

Chapter 4

Exploring and evaluating adoption of push-pull for management of *Eldana saccharina* by large-scale sugarcane farmers in KwaZulu-Natal

4.1 Introduction

The push-pull strategy, is promoted as part of an area-wide integrated pest management (AW-IPM) strategy against *Eldana saccharina* Walker (Lepidoptera: Pyralidae) in the South African sugar industry (Conlong and Rutherford, 2009; Rutherford and Conlong, 2010; Webster *et al.*, 2005) (Figure 4.1). For successful implementation of knowledge intensive pest management strategies such as IPM and push-pull, a thorough understanding of farmers' perceptions of pests and pest management is necessary (Röling *et al.*, 2004; Meir and Williamson, 2005; Khan *et al.*, 2008).

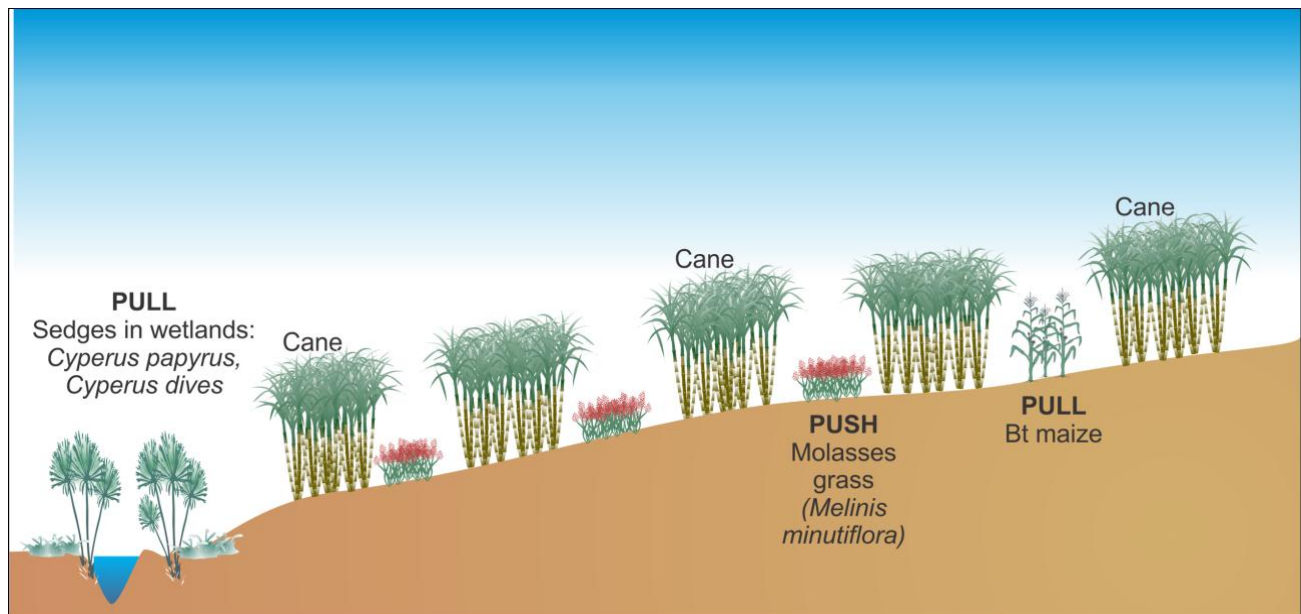


Figure 4.1. Diagram of the push-pull strategy recommended for control of *Eldana saccharina* in sugarcane.

In 2004, implementation of push-pull as part of IPM with large-scale farmers (LSGs) was initiated by the Local Pest, Disease & Variety Control Committee (LPD&VCC) and extension staff from the South African Sugarcane Research Institute (SASRI) in the Midlands North region of KwaZulu-Natal (Webster *et al.*, 2005) (See map in Chapter 2. Figure 2.1). Since implementation of the IPM approach, some progress has been made in raising awareness among LSGs about the increasing threat of *E. saccharina* in this area and the need for sustainable approaches to managing this pest (Webster *et al.*, 2009). However, not many LSGs had adopted push-pull by the start of 2011 (Webster pers. comm. 2012, Conlong pers. comm. 2012).

Further emphasis was placed on implementing push-pull in the region with the commencement of this two-year MSc research project in January 2011. The extension activities that formed part of this study and which were used to facilitate implementation of push-pull in the region included:

- conducting a pre-implementation survey to understand LSGs' knowledge and perceptions of *E. saccharina*, push-pull and IPM (Chapter 2; Cockburn *et al.* (2012))
- setting up farm-based push-pull field trials on four model farms (adaptive research, Chapter 5)
- hosting field days on model farms
- conducting surveys at field days to assess LSGs' interest in implementing push-pull
- visiting and advising interested LSGs on implementation of push-pull.

Considering the numerous activities to facilitate implementation of push-pull in the Midlands North region, it was important to evaluate the level of adoption of this technology. The Midlands North case study provided a valuable opportunity to better understand possible adoption drivers for push-pull as well as barriers to adoption. These could include social, technical, economic and environmental factors, as well as the LSGs' perceptions of the pest and the pest management strategy. The adaptive on-farm research on push-pull on model farms provided insight into practical problems with implementing this strategy at farm level.

The aim of this study was therefore to evaluate current adoption levels of push-pull in the Midlands North region and to make recommendations for improving rates of adoption, both in the Midlands North and in other sugarcane production areas. To achieve this aim, the research activities in this study were guided by the following objectives:

- estimating levels of push-pull adoption in Midlands North

- exploring potential adoption drivers and barriers for push-pull, in order to provide extension recommendations for improving adoption in the Midlands North region and in other regions of the South African sugar industry.

To achieve these objectives, a novel approach in analysing adoption of new pest management practices was applied to study the adoption of the push-pull strategy. A mixed methods social research design was used together with exploratory network analysis (Edwards, 2010). Exploratory network analysis is based on social network analysis (de Nooy *et al.*, 2005). Social network analysis is a recognised methodology in sociology whereby social researchers use graph theory and network-generating software to analyse social networks among individuals and organisations (de Nooy *et al.*, 2005; Marin and Wellman, 2011). Network analysis approaches have been adapted for use in other disciplines besides sociology, for example in knowledge networks of academic literature and citations (Spector *et al.*, 2001; Bezuidenhout, 2011; Bezuidenhout and Baier, 2011) and, recently, in interpreting and understanding complexities in sugarcane supply chain systems (Bezuidenhout *et al.*, 2012; Kadwa *et al.*, 2012; Sanjika *et al.*, 2012). A review of the use of network analysis across various disciplines is provided by Newman (2003).

Adoption of new agricultural practices takes place within a highly complex system in which social, technical, economic and environmental factors all play a role (Jakku and Thorburn; Fisher *et al.*, 2000; Vanclay, 2004; Llewellyn, 2011). Understanding complex systems is difficult (Spector *et al.*, 2001). This is also the case with integrated management of natural resources (Pahl-Wostl, 2007), which is intricately linked to implementation of ecologically sustainable pest management systems such as push-pull. LSGs' decisions to adopt a new agricultural technology requires behaviour change which, in itself, is also complex (Knowler and Bradshaw, 2007; Reimer *et al.*, 2012).

Network analysis tools can be particularly powerful when rapid learning about complex systems is needed (Bezuidenhout *et al.*, 2012). Pahl-Wostl (2007) emphasized the need for management of complex natural resource systems to be seen as learning rather than control. Learning models, for example system dynamics models or in this case, network analysis, can be useful in adoption studies as they can make explicit some of the complex factors that influence the adoption process (Fisher *et al.*, 2000). Thus, to facilitate learning around push-pull adoption, and to better understand the complexities of push-pull adoption, an exploratory network analysis methodology was used to elucidate possible barriers and drivers to the adoption of push-pull by LSGs.

4.2 Methods

A mixed methods approach, including qualitative and quantitative data, together with the exploratory network analysis, was used to investigate potential drivers and barriers to adoption. According to Creswell (2009), mixed methods approaches in which both qualitative and quantitative sources of data are collected and analysed can lead to better research insights than either qualitative or quantitative approaches on their own. Triangulation, i.e. using different forms of data to explore the same phenomenon, may result in improved understanding of networks compared to a more simplistic approach such as only studying the structural, quantitative characteristics of networks (Denzin, 1970; Edwards, 2010; Hollstein, 2011). Furthermore, using computer software to create visual representations of links in data through networks can provide a powerful extension to textual (qualitative) or numerical (quantitative) descriptions of that data (Bazeley, 2003).

The emphasis in this study was on exploratory, inductive data analysis. This meant that there was no hypothesis to be tested, but that analysis tools were used to explore the data and to allow patterns to emerge. This is an important premise of both qualitative data collection and analysis (Creswell, 2009) as well as exploratory network analysis (de Nooy *et al.*, 2005).

4.2.1 Study area

This study was conducted with LSGs and extension staff in the Midlands North region of KwaZulu-Natal. For a description of this area and an explanation of why this area was chosen for this study as a whole, refer to section 2.2.1 in Chapter 2.

4.2.2 Telephone survey

Data from the LPD&VCC (Webster pers. comm., 2012) were used together with telephone surveys to assess levels of push-pull adoption among LSGs in the Midlands North region. Telephone surveys have successfully been used to determine adoption of agricultural technologies and to explore drivers of adoption (D'Emden *et al.*, 2006; Llewellyn, 2011). Telephone surveys were used to further validate findings of the exploratory network analysis described below and to evaluate adoption of push-pull in the target region. The outcomes of the exploratory network analysis were used as a guide for the construction of the questionnaire for the telephone survey (Bezuidenhout *et al.*, 2012).

Adoption of an agricultural technology can be measured as a binomial variable i.e. simply the use of the innovation (yes/no), or as a continuous or categorical variable i.e. the extent of use

(none/partial/full) (D'Emden *et al.*, 2006). For a LSG to implement push-pull fully, a number of different management activities need to be undertaken. The most important of these is planting push and pull plants. Wetlands are a key resource within the push-pull system as they provide a habitat for *E. saccharina* in indigenous wetland sedges such as *Cyperus papyrus* L. and *C. dives* Delile (Cyperales: Cyperaceae) (Conlong, 1990) (Figure 4.1). Thus correct management of wetlands is important for push-pull to be effective. For the purpose of this study, adoption of push-pull was measured according to the planting of push and pull plants i.e. *Melinis minutiflora* P. Beauv. (Cyperales: Poaceae) (push plant: molasses grass); *Cyperus papyrus* and *C. dives* (pull plants); and Bt maize (pull plant) (Table 4.1). Wetland management was not taken into account as this is difficult to measure. Similarly, the proportion of land area on which LSGs have implemented push-pull was also not taken into account.

Table 4.1 Definition of push-pull adoption measures used in this study.

Level of adoption & code used in analysis	Implementation action taken by LSGs
No adoption (= 0)	No push or pull plants planted
Partial adoption (= 1)	Planted either push or pull plants i.e. one of either <i>M. minutiflora</i> / <i>C. dives</i> / <i>C. papyrus</i> /Bt maize
Full adoption (= 2)	Planted both push and pull plants i.e. <i>M. minutiflora</i> and one of either <i>C. dives</i> / <i>C. papyrus</i> /Bt maize

4.2.2.1 Sample selection

Purposive sample selection was used for the telephone surveys (Babbie, 2010). Since the aim of the survey was to evaluate adoption of push-pull and possible barriers to adoption, LSGs were selected for the survey on the basis that *E. saccharina* had been recorded on their farms within the last five years, or they were in a high risk *E. saccharina* area (Webster *et al.*, 2009). These are the LSGs whom one would expect to have a high motivation to adopt push-pull. For example, Khan *et al.* (2008a) found that high pest pressure was one of the main motivations for LSGs to adopt push-pull for stem borer control in maize. In this study, information on pest incidence per farm was obtained from the LPD&VCC pest manager (Webster pers. comm., 2012). Fifty three LSGs were interviewed, which represented 30% of the 176 LSGs currently registered on the LPD&VCC database (Webster pers. comm., 2012).

4.2.2.2 Questionnaires and interviews

A standardised questionnaire using both closed- and open-ended questions was designed for this survey (See Appendix F for the questionnaire). For the closed-ended questions, LSGs were asked to allocate a score between zero and 10, on a summated rating scale (de Vos *et al.*, 2011), for certain variables considered to be potential drivers of adoption (Table 4.2). These potential adoption drivers were informed by interpretation of the network and by using other important adoption drivers from recent literature on adoption of best management practices (Knowler and Bradshaw, 2007; Llewellyn, 2011; Baumgart-Getz *et al.*, 2012; Reimer *et al.*, 2012). Open-ended questions allowed for LSGs to express themselves freely about their reasons for adoption or non-adoption (Llewellyn, 2011).

Table 4.2 Summated rating scales used for closed-ended questions on potential adoption drivers.

Question	Summated rating scales
Please rate how effective you think push-pull is for controlling eldana:	0 = not effective, 10 = very effective
Please rate how much of a ' hassle ' it is to implement push-pull:	0 = no 'hassle', 10 = a lot of 'hassle'
Please rate your knowledge of how to implement push-pull:	0 = no knowledge, 10 = excellent knowledge
Please rate how important eldana management is amongst your farm management priorities :	0 = not a priority at all, 10 = top priority
Please rate how important environmental matters are in your farm decision-making:	0 = not important at all, 10 = very important

Interviews were all conducted over the telephone and recorded, and LSGs' responses were captured directly onto a computer database. LSGs were made aware that the interviews were being recorded, and they were assured that their personal information would be kept confidential. The questionnaire was tested with two LSGs prior to commencement of the survey and adjustments were made accordingly (Fink, 2009). Telephone surveys can result in reduced quality of data since respondents may feel hostile towards an unknown caller (Babbie, 2010). To ensure this did not happen, LSGs were notified about the survey by e-mail a week prior to the phone calls. Because of the involvement of the researcher in this farming community for 18 months prior to commencement of the surveys, the LSGs were all familiar with the researcher.

4.2.2.3 Analysis of telephone surveys

Data from the telephone surveys was analysed using descriptive statistics such as frequencies and percentages of responses per question which were represented in bar and pie charts (Fink, 2009). Open-ended questions were transcribed and analysed by emergent coding and content analysis of LSGs' responses, which was enriched with a qualitative analysis including recording pertinent verbatim quotes from LSGs (Creswell, 2009; Babbie, 2010). LSGs' responses to rating-scale questions were summarised into two categories: low score (0-5) and high score (6-10), and analysed using cross tabulations (Fink, 2009). Since the data were found not to be normally distributed, the non-parametric Mann-Whitney U test (for continuous score variables) and Pearson's Chi-square test (for categorical low/high score variables) were used to determine whether LSGs' responses to the adoption drivers' questions had a statistically significant effect on their level of push-pull adoption (Kaine and Bewsell, 2008).

4.2.3 Exploratory network analysis

The software used for the exploratory network analysis in this study, *Pajek*, is freely available on the internet (<http://pajek.imfm.si/doku.php>). Guidelines on the use of *Pajek* for exploratory network analysis were taken from de Nooy *et al.* (2005). The methodological steps and literature sources used in the design and analysis of the exploratory network analysis are summarised in Table 4.3.

4.2.3.1 Collecting and preparing input data

Collecting input data for network analysis can be done using quantitative and/or qualitative approaches (Edwards, 2010), however in this study the emphasis was on qualitative data sources. According to Hollstein (2011), a holistic ethnographic approach to collecting data for exploratory network analysis should be used to achieve as comprehensive an understanding of all possible influencing factors represented in the network. The research question for the network analysis was as follows: "What factors might be causing large-scale sugarcane farmers not to adopt push-pull?" The input data for the adoption network analysis for this study was collected from multiple sources:

- content analysis of open-ended questions from a survey carried out with LSGs on perceptions of *E. saccharina* and push-pull during May 2011 (See Chapter 2, Figure 2.10, 2.11)
- discussions with extension staff and other stakeholders at various meetings and field days focused on *E. saccharina* and push-pull
- discussions with LSGs, including the four model farmers who participated in push-pull trials, on *E. saccharina* management and push-pull implementation

- observations of practical field-level problems in implementing push-pull on model farms.

Table 4.3. Summary of step-by-step data collection and analysis process used for exploratory network analysis.

Steps	Literature sources
1. Collecting input data	(Edwards, 2010; Hollstein, 2011; Bezuidenhout <i>et al.</i> , 2012)
2. Preparing the data for input into <i>Pajek</i>	(de Nooy <i>et al.</i> , 2005; Bezuidenhout <i>et al.</i> , 2012)
3. Generating exploratory networks in <i>Pajek</i>	(de Nooy <i>et al.</i> , 2005; Bezuidenhout <i>et al.</i> , 2012)
4. Initial interpretation	(de Nooy <i>et al.</i> , 2005; Hanneman and Riddle, 2011a; Hanneman and Riddle, 2011b; Bezuidenhout <i>et al.</i> , 2012; Sanjika <i>et al.</i> , 2012)
5. Network validation and final interpretation	(Hollstein, 2011; Bezuidenhout <i>et al.</i> , 2012)
6. Adjustments and final network interpretation	(de Nooy <i>et al.</i> , 2005; Hanneman and Riddle, 2011a; Hanneman and Riddle, 2011b; Bezuidenhout <i>et al.</i> , 2012; Sanjika <i>et al.</i> , 2012)

To draw a network using *Pajek*, the list of factors influencing push-pull adoption had to be converted to vertices and arcs (de Nooy *et al.*, 2005). Each factor influencing adoption in the list represented one vertex. These vertices were connected to each other to show first order relationships (Bezuidenhout *et al.*, 2012) using undirected lines or edges (de Nooy *et al.*, 2005). Once the connections, or ties, between vertices were defined, the data was converted into a matrix which was used as input data for *Pajek* (de Nooy *et al.*, 2005).

4.2.3.2 Generating the exploratory network in *Pajek*

The network was generated using the Kamada-Kawai energy layout function in *Pajek* (Kamada and Kawai, 1989). According to de Nooy *et al.* (2005), this energy command is most suited to analysis of small networks such as the one in this study and provides stable results. Manipulations to the network, which aid in interpretation and presentation of the network, were also done in *Pajek*.

4.2.3.3 Interpretation and validation of the network

The network was interpreted by visual inspection, by identifying themes within the network and by comparing the vectors of the vertices representing various adoption constraints. Visual inspections

of networks can be supplemented with network structural indices such as vectors which can be calculated using *Pajek* software (de Nooy *et al.*, 2005; Hanneman and Riddle, 2011a). However, usually the structural indices are “just efforts to attach numbers to features that we naturally ‘see’ in graphs” (Hanneman and Riddle, 2011b). The properties of the network as a whole can also be used to analyse the network, for example the density or texture of the network (Hanneman and Riddle, 2011a) and areas within it or the extent to which the network is dominated by one central node (centralization) (Marin and Wellman, 2011).

Vectors are numerical values used to quantify various attributes of vertices in networks (de Nooy *et al.*, 2005; Edwards, 2010). There are a number of different vectors which can be used in analysing networks, and the most suitable one for this push-pull adoption network is the vector of ‘betweenness centrality’ (Hanneman and Riddle, 2011a). Centrality of a vertex within a network is used as an indicator of the vertex’s power or influence on other vertices within a network (Hanneman and Riddle, 2011a). It can also be used as an indicator of the brokerage ability of a vertex i.e. its ability to act as an agent between sub-groups or themes within the network. Betweenness centrality is a sum of the proportion of times that a vertex lies between other vertices within the network (Hanneman and Riddle, 2011a).

Two workshops were held with sugarcane push-pull experts to validate the exploratory push-pull adoption network. These workshops included two scientists, three extension workers and three LSGs. During these workshops, the exploratory network was presented to the participants. The construction and initial interpretation of the network was explained and they were asked to confirm whether the list of factors influencing push-pull adoption which was used in the construction of the network was complete. The network validation workshops were audio recorded to aid in further analysis of the network and to accurately capture the feedback from experts at a later stage. Once the validation of the network with experts was complete, the necessary adjustments were made to the network and a new network was generated for final interpretation and analysis.

4.3 Results

4.3.1 Estimating the level of push-pull adoption

4.3.1.1 Estimating the level of push-pull adoption from LPD&VCC data

According to information from the Midlands North LPD&VCC, almost a third of LSGs in the region have had *E. saccharina* recorded on their farms within the last five years (Table 4.4). Forty-eight of these LSGs were included in the telephone interviews, the remaining seven could not be contacted

or were not prepared to participate in the survey. The sample is however considered to be representative of the majority of “priority potential adopters” i.e. LSGs who are at risk of economic damage from *E. saccharina* to their sugarcane crop by virtue of the fact that this pest has been recorded on their farm within the last five years. According to the LPD&VCC data, 12% of LSGs in the region (21 LSGs), have started implementing push-pull by planting *Cyperus* spp. and/or *M. minutiflora*, and 22% indicated an interest in implementing push-pull (Table 4.4).

Table 4.4 Information on *Eldana saccharina* pest records and adoption of push-pull from Midlands North LPD&VCC data as at July 2012.

Adoption indicators	Number of LSGs	% of total LSGs in the Midlands North region (176)
LSGs who have had <i>E. saccharina</i> on their farms in the last 5 years (i.e. priority potential adopters)	55	31
LSGs who have purchased <i>Cyperus</i> spp. plants from the LPD&VCC manager between January 2011 and July 2012	21	12
LSGs known to have purchased <i>M. minutiflora</i> seedlings between January 2011 and July 2012 ^a	7	4
LSGs who indicated that they would like the LPD&VCC to contact them to advise them on push-pull implementation	38	22

^a Note: all LSGs who purchased *M. minutiflora* also purchased *Cyperus* spp.

4.3.1.2 Estimating the level of push-pull adoption from telephone survey data

A graphical representation of a cross-tabulation from the telephone survey data is shown in Figure 4.2. The variables compared in this figure are *E. saccharina* presence on the farm (yes/no) and adoption of push-pull (yes/no). Of the total number of LSGs who have had this pest on their farm (44), 30 have adopted push-pull i.e. 68% of priority potential adopters. This figure also shows that out of the 53 respondents interviewed during the survey, 36 have adopted push-pull (partial or full adoption) (68%), and 17 have not (32%). Fourteen LSGs who have had *E. saccharina* on their farms have not adopted push-pull. Understanding the reasons for non-adoption among this group is crucial, and this is explored further in section 4.3.2.1 and Figure 4.7 below. According to the data from the telephone survey, 20% of the total number of LSGs in the Midlands North region have

adopted push pull (partially or fully). Of the LSGs who have adopted push-pull, 27 have adopted it partially, and only 9 have adopted it fully (Table 4.1).

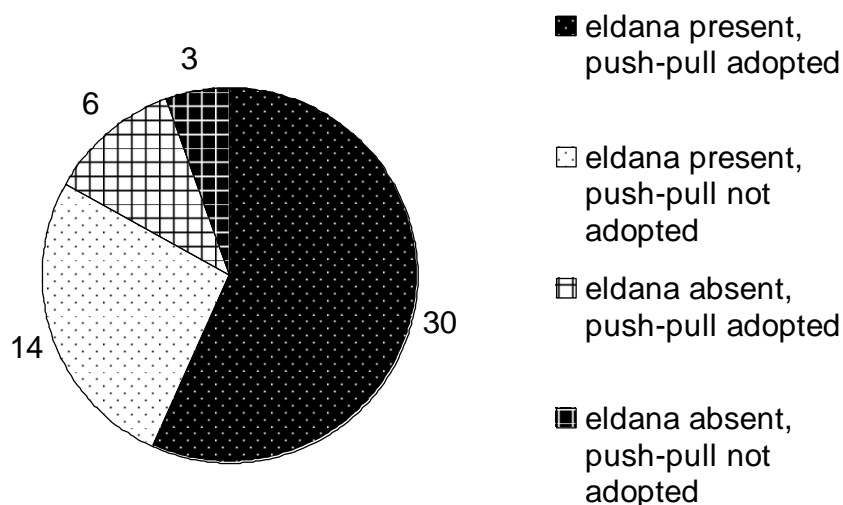


Figure 4.2. Number of large-scale growers who have had *Eldana saccharina* on their farm or not, and those who have adopted push-pull or not (data from contingency tables) (N = 53).

4.3.2 Exploring potential adoption drivers and barriers for push-pull

4.3.2.1 Results from exploratory network analysis to identify drivers and barriers of adoption

In the push-pull adoption network four main themes can be identified: farm management (shaded blue), knowledge (shaded green), people and society (shaded yellow) and effect of *E. saccharina* (shaded pink) (Figure 4.3). What follows is a description of the network using these themes as a guide.

The densest part of the network, with the highest concentration of ties and vertices, is around the costs and management ‘hassles’ (= hassles) vertices on the lower left section of the network i.e. the farm management theme shaded blue in Figure 4.3. The vertices surrounding costs and ‘hassles’ are almost all related to practical farm-level aspects of implementing push-pull. All of these management aspects are linked to either costs or ‘hassles’, as LSGs perceive them as costly activities or as a ‘hassle’. When LSGs say that something is a ‘hassle’, that implies that it takes additional management time and adjustments to management practices, which requires a change in the farmer’s behaviour (Reimer *et al.*, 2012), or a practice change (Llewellyn, 2011). In the network validation workshops, the participating LSGs who had been involved in push-pull trials,

disagreed with the prominent place which the costs vertex had in the network. They mentioned that LSGs who indicated that push-pull is costly are using it as a 'smoke screen' i.e. they are using it as an excuse for other reasons not to adopt push-pull. Although it has been shown through a cost benefit analysis that planting *M. minutiflora* as a repellent for *E. saccharina* is economically viable (Barker *et al.*, 2006), the costs vertex was not removed from the network. Since many LSGs did mention costs in interviews it is therefore a true perception which LSGs have and cannot be ignored.

The most central vertex in the network was knowledge of how to implement push-pull (= push-pull knowledge). This vertex acts as a connector, or broker, between the management theme of the network as described above, and the knowledge (green) and people and society (yellow) themes which are mostly in the upper right section of the network. The push-pull knowledge vertex is not directly connected to the management 'hassles' vertex, as knowledge has no first order relationship with 'hassles'. However, the individual management aspects which surround the 'hassles' vertex are all functions of push-pull knowledge and are perceived as 'hassles' by LSGs. For this reason these act as the link between the knowledge and 'hassles' vertices.

The people and society theme in the network is composed of three vertices: co-operation between farmers, legislation around pest management practices and extension support. Since IPM and push-pull should ideally be implemented at an area-wide level, co-operation between farmers is important for its success. Because wetlands play an important role in push-pull and *E. saccharina* management, and they are often a resource shared by neighbouring farmers, co-operation between farmers is important to maximise the efficacy of wetlands as a pull for *E. saccharina*. Co-operation can also reduce the 'hassle' of implementing push-pull for individual farmers, for example by

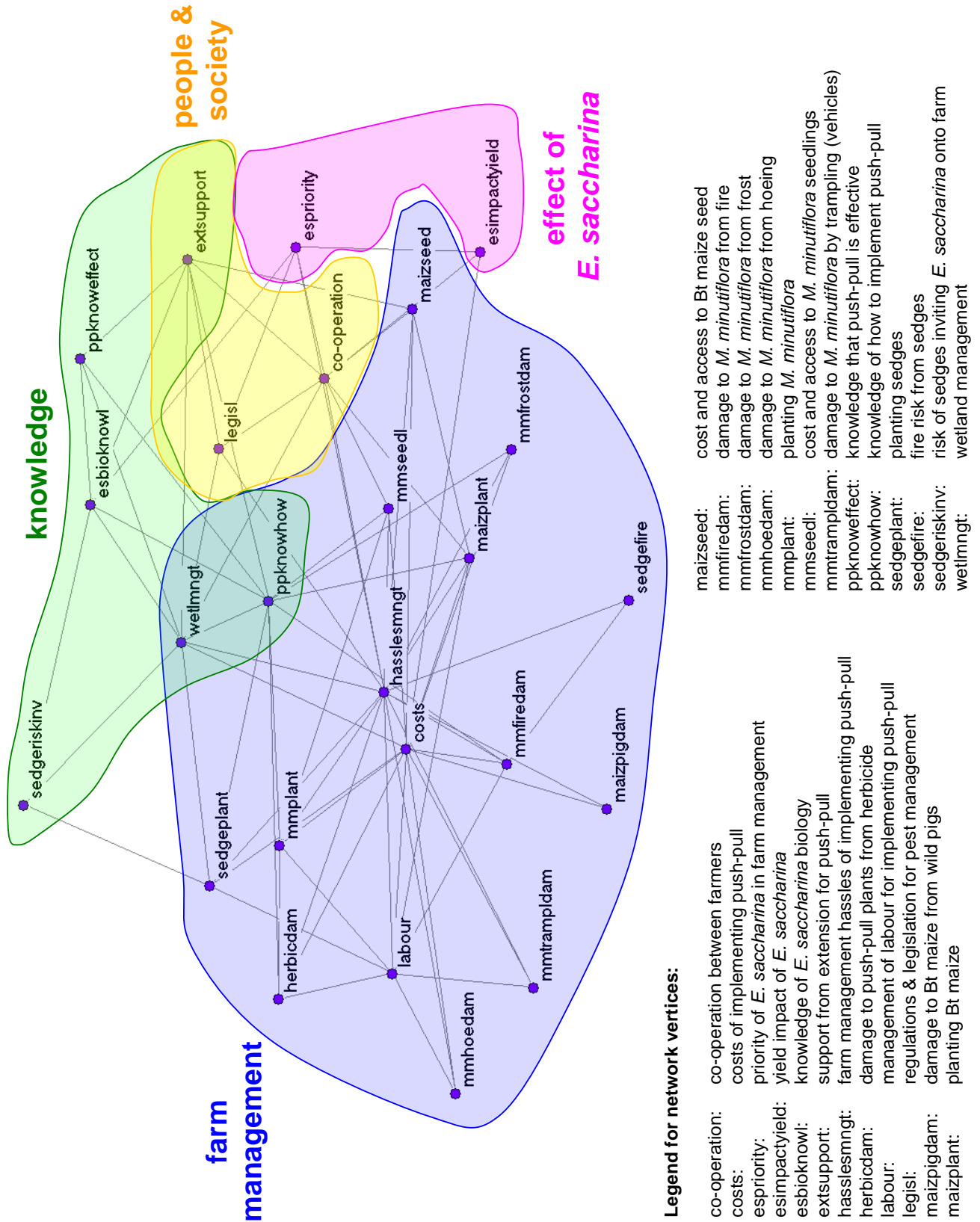


Figure 4.3. Exploratory network analysis showing themes and factors related to adoption of push-pull.

sharing seed, transport costs and logistics. Legislation on best management practices and sustainable practices could have an effect on adoption of push-pull by LSGs, but this can usually not be influenced by extension (Llewellyn, 2011). Currently, LSGs can still use insecticides for management of *E. saccharina* and they may well perceive insecticides as a viable alternative to push-pull. However, with increasing consumer pressure on agriculture to reduce reliance on agrochemicals (Urquhart, 1999; Kaine and Bewsell, 2008), future legislation and policy may force LSGs to adopt sustainable pest management approaches such as push-pull. Extension support is linked to push-pull knowledge which in turn links it to ‘hassles’ and all the specific push-pull management aspects, and this indicates the important role which extension has in the successful implementation of push-pull by LSGs. Wetland management and push-pull knowledge are both situated in an area of overlap between the management and knowledge sections of the network (Figure 4.3). This is because knowledge of push-pull is integral to its practical management at farm level. Managing wetlands is a knowledge-intensive process which requires firm knowledge of *E. saccharina* biology, push-pull and other non-push-pull wetland management aspects such as hydrological and vegetation factors (Macfarlane *et al.*, 2007).

The vertex labelled ‘sedgeriskinv’, on the top left corner (Figure 4.3), represents a commonly held perception among LSGs that planting sedges in their wetlands will attract (invite) *E. saccharina* onto their farm and provide it with a favourable habitat and therefore increase the risk of it becoming a pest in sugarcane. This perception is based on insufficient knowledge of *E. saccharina* biology and could determine whether LSGs adopt the practice of planting sedges on their farms. This will also affect LSGs’ approaches to managing their wetlands. If they believe that healthy wetlands including sedges, may provide favourable habitats for *E. saccharina* and are therefore a threat to their crop, the LSGs are less likely to invest in management of wetlands.

The final theme of the network is the effect of *E. saccharina* on the crop. The two vertices in this theme are the priority of *E. saccharina* for LSGs (pest priority) and its impact, or perceived impact, on yield (yield impact). These two vertices occur on the far right-hand side of the network. Pest priority links directly to ‘hassles’, since management activities to address more important production constraints are less likely to be perceived a ‘hassle’ than those for a lower priority constraint. Similarly, when pest priority increases this will affect co-operation between LSGs on AW-IPM and wetland management. The yield impact, or pest pressure, of *E. saccharina* will directly affect the pest priority which could result in a reduction in the ‘hassle factor’ of implementing push-pull.

An analysis of the structural properties of the network can be useful to corroborate the visual inspection (Figure 4.4). In the push-pull adoption network, the three vertices with the highest values for the betweenness centrality vector are 'hassles' (14.89), costs (8.40) and push-pull knowledge (5.47) (Figure 4.4). Note that the size of the vectors in the figure is proportional to the value of their betweenness centrality vectors. The vector values in the figure have all been multiplied by 50 to make the size difference between vertices easier to distinguish for presentation purposes. The high vector values for the perceived 'hassle' and cost of implementing push-pull indicate that these two issues may be the strongest barriers to adoption as they are connected to so many other problems regarding implementation. The push-pull knowledge vertex acts as a broker, or agent (Hanneman and Riddle, 2011a), between the management and knowledge themes in the network. This is confirmed by its high betweenness centrality vector value (5.47). Wetland management also has one of the highest betweenness centrality vector values in the network (5.23) which may indicate its importance in all three major themes in this network: farm management, push-pull knowledge and society.

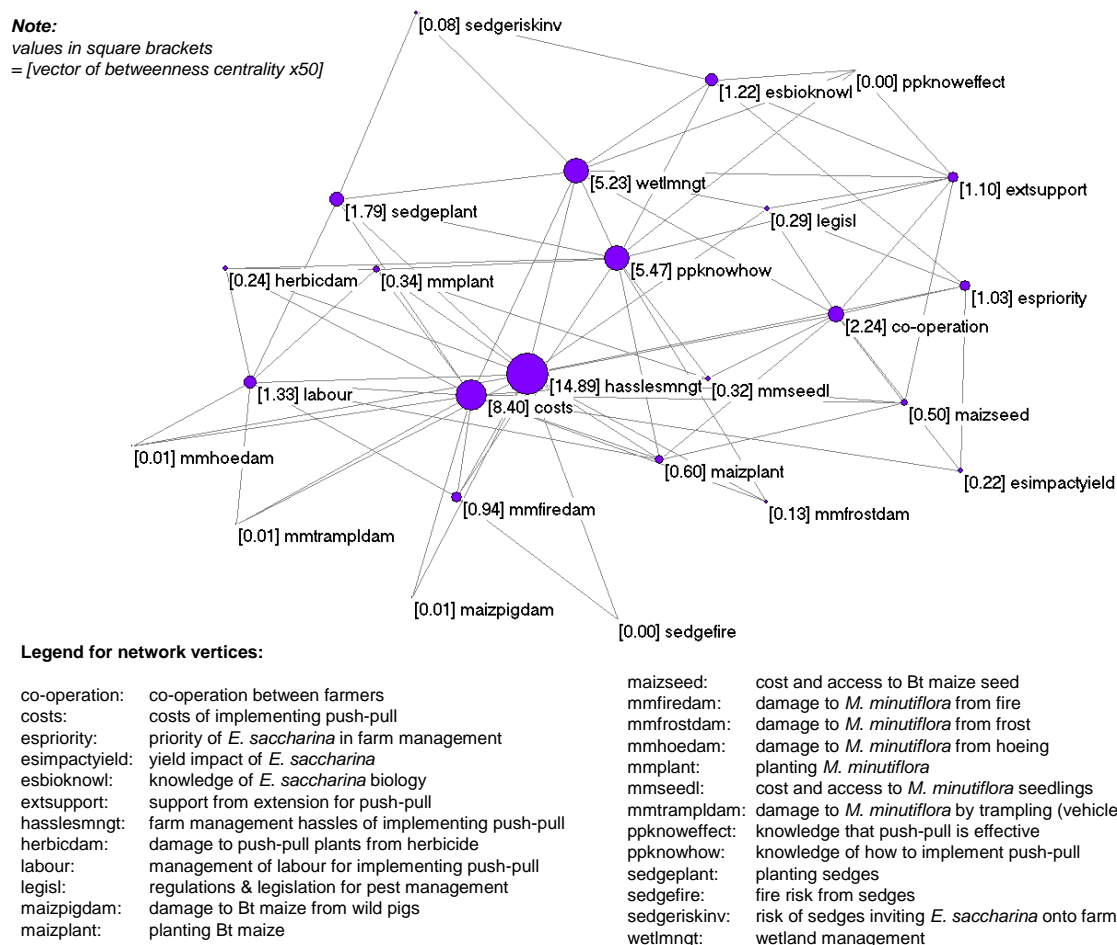


Figure 4.4. Exploratory network analysis showing factors affecting push-pull adoption and their vectors of betweenness centrality.

4.3.2.1 Results from telephone survey to further investigate drivers and barriers of adoption

The median scores for each of the potential adoption drivers which LSGs were asked to rate on a scale from zero to 10 are shown in Figure 4.5. A zero score is 'low' and a score of 10 'high' for each question.

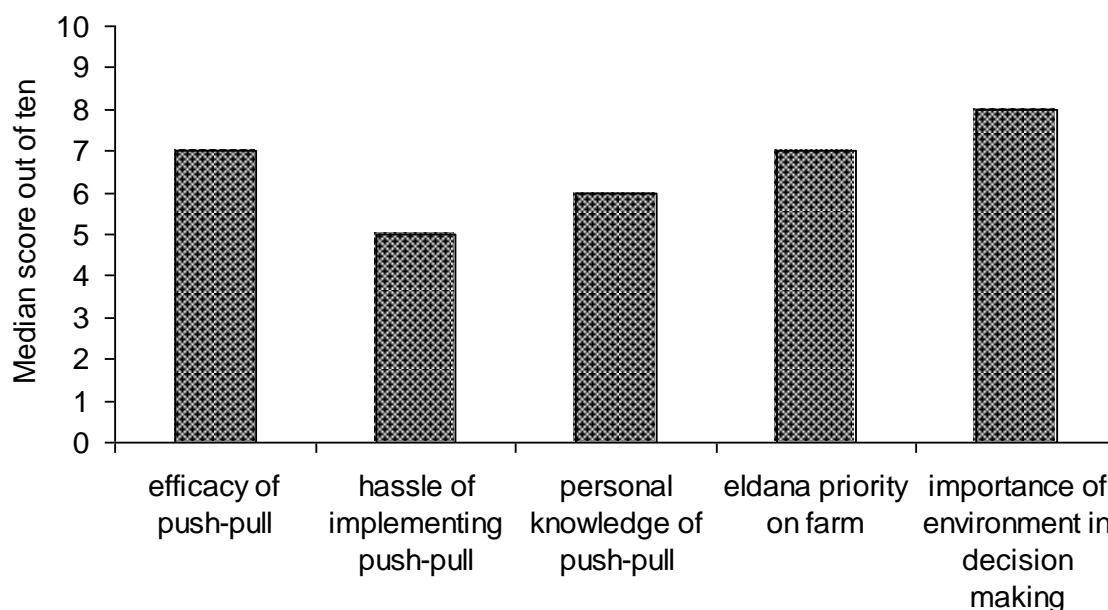


Figure 4.5. Median scores for the five potential adoption drivers allocated by large-scale growers during telephone surveys (Note: A zero score is 'low' and a score of 10 'high' for each question) (N = 53).

The potential adoption driver with the highest score was 'importance of the environment in farm decision making', which shows that sugarcane LSGs in the Midlands North consider environmental and conservation matters as important in their farming practices. While 70% of LSGs considered push-pull to be effective, many were hesitant to rate its efficacy since they had not experienced it themselves. Across all respondents the 'hassle' of implementing push-pull was rated as moderate. The median score for LSGs' personal knowledge of how to implement push-pull was six out of ten, and here too LSGs who had not implemented push-pull were not confident in their answers. The respondents seemed to recognise *E. saccharina* as a relatively important threat as the median score was seven out of ten.

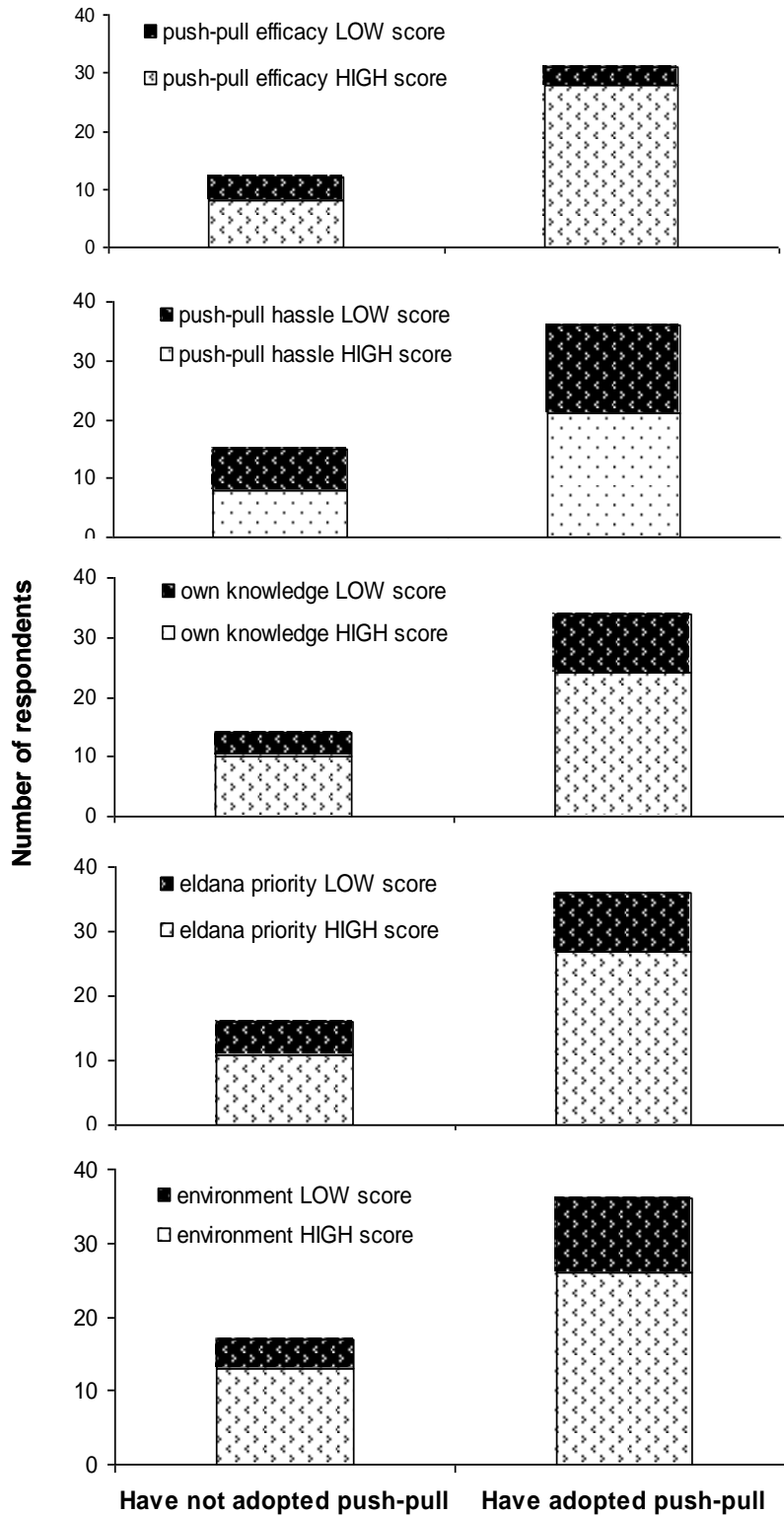


Figure 4.6. Graphical representation of contingency table between score categories of potential adoption drivers and push-pull adoption and non-adoption (from telephone survey data) (N = 53).

Mann-Whitney U tests and Pearson's Chi-square tests were used to determine whether these adoption drivers had any effect on LSGs' adoption or non-adoption of push-pull. Neither the Mann-Whitney U nor the Chi-square tests showed a significant effect of the five potential adoption drivers on LSGs' adoption of push-pull. This result could be due to the relatively small sample size. For example, for a Chi-squared test to be effective, each cell in a cross-tabulation must have no less than five cases. However, in our data set we had few non-adopters, as well as some questions which LSGs did not answer, which resulted in many of the cells having less than five cases. The tests for statistical significance were thus inconclusive.

The cross-tabulations used as a descriptive measure of the relationship between the potential adoption drivers and LSGs' adoption or non-adoption of push-pull are shown as bar graphs in Figure 4.6. This figure also serves to illustrate the high number of adopters and the fact that there were no strong differences between adopters and non-adopters in their scoring of the potential adoption drivers.

One can however see some patterns in Figure 4.6. For example, the vast majority of adopters (90%) rated push-pull efficacy to be high. More than 70% of adopters assigned high values to their own knowledge of push-pull, the priority of *E. saccharina* in their management, and environmental matters. Due to the inconclusive nature of the analysis on this data set however, these observations should not be given much weight on their own, and should be validated, for example by triangulation with other data sources.

Open-ended questions from the telephone survey were analysed using qualitative approaches. The results of the coded content analysis for four of the open-ended questions are shown in Figure 4.7, along with selected verbatim quotes from the telephone interviews which substantiated the findings of the content analysis. LSGs had a positive and optimistic attitude towards push-pull for the control of *E. saccharina* (Figure 4.7A). Only five respondents (9%) were openly sceptical about push-pull. When LSGs who had adopted some aspect of push-pull were asked what had motivated them to start implementing it, (Figure 4.7B), most mentioned either the increasing pest threat (62%) or intervention from extension services (38%). LSGs' awareness of the economic importance of *E. saccharina* in coastal sugarcane areas was also apparent from their responses and they seemed to recognise the opportunity for preventative action. When LSGs who had not adopted push-pull were asked why they had not (Figure 4.7C), the most frequent response was that push-pull was a 'hassle' to implement because of management adjustments and increased need for resources such as labour (33%). Others said that they didn't feel the threat of *E. saccharina* was significant enough

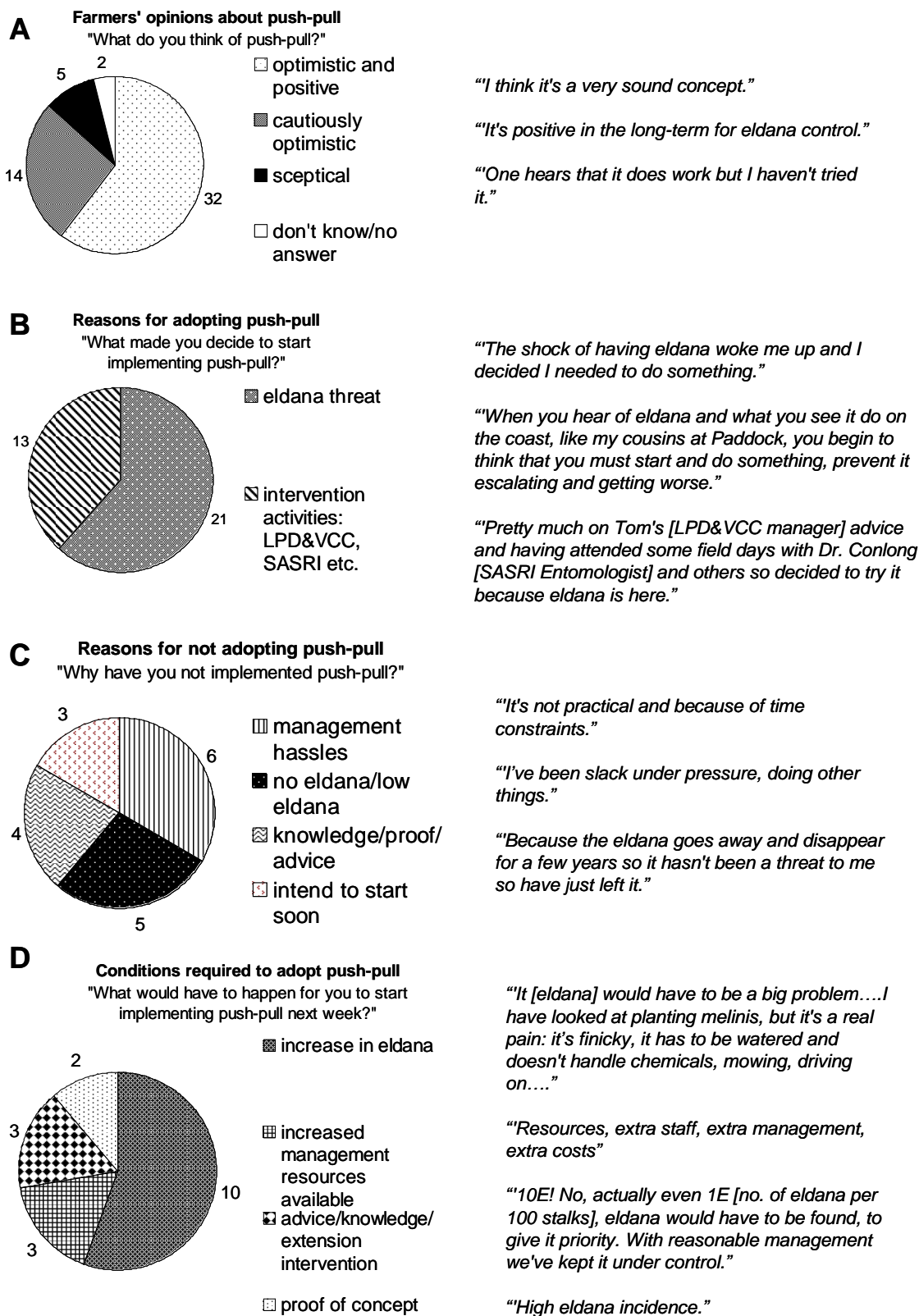


Figure 4.7. Graphical representation of content analysis carried out on large-scale growers' responses to open-ended questions in (numbers represent frequency of responses per category).

to warrant adoption (28%). Some LSGs felt they needed more advice and knowledge on how to implement push-pull (22%) and some needed convincing that the concept works (17%). When non-adopters were asked what conditions would motivate them to adopt push-pull in the near future (Figure 4.7D), the most frequent response was an increase in the threat of *E. saccharina* (56%). LSGs also suggested that additional support in terms of knowledge and advice (17%), as well as proof of the efficacy of push-pull would motivate them to begin implementing this strategy on their farms (11%) (Figure 4.7D).

4.4 Discussion

4.4.1 Estimating the level of push-pull adoption

Results of the telephone survey indicated that push-pull adoption levels are higher than suggested by LPD&VCC data, which is likely because the LPD&VCC data has not incorporated new adoption which has occurred during the most recent months. This study showed that 20% of LSGs in the Midlands North partially or fully adopted push-pull. If cumulative adoption within a target group is plotted, the curve is usually s-shaped which starts out low and becomes steeper as adoption rate increases until it reaches a plateau (Peshin *et al.*, 2009; Llewellyn, 2011; Reimer *et al.*, 2012). Llewellyn (2011) showed this for the adoption of no-till practices in Australia, and from a level of 20% onwards, the adoption rate increased. This 'tipping' point at which adoption rate starts to increase rapidly, depends on a multitude of factors within that system (Peshin *et al.*, 2009b). It will be interesting to see whether adoption of push-pull in the Midlands North region will rapidly increase from its current level of 20% within the next few years.

This 20% adoption does however over-inflate the success of push-pull among LSGs, since only 9 LSGs (i.e. 5%) have adopted both a push and pull component. Although previous studies showed that push (Barker *et al.*, 2006) and pull (Kasl, 2004) plants on their own reduced damage caused by *E. saccharina* on sugarcane, the recommended system does incorporate both a push and pull component for maximum efficacy. To explain the discrepancy between partial and full adoption, the management activities involved in adoption of either a push or a pull on its own or in combination need to be considered. LSGs who only implemented push-pull partially, in almost all cases planted sedges, *Cyperus* spp., in their watercourses. This was facilitated by the LPD&VCC manager who provided potted seedlings of *C. dives* and *C. papyrus* for sale to LSGs as a 'pull' plant for *E. saccharina*. Although there were sufficient natural source populations of these plants available on farms, the convenience of having potted seedlings available on order which are delivered to the farm has had a huge impact on push-pull implementation by the LSGs. These *Cyperus* spp. grow

easily if planted from potted seedlings in the correct areas on the farm, and require very little maintenance once they have been planted. To quote a LSG from the telephone interviews:

“Doing the sedges was very easy and not really a ‘hassle’. You just need to get round to doing it.”

The push component (*M. minutiflora*) however, is seen as much more of a ‘hassle’ and requires a lot more resources and adjustments to management practices. This is most likely the main farm-level or management barrier to full adoption of push-pull. To quote some LSGs:

“The melinis grass is a bigger problem. The sedges are very easy. Management of melinis is difficult [and] needs a change of mindset.”

“If you had to go into molasses grass etc. it would be more of a ‘hassle’, but the way I do it with just a few sedges etc. then it’s okay.”

Adoption of a knowledge-intensive new farming practice such as push-pull requires access to suitable information and learning opportunities for farmers (Meir and Williamson, 2005; Llewellyn, 2007). Although no formal survey of adoption was completed before commencement of this project, discussions with stakeholders including leading LSGs and extension staff indicated that adoption increased during this project (2011-2012). This can be attributed to a number of factors which include increased extension activities, i.e. knowledge sharing and learning opportunities (Llewellyn, 2007), improved access to inputs (e.g. *Cyperus* spp.), and increased pest pressure (Kaine and Bewsell, 2008) due to drought during the 2010/2011 season. It was previously reported that LSGs requested access to more knowledge and specific information on the practical aspects of implementing push-pull (Chapter 2; Cockburn *et al.*, 2012). LSGs themselves attributed adoption of push-pull in part to extension activities, which provided both knowledge and advice as well as improved access to inputs, as is evidenced by these quotes from the telephone interviews:

“It’s something where we get support e.g. the LPD&VCC team that comes round they also help with implementation”

“Eldana [levels] and basically you guys coming out to chat, that’s what got me started”

“I was approached by Tom a while ago with plant material”

Llewellyn (2011) mentioned that drought was an example of a learning-based trigger for adoption. This is ascribed to the benefits of implementing a new practice only being apparent after increased environmental pressure, such as *E. saccharina* which is known to be more damaging in dry seasons.

4.4.2 Exploring potential adoption drivers and barriers for push-pull

Most issues in the push-pull network were related to farm-level management ‘hassles’. This is the densest part of the network and the ‘hassles’ vertex also has the highest vector of betweenness centrality (Figure 4.4). LSGs’ comments on management ‘hassles’ as reasons for not adopting push-pull (Figure 4.7 C & D), mostly centred around planting of *M. minutiflora* (See quotes in 4.4.1 above) which confirms that this aspect is likely the biggest barrier to adoption of push-pull. The compatibility of a new management practice with a LSG’s current practices is an important driver (Kaine and Bewsell, 2008; Khan *et al.*, 2011) which cannot be ignored in push-pull adoption. Röling *et al.* (2004) pointed out that the ‘farmer’s veto’ can play an important role in non-adoption of new agricultural practices. While researchers and extension workers may provide the knowledge, learning and input support necessary, the farmer can exact his/her veto and not adopt the technology if it is not suitable to the on-farm context of the farmer, who makes the final management decisions. The importance of compatibility and farm context was also shown to be true for apple farmers’ successful adoption of IPM in Australia (Kaine and Bewsell, 2008), and maize farmers’ adoption of push-pull in Kenya (Khan *et al.*, 2011). Urquhart (1999) emphasized the management-intensive nature of IPM, and highlighted that agricultural practices like this may not be suitable for adoption by all farmers. Knowledge intensive practices such as push-pull, within an IPM framework, require commitment from farmers because “adopting IPM requires more intensive management, better management skills, and much extra administration” (Urquhart, 1999). It must be accepted that not all farmers can afford to practice or are interested in this high level of management. There are also many other social and cultural factors which influence a farmers’ decisions to adopt, and these cannot be discounted (Vanclay, 2004).

The most central vertex in the network is push-pull knowledge. This vertex played a role as a broker between the knowledge theme and the farm management theme (Figure 4.3 & 4.4). In social networks, this brokerage role of important vertices indicate actors who are powerful and influential players within a network (Hanneman and Riddle, 2011a). The role of extension is to provide knowledge support to LSGs and thus this is the vertex in the network which extension is most able to affect the rest of the network. Both adopters and non-adopters of push-pull mentioned knowledge, information and advice as relevant to their decisions to adopt or not adopt (Figure 4.7 B, C & D). In the network, the knowledge vertex did not link directly to the ‘hassles’ vertex, but it did so through the many smaller vertices representing specific management activities for push-pull, for example planting and labour. The more experience a LSG has with a particular practice, the more knowledgeable he will be on how best to integrate that practice with other farm activities, which will

in turn result in a reduced 'hassle' factor over time. LSGs themselves recognise this, as these quotes from the telephone interviews show:

"Is quite a big 'hassle', but the 'hassle' reduces over time as you get to know it"

"Starting is a 'hassle', but once you're into it, it won't be a 'hassle'"

An additional anecdote, summarised from informal discussions with one of the LSGs who has fully implemented push-pull, including *Cyperus* spp., Bt maize and molasses grass, further illustrates this:

*Mr. Brown (not his real name) started implementing push-pull about five years ago. He has seen his neighbour implementing push-pull and they have learnt from each other. He has planted molasses grass in many areas all over his farm and propagates the plants himself. He has spread *Cyperus* spp. throughout his water courses and neighbours and the LPD&VCC now use his farm as a source of *Cyperus* spp. plant material. He regularly plants Bt maize as a green manure in resting sugarcane fields as he feels that "every bit helps" in reducing the effect of *E. saccharina*. When asked whether these activities aren't a 'hassle' to him he replied that he didn't do it all at once and that he does most of the push-pull work on rainy days. His labour cannot do the usual sugarcane field work on rainy days so he feels that getting them to plant push-pull plants is a good way of keeping them occupied and the plants take well in wet conditions.*

Mr. Brown has demonstrated that by implementing push-pull bit by bit he has learnt how best to fit it into his management schedule and he doesn't perceive it as a 'hassle'. The same holds true for IPM adoption by citrus farmers, which is most successful when farmers adopt it slowly, orchard by orchard (Urquhart, 1999). Mr Brown's knowledge of how best to plant, manage labour and access inputs has reduced the 'hassle' for him. This shows that the role of knowledge in reducing the perceived 'hassle' of implementing push-pull, as shown by the network, is a powerful tool for facilitating adoption. The way Mr. Brown learnt with his neighbour also showed the importance of local, experiential group learning, which Llewellyn (2007) regards as valuable in improving adoption of technologies. Within the knowledge section of the network, the knowledge that push-pull is effective vertex is also one which can be influenced by extension. Access to clear information about a new technology which demonstrates its efficacy is recognised as key for successful adoption (Khan *et al.*, 2011). There is still some scepticism among LSGs, and this is best addressed by providing opportunities for LSGs to "see for themselves" that push-pull is effective, for example on a neighbour's farm. This kind of evidence takes time to develop and needs extension support. The fact that most LSGs rate the efficacy of push-pull quite highly with a median score of 7 (Figure 4.5) and 90% of adopters giving it a score above 5 out of 10 (Figure 4.6) showed that there is enough

evidence available to make an informed decision about the potential benefits of adopting push-pull. This was also shown by the positive attitudes of most LSGs towards push-pull (Figure 4.7A) as was also reported in Chapter 2 and by Cockburn *et al.* (2012).

In the people and society section of the network, extension support is probably the most important vector, since it links to knowledge which has been shown to influence adoption. Should legislation on pest management practices ever come into force, this will have to be monitored by extension staff, and will likely influence adoption of ecologically-sensitive and sustainable practices such as push-pull. Co-operation between LSGs is important for the success of AW-IPM (Cumming and Spiesman, 2006), and this is also a factor which needs to be mediated by extension staff, in particular around shared resources such as wetlands.

The level of pest pressure, or yield impact of *E. saccharina*, plays an important role in push-pull adoption. In this section of the network which shows the effect of *E. saccharina* (Figure 4.3), 56% of non-adopters said that an increase in pest levels would motivate them to adopt (Figure 4.7D). In several telephone interviews, LSGs said that they had had higher than usual *E. saccharina* in the previous season and they planned to implement push-pull within the next year. An anecdote from the LPD&VCC, Tom Webster, also supports this finding:

“Last week I got a call from Mr. Smith (not his real name) about his eldana survey. The [LPD&VCC] teams found eldana on his farm for the first time and he phoned me to order sedges. He’s been saying for a long time that he thinks push-pull is a good idea and wants to start it, but he needed the eldana numbers to give him a wake up call. Now he suddenly wants to order sedges!”

Kaine and Bewsell (2008) and Khan *et al.* (2008a) also reported that increases in pest pressure influence farmers’ adoption decisions. Reimer *et al.* (2012) and Baumgart-Getz *et al.* (2012) discussed the importance of farmers’ perceived benefit of a new practice in the decision to adopt and reported that increased pest pressure would directly increase the economic benefit of implementing a pest management practice. An increase in pest pressure could possibly also reduce the perception that implementing push-pull would be a ‘hassle’, as it would mean that the priority of managing *E. saccharina* on the farm would increase. This quote provides evidence for this (Figure 4.7D):

“Eldana would have to be found [on my farm], to give it priority.”

Increased pest pressure and the resultant change in priority of pest management can reduce the perceived 'hassle' and would likely lead to an increase in adoption.

4.5 Conclusion and recommendations

Through the exploratory network, a number of leverage points were identified which could aid in reducing barriers to adoption and 'simplifying' the current network. To illustrate this point, one could consider if the LPD&VCC manager was not providing potted *Cyperus* spp., sedge supply would be an additional vertex in the network which would have added to the complexity and increased the size of the 'hassles' vertex even more. The fact that the access to this plant material is not a problem has already reduced the size and complexity of the network. This illustrates how each node, if addressed effectively, is an opportunity to improve adoption of push-pull. The biggest leverage points, identified through the network analysis, i.e. the most central and highly connected vertices, were 'hassles', costs and knowledge.

Providing advisory services and access to knowledge is a primary function of extension, and the LPD&VCCs also serve as important knowledge and advice support structures for pest management in the South African sugar industry. This study has shown that the SASRI extension staff and LPD&VCC management have been successful in providing knowledge regarding the threat of *E. saccharina* to LSGs (Chapter 2; Cockburn *et al.*, 2012) and, in particular, on suitable and effective pest management practices in the Midlands North region. The need for more specific knowledge on practical details of planting push-pull (described in Chapter 2), along with scepticism shown by some LSGs, calls for extension services to provide more experiential and local learning opportunities in groups (Llewellyn, 2007). Kaine and Bewsell (2008) emphasized the need for LSGs to learn and experiment to evaluate different management options within their farm conditions and within the realities of commercial production conditions.

The perception that push-pull is a 'hassle' and is a costly new management practice also needs to be addressed by extension. The most effective way to 'teach' LSGs that push-pull does not have to be a 'hassle' and is not costly is also through experiential learning, as is shown by the story about Mr. Brown. Although a cost-benefit study has been done to prove the economic benefits of push-pull (Barker *et al.*, 2006), LSGs still need to experience it first hand.

Pest pressure is a variable which extension cannot influence, but which can provide opportunities, for example in drought years, for increased adoption rates. Since the *E. saccharina* pest pressure in the Midlands is still relatively low (Goebel *et al.*, 2005), one should guard against unrealistic

expectations from LSGs. Some pro-active LSGs may well adopt push-pull pre-emptively, while others may well exercise their 'farmers' veto' and wait until it is economically more realistic to adopt this new practice.

The impact which high pest pressure can have on adoption could be seen as an opportunity in areas where *E. saccharina* pest pressure is already high. What this study has shown is that suitable learning opportunities, knowledge and input support can all be drivers of adoption for push-pull. Extension staff in other areas where farmers have not yet adopted push-pull need to take advantage of the lessons learnt in the Midlands North region and provide local, hands-on experiential learning opportunities such as model farms and regular group meetings, along with sufficient support for push-pull planting inputs, to facilitate area-wide implementation of this strategy for sustainable management of *E. saccharina*.