality gives a widely dispersed list of highly connected traders, with less distance to traverse to reach even outlying traders, as compared to the rankings produced by the other measures. Moreover, as mentioned in the methodology section, degree centrality is quite robust to missing data,¹⁰ leading to a high level of confidence that a ranking by degree would give SOBA an accurate picture of pivotal individuals. Lastly, degree centrality produced a highly geographically diverse group of traders, as shown in Table 6, below.

Closeness centrality (2), as a measure of the mean distance between a given node and other nodes, tends to rank as highest those nodes that are centrally located in a network, in a topological sense. That is to say, traders with a high closeness centrality are sitting close to the middle of the trade network. However, this does not necessarily indicate that their positions afford them a greater level of influence over the extended network of traders, especially those operating in more distant areas. Note that none of the traders from outlying areas (such as Kambia - red, Kabala – purple, or Kenema – dark blue) fall among the top 14 by closeness centrality.

| Table 6: District Representation/Centrality | | | | |
|--|---------------|------------------|--------------------|--------------------|
| District | Degree | Closeness | Eigenvector | Betweenness |
| Western Urban (Freetown) | 1 | 3 | 3 | 2 |
| Western Rural (Waterloo) | 1 | 1 | 1 | 2 |
| Bombali | 5 | 4 | 8 | 4 |
| Port Loko | 5 | 5 | 0 | 5 |
| Kambia | 3 | 0 | 0 | 1 |
| Kabala | 0 | 0 | 1 | 0 |

Eigenvector centrality (3), indicates the degree to which one’s neighbors are highly or poorly connected. In this case, eigenvector ranking produced a list of traders clustered around Mamud Bundu (circled red), a Freetown-based trader with extensive networks and many close trade relationships with other high-degree traders (and one of only three traders to make all four lists). The presence of that cluster seems to have overpowered the other actors, from the perspective of this centrality measure, with the result that it highlights a small group of well-connected individuals, most of whom trade with each other. This hardly seems to be a useful measure for identifying pivotally located individuals across the trade network. As with closeness centrality, the traders identified by eigenvector centrality represent a tight geographic area (Table 6).

Betweenness centrality (4) was identified by Smith and Moody as the centrality measure most sensitive to missing data. For that reason alone, it is probably a less useful metric for socio-economic network analyses

¹⁰ Moody and Smith analyzed in-degree (one aspect of degree in a directed network), but in the case of trade relations, in-degree based on buyer/seller status would not necessarily indicate which actor was in a more influential position (i.e., the buyer or the seller). We therefore used degree centrality regardless of the direction of trade relations.

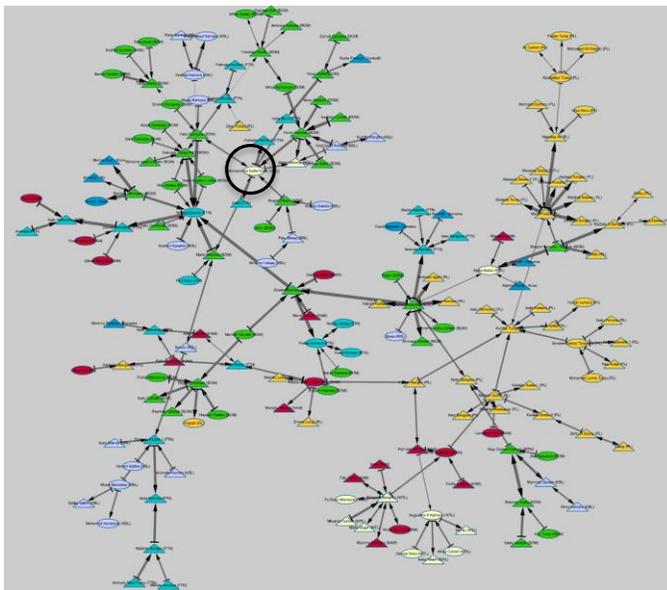
such as this one, with high susceptibility to missing data. However, betweenness centrality ranking in this case produced a list of actors that was more than 70 percent identical to degree centrality, with 10 traders appearing on both lists of 14. Considering that betweenness centrality examines the degree to which a given node lies on pathways between other nodes, this could indicate that most of the traders ranking as highly connected (with high degree centrality scores) are also in position to connect large numbers of other traders, at least for the universe of trade relationships we managed to gather. Also, the fact that the metric least susceptible to missing data (degree centrality) produced results that are close to the metric most susceptible to missing data (betweenness centrality) could also indicate that our dataset is more complete than we feared. However, that is impossible to verify.

Focusing on the results from use of degree centrality for the reasons stated above, we generated **a list of pivotal actors across the ego/alter network SOBA could use as leverage points**, based solely on an analysis of features observed within the network. At the same time, **the degree centrality ranking could also populate a list of sentinel actors, simply by randomly selecting a dozen or so actors** from the longer list for periodic follow-up.

NETWORK ANALYSIS WITH QUALITATIVE FOLLOW-UP

While the list of highly central traders is useful, a fuller picture of the social institutions that influenced trade

Graph 1: Largest Cluster in the Ego/Alter Network



relationships emerged as a result of targeted qualitative follow-up interviews. For example, one of the most pivotal agents from both degree and betweenness centrality measures is Mohammed Keffel Kanu (circled), a trader in the Waterloo market at the inland tip of the Freetown peninsula. In the larger (ego/alter) network analysis, his pivotal position is evident (see black circle in Graph 1, left).

Mr. Kanu is a high-volume trader providing an end market (or penultimate market, at most) for many upcountry traders. His buyers are local retailers selling in Waterloo and Freetown, while he buys from traders and farmers around the country. He directly finances around 60 farmers per year and has been buying from some of the same farmers since the 1990s. He has a large network of

long-term trading partners and the basic institutional arrangements he maintained with them, discussed individually below, were echoed in qualitative interviews with other traders around the network.

EMBEDDED FINANCE FOR TRUSTED PARTNERS

On one hand, Mr. Kanu (pictured at right) finances agricultural production for approximately 60 farmers annually, allowing him to lock up supply ahead of the cultivation season. He provides cash, food (usually rice), seeds and fertilizer. He denies charging interest on these loans, but it is reasonable to conclude that he recovers interest in the process of negotiating repayment terms as a percentage of a borrower's produce, which takes place at harvest time. In nearly every interview the research team spoke with traders and farmers who either provided or received cash and in-kind credit under similar terms. Asked whether these loans could be viewed as exploitative, Mr. Kanu responded that stiff competition for farmers among traders meant that one had to treat them well. Qualitative interviews with nine farmers indicated that significant suspicion of trader commitments was widespread, although that was at least partly due to the sub-sector's low liquidity and resulting delayed payments.



DELAYED PAYMENTS (INFLUENCED BY LOW LIQUIDITY AND PUSHING RISK UPSTREAM)

In addition to providing embedded services like finance and input supply to trade partners, Mr. Kanu also frequently transacts with delayed payments – another common feature in Sierra Leone's vegetable market system. From the farm gate to the retail point, it was evident in multiple interviews that non-cash transactions were normal. While there was a strong preference for dealing in cash immediately upon sale, a general lack of cash availability meant that many traders and farmers were forced to wait until sales were completed further downstream in order to be paid. When cash did trade hands, it would then cascade back upstream. That delay could take anywhere from one week to more than a month, and offered buyers an opportunity to shunt risk back upstream by lowering their previously agreed purchase price to account for a fall in prices or produce that spoiled before it was sold – they would simply refuse to pay the full amount previously agreed. In a situation where traders paid cash at the farmgate the trader would then take all the risk of selling, but in the Sierra Leone vegetable market cashless transactions meant that risk was continually pushed back to the seller. The common occurrence of partial payments owing to spoilage, in turn, was a significant source of mistrust between trade partners. In summary, the low level of cash availability in the trade network had two significantly negative impacts: it centered risk on the smallholder farmers supplying traders, and it fostered mistrust between actors in the network, especially farmers and traders.

“[Other traders] usually pay for the vegetable after sale. They are not reliable. As said already, even after price is agreed, they would change if prices fall but will not add if prices increase in the market.” – *Theresa Bangura, farmer and trader in Songo Town, Moyamba district*

TRUST-BASED NETWORKS

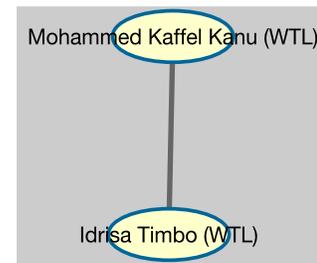
In this environment, differences in levels of trust were important. The fact that so many transactions in the vegetable market system involved delayed settlements, combined with the need to lock up production by informally financing farmers, meant that traders like Mr. Kanu often confined most of their trade to more trusted partners. These trust networks in some cases allowed for vegetables to move across the length of Sierra Leone, from farmer to consumer (from Kabala to Freetown), without cash payment until retail. While it is fascinating to witness the emergence of trade networks built upon trust-based relationships, it must also be recognized that this is a sub-optimal solution to a problem that stems from low money supply and extremely poor access to finance. A better solution would be a more dynamic vegetable trade system in which farmers

accessed better credit terms through formal financial service providers and traders paid them immediately in cash. For now, however, SOBA can work within the trust networks to try to improve the system's performance to the benefit of all actors, including smallholder farmers.

But would Mr. Kanu be a useful partner for SOBA? There are two potential avenues for influencing change: through trade relationships and/or through social relationships. Mr. Kanu has a network of producers from whom he regularly purchases and he maintains long-term trade relationships with traders in more distant markets, so it is reasonable to expect that he could affect some change through their trade relationships. But the extent of his reported social networks is altogether different (Graph 2). From that perspective, he moves from being highly connected to being extremely isolated.

Mr. Kanu is central from a trade perspective – he provides a valuable end market for a large number of traders. But for SOBA's purposes he could merely signpost a potential blockage. Although they may be productive partners for facilitating the improved performance of the market system, traders like Mr. Kanu may also have limited influence. Worse, they could be bottlenecks operating at cross-purposes to the goal of more dynamic trade with equitable gains. Looking broadly at the way the communication network and trade network wove together gives a large number of additional leverage points that may be more promising.

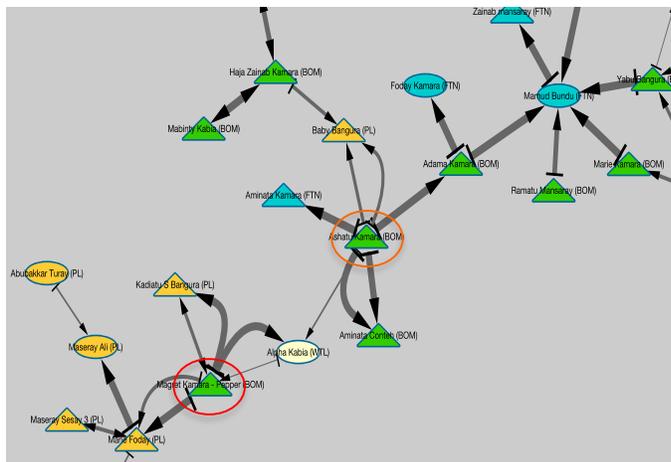
Graph 2: Mr. Kanu's Non-Trade Connection



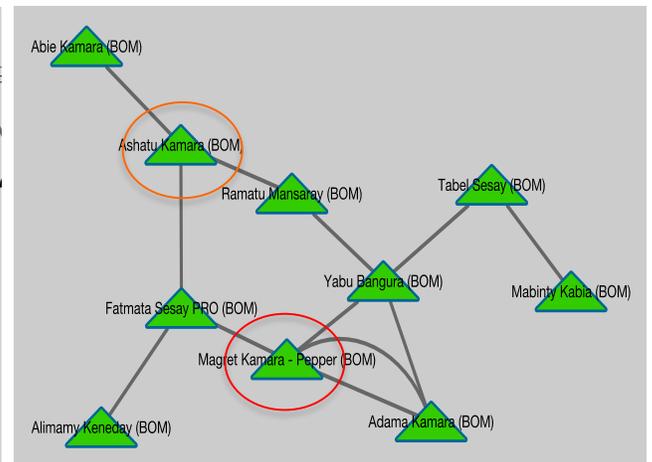
LOOKING AT MORE THAN TRADE – THE SOCIAL EMBEDDEDNESS OF ECONOMIC NETWORKS

Purely from a trade perspective, there are dozens of individuals in the observed network who, like Mr. Kanu, are positioned to act as facilitators or bottlenecks, with the potential to strongly influence prices, information flow and market access.

Graph 3: Ego/ego Trade Network



Graph 4: Bombali Non-Trade Cluster



However, an analysis of redundancy and the potential for control that only considered trade relationships would ignore the underlying social structure indicated by non-trade communication networks. The non-trade communication relationships involving many of the same Bombali-based (green) actors in the fragment

Graph 3 above shows a dense, localized cluster of individuals exchanging information while trading with some of the same partners, though not with each other.¹¹ Note, in particular, Magret Kamara – Pepper (circled red) and Ashatu Kamara (circled orange).

Graph 4, (above), shows Bombali women traders (green) in the ego/ego network analysis who lie on either side of several bridges (Alpha Kabia and Mamud Bundu, plus Baby Bangura, a female trader in Port Loko). Focusing on Alpha Kabia (pale yellow), he looks like a bridge spanning two otherwise separate trade clusters. However, the non-trade network (Graph 4) shows a dense cluster of traders who exchange price information, including the same actors that seem to be separated by Mr. Kabia. Again, Magret Kamara – Pepper and Ashatu Kamara are circled above. **Thus, each of the Bombali traders is also connected in a highly localized non-trade communication network.**



In qualitative follow-up interviews, the picture becomes clearer. The women in the Bombali communication cluster share a storage shed in the Makeni Town central lorry park, rented from the local council by Fatmata Sesay PRO. They pay Ms. Sesay a per bag storage fee for the use of the shed, but enjoy a number of other benefits from their informal group. For one, Ms. Sesay provides what amounts to wholesale finance to many of the other women in the cluster, allowing them to finance farmers ahead of cultivation. Between all of Ms. Sesay's regular associates, they probably reach a few thousand farmers each season.¹² They also share market information among themselves, including prevailing prices and market opportunities.

The social arrangements surrounding vegetable trade are not only present but extremely relevant to an understanding of how the market system operates – illustrating how traders access information and informal financial services, for example. **Informal groups such as the Bombali cluster provide a likely opportunity for influencing the performance of the vegetable market system, in addition to high-volume nodes such as Mr. Kanu and the rest of the list of central actors discussed above.**

LOCALIZED COMMUNICATION NETWORKS

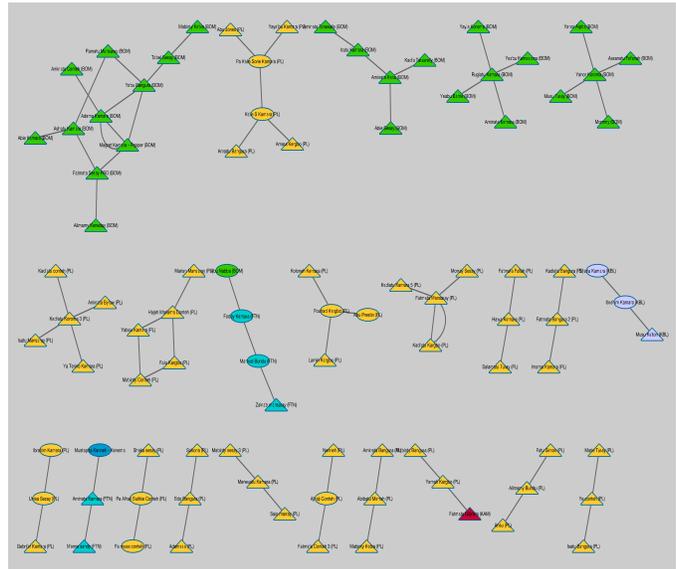
The assertion that communication networks are highly localized is bolstered by a broad view of the network graph that results from mapping non-trade price communication relationships. Graph 5 shows this broad view. Two salient facts are immediately obvious – non-trade price communication stays within small clusters of traders, and these clusters rarely cross district boundaries (districts in which traders operate are denoted by node color. Only two fragments include nodes of more than one color).

¹¹ Or at least not often trading with each other.

¹² The breadth of local cluster reach to farmers should be verified with follow-up research

Like the non-cash transactions that enable traders to work around the general lack of liquidity in the trade system, the localized nature of communication networks is probably both good and bad. It is good in the sense that it provides SOBA with extremely useful insights into local support structures and helps (predominantly female) traders access market information. However, the localized nature of communication is unfortunate because it indicates how few traders regularly access non-trade partners in distant markets to verify price information, which in turn could bolster their negotiating power. Not only was non-trade communication localized, it was also horizontal. About 82 percent of reported non-trade communications occurred between enterprises operating at about the same level in the supply chain.

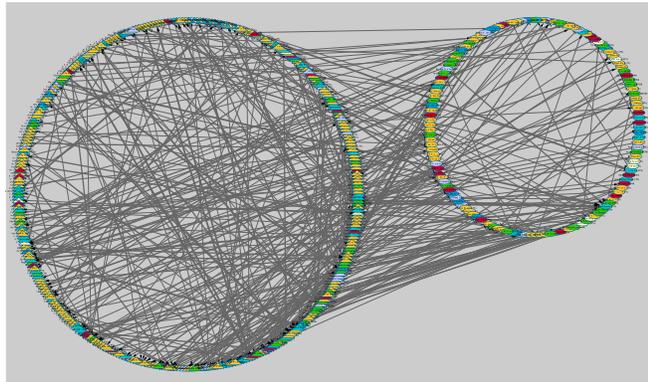
Graph 5: Non-Trade Communication Network



GENDERED TRADE AND COMMUNICATION RELATIONSHIPS

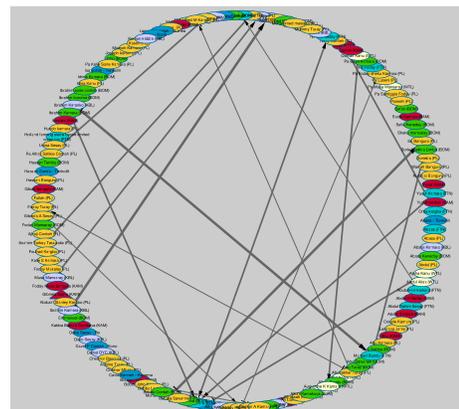
An analysis of gendered trading behavior further supports the notion that groups of women could be the path of least resistance to improving market performance. Graph 6, right, shows trade between women (larger circle) and men (smaller circle).

Graph 6: Trade Between Women and Men



Trade between men only (Graph 7, below) constituted just 6.8 percent of relationships, despite being 27.6 percent of the observed population (among the ego/ego population, there were no reported trade relationships between men).

Graph 7: Trade Between Men



Trade between women constituted another 55.9 percent of relationships. The remainder, approximately 37 percent of trade relationships, occurred between men and women.

Moreover, examining the eigenvector centrality in the ego/ego network analysis, men had 5 of the top 15 eigenvector centrality scores, despite only accounting for 19.4 percent of the ego/ego population. This means that men were disproportionately likely to be connected by trade to highly connected women.

Examining gendered **communication** relationships (as opposed to trade relationships), one observes a sharper gendered homophily among women for reported non-trade price communi-

cators – that is to say, *female traders were much more likely to communicate with non-trade partners of the same sex*. Table 7 compares trade relationships and communication relationships, using the full network dataset. Women trade with other female traders in 55.9 percent of reported relationships, but exchanged price information with non-trading female traders in more than 72 percent of communication relationships. The same change (6.8 percent vs. 8.3 percent) is hardly apparent for male traders, indicating that **female traders in Sierra Leone’s vegetable market system are far more likely than men to gather price information from among the members of their own sex. In other words, female social and communication networks significantly influence female trader business practice and performance.**

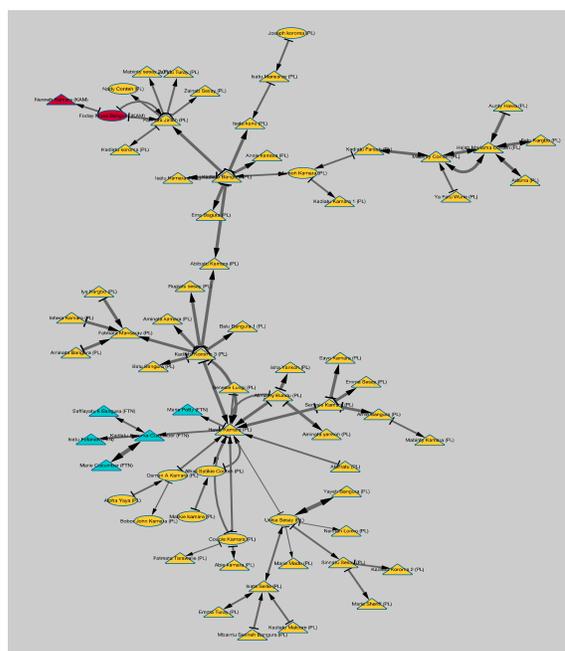
| Table 7: Trade vs. non-trade relationships, by sex | Trade | Non-trade price coms |
|--|-------|----------------------|
| Women – women | 55.9% | 72.2% |
| Men – men | 6.8% | 8.3% |

FRAGMENTATION IN THE NATIONAL VEGETABLE TRADE NETWORK

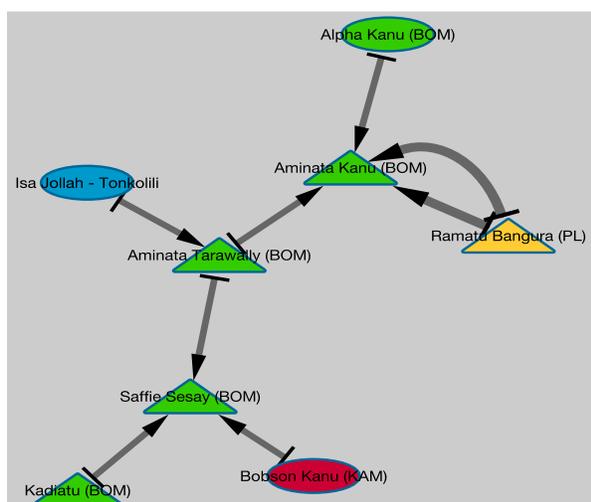
In addition to the distinct trade and communication network structures, and the findings of strongly gendered trade and communication homophily, it was also evident both from the network analysis and the qualitative follow-up that the network in Sierra Leone is highly fragmented.

The Port Loko cluster (Graph 8) typifies the fragmentation in the trade network – no doubt there are additional ties to traders outside of Port Loko, but the fact that they did not show up in data collection likely means that these additional ties are weak. The significant relationships for these traders extend between Kambia (red) and the Freetown/Waterloo markets (blue) – but mostly they

Graph 8: Port Loko Trade Cluster



Graph 9: Bombali Fresh Vegetable Cluster



focus on vegetable trade within Port Loko, itself, considering that the only reported connection to the Freetown and Waterloo markets takes place through one centrally located actor.

Another small cluster (Graph 9), including only traders of fresh vegetables (lettuce, tomatoes, cucumbers, etc.) in Bombali, also shows the local focus of buying and selling of some pieces of the network. These women source vegetables from close distances (at the farthest, nearby chiefdoms of neighboring districts).

In qualitative follow-ups after survey data collection, we discovered an entirely separate trade network pulling vegetables from Moyamba and a few other districts into Waterloo through a major trader (similar in size to Mr. Kanu, discussed above) that had not appeared once in our dataset. It is reasonable to guess that a few more distinct networks exist in the Sierra Leone vegetable market system, with at least one additional network likely rooted in Koinadugu district. **This only adds weight to the argument that, in addition to identifying a few pivotal players who could serve as leverage points for broad-based change across the market system, SOBA should also localize its efforts by tapping trader social networks in each market town.** If there are distinct trade networks, the assumption that targeting behavior changes by key individuals would spread across an entire market system is unjustified because the market system is not well connected enough. By also working through localized clusters, the problem of market fragmentation would largely be avoided.

FARMER PERCEPTIONS – QUALITATIVE FINDINGS

Recognizing that we had a reasonably clear picture of vegetable trade and information flow among traders but no corresponding idea of the farmer and consumer satisfaction with the state of vegetable trade, the research team complemented data collection with traders with a round of interviews with farmers we identified through the survey respondents. While the vegetable market system seemed to be working adequately for most traders, it appears that farmers have a much lower opinion of the fairness of trade.

Farmers were less trustful of the information provided by traders unless they were in a financial relationship with those traders.¹³ In that case, they tended to express a more positive opinion. Farmers also frequently mentioned dissatisfaction with price variations and the fact that traders would pay less than agreed, as a result. As noted above, delayed payment arrangements have damaged farmer perceptions of the reliability of traders (probably for good reason). Many farmers interviewed said they would like a larger network of trade partners so that they could shop for better prices.

One farmer who was particularly satisfied with his trade relationships both received inputs and finance from his trade partners and had contacts at the Waterloo market who kept him informed of current prices, enabling him to bargain for a better price. He had two very different sources of information (trade partners and long-distance non-trade partners).

This is not to say that direct market access is a viable or fitting solution. One Koinadugu farmer sold her crop directly to traders in Freetown but still complained about a lack of alternative market opportunities. Despite her long-distance trade relationship, she nonetheless felt confined by her lack of awareness of other opportunities. **Farmers wanted a broad range of options, whether to local traders or distant agents, or both.** In addition to trade woes, their most commonly mentioned constraints were poor input access, damage caused by pests and diseases, and lack of finance for paying agricultural labor.

IMPACT OF THE EVD OUTBREAK ON FARMERS AND TRADERS

In the final stage of qualitative interviews, the research team also gathered information on the recent EVD outbreak's impact on vegetable trade. One of our central questions was, in a market system with so much

¹³ By financial relationship, we mean a transactional relationship in which cash or in-kind credit was provided by one party to the other.

trust-based produce movement, delayed payments and informal finance, what did a partial shutdown of trade do to these relationships? Who suffered the losses? Who recovered quickly?

Anecdotally, it appears that farmers bore the brunt of losses. This was a result of the timing of movement lockdowns put in place as part of a slew of quarantine measures, in which many farmers found themselves with a season's worth of produce and nowhere to sell it, as well as the terms of finance. There was a significant amount of loss due to spoilage. Also, traders providing informal finance to farmers would allow for delayed repayment in case of crop failure (or market failure, in the case of EVD), but would still hold the farmer to full repayment over time. One farmer complained of the "huge debt on my neck" resulting from the market shutdown in the EVD response.

In terms of recovery, traders seemed to recover much more quickly, expressing optimism about the current market trend and their prospects for business growth as Sierra Leone emerged from the EVD outbreak. Farmers, on the other hand, reported significantly less working capital as a result of the losses they incurred during the outbreak period. Long-term trade relationships, themselves, seemed to be undamaged except for those cases in which a trading partner died of infection.

V. KEY FINDINGS AND IMPLICATIONS FOR SOBA'S PROGRAMMING

UNDERSTANDING VEGETABLE TRADE NETWORKS

The research yielded several useful observations about Sierra Leone's vegetable market system. We found a large number of centrally located actors that were positioned to act as bottlenecks as well as potential leverage points. We also found a highly localized non-trade communication network that offered significant opportunities for introducing valuable information and other resources into the market system. That non-trade communication network showed a significant level of gendered homophily, leading to the notion that it would be feasible to work through networks of female traders. We also observed that the vegetable system is highly fragmented, with multiple overlapping network fragments that spanned large sections of the country, but showed little or no trade linkages with one another – belying the notion that a handful of pivotal actors could be targeted to foster widespread change across the national market system. Lastly, using a combination of network analysis and qualitative follow-up, we also explored the social embeddedness of vegetable trade, discovering widespread practices of input and credit provision between actors in the system.

A basic parametric analysis of the observed network yielded a list of actors that would provide useful leverage points for SOBA, although the fragmented nature of the national market system (with several network fragments sourcing from various areas of the country and occasionally overlapping, but not significantly interacting) meant that leverage points would need to be identified in each of the fragments – requiring additional research. In addition, randomly selecting actors from across the parametric ranking of the network would also be useful for identifying sentinel points (individuals, not to be confused with sentinel indicators) SOBA could use to evaluate the spread of new information and trading practices across the network.

CONSTRAINTS TO GROWTH OBSERVED IN SIERRA LEONE'S VEGETABLE MARKET SYSTEM

The network analysis and qualitative interviews revealed several broad constraints to growth, each explored below:

- **Liquidity** – poor liquidity leads to significantly delayed payments, spreading risk across longer time periods, and in turn stoking suspicion and allegations of cheating between trade partners. More cash in the market system would meet traders' and farmers' strong preferences for immediate payment. We found a significant amount of trust-based, long-distance trade relationships that allowed for produce to move from farm to retail with cash payments delayed to the end of that cycle; yet this is in response to poor liquidity, not an optimal arrangement. However, the question of how to influence the volume of cash available to traders, and whether it is an economy-wide problem, is an area SOBA should investigate to improve performance of and benefits in the system.
- **Finance** – related to liquidity, improved access to finance would increase production and trade, but the current environment for financial services is prohibitive.
- **Input quality** – roughly half of all traders also deal in agricultural inputs (seeds and fertilizer), but the quality of inputs is a frequently cited constraint to productivity.
- **Rural transport** – expensive and often damaging to vegetables, the farm-to-market link is most in need of strengthening. Transport between large market centers appears to be satisfactory.
- **Perishability and storage** – often cited as the reason for reduced payments post vegetable sale. Weekly vegetable stock turnover requires interim options to improve longevity, like cold storage.
- **Market intelligence** – strong local communication relationships highlight indigenous social networks that provide an opportunity for SOBA to piggyback improved information and services on trade, reaching smallholders via local intermediaries. However, alternative means of price verification, with farmers and small-scale traders able to check prices in distant market centers, would boost bargaining power and increase trust in trade relationships.

POTENTIAL INTERVENTIONS FOR SOBA

The value of this network analysis is ultimately in its ability to provide useful information that informs SOBA's intervention strategy. It illuminated the following recommended target interventions and potential avenues for change worth testing. These include:

- **Facilitate the formation of trader-service hubs.** The cluster of female traders in Makeni offers an insight into innovative, group-based trade solutions that SOBA could expand and support. Specifically, these solutions combine wholesale financing and on-site storage options as a social hub. Combining financing with control over inventory is an easier avenue to third party financing. Moreover, by linking in information and social networks, the female trader peer group accessed wider price and product information that may account for their larger trade networks and overall sales.
- **Tap social networks.** Targeting female trade and farm social networks as an avenue through which to push and to spread critical information, such as price information, availability and use of improved inputs, and new buyers.
- **Forge new trade relationships.** Creating opportunities for new trade and communication relationships to emerge, such as trade fairs, may help to establish broader trade and communication options that shake current state of captured relationships. Because much of the trade appears to fall within

long-term trust networks, cash-based trade and thus new financing options that facilitate this practice for traders may also be needed.

- **Improve outgrower practices.** Most vegetable traders run outgrower programs, offering a range of inputs, cash, information and guaranteed market to farmers. However, the nature of the relationships as well as the quality and quantity of the produce traders receive has not proved effective. New incentive structures alongside improved inputs and better information may improve income and trade outcomes for both parties.
- **Link ag-dealers.** SOBA has already made significant progress toward growing improved ag-input distribution networks, expanding input product ranges, and integrating better advisory services. Working with ag-dealers to explicitly target vegetable traders as a key consumer segment – and by extension the farmers that they work with – offers an exciting opportunity to increase performance all around.

POTENTIAL LEVERAGE POINTS FOR SOBA

It is not feasible to think we can identify a few pivotal traders in the national vegetable market system and influence broad-based change through them, as we had hoped at the outset. This is due to several factors. One, the national market system is too fragmented to give any individual enough influence; this could also be a good thing, for the same reason. Second, traders closer to farmers tend to organize into smaller supportive clusters that enable significant resource movement through trust-based relationships, with only marginal participation by high-volume players in distant markets. That is to say, **the opportunity appears to be more localized.** However, SOBA can use the list of pivotally positioned traders identified through the degree centrality analysis as leverage points within that trade fragment – with the caveat that additional analysis will be necessary to identify similarly positioned traders in the other fragments.

Also, given the localized nature of supportive clusters, SOBA could employ network analysis on a smaller scale to uncover communication networks among traders in market centers around Sierra Leone, thereby identifying influencers in the localized networks.

VI. USES AND LIMITATIONS BY THE BROADER MARKET SYSTEMS COMMUNITY

Through application on the SOBA project, this research also attempted to evaluate network analysis as a tool with broader utility for market system practitioners globally. Network analysis is a very useful tool for gaining insights into market system dynamics, given its ability to finely parse relationships between agents in a system. SNA is also excellent for mapping out network structures and capturing information about resource flows within a system.

In addition, it is also useful in seeing sentinel indications of network changes, when capacity allows for sufficiently comprehensive sampling sizes.

Quite a few limitations exist, however. We found that the tool is extremely powerful, but time- and cost-intensive (see snapshot of the resources involved in this research in section III, Methodology). It also requires significant familiarity with graph theory and knowledge of network mapping software.

Moreover, focusing on trade relationships (i.e., actual commerce/transactions) alone yields a partial and potentially misleading portrait of relationships in a given system. We found that looking at three layers of the market system, simultaneously, yields the most insight:

1. Commerce (transactions) between traders (network analysis)
2. Social organization around market information among traders (network analysis) and
3. Collaborative institutions among competing and non-competing actors in the market system (qualitative follow-up interviews based on the network analyses).

In fact, **the third level of analysis, combining the qualitative and quantitative information, turned out to provide more useful insights** than the other two. This is because while SNA is very useful in understanding networks – a key component of systems and in understanding systemic change - it is weak in the area of capturing information about norms of behavior – another key component in understanding systemic change. This is unless it is accompanied by a qualitative analysis that seeks to uncover “the social embeddedness of economic interaction,”¹⁴ as the SOBA tool trial explores.

Additionally, it would have been impossible, if not a waste of time, to map out the whole market system. This research stopped far short of interviewing every possible trader. However, it did manage to capture significant portions of the vegetable market, and the piece of the market we mapped out illuminated institutions and opportunities that we believed were likely to pertain to the wider market system.

Thus for both the early signs and evaluative functions, SNA’s utility for observing changes in a network lies in the type of methodology employed. SNAs that sample every actor in a network (i.e., a census approach) or that are able to use a snowball in a small network where a large proportion of the total network can be captured can be confident in their ability to understand the nature of the agents in the system and the relationships between them. For larger networks, however, there can be much less certainty about the proportion of the network that is being studied and therefore how representative the findings are. For example, the vegetable market system in Sierra Leone includes thousands of actors and relationships, and almost certainly changes throughout the growing season in addition to fluctuations from irregular influences, like the EVD outbreak. This is probably common for market systems.

Bounding the network analysis when using a snowball method (i.e., returning to study the same population in subsequent applications) is one response, but does create trade-offs in terms of entry and exit of agents and in larger networks does create concerns about how representative the observed changes are of the entire network. The difficulty of knowing when a network analysis has exhausted the list of actors and their relationships in a market system also means that it can be difficult (if not impossible) to confidently determine how representative a given network map is of the actual set of actors and relationships in a market system. A network analysis of uncertain completeness can still give useful information about trade relationships, and when complemented with qualitative follow-up it can lead to a significant amount of useful information about underlying norms of behavior (as this trial with SOBA did). But in such applications the tool is most helpful as a

¹⁴ Granovetter, Mark, “The Impact of Social Structure on Economic Outcomes,” *Journal of Economic Perspectives* – Vol 19, No 1 – Winter 2005.

diagnostic exercise – understanding the system’s dynamics – rather than attempting to infer systemic change over time.

The following table outlines the appropriate use of various sampling methods with SNA.

| Sampling | Knowledge of agent population | Knowledge of relationships | Appropriate use |
|------------------------------------|-------------------------------|----------------------------|-------------------------------------|
| Roster (census) | High | High | Diagnostic and comparison over time |
| Snowball in a small network (<100) | High | High | Diagnostic and comparison over time |
| Snowball in a large network (>100) | Low | Low | Diagnostic only |

Lastly, given the time- and cost-intensive nature of network analysis, in order for it to be widely applicable by market systems programs, we would need to develop a “network-light” approach. Such an approach would keep the insight into social institutions developed by snowballing through trade relationships, while stopping short of the exhausting and potentially cost-ineffective parsing of trade relationships that is characteristic of a “full” network analysis.

ANNEX A: QUESTIONNAIRE

The questionnaire used to gather data during quantitative data collection is below. It allowed for one respondent per survey, with space for reporting up to eight trade partners, eight non-trade price communication partners, and eight none-trade market opportunity communication partners.

Location (brief description)

Section A: Business Information

District

Chiefdom

Section

Community/ Village/ Town

Name of informant

Name of Business

Telephone #

Sex of informant

Age of informant

Is the informant the owner?

What position does informant hold?

How many people work here?

How many are paid employees?

Do you trade? (exotic vegetables, local vegetables, seeds, agro-chemicals and fertilizers)

What type of enterprise is this? [small vegetable trader, large vegetable trader, cooperative/trade association, other trader (non-veg), agro-input show, retail shop, transporter]

Size of operation (average daily revenue: all of the money taken in by the business in an average day)

How many days in a week do you sell vegetables?

How many times/how often do you buy vegetables in a week?

Each time that you buy vegetables, how much do you spend on average?

Products/services provided (onions, tomatoes, carrots, cabbage, eggplant, lettuce, green beans, parsley, radish, cauliflower, garden eggs, hot peppers, seeds, chemicals, fertilizer, other ag-inputs/services, retail goods, transport service)

What proportion of total annual revenue is generated from exotic vegetable resale or trade (exotic vegetables are listed #1-10 above)?

Are you aware of any ag-input (seed, chemical, fertilizer, equipment) resellers in the Lungi area?

How many resellers are you aware of? (very many, many, some, not many, none at all)

Section B: Trade partners with whom you trade exotic vegetables

Contact name

Name of Business

Location: District

Chiefdom

Community/Village/Town

Address or where the contact can be found

Description of how to find the trader

Telephone #

What type of enterprise/person is this? (What do they do?)

Considering this trading partner, are you usually buying from, or selling to, this person or company?

How frequently do you trade with the person or company?

How large is the trade that your carry out with this person/company?

Do you exchange price information with this trading partner?
How useful is this price information, in your opinion?
How often do you make decisions based on this price information?
Do you exchange information about new or expanded sales or demand opportunities with this trading partner?
How useful is this information about new or expanded sales or demand opportunities, in your opinion?
How often do you make decisions based on this information?
Do you have other persons/companies that you trade with?

Section C: Non-trade price communication

Regarding your business, please tell me the companies and persons with whom you exchange information about the PRICES of EXOTIC VEGETABLES but do not necessarily trade with

Contact name

Name of company

Location: District

Chiefdom/Village

Address or where the contact can be found

Description of how to find the trader

Telephone #

Contact direction. Are you contacting them, are they contacting you, or is the connection fairly even?

Frequency. How often do you communicate about this market? (daily, 2-3 times/week, 4-5 times/week, 1 time in a week, 1 time in a month, 1 time in every 3 months, twice in a year, occasionally)

How useful is this price information, in your opinion?

How often do you make decisions based on this price information? [WRITE IN] (100%= all of the time; 0%=none of the time)

Do you also exchange information about new or expanded sales or demand opportunities with this contact?

If so, how useful is the information about new or expanded sales or demand opportunities that you receive from this contact, in your opinion?

How often do you make decisions based on this information about new or expanded sales or demand opportunities? ENTER PERCENTAGE! [WRITE IN] (100%= all of the time; 0%=none of the time)

Section D: Non-trade communication about new or expanded sales or demand opportunities

Regarding your business and aside from the contacts already mentioned, is there anyone else with whom you exchange information about new or expanded sales or demand opportunities of vegetables? [Not a trade partner, and not someone with whom you exchange price information.]

Contact name

Name of company

Location: District

Chiefdom/Village

Address or where the contact can be found

Description of how to find the trader

Telephone #

What type of enterprise/person is this? (What do they do?)"

Contact direction. Are you contacting them, are they contacting you, or is the connection fairly even?

Frequency. How often do you communicate about this market?

How useful is the information about new or expanded sales or demand opportunities that you receive from this contact, in your opinion?

How often do you make decisions based on this price information? [WRITE IN] (100%= all of the time; 0%=none of the time)

Do you have more contacts from which you access information about new or expanded sales or demand opportunities but do not get price information and do not trade with?

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