Chapter 7

Conclusions and Recommendations

7.1 Introduction

In Chapter 1, the importance of *Eldana saccharina* Walker (Lepidoptera: Pyralidae) as the primary pest of sugarcane in South Africa, and the need for implementation of sustainable approaches to its management was demonstrated (Goebel *et al.*, 2005; Singels *et al.*, 2012). Research at the South African Sugarcane Research Institute (SASRI, 2005) into the biology of *E. saccharina* and its host plants has culminated in the recommendation of a an area-wide integrated pest management (AW-IPM) programme for management of this pest (Webster *et al.*, 2009), incorporating push-pull (Barker *et al.*, 2006) and good crop management practices (SASRI, 2005; Conlong and Rutherford, 2009; Rutherford and Conlong, 2010).

This study facilitated the implementation of push-pull for control of *E. saccharina* in sugarcane in the Midlands North region of KwaZulu-Natal, South Africa. This was achieved through development of a working model for the implementation of push-pull, as a part of integrated pest management (IPM). For development of the working model, four objectives were set, the outcomes of which are described separately below. In the final two sections of this chapter, recommendations for future research are made and a final synthesis of the work is presented. A photographic essay summarising this thesis is provided in Appendix J.

7.2 Objective 1: Determine farmers' production constraints and their knowledge and perceptions of *E. saccharina*, push-pull and IPM

Literature on the adoption of IPM emphasizes the need to understand farmers' knowledge, perceptions and practices with regards to pests and pest management (Röling and van de Fliert, 1994; Meir and Williamson, 2005; Khan *et al.*, 2008a). Hence Chapter 2 reports on a study of large-scale sugarcane growers' (LSGs) knowledge and perceptions of *E. saccharina*, push-pull and IPM.

It was shown that LSGs in the Midlands North region have a good basic knowledge of *E. saccharina*, push-pull and IPM but a need for more detailed and practical knowledge for them to successfully implement this system was identified. Farmers indicated a preference for farm-based experiential learning opportunities. This is consistent with current recommendations in the literature (Llewellyn, 2007; Peshin and Dhawan, 2009; Khan *et al.*, 2011), in which farmers' participation in the dissemination of pest management information was shown to be crucial for successful implementation. The LSGs' positive attitude and good basic knowledge of push-pull, coupled with their high levels of education, high land tenure security and interest in environmentally sustainable farming measures (Maher and Schulz, 2003) indicate that push-pull implementation with LSGs is likely to succeed in this region.

In Chapter 3, the feasibility of implementing push-pull for control of *E. saccharina* with small-scale growers (SSGs) in the Midlands North region was explored using a mixed methods approach. Sugarcane was shown to play an important role in the livelihoods of SSGs in this region. This household income provided by the sugarcane crop increases food security and allows for parents to pay for education of their children. This is consistent with other studies which have discussed the importance of sugarcane for rural development (Eweg, 2005b; Armitage *et al.*, 2009; Sibiya and Hurly, 2011).

Sugarcane was recognised by these SSGs as their most important crop within an integrated cropping-livestock system, however farmers perceived weeds and input costs as their primary production constraints, and not *E. saccharina*. Way *et al.* (2003) have found *E. saccharina* incidence and damage to be much lower in SSG fields compared to LSG fields in other regions of the sugar industry. In addition, Local Pest, Disease & Variety Control Committee (LPD&VCC) pest survey data support the finding that *E. saccharina* is not a serious threat to SSG sugarcane production in the Midlands North region. These are the most likely reasons for them not regarding *E. saccharina* as a production constraint. Further to this, research into SSGs' knowledge of insect pests in sugarcane and food crops showed that farmers had relatively poor knowledge of sugarcane pests in comparison to vegetable pests. They lacked knowledge on effective control measures, including biological control by beneficial insects and IPM. This has been found for small-scale growers of other crops in sub-Saharan Africa, for example vegetables in Botswana (Obopile *et al.*, 2008) and cotton in Kenya (Midega *et al.*, 2012). This chapter concludes that implementation of push-pull for SSGs in the Midlands North is currently not a priority, and that extension efforts should focus on weed management and reducing the impact of costly inputs for sugarcane production. However, since the threat of *E. saccharina* in the Midlands North is on the increase

(Webster *et al.*, 2009), farmers should be given opportunities to learn more about sugarcane pests and pest management.

7.3 Objective 2: Evaluate current adoption levels of push-pull among large-scale growers and explore drivers and barriers of adoption

In Chapter 4, it was reported that 20% of farmers in the Midlands North region have adopted some aspect of push-pull, but that only 5% adopted both a push and a pull component. This was ascribed to the perceived ‘hassle’ of planting *Melinis minutiflora* P. Beauv (Cyperales: Poaceae), the push component currently recommended as a repellent to *E. saccharina* moths.

Exploratory network analysis, a new method for understanding the complexity of adopting a knowledge-intensive management practice such as push-pull, was used in Chapter 4. The network indicated important leverage points which could be used to improve adoption of this technology. For example, it showed that farmers’ perceptions that push-pull is a ‘hassle’ and costly, are important barriers to adoption of push-pull. Knowledge of push-pull played a key role in the network and by increasing the farmers’ knowledge and experiences with implementing push-pull, the perception of push-pull as a ‘hassle’ could likely be reduced. This would require commitment from LPD&VCC staff and extension staff at South African Sugarcane Research Institute (SASRI). Efforts by the LPD&VCC manager to provide inputs, in the form of sedges (*Cyperus* spp.), have certainly increased the adoption rate in the region, as is also evidenced by quotes from farmers. As has been shown in the literature (Llewellyn, 2007; Kaine and Bewsell, 2008), farmers learn best in small groups in their local context where they can experiment together and learn from each other, and this is recommended to improve implementation and adoption of push-pull and IPM for control of *E. saccharina*.

7.4 Objective 3: The use of model farms to determine the efficacy of push-pull for control of *E. saccharina*, and to provide hands-on learning

As was shown in both Chapters 2 and 4, LSGs requested hands-on learning opportunities to increase their knowledge of push-pull and improve implementation. Four model farms were set up and used to host field days for visiting farmers and to conduct on-farm trials for push-pull. Furthermore, planting push-pull trials with farmers allowed for host farmers to gain practical experience in implementation of push-pull and to adapt the system to suit their farming practices. They passed this knowledge on to others at field days, and this will be collated into a single set of guidelines, and made available to farmers after completion of this study.

Two of the four on-farm field trials reported in Chapter 5 showed that *M. minutiflora* can effectively reduce damage to sugarcane from *E. saccharina,* and thus provide economic benefits to farmers. The results from the other two trials were inconclusive and were jeopardised by problems in crop management, such as poor variety choice and maturing sugarcane beyond recommended ages, which increased pest numbers in push-pull treatment areas compared to control areas. This highlighted the importance of implementing push-pull within an IPM framework, in which good crop management is imperative. For analysis of field data, a sub-sample of the 18-month data set was selected, based on knowledge of *E. saccharina* biology (i.e. peaks in moth activity in November and April (Atkinson, 1982)) and on knowledge that *M. minutiflora* required a few months to establish sufficient biomass to have an effect on egg-laying moths. This demonstrated the knowledge-intensive nature of push-pull and IPM implementation, which requires commitment and collaboration between farmers, extension staff and researchers, to be successful. The importance of collaboration between multiple stakeholders for successful implementation of improved agricultural practices is widely recognised (Leeuwis, 2004; Vanclay, 2004; Nederlof *et al.*, 2007).

7.5 Objective 4: Contribute to the understanding of stem borer ecology and demonstrate the importance of wetlands for providing ecosystem services on sugarcane farms

In Chapter 6, surveys for stem borers in wild host plants growing in wetlands on sugarcane farms revealed a high species diversity, which included their natural enemies (parasitoids). It was thus shown that these wetlands provide natural habitats for stem borers (such as *Pirateolea piscator* Fletcher comb. n. (Lepidoptera: Noctuidae), which can be regarded as a potential biosecurity threat to sugarcane), but more importantly, their parasitoids.These wetlands need to be conserved and managed carefully, as was recommended by Polaszek and Khan (1998), and more recently by Mailafiya (2011) and Moolman *et al*. (2012).

Wetlands not only provide habitat for wild non-pest stem borers but also for *E. saccharina,* as its favoured wild host plants *Cyperus dives* Delile (Cyperales: Cyperaceae) and *C. papyrus* L. (Cyperales: Cyperaceae) are obligate wetlands plants (van Ginkel *et al.*, 2011). In Chapter 4, the exploratory network analysis indicated that wetland management was an important aspect for successful adoption of push-pull by farmers, and wetland health assessments reported in Chapter 6 were used to develop a tool allowing farmers to assess and manage wetlands on their farms. Since wetlands provide ecosystem services, they are always a resource on a farm. However, the ecosystem services which wetlands provide on sugarcane farms go beyond the well-known hydrological and water quality regulatory functions (Kotze *et al.*, 2007). Wetlands also provide vital pest regulatory services to farmers, and by increasing the biodiversity in the agroecosystem they improve the stability of the system (Altieri and Nicholls, 2004), and thus need to be conserved and managed correctly.

7.6 Recommendations for further research and extension activities

The social research presented in Chapters 2, 3 and 4 has for the first time involved farmers directly in implementation of pest management strategies in the South African sugar industry. The results of this work have demonstrated the importance of understanding farmers' perspectives on pests and pest management. By combining social research and farm-based experiential learning opportunities, implementation of push-pull for control of *E. saccharina* is likely to be successful in the Midlands North region. The challenge for the sugar industry now lies in taking the working model presented in this study further, and implementing it in other areas of the South African sugar industry, particularly in coastal regions where *E. saccharina* causes higher economic losses than in the Midlands North (Goebel *et al.*, 2005). Collaboration between researchers, extension staff and farmers is going to be crucial for the successful implementation of this knowledge-intensive approach to pest management. The model of implementing a new farming practice by improving researchers' awareness of farmers' constraints, knowledge and perceptions and by increasing farmer participation should also be used for development and implementation of other research projects at SASRI. The approaches for small- and large-scale growers in each region of the sugar industry will need to be different, as their socio-economic, and even agroecological contexts are different (Mahlangu and Lewis, 2008). It is time for the sugar industry to move away from the traditional top-down transfer of technology paradigm in research and extension, to a more participatory approach. According to Warner (2008), implementation of agroecological practices, of which push-pull and IPM are examples, requires shifts in the roles of farmers, extension staff and researchers. Rather than researchers being represented as knowledge superiors in knowledge to farmers (Leeuwis, 2004), researchers need to recognise that farmers are the experts on their land and that the best solutions to agricultural problems can only be found where farmers and researchers build partnerships and work together with mutual respect (Leeuwis, 2004; Vanclay, 2004; Warner, 2008).

Further directions for research into improving the scientific base of push-pull and *E. saccharina* habitat management have also emerged from this study, particularly in Chapters 5 and 6. The most pressing of these is the need for push-pull field trials in regions of the sugar industry where *E.*

saccharina is causing higher economic damage than in the Midlands North region. There the impact of push-pull on pest numbers and damage will be higher, and lead to better data sets to further quantify the effect of this method. In areas with high pest levels, detailed studies on the amount of *M. minutiflora*, and the distance which its effect covers, can be completed. *Melinis minutiflora* has been shown to be effective in reducing damage due to *E. saccharina* in Chapter 5 of this study and in other field trials (Kasl, 2004; Barker, 2008), and it is also known to be a good quality forage grass, have tick-repellent properties (Mwangi *et al.*, 1995), and reduce the effect of weedy creeping grasses on sugarcane (Conlong and Campbell, 2010). Thus farmers can only benefit from such trials being conducted on their farms. Trials can then have the multiple benefits of further testing the science of push-pull, and also contributing to farmers' experiential learning about the method.

By demonstrating the important pest regulatory ecosystem services which wetlands provide (Chapter 6), a whole new set of research questions has been raised. Research has shown that the size of natural habitat fragments such as wetlands can have an effect on pest species and their natural enemies (Tscharntke *et al.*, 2002; Elzinga *et al.*, 2005), and the size of wetland habitats needed to 'protect' certain areas of sugarcane from stem borers, including *E. saccharina*, needs to be determined. The movements of *E. saccharina*, and its natural enemies, between the sugarcane habitat and the wetland habitat also need to be studied further. The outcomes of both of these proposed research topics will aid in valuing the pest regulatory ecosystem services provided by wetlands, which will provide farmers with economic motivation to conserve and manage their wetlands. This is particularly important in the light of the high costs of removing invasive alien plants from wetlands, which is a key aspect of wetland rehabilitation and management (Turpie *et al.*, 2008).

To provide suitable habitats for *E. saccharina* in cooler inland areas, research needs to be conducted on the suitability of host plants such as *Cyperus latifolius* Poir (Cyperales: Cyperaceae), and similar species, which occur naturally in these areas. Alternatively, trials need to be undertaken with the known favoured host plants of *E. saccharina* (*C. dives* and *C. papyrus*) to determine whether they can establish sufficient populations in cooler inland areas, despite these being outside of the natural range of these two species (van Ginkel *et al.*, 2011).

7.7 Closing synthesis

This study has made an important contribution to the science of agroecology in the context of sugarcane pest management. Agroecology is a growing scientific discipline, in which farmers and researchers work together as partners to achieve sustainable agricultural production by optimizing biological and technological components of farming within ecological principles (Warner, 2008; Wezel *et al.*, 2009). Agroecological practitioners recognise that farmers have local knowledge and experience which is invaluable (Altieri and Nicholls, 2004). The farmers' socio-economic and agro-ecological context is taken into account in the development and implementation of improved agricultural practices, and environmental sustainability is seen as an essential goal of farming. These are also the fundamental principles of the SUSFARMS system currently being promoted in the South African sugar industry (Maher, 2007). By implementing the working model suggested in this study, push-pull could act as a driving force for agroecology in the South African sugar industry. If followed correctly, it will move sustainable farming practices off the pages of journals and manuals, onto farmers' fields.