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Assessing information sharing from plant clinics in China and Zambia through social network analysis

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ABSTRACT

Purpose: This paper explores the information sharing between farmers clustered around a formal plant health information source, using six case studies of plant clinics in China and Zambia.
Design/methodology/approach: A survey was carried out with 327 farmers; six plant doctors were interviewed and plant clinic records reviewed. Data were analysed using social network analysis and descriptive statistics.
Findings: Clinic attendees shared plant health information with an average of 4.6 other farmers in China and 3.8 farmers in Zambia. However, the effective secondary reach of plant clinics, i.e. clinic attendees sharing information with non-attendees, was considerably lower, especially in China, where most sharing took place among clinic attendees. The Zambian plant clinics, managed by public extension services, show a more open pattern where information is also shared with non-attendees.
Practical implications: Plant doctors could play a more proactive role in bridging formal and informal networks to enhance the diffusion of plant health information within farming communities. Strategies to optimize the secondary reach of plant clinics should be informed by the agro-ecological and socio-economic context, as well as the type of organization operating the service.
Theoretical implications: The type of production system (degree of market orientation) and clinic's institutional setup (private vs. public sector) determine the characteristics of the social network around it. The closed, crop-specific networks in China result in high uptake of advice but limited secondary reach. The open, more crop-diverse networks in Zambia have higher secondary reach but lower uptake.
Originality/value: This is the first study examining how information travels within social networks linked to plant clinics, and patterns of information sharing and use.

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Introduction

Rural advisory or extension services[1] are fundamental in supporting farmers to deal with existing and new challenges by enhancing information exchange and capacity for

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collective action (Bourne et al. 2017). Managing plant health, in particular, constitutes a permanent challenge to smallholder farmers who face unpredictable changes in pest and disease patterns and pressures due to climate change and increasing global mobility of people and produce (Bebber, Holmes, and Gurr 2014). However, in low-income settings, timely and accurate plant health information and advisory services are often scarce or non-existing (Smith et al. 2008).

In order to address this, Plantwise,[2] a global programme managed by CABI, is working to strengthen plant health advisory services to smallholder farmers by promoting networks of plant clinics. A plant clinic is operated as a simple community-based service, open to everyone and run by 'plant doctors' (local extension workers) who have received special training in field diagnostics and plant healthcare. A plant clinic is usually equipped with simple examination tools (scissors, knife, magnifier), reference materials and visual aids, such as photo sheets and factsheets. Normally the plant doctors combine plant clinic work with their regular extension activities. Plant clinics can be stationary or mobile and they typically operate from public locations such as local markets, community premises or farmer cooperatives on a weekly or fortnightly basis (Danielsen and Kelly 2010). Farmers seek advice at a plant clinic to address their actual crop health problems. They bring samples of affected crops and the plant doctor diagnoses the problem and provides a prescription with suitable management advice. The recommended treatment consists of agronomic measures and/or application of pesticides, guided by integrated pest management (IPM) principles (Danielsen et al. 2013; Ochilo et al. 2018).

Studies conducted in Malawi, Nepal, Costa Rica and Rwanda have demonstrated that the plant clinic model of face-to-face consultations with trained staff, supported by written prescriptions and/or fact sheets, is effective to deliver high-quality plant health advice targeted farmers' specific problems (Bentley et al. 2018; Silvestri, Macharia, and Uzayisenga 2019). Additionally, the Plantwise programme expects that the delivery of relevant, high-quality advice at the plant clinics will stimulate information sharing among farmers through informal networks, thus reaching scale through farmer-to-farmer exchange. Such informal spread of information is expected to contribute to the objective of the plant clinics in providing plant health advice to farmers, as stated in the Plantwise strategy for 2015–2020: '(…) farmers will be reached through spill-over effects, or secondary reach, as farmers share new knowledge with neighbours and family' (Plantwise 2015).

Within the field of agricultural extension, it is well understood that dissemination of information not only happens through formal extension channels but also through other formal and informal relationships (e.g. Putnam 1993). The field of Agricultural Innovation Systems (AIS) in particular has drawn attention to the importance of relationships and interactions between actors within the agricultural systems to exchange information and facilitate innovation (e.g. Spielman et al. 2011). Social networks play a significant role in facilitating information flows, building social capital, supporting learning and thus increasing farmers' awareness and adoption of new agricultural technologies (Thuo et al. 2014; Weyori et al. 2018). Though formal actors such as agricultural research departments or extension agents play an important role in facilitating information sharing, other actors and networks play a role in relaying that information through secondary pathways to a wider network (Mapila et al. 2016), in particular when formal systems are weak or difficult to access by farmers (Isaac et al. 2007; Van Rijn, Bulte, and Adekunle 2012; Weyori et al. 2018). Such informal networks are defined by Rose

(2000) as 'face-to-face relationships between a limited number of individuals who know each other and are bound together by kinship, friendship, or propinquity'. Because 'membership' in these social networks is associated with certain 'rights', they can serve as an important means for individuals and households to access information and other economic resources. Evidence from Ethiopia (Krishnan and Patnam 2014) and Kenya (Fischer and Qaim 2012) also show that social learning is a powerful catalyst for the adoption of new technologies through promoting information flows.

In recent years, social network analysis (SNA) is increasingly used to gain a better understanding of the functioning of formal and informal networks in the dissemination of information and the adoption of new agricultural practices. Granovetter (1973) proposed that a closed network makes it more likely that information obtained through this network is redundant as it reinforces commonly held beliefs and knowledge within the network. Open networks, on the other hand, include many 'weak ties' that form bridges between disparate parts of a social system, thus conveying new information that may not be available to parts of the social system otherwise (Krackhardt, Nohria, and Eccles 2003; Borgatti and Halgin 2011). However, strong ties within closed networks motivate compliance, are easily available and constitute a base of trust (Krackhardt, Nohria, and Eccles 2003).

Some studies (e.g. Isaac et al. 2007; Weyori et al. 2018) found a core-periphery structure in social networks, where 'core farmers' are typically accessing information from (formal) external sources more frequently while also being well integrated into local social networks, and as such facilitate the movement of information to other farmers on the periphery. Though the ties with formal institutions may be weak, they are still crucial bridging ties to facilitate access to agricultural information and stimulate adoption (Spielman et al. 2011; Thuo et al. 2013). Van Rijn, Bulte, and Adekunle (2012), indeed, confirmed in their study that so-called structural bridging social capital, i.e. networks that extend beyond the local village and connect to external sources of agricultural knowledge, is strongly associated with the adoption of new agricultural practices among smallholder farmers.

Although there is a growing body of literature on the importance of social networks for agricultural innovation, little is known about farmer-to-farmer sharing of crop-specific plant health recommendations delivered at plant clinics. Hussain et al. (2016) found that plant clinic attendees in Malawi, Zambia, Sri Lanka and Vietnam share plant health information with an average of three farmers, but so far, no studies have looked at the dynamics of farmer-to-farmer exchange beyond this. This paper presents the findings of an exploratory study addressing the following questions: How is plant health information spread and used within the informal networks of farmers who attended plant clinics? We use the Plantwise programme as a case study and trace how plant health recommendations provided by plant clinics are passed on between farmers in different contexts. The study makes use of SNA to examine information sharing among farmers and to discuss the implications for the dissemination of (plant health) information through farmer-to-farmer exchange.

Methodology

We used SNA as the main approach to assess how information from plant clinics spreads through informal networks within local communities. We further used plant clinic records, semi-structured interviews and secondary information on the clinic operations to explore patterns of information sharing in the given contexts. China and Zambia were selected for this study as examples of the diverse country contexts in which the Plantwise programme operates. SNA is the process of investigating social structures. It characterizes networked structures in terms of *nodes* (individual actors, people, or things within the network) and the *ties, edges*, or *links* (relationships or interactions) that connect them (Scott 2000; Borgatti and Halgin 2011).

The spread of plant health information from the clinics is understood as primary and secondary reach. *Primary reach* refers to the farmers receiving information and advice directly from plant doctors at the plant clinics (first-line recipients), while *secondary reach* refers to farmers who received plant health information indirectly through spillover effects as a result of information sharing by first-line recipients with neighbours and relatives (second-line recipients).

Sampling

Six regularly operating plant clinics (weekly or biweekly), three in each country, were sampled for the study. In China, the clinics were purposively selected among the 32 plant clinics in the Beijing Area to represent the diversity of actors operating clinics in China: Government (Changping District Plant Protection Station, Beijing), private sector agrodealer (Fangshan District, Beijing) and a cooperative (Daxing District, Beijing). Though operated by a government agency, the Changping plant clinic is based at a cooperative (Table 1). All three plant clinics operate once a week. In contrast, all Zambian plant clinics are operated by staff from the Ministry of Agriculture and Livestock, twice a month. Three out of the 48 plant clinics currently operating in Zambia were purposively selected from rural areas of Lusaka and Central Provinces based on their relative reachability from Lusaka: Kanakantapa, Mpanshya and Luanshimba (Table 1).

We used a purposeful sample of 327 farmers from the clinic areas (141 from China, 186 from Zambia), using a snowball-sampling method (see for example Scott 2000). Between 15 and 30 first-line recipients (clinic attendees) per clinic were selected from clinic records by the plant doctors. In China, though first-line recipients were randomly selected from the plant clinic records, not all sampled farmers could be reached. So plant doctors assisted the selection of the first-line recipients to replace the respondents that could not be contacted. Plant clinic records in Zambia appeared to be incomplete and inaccurate, which did not allow for a random sampling of first-line recipients. Instead, they were selected by the

Table 1. Characteristics of the selected plant clinics in China and Zambia.

China	Changping	Fangshan	Daxing
District, Province	Changping, Beijing	Fangshan, Beijing	Daxing, Beijing
Operator	Changping District Plant Protection Station (based at a strawberry cooperative)	Input supplier	Cooperative (run by cooperative staff)
Clinic regularity	All: Once a week		
Zambia	**Kanakantapa**	**Mpanshya**	**Luanshimba**
District, Province	Chongwe, Lusaka	Rufunsa, Lusaka	Kapiri Mposhi, Central
Operator	All: Department of Extension, Ministry of Agriculture		
Clinic regularity	All: Twice a month		

plant doctors. In both countries, it is thus likely that the sample of first-line recipients is biased towards the plant clinic attendees that are well connected to plant doctors.

Second-line recipients (farmers receiving information from clinic attendees) were identified by first-line recipients during the interviews (Table 2). The number of second-line recipients invited for interviews depended upon the number of people that the first-line recipient passed on the clinic message. Most first-line recipients provided contact details of up to three farmers to whom they had passed on the message. In a few cases (two of 48 first-line recipients in China and five of 69 first-line recipients in Zambia) the message had been shared with a larger number in which case we put a maximum of five to the number of second-line recipients we would follow up with, so for these respondents we may have missed additional second-line recipients.

In China, 116 names of second-line recipients were provided of whom 93 were included in the sample (80%). In Zambia, 165 names of second-line recipients were provided, of whom 117 were included in the sample (71%). In Zambia, fewer second-line recipients could be found because of the larger distances and the fact that the study was conducted at the start of the raining season. Farmers were thus in their fields busy planting, which made it difficult to contact/locate some of them during the data collection period for this study. Overall, this resulted in interviews with a total of 48 first-line and 93 second-line recipients in China and 69 first-line and 117 second-line recipients in Zambia (Table 2). However, several of the sampled second-line recipients indicated that they also attended plant clinics: 83% in China and 36% in Zambia (Figure 1). In our analysis we consider the first-line recipients and the second-line recipients that indicated they attended plant clinics as 'plant clinic attendees', or in short, 'clinic attendees'. Second-line recipients who have not attended plant clinics themselves are referred to as 'non-attendees'. No significant trend could be detected in either country whether second-line recipients who were also plant clinic attendees visited the plant clinics before or after the first-line recipients.

As the snowball-sampling technique is non-probabilistic, the results have to be interpreted taking the following biases into account: The respondents (first-line and second-line recipients) are closely connected to plant clinics, which means that the clinic is an important source of information by default. The results cannot be extrapolated to all farmers in the research area as the sample is specifically describing the farmers within the social network of the plant clinics, and thus not representative of smallholder farmers in the region in general.

Table 2. Number of farmer respondents sampled for the survey by country and plant clinic area.

China	Changping	Fangshan	Daxing	Total
First-line recipients	15	18	15	48
Second-line recipients	46	16	31	93
Total	*61*	*34*	*46*	*141*
Clinic attendees	54	32	39	125
Non-attendees	7	2	7	16
Zambia	**Kanakantapa**	**Mpanshya**	**Luanshimba**	**Total**
First-line recipients	20	30	19	69
Second-line recipients	21	45	51	117
Total	*41*	*75*	*70*	*186*
Clinic attendees	26	32	53	111
Non-attendees	15	43	17	75

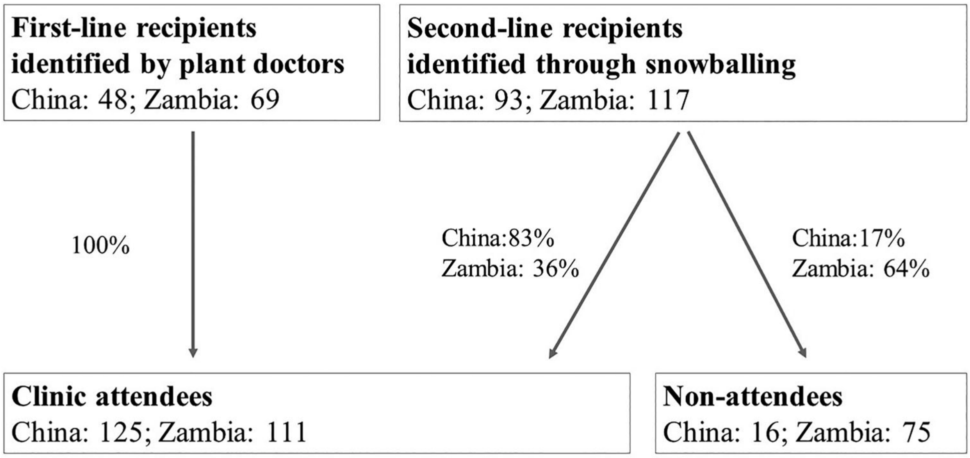

Figure 1. Sample structure for the farmer survey.

Study methods

A survey was carried out in 2016 with the sampled farmers to assess their information seeking and sharing behaviour. Farmers were asked about their preferred sources of plant health information, their information sharing practices and how they perceive and use the information from plant clinics directly or indirectly. Semi-structured interviews with plant doctors were done at the selected plant clinics to identify opportunities and constraints in plant health advisory services and information sharing. Plant clinic records from January to October/November 2016 were reviewed for each country to establish clinic attendance (i.e. primary reach) and gender patterns of clinic attendance as well as types of crops brought to the clinics. The Zambian plant clinic data are kept in the Plantwise Online Management System (POMS)[3] while the Chinese data are kept in a similar system managed by the Beijing Plant Protection Station.

Analysis

Farmer characteristics, including their use of plant health information sources, were analysed using descriptive statistics. Differences in perception and use of plant health recommendations between first- and second-line recipients were analysed using the Chi-square test. The information-sharing patterns were visualized through socio-grams in which nodes represent first and second-line recipients of plant clinic information and ties represent the sharing of information obtained from the plant clinics. SNA uses several metrics to analyse the network of information sharing, as well as the centrality and influence of individuals within the network. The degree of connections, i.e. the number of fellow farmers the clinic attendees shared the information with, was used as a centrality measure in this study.

External–internal (E–I) values were calculated based on Scott (2000) to provide a preliminary indication of the level of sharing between and within gender groups. An E–I score of + 1 means that all links are external to the subunit, e.g. men only share with women or vice versa. An E–I score of 0 means that links are equally divided, e.g. men and women share equally with each other. An E–I score of −1 means that all links are internal to subunit, e.g. men and women share only within their own gender group.

Based on the results on farmer attendance, SNA metrics (degree of connection, E–I scores) and farmer perception and use of clinic information, we discuss the primary and secondary reach of the plant clinics and the implications for future interventions.

Results

Clinic attendee and sample characteristics

Plant clinic attendance

Plant clinic attendance is registered in the plant clinic records. In China, the input-supplier (private sector) operated plant clinic in Fangshan, received considerably more queries (956) compared to the other two clinics (299 in Changping and 384 in Daxing) in the study period (January to October/November 2016) (see Table 3). This can most likely be explained by the larger geographical catchment area of the input supplier in Fangshan compared to the two cooperatives (3 districts vs. 1 district). The agrodealer not only attracts a larger range of clients that travel larger distances to the agrodealer shop/plant clinic, but the agrodealer also runs mobile clinics as part of the business model. Zhang et al. (2017) confirm that clinics run by agrodealers have larger geographic reach compared to the other service models.

According to POMS, the three selected plant clinics in Zambia had received 45 (Kanakantapa), 113 (Luanshimba) and 704 (Mpanshya) farmer queries in the study period (Table 4). However, the Zambian clinic records were perceived to underestimate the number of queries compared to the Chinese clinic records (observation by the research team). Studies from other countries have shown that data transfer procedures as well as

Table 3. Characteristics of the Chinese plant clinic attendees[a], overall and in the study sample.

	Plant clinic			
Variable	Changping	Fangshan	Daxing	Overall
Total clinic records[b]	299	956	384	1639
Female attendees in records[b]	57%	19%	31%	29%
Female attendees in sample[c]	67%	50%	53%	58%
Geographical spread of clinic attendees[d]	1 district, 15 villages	3 districts, 8 towns	1 district, 10 villages, mainly 6 villages in Lixian town	
Average age[c]	52 years	47 years	52 years	51 years
% youth (≤ 30 years)	0%	0%	0%	0%
Farmer type[c,d]	Mostly smallholder farmers	20% large-, 50% medium-, 30% smallholder	Smallholder vegetable producers	
Member of a farmer organization[c]	76%	34%	67%	62%
Main crops grown by clinic attendees[b,c]	Strawberry	Vegetables, fruits and flowers	Vegetables	
% of queries on dominant crop[b]	100%	63%	83%	

[a]Includes the second-line recipients that turned out also to be first-line recipients.
[b]Source: Plantwise China information system (Beijing Plant Protection Station) (period January–October 2016).
[c]Source*:* Survey.
[d]Source: Plant doctor interviews.

Table 4. Characteristics of the Zambian plant clinic attendees[a], overall and in the study sample.

Variable	Plant clinic: Kanakantapa	Mpanshya	Luanshimba	Overall
Total clinic records[b]	45	704	113	862
Female attendees in records[b]	11%	40%	25%	39%
Female attendees in sample[c]	15%	34%	57%	41%
Geographical spread of clinic attendees[b,d]	1 district (Chongwe), 10 villages/locations	1 district (Rufunsa),13 villages/locations	1 district (Kapiri),17 villages/locations	
Average age[c]	46 years	50 years	52 years	49 years
% youth (≤ 30 years)	4%	13%	2%	5%
Farmer type[c,d]	Mostly smallholder farmers	Mostly smallholder farmers	Mostly smallholder farmers	
Member of a farmer organization[c]	81%	91%	98%	92%
Main crops grown by clinic attendees[b,d]	Vegetables(not specified)	Fruits/Vegetables(not specified)	Vegetables(not specified)	
% of queries on dominant crop[b]	83%	38%	56%	

[a]Includes the second-line recipients that turned out also to be first-line recipients.
[b]*Source*: Plantwise Online Management System (POMS) for Zambia (period January–November 2016).
[c]*Source:* Survey.
[d]*Source*: Plant doctor interviews.

insufficient staff and IT capacity limit entry of data into the system, resulting in the under-reporting of plant clinic consultations (Posthumus and Sluijs 2017; Majuga et al. 2018). The geographic reach of the Zambian clinics is limited to the district they are based in. It should be noted that the districts in Zambia are larger in terms of area, but have a lower population density compared to the districts in Beijing Province in China.

Gender and age

The plant clinic records show that more men than women attend plant clinics in both countries. In China, the overall female attendance at the three plant clinics was 29% (Table 3) in the study period, ranging from 19% at the private sector operated plant clinic (Fangshan) to 57% at the government-operated plant clinic based at a strawberry cooperative (Changping). The female attendance in Zambia was 39% overall at the three clinics, ranging from 11% in Kanakantapa to 40% in Mpanshya (Table 4). However, the proportion of women was higher among the sampled clinic attendees: 58% in China and 41% in Zambia. The average age of the sampled farmers was around 50 years in both countries, while the proportion of youth attendees (≤30 years) was zero in China and very low (5%) in Zambia (Tables 3 and 4).

Organization of farmers

In China, 62% of the sampled clinic attendees indicated to be a member of an agricultural organization, in particular, market-oriented cooperatives (Table 3). The percentage of farmers affiliated to an organization is higher among attendees of the cooperative-based clinics (76% in Changping and 67% in Daxing) compared to the private sector operated clinic attendees (34%) (Table 3). This is not surprising as the cooperative-based clinics are likely to be visited by the cooperative members in particular. Overall, 92% of the sampled clinic attendees in Zambia belong to one or more organizations (Table 4), among these cooperatives and farmer associations, youth groups, women's clubs and other community groups.

Farming systems

In China, the average land size of the sampled clinic attendees is 0.17 ha of arable land and 0.20 ha of greenhouses. The users of the cooperative-based plant clinics are relatively homogenous in terms of land use (crops) and land size. In contrast, the sampled attendees to the private sector operated plant clinic (Fangshan) show more heterogeneity: both large and smallholders attend the clinic with queries on different crops (Table 3). In particular farmers in Changping show a high degree of homogeneity; they are highly specialized, all grow a similar crop (strawberry), are of similar land size, often a member of the same market-oriented cooperative and live relatively close to each other. In Zambia, sampled farmers are rather homogenous regarding land size with an average of 2.5 ha and a little variation between users from the different clinics. All sampled clinic attendees are characterized as smallholder farmers with mixed cropping systems (Table 4) producing for both subsistence and for the markets (cash crops and surpluses of food crops).

Farmers' information sources

Figure 2 shows the plant health information sources used by the sampled clinic attendees and non-attendees in China and Zambia. In China, farmers indicated they accessed information from more sources compared to Zambia. Respondents in China obtained information from an average of 3.6 different sources; in Zambia this was 1.9 sources.

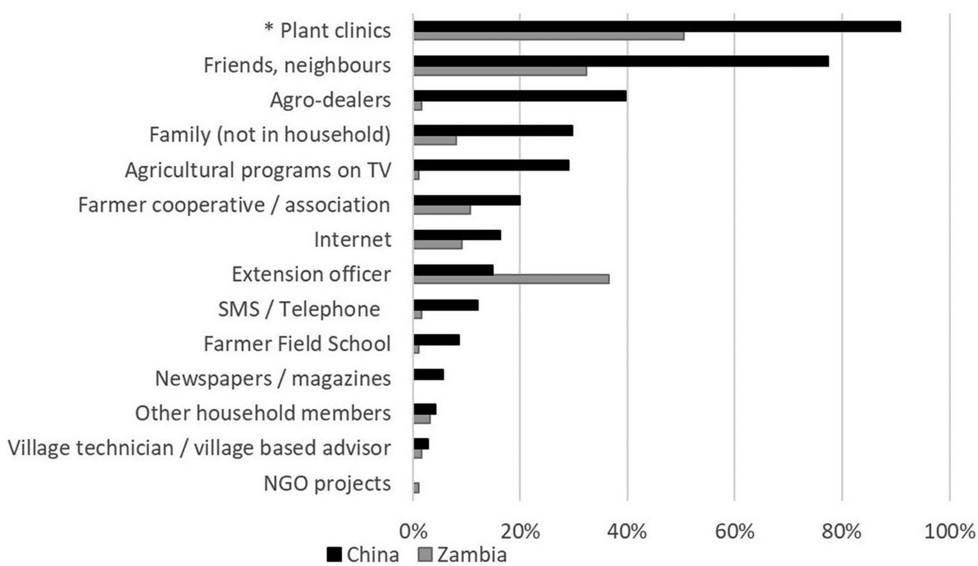

Figure 2. Plant health information sources used by % surveyed farmers (plant clinic attendees and non-attendees) in China and Zambia. (*Responses from plant clinic attendees only).

For the sampled clinic attendees in both China and Zambia, plant clinics are the most used source of plant health information (Figure 2). Farmer-to-farmer exchange is important in both countries. Friends and neighbours are the second source of plant health information after plant clinics in China and third after plant clinics and public extension agents in Zambia. In China, private sector input suppliers are referred to plant health information more often than in Zambia.

Sharing and uptake of plant health recommendations

Plant health recommendations

The sampled farmers reported the plant health recommendations they received at the plant clinics (first-line recipients) or from fellow farmers (second-line recipients). The China sample contained a total of 208 recommendations (reported by 141 farmers), and the Zambia sample contained 361 recommendations (reported by 183 farmers). The recommendations were specifically addressing strawberry, fruit and vegetables in China and vegetables and grains in Zambia. The reported recommendations in China consisted mostly of chemical measures, whereas most of the reported recommendations in Zambia were agronomic measures (e.g. crop rotation, field hygiene) (Table 5). The majority of farmers reported that they had fully applied the recommended measures for plant health, though the farmers in China reported this more frequently (over 90%) than farmers in Zambia (over 70%).

The Chi-square test was applied to determine any significant differences between first-line and second-line recipients regarding level of application (fully, partially or not at all). The only significant differences ($p < 0.05$) found were that in Zambia: a larger percentage (70%) of first-line recipients applied the chemical recommendations fully compared to second-line recipients (47%), and inversely, a larger percentage (20%) of second-line

Table 5. Plant health recommendations from plant clinics received and applied by first-line and second-line recipients.

	China ($n = 208$)[a]			Zambia ($n = 361$)[b]		
Recommendations received[c]	First-line recipients	Second-line recipients	*p*-value	First-line recipients	Second-line recipients	*p*-value
Chemical recommendations	*51%*	*64%*	*0.188*	*31%*	*30%*	*0.939*
Fully applied	98%	94%	0.375	70%	47%	0.014*
Partially Applied	0%	1%	0.478	6%	20%	0.033*
Not applied	2%	5%	0.906	18%	22%	0.632
Not applicable	0%	0%	–	6%	12%	0.303
Agronomic recommendations	*35%*	*26%*	*0.188*	*69%*	*70%*	*0.939*
Fully applied	96%	97%	0.906	74%	75%	0.852
Partially Applied	0%	0%	–	12%	8%	0.245
Not applied	4%	3%	0.906	9%	9%	0.876
Not applicable	0%	0%	–	4%	7%	0.348
N	80	128		163	198	

Note: *p*-values are based on the Chi-square test; *$p < .05$.
[a]Received by 141 farmers, i.e. on average each farmer received more than one recommendation.
[b]Received by 183 farmers, i.e. on average each farmer received more than one recommendation.
[c]The table only includes queries that contained either chemical *or* agronomic recommendations; mixed recommendations are not included in the table.

recipients applied the chemical recommendations partially compared to first-line recipients (6%).

The respondents were asked to what extent the recommendations that originated from the plant clinics responded to their plant health issues (Table 6). In China, both first- and second-line respondents were equally positive about the clarity of the diagnosis and recommendation, as well as the applicability, relevance, affordability and availability of the recommended solution. In Zambia, however, first-line and second-line recipients gave significantly different answers. Most first-line recipients (over 90%) stated that the diagnosis and recommendation were clear. The majority also stated that the recommendation was applicable and relevant, but their answers imply that the solutions were not always affordable or available. Second-line recipients, however, were less affirmative on these aspects. It implies that some parts of the recommendations are distorted or omitted when passed on to second-line recipients as the first-line recipients may not be able to provide the same detailed and/or relevant information as the plant doctors. Note that up to 25% of second-line recipients in Zambia indicated that the recommendation was not applicable, which implies that information was passed on even if not relevant to the second-line recipient, or the distortion of the information made it irrelevant.

Information sharing between farmers

The sampled clinic attendees indicated that they shared the information received at the plant clinic with an overall average of 4.6 other farmers in China and 3.8 other farmers in Zambia (degree of connection) (Table 7). However, this includes information sharing with other clinic attendees (Figure 1). When adjusting for the proportion of second-line recipients who were *also* clinic attendees, we see considerably lower numbers of information sharing with non-attendees: 0.8 in China (17% of 4.6) and 2.4 in Zambia (64% of 3.8) (Table 7). In both countries, surveyed farmers reported they mostly shared the information with their spouse, friends and neighbours (China: 57% sharing with spouse, 23% with friends and 66% with neighbours; Zambia: 57% sharing with spouse, 46% with friends and 23% with neighbours). In Changping and Daxing, farmer-to-farmer information sharing mainly happens among members of the cooperative (survey, data not shown). No correlations could be found between the degree of information sharing and personal characteristics (e.g. age, gender, level of education, group membership) of first-line recipients. It should be noted though, that the sample used here is not suitable to identify such relationships.

Ten per cent of the sampled Chinese attendees indicated not to share information with other farmers. In Zambia, this was 9%. A common reason for not sharing the plant health recommendations was the perception that the information was only relevant to the recipient, and would not address problems of other farmers. Farmers also reported that they preferred not to share information, or, in Zambia only, had no opportunity to share, felt unable to advise others or considered other farmers not interested (Figure 3).

Information sharing between sexes

The E–I scores listed in Table 7 provide a preliminary indication of the level of sharing between men and women. In Changping and Fangshan (China) and in Mpanshya (Zambia) the sharing between women and men and vice versa is almost equal to the degree of sharing within the same gender group (E–I score close to zero). In Kanakantapa

Table 6. Farmers' assessments of plant health recommendations received from plant clinics, directly and indirectly (through neighbours and friends).

Plant clinic recommendation		China			Zambia		
		First-line recipient	Second-line recipient	*p*-value	First-line recipient	Second-line recipient	*p*-value
Quality: Diagnosis was clear	Not applicable	0%	2%	0.552	2%	17%	0.008**
	Fully	98%	93%		94%	77%	
	Partially	3%	4%		5%	3%	
	Not at all	0%	0%		0%	2%	
Quality: Recommendation was clear	Not applicable	0%	2%	0.104	3%	18%	0.012*
	Fully	100%	89%		92%	78%	
	Partially	0%	9%		5%	2%	
	Not at all	0%	0%		0%	2%	
Applicability: Recommendation was easy to apply	Not applicable	0%	2%	0.338	5%	23%	0.006**
	Fully	100%	95%		77%	63%	
	Partially	0%	3%		17%	10%	
	Not at all	0%	0%		2%	3%	
Relevance: Recommendation was addressing the problem	Not applicable	0%	2%	0.287	6%	26%	0.003**
	Fully	97%	89%		74%	51%	
	Partially	3%	9%		18%	17%	
	Not at all	0%	0%		2%	5%	
Affordability: Recommendation was affordable	Not applicable	0%	2%	0.301	6%	25%	0.000***
	Fully	98%	91%		55%	41%	
	Partially	2%	7%		35%	19%	
	Not at all	0%	0%		5%	14%	
Availability: Recommendation was available	Not applicable	3%	4%	0.395	9%	24%	0.035*
	Fully	95%	95%		42%	42%	
	Partially	0%	1%		32%	18%	
	Not at all	3%	0%		17%	17%	

p-Values are based on the Chi-square test; $*p < .05$, $**p < .01$, $***p < .001$.

Table 7. Information sharing by plant clinic attendees in China and Zambia.

China	Changping ($n = 54$)	Fangshan ($n = 32$)	Daxing ($n = 39$)	Total ($n = 125$)
Degree of connection[a]	5.0	4.0	4.5	4.6
Effective secondary reach[b]	0.8	0.7	0.8	0.8
E–I Scores (information sharing between gender groups)	−0.043	−0.077	−0.360	
Zambia	**Kanakantapa ($n = 26$)**	**Mpanshya ($n = 32$)**	**Luanshimba ($n = 53$)**	**Total ($n = 111$)**
Degree of connection[a]	4.8	3.2	3.7	3.8
Effective secondary reach[b]	3.1	2.0	2.4	2.4
E–I Scores (information sharing between gender groups)	−0.789	−0.048	0.224	

[a]Average number of people with whom clinic attendees shared information obtained at the plant clinic.
[b]Degree of connection adjusted for the proportion of second-line recipients who were also clinic attendees (83% in China, 36% in Zambia). Effective secondary reach = [degree of connection] × [% non-attendees].

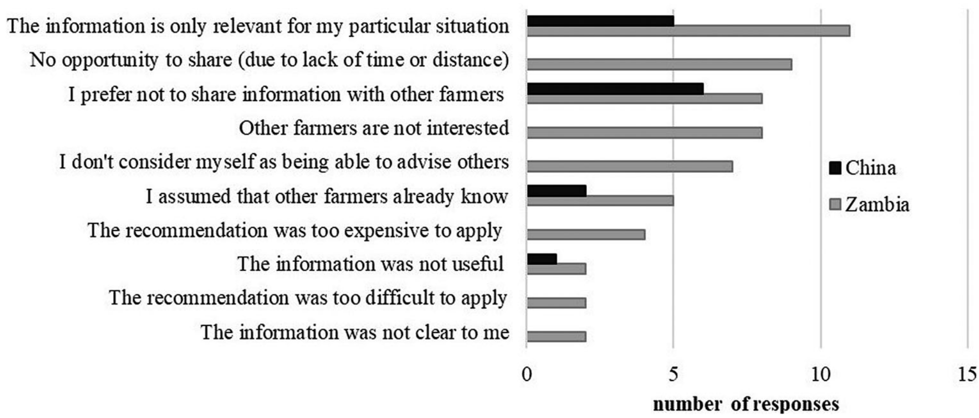

Figure 3. Farmers' reasons for not sharing plant health recommendations received at plant clinics.

(Zambia) most sharing seems to occur between individuals of the same sex, while the same happens to a lesser extent in Daxing (China) (negative E–I scores). In Luanshimba (Zambia) there is a slight tendency of the opposite happening, i.e. information sharing occurring more between individuals of opposite gender groups (positive E–I score). However, the size and structure of the sample do not allow a firm conclusion on this.

Social networks

Figures 4 and 5 show a plant clinic socio-gram for each country, representing the most (Daxing) and least (Mpanshya) dense information-sharing patterns of the six plant clinics. In the case of Daxing (Figure 4) we see that many second-line recipients are also linked to the plant clinic. These connections appear as 'triads' between the nodes of the plant clinic, a first-line recipient (p) and a second-line recipient (s). There are relatively few non-attendees connected to the network as most clinic attendees share information with other clinic attendees. In contrast, the social network in Mpanshya is open, with many clinic attendees forming bridges to non-attendees (Figure 5). The information-sharing patterns in China, in particular for the two plant clinics based in a

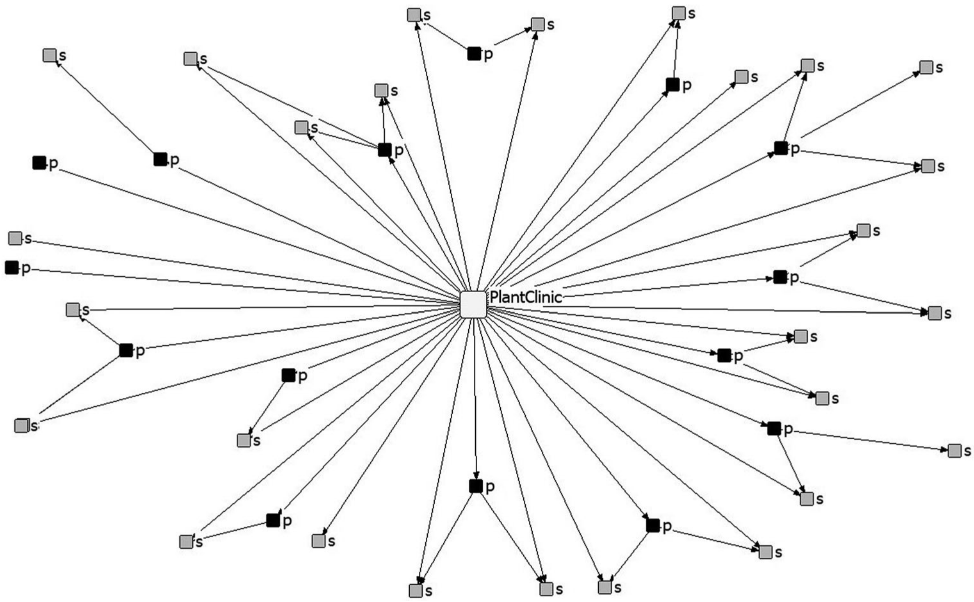

Figure 4. Information sharing between sampled first-line users (p) and sampled second-line users (s) of the Daxing plant clinic (China) ($n = 46$). The boxes represent individual farmers.

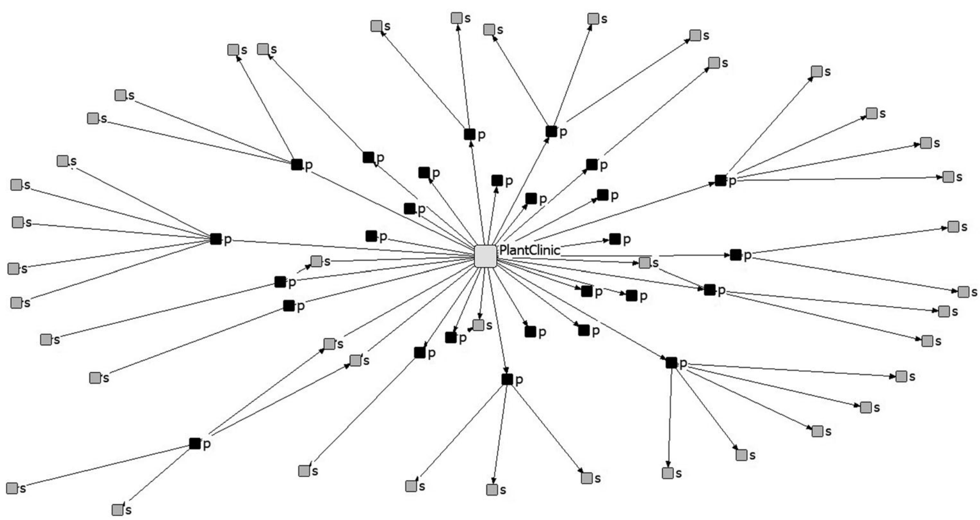

Figure 5. Information sharing between sampled first-line users (p) and sampled second-line users (s) of the Mpanshya plant clinic (Zambia) ($n = 75$). The boxes represent individual farmers.

cooperative, are relatively closed compared to the open patterns in Zambia. The information-sharing pattern around the (partly mobile) plant clinic operated by an agrodealer in Fangshan, China, is more similar to the plant clinics in Zambia regarding the openness of the structure.

Discussion

Social networks – and the information sharing that takes place within these networks – facilitate farmers' access to knowledge and opportunities for social learning and innovation (Spielman et al. 2011). This study confirmed the main assumption of the Plantwise programme that information sharing with neighbours, friends and relatives is common among the sampled farmers (average degree of connection was 4.6 for China and 3.8 for Zambia). Other studies have also found that farmers value information from interpersonal sources they can easily relate to (Isaac 2012; Wood et al. 2014; Hampson et al. 2017). Nevertheless, the findings also indicate that formal sources are more often recognized as credible sources, whereas neighbouring farmers are important as sounding board due to their proximity and availability. In both countries the plant clinics became the most important source of information on plant health for clinic attendees. The appreciation of plant clinics as sources of information is based on the availability and the quality of information (see Table 6).

However, the results also show that in the study areas in China, the information-sharing patterns are relatively closed; in other words, the number of peripheral farmers who are not directly linked to the plant clinic (i.e. non-attendees) is relatively small (effective secondary reach of 0.8). In contrast, in Zambia, the information-sharing patterns are more open; that is, the proportion of information sharing with peripheral farmers (non-attendees) is relatively higher (effective secondary reach of 2.4).

The findings suggest that the level of specialization in farming and the social context are important factors that influence information sharing behaviour of first-line recipients. The cooperative-based plant clinics in China have a smaller primary and secondary reach and homogeneous clientele, suggesting that it is predominantly serving the cooperative membership. The other plant clinics that are operated by an agrodealer (Fangshan, China) or extension agents (Zambia) have a larger primary and (in Zambia) secondary reach, serving a more diverse farmer clientele.

The level of 'compliance' with the shared plant health recommendations in China was very high, with 96% of the plant health recommendations being fully implemented, compared to 75% of recommendations in Zambia (based on self-reporting). Because of the specialization of farmers in China (i.e. they share similar crops and plant health problems), and the collective marketing of their crops in the case of the cooperative-based plant clinics, there is an immediate added value in sharing information between cooperative members because of their mutual dependency. Sharing information with farmers outside the cooperative (who may grow different crops, face different pest problems and sell their produce elsewhere) has arguably less benefit for the clinic attendees. The social networks of the cooperative-based plant clinics in China could be considered as 'cliques' with a strong sense of belonging (cooperative members) and pressure to conform (for collective marketing reasons). As such, one could argue that the cooperative-based networks in China foster contagion, i.e. information sharing and uptake of recommendations within the network (Monge, Hartwich, and Halgin 2008). Witt, Pemsl, and Waibel (2008) suggest that a critical mass of 5–15% of farmers holding a particular knowledge within a community is required to expose the rest of the group to the same information through secondary reach. Additionally, Isaac (2012) argues that such dense networks may be required for trust-based collective action.

In Zambia, on the other hand, the public extension-based plant clinics served a more diverse clientele. Farmers are more geographically dispersed and have more diversified cropping systems dominated by food crops of which surpluses are sold on the local market. The first-line recipients shared plant health information more frequently with non-attendees compared to China. However, sharing plant health information with other farmers in such a diversified setting (many crops and plant health problems) *presumably* has less immediate benefit since their mutual dependency for meeting market standards is lower than in China. The results show that a significantly smaller proportion of the second-line recipients in Zambia thought that the plant health recommendations were clear, relevant and applicable than first-line recipients. This is likely to be a result of the following factors: (i) the diversity of crops and issues, making specific recommendations less relevant for other farmers, (ii) some distortion in the message while passing on information to other farmers; or (iii) lower motivation of second-line recipients to apply the recommendation. It was observed that in particular chemical recommendations were less frequently applied by second-line recipients than first-line recipients in Zambia. Nonetheless, informal information sharing is important in resource-poor and information-scarce areas. Farmers in sub-Saharan Africa often lack the knowledge and information necessary to manage the diversity of plant health problems appropriately (Abate, Van Huis, and Ampofo 2000). For example, Lwoga, Stilwell, and Ngulube (2011) found that the major information and knowledge gaps among farmers in Tanzania related to control of plant diseases and pests, while friends and neighbours were the main source of agricultural information, followed by public extension officers and relatives.

The high degree of organization among the sampled Zambian farmers (81–98%) provide them with several networks/groupings with whom to exchange information and ideas, and these could be targeted more specifically by the plant doctors. As clinic attendees in Zambia readily share their obtained knowledge within these informal networks, the plant clinics could give more attention to farmer-to-farmer exchange on generic plant health management practices and making sure that information is being shared without distortion. While farmer organizations are known to stimulate collective action for a shared purpose, such as marketing, it is harder to mobilize communities to engage collectively in managing plant health. Due to the transboundary nature of crop pests and diseases, collective action is often required to manage them effectively. Little does it help that a farmer keeps her plot clean of contagious plant residues or alternative host plants, if her neighbour does not. A study by Parsa et al. (2014) established that one of the main obstacles to the adoption of IPM practices was the requirements for collective action within farming communities. From this study we cannot establish whether, or to what extent, plant clinics encourage social learning and collective action. This is an important aspect that needs to be further examined.

The study also looked at the effect of gender on information seeking and sharing behaviour. The clinic records showed that the overall proportion of female clinic attendees in the study areas was 29% in China and 39% in Zambia. This is similar, in the case of China, and low, in the case of Zambia, compared to the proportion of women engaged in agriculture in the two countries: 24% in China and 62% in Zambia (ILO 2018). Research from Uganda, Ghana, Sri Lanka, Kenya and Rwanda shows that most often women are under-represented at plant clinics (Karubanga, Matisko, and Danielsen 2017; Lamontagne-Godwin et al. 2017; Musebe et al. 2018; Majuga et al. 2018), thus confirming women's general challenges with accessing agricultural advisory services in many low-income countries (Meinzen-Dick et al. 2011). Overall, information sharing between men and women was found to be fairly equal to information sharing between individuals of the same sex, except in Kanakantapa in Zambia where there was more information sharing within the same gender group. However, more conclusive evidence on this requires a larger and random sample than the one used here. Farmer-to-farmer exchange could be a useful strategy to relay clear and simple plant health messages to women farmers where they, such as in Zambia, face barriers to visit plant clinics and seek information themselves.

This is the first study that examines how information spreads through social networks that are connected to plant clinics. The findings are based on non-probability samples (linked to plant clinics) in China and Zambia and can thus not be extrapolated to smallholder farmers in general. More research is needed to understand what makes information travel from primary to secondary users (e.g. personal characteristics, context, social network structures) and how it is understood and used by the recipients, men and women alike. To do this, a larger sample is needed to map the social network around the clinics and study the drivers for information sharing. Future research should also look more closely at the type of information farmers share and how transfer of messages from the plant clinics can be optimized with optimal reach and minimal loss and distortion. Whether and how farmer-to-farmer sharing of information from plant clinics can contribute to strengthening collective action on pest and disease management also remains to be investigated.

Conclusions

Both in China and Zambia, the sampled farmers (clinic attendees) stated that the plant clinics are their main source of plant health information and that they are willing to share that information with others. Yet, the purpose and effects of sharing information are likely to differ depending on the institutional setting of the plant clinic and the prevailing type of production system. The cooperative-based plant clinics in China showed 'closed' patterns of information sharing with frequent sharing of information on common crop issues among clinic attendees but little sharing with farmers who were not cooperative members. As a result, the secondary reach is low. Collective marketing of commercial crops and hence the need to adhere to defined quality standards, provide clear incentives for sharing information with peers. In the more 'open' patterns of information sharing linked to the plant clinics run by the public extension service in Zambia, there is larger secondary reach, i.e. clinic attendees share information from the plant clinics with relatively more non-attendees. However, the immediate impact of this information sharing may be less, because farmers deal with a larger diversity of crops and hence, plant health issues.

Plant clinics play a role as a gateway to external sources of information, thus injecting plant health information into existing social networks within farming communities. Yet, the plant clinic role as an 'information broker' remains relatively undefined. There is scope for further exploring this role. For example, plant doctors could be trained as 'information brokers' to strengthen the connection between formal and informal networks and disseminate plant health information (e.g. pamphlets, factsheets) that is targeted to the specific production systems and farming populations. This study shows that strategies to optimize secondary reach of plant clinics through farmer-to-farmer exchange should be informed by the agro-ecological and socio-economic context within which the information is disseminated, as well as the type of organization operating the plant clinics.

Notes

1. In this paper, the terms 'extension services' and 'advisory services' are used interchangeably.
2. CABI's Plantwise programme has established networks of plant clinics in over 30 countries in Africa, Asia and the Americas since 2011 (www.plantwise.org).
3. POMS is an online database of farmer queries captured at plant clinics by plant doctors. Records include name and place of the farmer, type of crop presented, diagnosis and advice given.

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