Agronomy for Sustainable Development (2022) 42:90
https://doi.org/10.1007/s13593-022-00814-3

RESEARCH ARTICLE

Gendered perception of change in prevalence of pests and management in Zimbabwe smallholder irrigation schemes

Liboster Mwadzingeni[1] · Raymond Mugandani[2] · Paramu L. Mafongoya[1]

Accepted: 27 July 2022 / Published online: 1 September 2022

Abstract

A better understanding of gendered perception on the prevalence and management of pests in irrigated agriculture in the context of a changing climate can help recommend more gender-sensitive policies, particularly in smallholder farming systems. Limited studies have been conducted to assess gender differences in perception of the prevalence and management of pests among smallholder irrigation schemes especially in Zimbabwe. This study is the first one to assess gendered perceptions on the change in prevalence and management of pests in Exchange, Insukamini, and Ruchanyu irrigation schemes in Zimbabwe. Semi-structured questionnaires were administered using face-to-face interviews with participants. Data from focus group discussions and key informant interviews were used for validating data from questionnaire interviews. Mann-Whitney *U* test was employed to assess perception on the prevalence of pests between male and female farmers. Findings from this study depict that the females perceived a higher prevalence of bollworms (*Helicoverpa armigera*) ($P \leq 0.01$), fall armyworms (*Spodoptera frugiperda*) ($P \leq 0.01$), red spider mites (*Tetranychus urticae*) ($P \leq 0.01$), and maize grain weevils (*Sitophilus zeamais*) ($P \leq 0.01$) than males, while males perceive a higher prevalence of termites (*Isoptera*) ($P \leq 0.01$) and cutworms (*Noctuidae*) ($P \leq 0.01$) than females. Both male and female farmers perceived a greater increase in prevalence of aphids (*Aphidoidea*). Here, we show that farmers' perceptions of changes in pest prevalence and pest management strategies differ by gender. Gender perception on change in prevalence of pests can be a valuable resource for the sustainable development of smallholder irrigation farming system and scientific research.

Keywords Pest control · Female farmers · Male farmers · Food security · Pesticides · Pest management capacity

1 Introduction

Crop production is threatened by climate change, particularly in arid and semi-arid regions of the world (Nhemachena et al. 2020). Irrigation offers a credible entry point to adapt to the negative impacts of climate change in these regions. However, despite their enormous benefits in reducing moisture stress, irrigation might encourage the proliferation of new and emerging pests (Gullino et al. 2021). Irrigation results in humid conditions that contribute to the build-up of pests, reaching an outbreak (Sithanantham et al. 2002). In order to take advantage of the role played by irrigation in climate change adaptation, pest management is crucial to reduce pest-related losses and improve agricultural productivity. Therefore, understanding pest management from the lens of the farmer is important for the successful control of insect pests under irrigated agriculture, more so given that climate change has significant implications for insect pests in agriculture (Shrestha 2019). Thus, perception of the prevalence of pests is increasingly becoming important in pest management in view of the economic damage caused by pests.

Globally, an average yield loss of 21.5% for wheat (*Triticum*), 30.0% for rice (*Oryza sativa*), 22.5% for maize (*Zea mays*), 17.2% for sweet potatoes (*Ipomoea batatas*), and 21.4% for soya bean (*Glycine max*) can be attributed to pests alone (Savary et al. 2019; Gullino et al. 2021). Pests are more economically relevant in Africa, where crop losses equivalent to approximately USD 4.4 billion were attributed to pests from 1980 to 1990 (Biber-Freudenberger et al. 2016).

✉ Liboster Mwadzingeni
libomwadzi@gmail.com

[1] School of Agriculture, Earth and Environmental Sciences, University of KwaZulu-Natal, Carbis Road, Scottsville, Pietermaritzburg 3201, South Africa

[2] Faculty of Agriculture, Environment and Natural Resources Management, Midlands State University, Gweru 9055, Zimbabwe

Available evidence shows that climate change contributes to the increased risk of pests affecting crops across the agricultural systems of Africa (Dhanush et al. 2015; Karuppaiah and Sujayanad 2012; Bjorkman and Niemela 2015). In sub-Saharan Africa (SSA), crop pests alone result in the loss of one sixth of agricultural productivity (Dhanush et al. 2015). More specifically, in 2018, an estimated yield loss of 11.6% was attributed to the fall armyworm (FAW) in Zimbabwe, albeit from two districts only (Baudron et al. 2019).

Irrigation development may exacerbate the agricultural losses attributed to pests. Empirical evidence shows that some pests, such as fall armyworm (FAW), which cannot survive in cold conditions, favor warm moist conditions (Nagoshi et al. 2012). Meanwhile, for infection, fungi prefer high relative humidity or wet leaf surfaces (Cairns et al. 2012). Thus, these might have implications for infection rates in irrigated agriculture. Increased warming conditions increase irrigation water demand on already water stressed systems (Nhemachena et al. 2020). By the 2070s or 2080s, increasing evaporative demand due to higher temperatures and longer growing seasons might raise crop irrigation requirements globally by 5 to 20%, or even more (Gornall et al. 2010). Irrigation of maize in the region has enhanced insect-vector populations, resulting in higher Maize streak virus pressure in irrigated crops (Gullino et al. 2021). Pest outbreaks were widespread in SISs, according to a study conducted in KwaZulu-Natal (Matthews 2017). Meanwhile, a study in Namibia acknowledges that irrigation areas are an environment where pests outbreaks are rampant (Charamba et al. 2018). These studies show that irrigation has its own share of challenges as far as pests are concerned. The impacts of pests will be felt more by smallholder farmers who have limited economic means to cope with the impact of climate change (Biber-Freudenberger et al. 2016). For instance, a majority of farmers in Africa have limited capacity to purchase insecticides (Sisay et al. 2019).

Over the years, SSA has embarked on massive investment in irrigation systems (Xie et al. 2014), including smallholder irrigation schemes. In Zimbabwe, by the year 2020, a total of 450 smallholder irrigation schemes on an area of 26 000 ha have been developed in rural areas (GoZ 2020). These have immensely benefited rural communities through employment creation, income generation, and broaden livelihood options.

In developing countries such as Zimbabwe, both males and females are involved in agriculture, but women provide 70% of the total labor force in agriculture (FAO 2017; Huyer and Nyasimi 2017). At the same time, there is a significant proportion of female participation in irrigated agriculture in Zimbabwe (FAO 2017). Nonetheless, women have limited access to extension services, education, credit, agricultural inputs (Fu and Akter 2016), and capacity-building due to structural barriers that create gender gaps and inequalities (Huyer and Nyasimi 2017; Wang et al. 2017). These gender inequalities, if not recognized, have severe repercussions on agricultural transformation and development (FAO 2010). A gendered approach to farmers' perception on the implications of irrigated agriculture on pest prevalence is imperative to reduce crop losses and avert food insecurity. This is particularly relevant for a majority of countries in SSA region, including Zimbabwe. In the majority of the countries in SSA, women provide 50% of the labor force (Raney et al. 2011) while in Zimbabwe, women constitute 70% of the agricultural labor force (FAO 2017). Paradoxically, female farmers in Africa, "are excluded from conversations that determine agricultural policies, while discriminatory laws and practices deprive them of their land, their rights, and their livelihoods" (GFFW 2015). In Zimbabwe, there is an improved push towards the principle of 'leaving no one behind' (MoHCC 2017) and the concept of gender equality and policies to promote gender-sensitive agricultural training (FAO 2017). Thus, it is crucial to understand the gendered dimension of the implications of climate change on pest prevalence in the marginal rural areas of Zimbabwe , where a large proportion of population is being left behind (Machingura and Nicolai 2018), to formulate policies that address the gendered aspect of pest management, including the effective allocation of human and financial resources.

Perception is a cognitive contact with the surrounding environment, based on an individual's primary awareness, learning, memory, expectation, and attention (Bernstein 2018). Perception of the threat of environmental problems influences environmental attitude and ecological behavior, hence determining the practices individuals engage in (Milfont et al. 2010). Perception of the prevalence of pests translates into decisions on pest management practices in response to changing occurrence of pests (Awudzi et al. 2021). Incorrect pest perception can result in uneconomic use of pesticides and poor integration of pest management as farmers lack knowledge on the environmental and economic importance of target pest (Awudzi et al. 2021). Therefore, there is need to assess farmers' perception on change in prevalence of pests in SISs in order to understand its contribution to pest management.

The gendered evaluation of pests specifically focusing on irrigation agriculture has received limited research attention. Such studies are particularly relevant in SSA and especially in Zimbabwe, considering the attention given to irrigated agriculture and the role played by women in these farming systems.

Unfortunately, to the best of our knowledge, the gendered perception of pest prevalence research is scarce in Zimbabwe. This is a paradox, given that a majority of women are farm laborers and involved in pest control. This article seeks to use the gendered perception on the changes in prevalence of pests, assess pest management, and recommend policy implications in the context of irrigated agriculture under climate change in smallholder irrigation schemes of Zimbabwe. This study seeks to assess the interaction between trends in pest problems and farmers' choices of intervention.

2 Methodology

2.1 Study area

To answer the objectives of this study, we conducted our research in three smallholder irrigation schemes in Midlands Province, Zimbabwe (Fig. 1). We selected Midlands Province for this study since it is among the top three provinces with the highest number of smallholder irrigation schemes (GoZ 2020). Therefore, this study will be of significant reference to gendered perception on the prevalence and management of pests in relation to climate change in Zimbabwe and the SSA region.

Three schemes, namely Exchange, Insukamini, and Ruchanyu, were considered for this study. Exchange irrigation scheme is located in Silobela communal area, Kwekwe District, approximately 60 km North-West of Kwekwe town. It has about 168.8 ha of irrigable land developed partly from 1973 and 1985 (SIRP 2017, Nyamayevu et al. 2015). A total of 982 households currently occupies Exchange irrigation scheme. The scheme is in an agroecological zone (AEZ) IV with semi-arid climatic conditions, receiving an average rainfall ranging from 450 to 650 mm (Chanza et al. 2019). The soils are highly fertility clay loam. Irrigation water is drawn from Exchange dam. Maize and sugar beans (*Phaseolus vulgaris*) are the main crops grown in Exchange irrigation scheme, yielding an average of 15t and 2.1t per ha, respectively (SIRP 2017). Farmers in the scheme have challenges to reach a more reliable market due to poor road network (SIRP 2017).

Insukamini irrigation scheme is located in Lower Gweru communal area, Gweru District, Midlands province, Zimbabwe. It is nearly 45 km North-West of Gweru, the Midlands provincial town. It has a total of 41 ha developed in 1988 and is occupied by 125 households (Matsa 2012). The scheme is located in AEZ IV, with annual rainfall ranging from 600 to 800 mm (Matsa 2012). The soils in the scheme are sandy loam and clay loam. Its water comes from Insukamini dam through a 1.6-km-long concrete canal. The principal crop farmed in the Insukamini irrigation network is maize.

Ruchanyu irrigation scheme is located in Shurugwi district, about 62 km south-west of Gweru town. It has about 27 ha of irrigable land developed in the early 1980s (Mhembwe et al. 2019). A total of 85 households currently operates the scheme

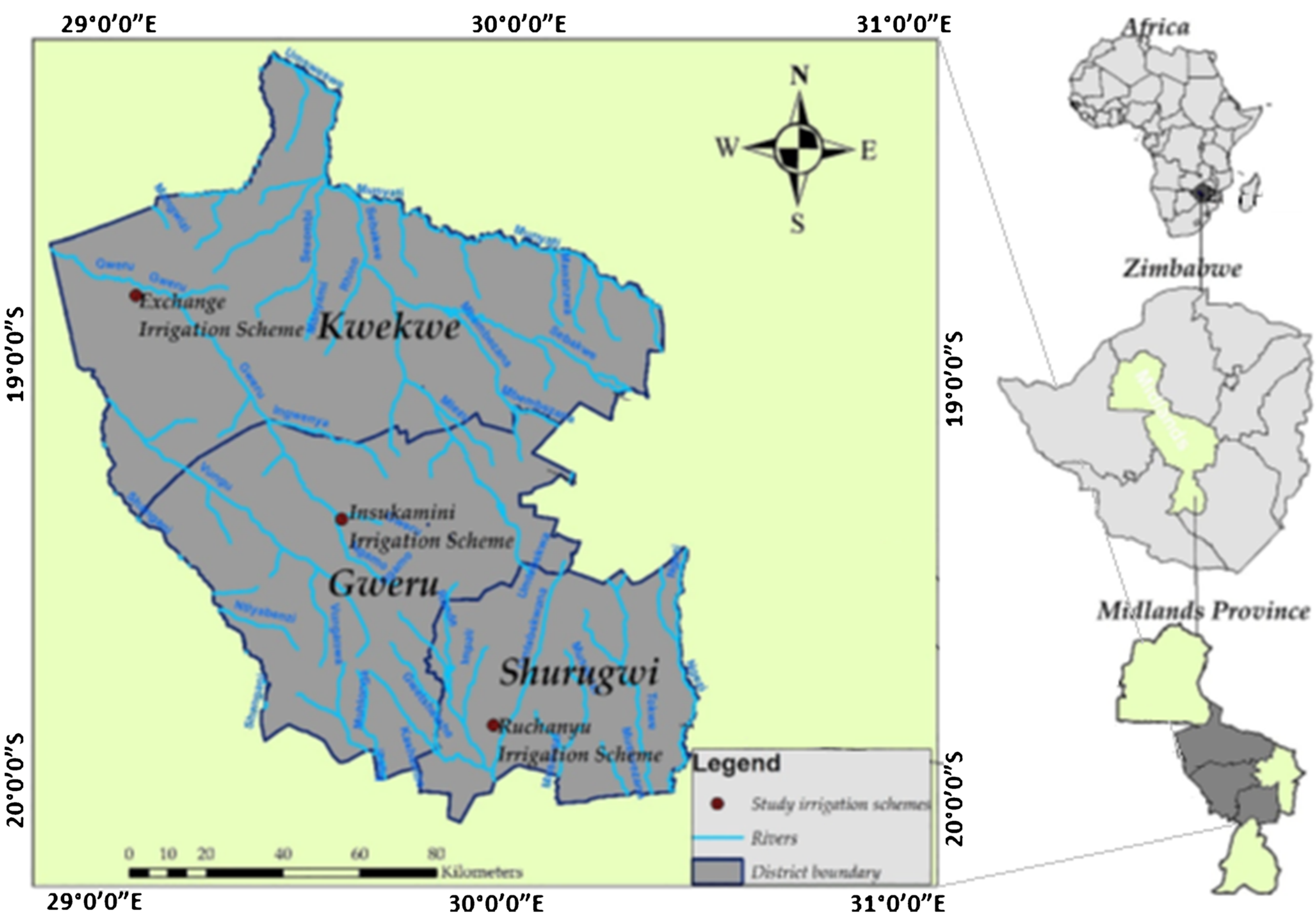

Fig. 1 Map of the study area

(Mhembwe et al. 2019). It is in AEZ III with annual rainfall ranging from 650 to 850 mm (Mhembwe et al. 2019). The soils in the scheme are classified as sandy loam (Mhembwe et al. 2019). Water is pumped from Mutevekwi River (Mhembwe et al. 2019). Maize is the main crop grown by farmers in the scheme. The farmers do not have a well-established market for the crop, as the local market cannot purchase all the produce.

2.2 Data collection

A questionnaire survey was used to collect data for this study. In questionnaire-based survey, a total of 200 men and 117 women participated. A total of 29 females and 32 males participated in six focus group discussion (FDGs). A total of six FDGs were segmented into three groups of males and three groups of females to preserve gender differences and allow females to participate fully in the absence of men. A total of 7 male and 6 female key informants (KIIs) were interviewed. Data collected using FGDs and KIIs were triangulated with the findings from the questionnaire. Gender, social class, and age were considered when choosing participants from FDGs and KIIs for equal representation. We did a pilot study to test the suitability of the data collection tools for the study. We used a random selection to select 317 participants for this study. We used a sample selection formula in Eq. (1) below to calculate the sample size. FGDs were done with 10–15 randomly selected participants who did not participate in questionnaire interviews. FGDs help to have a clear understanding of perception on the prevalence of pests in the schemes. KIIs provide expert information about changes in pests, pest control, and crops affected by each type of pest.

$$n = \frac{N}{Ne^2} \quad (1)$$

where is n sample size, N population, and e confident interval

For this study, we administered a semi-structured questionnaire using face-to-face interviews with the respondents. Farmers were asked to rank the prevalence of pest that includes cutworms (*Noctuidae*), red spider mites (*Tetranychus urticae*), maize grain weevils (*Sitophilus zeamais*), fall armyworms (*Spodoptera frugiperda*), bollworms (*Helicoverpa armigera*), and termites (*Isoptera*). Pest were communicated using pests' local names of and their photograph for easy identification. Respondents were able to accurately identify pests and were able to distinguish them due to their increased contact with extension workers who were stationed at schemes. These findings were in contrast with Mkenda et al. (2020) which have shown relatively poor awareness of some insect groups among some smallholder farmers. The participants were asked the following questions: can you please rank the changes in prevalence of the following pests in past 10 years? (strongly decrease [1], decrease [2], no change [3], increase, strongly increase [5]); which major strategy do you use to control insect pests? (insecticides [1], biological [2], cultural [3], integrated insect pest management [4]); how frequent do you spray these chemical insecticides? (twice/week [1], once/week [2], twice/month [3], once/month [4], once visible [5]).

2.3 Data analysis

Data for this study was collected using a five Likert scale response. This was due to our interest in participants' perception of the prevalence of pests in response to climate change. SPSS version 27 was mostly utilized for statistical data analysis, whereas Excel was used to create graphs. For this study, data was collapsed to a binary response. Responses with Strongly Decrease and Decrease were coded (0); No Change were coded (1), while those with Increase and Strongly Increase were coded (2). The codes listed above were used as the dependent variables indicating amount of change in prevalence, with gender as the independent variable to test whether the ranked perception of change differs. Mann-Whitney U test was used to compare perceived change in pest prevalence according to farmer gender. We did not actually survey current prevalence of pests, but rather perception of changes in pest prevalence. The Mann-Whitney U test was used to test the null hypothesis that there is an equal perception of the prevalence of pests between male and female respondents since the respondents are from the same set of schemes. The differences in perception on the prevalence of pests were considered significant at $p = 0.05$. Chi-squared test was used to test differences between male and female farmers in term of socio-demographic factors and pests management approaches in many individual tests, except for age which was tested using the ANOVA.

3 Results and discussion

The socio-economic characteristics of respondents of this study are shown in Table 1. Results show that male farmers were significantly more likely to be married than female farmers ($P \leq 0.01$). On average, both male and female participants in the schemes were literate. The schemes consist of aging scheme farmers averaging 55 years for males and 54 years for females.

There were statistically significant differences ($P \leq 0.05$) between male and female farmers on knapsack sprayer ownership, where more males (64.1%) owned knapsack sprayers compared to their female (50%) counterparts.

Table 1 Socio-demographic and economic attributes (significance code: * $p \leq 0.05$, ** $p \leq 0.01$, *NS* not statistically significant, *SD* standard deviation).

Variable	Male		Female		Significant level
	Mean (SD)	Percentage	Mean (SD)	Percentage	
Marital status (Married)		89.5		46.2	**
Education (years)	9 (3)		8 (3)		
Age (years)	55 (13)		54 (13)		
Fulltime farmer		86.0		92.3	NS
Knapsack sprayer owners		64.1		50	*

3.1 Perception of pest prevalence

In general, Fig. 2 illustrates that scheme farmers perceive an increase in prevalence of pests under climate change. A changing trend of pests due to climate change is evident in Zimbabwe (Kutywayo et al. 2013; Ch 2013; Mafongoya et al. 2019). The outbreak of pests is a constraint to agriculture production in Zimbabwe and climate change results in rising pest pressure (Mafongoya et al. 2019). Female farmers are increasingly involved in controlling pests, which contributes to their awareness of the prevalence of pests. Earlier studies on pest prevalence have been based on simulations and laboratory and field experiments to determine the prevalence of pests (Kutywayo et al. 2013; Gullino et al. 2021), which may be of limited implications for pest management in the smallholder farming sector. This study will help policymakers to improve policies through understanding the gendered perception on the change in prevalence of pests in Zimbabwe. Results from this study found gender differences in perception on the change in prevalence of pests.

The results for assessing the gendered perception of changes in pest prevalence are shown in Tables 2 and 3. The results reveal a gendered perception of changes in pest prevalence in the three schemes considered for this study. Tables 2 and 3 highlighted that farmers in smallholder irrigation schemes were aware of the changing prevalence of crop pests. Generally, the respondents have perceived an increase in prevalence of pests. The results are consistent with findings by Gullino et al. (2021), who found that the majority of studies in cereals and horticultural crops indicate a spike in pests risks in subtropical agricultural systems under climate change. Increase in prevalence of pests results in rising plant health problems in agricultural systems (Gullino et al. 2021). Studies like Juroszek et al. (2020) and Bjorkman and Niemela (2015) indicate that pest risk will increase in agricultural ecosystems under climate change, and impacts vary with the system's potential and natural ecosystem. Invasive expansion of pests results in economic and social damage by decimating crops (Juroszek et al. 2020). According to Edmonds (2013), prevention, mitigation, and adaptation are needed to reduce projected pest risks in agriculture.

The prevalence-change codes in Fig. 2 show that pests like aphids, cutworms, bollworms, red spider mites, whiteflies (*Aleyrodidae*), and FAW are becoming more severe. According to Shaw and Osborne (2011), climate-driven crop management adaptations like irrigation have permitted year-round crop cultivation, as well as increasing pests and vector prevalence. The increase of crop pests reduces availability and access to appropriate quality of food through yield reduction of food and cash crops, reducing the utilization of food with additional and inappropriate pesticide use, making food unhealthy for humans and livestock (Van der Fels-Klerx et al. 2016, FAO 2008), and consequently, reduce the stability of food through direct losses and reduction of income (FAO 2008). However, perception of change in pest prevalence is essential to predict their impacts on crop yields and project pest management practices (Scherm 2004, Andrew and Hill 2017, Katsaruware-Chapoto et al. 2017).

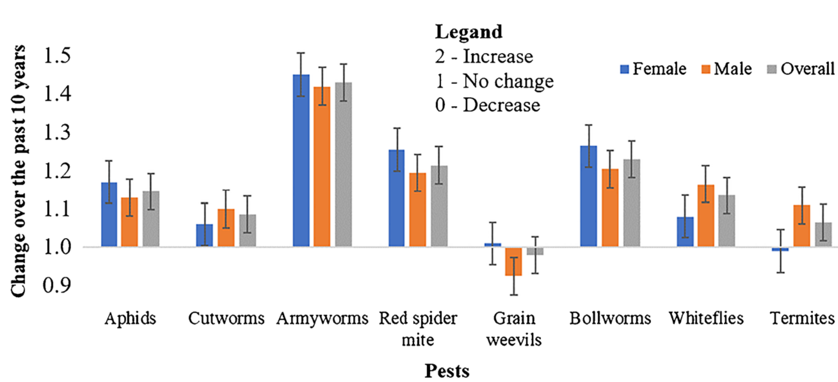

Fig. 2 Perception of change in pest abundance due to climate change according to gender

Table 2 Ranks of gendered perception on change in pest prevalence (*N* the number of respondents who paid attention to the prevalence of a particular pest, mean rank shows the gender's level of perception on changes in pest prevalence, sum of ranks—shows genders' total rank of perception on changes in pest prevalence). The "ranks" here are derived by ordering the entire data set (gender aggregated) of prevalence-change codes for each pest from lowest to highest, and then disaggregating by gender and calculating a mean of the rank values.

	Gender	*N*	Mean rank	Sum of ranks
Aphids	Female	116	156.66	18172.00
	Male	192	153.20	29414.00
	Total	308		
Cutworms	Female	116	150.07	17408.50
	Male	192	157.17	30177.50
	Total	308		
Fall Armyworms	Female	116	155.20	18003.20
	Male	192	152.02	29187.84
	Total	308		
Red spider mite	Female	116	164.12	18873.50
	Male	192	147.11	28097.50
	Total	308		
Maize grain weevils	Female	116	158.40	18374.40
	Male	192	145.47	27930.24
	Total	308		
Bollworms	Female	116	152.42	17680.72
	Male	192	146.60	28147.20
	Total	308		
Whiteflies	Female	116	143.74	16674.00
	Male	192	158.68	29991.00
	Total	308		
Termites	Female	116	143.99	16703.00
	Male	192	158.53	29962.00
	Total	308		

The perception of pest prevalence shows that female farmers perceive a greater increase in prevalence of most pests than males, who perceive a bigger increase in the prevalence for only three types of pests (Table 2). Male and female farmers have a similar perception of the change in prevalence of aphids. Thus, in relation to female participants, male participants perceive an increase in prevalence of cutworms (U = 10622.50, $p \le 0.01$).

In contrast, female farmers perceive a bigger increase in FAW prevalence than their male counterparts (U = 10848.00, $p \le 0.01$). On the other hand, female participants significantly perceive a higher increase in prevalence of red spider mites than male participants (U = 9761.50, $p \le 0.01$). Similarly, female farmers perceive no change, while male farmers perceive a substantial decrease in prevalence of maize grain weevils than female participants (U = 10088.50, $p \le 0.01$). Also, female farmers significantly perceive an increase in prevalence of bollworms than male farmers perceive on change (U = 10776.50, $p \le 01$). Further, female farmers perceive no change, while male farmers perceive an increase in prevalence of termites (U = 9917.00, $p \le 0.01$) (Table 3).

This study shows that perception of the change in prevalence of pests significantly differs between male and female participants, creating winners and losers in the face of climate change. Perception of change in pest prevalence vary with gender. Farmers who took part in the focus groups revealed that their perspective of pest prevalence has changed as a result of their experiences with pest outbreaks, pest control, crop losses, and extension worker awareness. Farmers who participate in FGDs suggest that their perception on the prevalence of pests shapes how they manage pests.

In contrast, male farmers perceive a higher increase in prevalence of cutworms, termites, and whiteflies (Tables 3 and 4). The perception of the change in prevalence of most pests relates to variation in moisture regimes, determining the group which is more exposed to pests under water stress and excessive water application conditions. Our findings suggest that female farmers participate in irrigation farming and pest control during the water-stressed period and when irrigation water is abundant. Meanwhile, several studies identify seasonal migration of male farmers (Mohammed 2019, Biswas et al. 2019, Choithani et al. 2021), leaving female farmers

Table 3 Mann-Whitney *U* test for perception on change in pest prevalence (*Asymp. Sig.* asymptotic significance, *p-value* p-value based on the normal approximation, *Exact Sig.* actual significance p-value). If Asymp. Sig. (2-tailed) and Exact Sig. (2-tailed).

	Aphids	Cutworms	Fall armyworms	Red spider mite	Maize grain weevils	Bollworms	Whiteflies	Termites
Mann-Whitney U	10886.00	10622.50	10848.00	9761.50	10088.50	10776.50	9888.00	9917.00
Wilcoxon W	29414.00	17408.50	17634.00	28097.50	16874.50	29112.50	16674.00	16703.00
Z	0.357	–0.720	–0.363	–1.768	–1.323	–0.435	–1.540	–1.491
Asymp. Sig. (2-tailed)	0.157	0.000	0.001	0.000	0.003	0.000	0.094	0.000
Exact Sig. (2-tailed)	0.157	0.000	0.001	0.000	0.003	0.000	0.094	0.000
Exact Sig. (1-tailed)	0.081	0.000	0.000	0.000	0.002	0.000	0.047	0.000
Point probability	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Table 4 Major pests, perception of pest prevalence, and strategies used to control pest (significant codes: * - $p \leq 0.05$). Farmers were allowed to select one strategy.

Pests	Gender	Pest management strategies (%)		
		Insecticides	Cultural	Integrated pest management
Aphids	Male	63.80	0.00	37.20
	Female	57.70	1.90	38.50
Cutworms*	Male	66.70	0.00	33.30
	Female	72.70	6.10	21.20
Fall Armyworms	Male	72.10	0.00	26.40
	Female	64.40	2.70	31.50
Red spider mites*	Male	68.50	0.00	31.50
	Female	80.30	1.60	14.40
Maize grain weevils	Male	70.90	0.00	27.30
	Female	73.90	4.30	21.70
Bollworms	Male	69.10	0.00	29.80
	Female	62.50	3.60	32.10
Whiteflies	Male	67.70	0.00	31.20
	Female	68.30	2.40	29.30
Termites	Male	67.50	1.20	30.10
	Female	68.40	5.30	23.70

responsible for farming activities. Women are key players in SISs in rural areas in Zimbabwe (Chazovachii 2012). This is not surprising since male farmers are seasonally involved in off-farm activities leaving females to takeover irrigation farming duties (Chazovachii 2012).

Perception of the change in prevalence of pests is an essential factor in implementing effective pest management practices (Katsaruware-Chapoto et al. 2017). From this study, the gendered perception of the change in prevalence of pests is critical for better awareness of the gendered view of the change in prevalence of pests in SISs and the area in which future investment might need to be directed. These findings imply that the gender of the person does not limit their perception of change in pest prevalence; hence, views from both males and females on pest trends should be valued equally. Consequently, female farmers are equally observers of pest incidences as their male counterparts (Atreya 2007; Whyte 2014). Their context of observations should be well understood and considered during policy formulation and decision-making.

Results in Tables 2 and 3 of the gendered perception of change in pest prevalence may relate to variation in gender roles, asset endowments, crop choices, pest management, asset endowments, and resource ownership (Sharaunga and Mudhara 2021; Whyte 2014; Atreya 2007). In Zimbabwe, men have greater access, ownership, and control of resources and services than women (FAO 2017). Given that the majority of female household heads were unmarried (Table 1), they own land and experience control over production decisions and expenditure (Badstue et al. 2020). Unmarried women in SISs in Zimbabwe actively participate in male-aligned farming activities and make choices on crops grown (Chazovachii 2012). Hence, they are actively instrumental in monitoring and controlling pests as their male counterparts. However, considering that their high literacy rate and involvement in full-time farming are similar to that of male farmers (Table 1) (Chazovachii 2012), their perception of the change in prevalence of pests is of significant importance.

Additionally, the prevalence of patriarchal society and traditionally the confinement of women in homes influences the crops they grow and pests they are likely to observe, improving their perception of the change in prevalence of such pests (FAO 2017). Despite the ability of female farmers to observe the change in prevalence of pests, their frequency of spraying was lower compared to that of men and experienced poor pest management compared to male farmers. This may be attributed to asset endowment and dominant ownership of production resources by men (Atreya 2007), as the majority of knapsack sprayers are owned by male farmers.

The significant relationship between gender and perception of the change in prevalence of maize grain weevils ($p \leq 0.01$), where women have a significant perception of a higher increase in prevalence of maize grain weevils than men, might relate to the role of women in the household. Women are mostly responsible for preparing food for the household, giving them better access to post-harvest storage facilities than men (Savari et al. 2020, Mclaughlin et al. 2003, Mazuru 2019). Maize weevils are mostly encountered in stored food in the home, not in the field. Nevertheless, this study shows that males significantly perceived an increase in prevalence of

FAW, bollworms, and whiteflies compared to females ($P \leq 0.01$). According to FAO (2017), men and women participate in crop and horticultural production; hence, the perception of the change in prevalence of pests of both male and female farmers is substantial.

Despite female farmers' perception of rising trends of pests, they have reported that they are facing challenges in pest management. Male farmers are significantly more likely to own knapsack sprays compared to female farmers. Technological uptake by women in Zimbabwe depends on its ease to use and friendliness (FAO 2017). Similarly, the spraying frequency of female farmers is lower than that of their male counterparts, despite their perception of increasing incidences of pests. According to FAO (2017), there is gendered ownership of valuable resources in rural Zimbabwe and access to training and extension services. Gender-sensitive training and extension services are critical to address gendered pest management challenges. According to Kawarazuka et al. (2020), women's failure to spray is due to limited financial resources, knowledge, and access to information (Kawarazuka et al. 2020). Further, females and males were found to adopt different pest control methods (Kawarazuka et al. 2020); hence, there is a need to assess and consider gendered pest control methods. In a study in KwaZulu-Natal, South Africa, poor capital asset endowments, socio-economic factors, livelihood strategies, and transforming structures and processes were blamed for challenging investment opportunities of female farmers in rural communities (Sharaunga and Mudhara 2021).

Change in pest prevalence can be exacerbated by climate change (Gullino et al. 2021) and the condition of the scheme. Among the conditions experienced in the scheme is the excessive application of water which could result in fungi infestation. Also, scheme farmers differ their crop rotation cycles across seasons, pose a challenge of rotating pests as they can shift from the host plot to the next across seasons given that plots are closer to each other. Further, growing the same crop across the scheme during the same season posed challenges as some farmers were not controlling pests, making pests more invasive and spreading faster. For instance, most of the harvested onions in Insukamini were not sold due to an increased supply. Implementing collective decisions on pest control in SISs is difficult due to the myriad of challenges that the scheme farmers face.

3.2 Gender and pest management

Table 4 illustrates the relations between gender and strategies used to control pests considered for this study. Several existing methods of control of pests are categorized under insecticides, cultural, and integrated pest management (IPM). Although farmers in the scheme use a variety of pest management strategies, use of pesticides was dominant across the pests considered for this study. However, high chemical insecticides application rate is highly associated with insecticide resistance (Tibugari et al. 2012). Although pesticides minimize crop loss, they result in contamination of the ecosystem and undesirable health effects (Barzman et al. 2015). Nonetheless, Scott et al. (2018) recommend that the use of nanotechnology-produced pesticides may potentially improve the efficacy and safety of pesticides; however, its availability in developing areas is a limiting factor.

There is significant gender variation on the pest management strategies for cutworms and red spider mites ($p \leq 0.05$) (Table 4). Females use pesticides more than males to control cutworms and red spider mites, whereas males utilize IPM more than females. Some measures of pest control utilized during IPM include proper field management, use of resistant varieties, and crop rotation. An IPM strategy is a practical and recommended option for reducing the usage of chemical pesticides. (Munkvold and Gullino 2020) and (Thomas et al. 2017) recommend integrated IPM, among other strategies, to control pests in face of increasing threats from pests due to climate change. Therefore, we recommend farmers to adapt to integrated pest management strategies related to the diversity of their farming system, capacity, and agroecosystems' nature. For the rest of the pests studied, there was no significant gender variation in pest management measures (Table 4). The type of pests being controlled contributes to gender variation in pest management strategies.

However, there is much room to improve pest management on farms resulting in cost-benefit improvements. Jactel et al. (2020) suggest using an interdisciplinary approach as an important way to manage the new and emerging pest species by considering knowledge gained from different disciplines. Crop insurance is also an attractive alternative to protect farmer's livelihood under climate change. It is evident that climate change is increasing the problem related to pests in managed ecosystems. Surveillance, monitoring, and pest risk analysis are vital for evaluating the introduction, spread, and economic consequences of pests and are essential to identify potential pest management options to reduce the risk of pests to acceptable levels (Gullino et al. 2021). Climate-smart pest management based on selected existing management methods enhances mitigation and strengthens resilience. Pest management improvements is valuable, with or without climate change scenarios. Dilling et al. (2015) assert that there is much potential to improve on-farm and regional pest management systems. Building pest management capacity in farming systems is of paramount importance to maintaining current and future food security and managing financial risks. Adjusting plant protection protocols to suit current and future climate change scenarios is crucial to maintaining and preserving current and future food security (Gullino et al. 2021).

Table 5 indicates the gendered frequency with which chemical pesticides are sprayed to combat various pests. As shown in Table 5, farmers, there is a significant ($p \leq 0.05$)

Table 5 Frequency of spraying chemical pesticides (significant codes: ** - $p \leq 0.01$).

Pests	Gender	Twice a week	Once a week	Twice a month	Once a month	Once visible
Aphids	Male	5.30	34.00	25.00	15.40	1.10
	Female	9.60	46.20	38.40	3.90	1.90
Cutworms	Male	5.10	33.30	39.70	39.70	2.60
	Female	6.10	33.30	27.30	27.30	0.00
Fall Armyworms	Male	11.60	28.70	34.90	20.90	3.10
	Female	9.60	38.40	23.30	21.90	1.40
Red spider mites	Male	4.50	36.00	36.10	19.10	2.20
	Female	6.60	26.20	38.20	24.60	1.60
Maize grain weevils	Male	9.10	20.00	43.6	21.80	5.50
	Female	4.30	34.80	26.10	26.10	4.30
Bollworms**	Male	16.00	20.20	40.40	19.10	4.30
	Female	10.70	37.50	21.40	25.00	0.00
Whiteflies	Male	11.80	29.00	40.90	16.10	2.20
	Female	14.60	39.00	26.80	17.10	0.00
Termites	Male	3.60	34.90	38.60	20.50	3.60
	Female	2.60	26.80	28.90	26.30	2.60

gendered variation on application frequency of chemical to control bollworms. On control for bollworms, more male farmers spray a minimum of twice a month than female farmers. However, for the rest of the pest, the relationship is not significantly different for male and female farmers.

3.3 Policy implications of the study

The increase in prevalence of pests due to climate change is transforming food safety policies (Carvalho 2017), food security policies (Gregory et al. 2009), phytosanitary measures (Eschen et al. 2015), and pest management policies and practices (Heeb et al. 2019). Hence, perception of the change in prevalence of pests is an integral element of policy formulation in recent years. Several studies encourage the need to understand the impact of pest prevalence on food safety (Carvalho 2017), food security (Savary et al. 2019), and pesticide management strategies (Andrew and Hill 2017) through understanding human perception, which shapes their behaviour and attitude of farmers.

Pests are an integral part of the food systems and have impacted crop production via crop yields losses (Gullino et al. 2021). In the context of climate change, pests are believed to expanding their range, increasing in population and increasing their generations (Gullino et al. 2021; Biber-Freudenberger et al. 2016). Male and female farmers participate in crop production (Akter et al. 2016) and pest management (Wang et al. 2017). Therefore, an improved understanding of the gendered perception of the change in prevalence of pests may enable policymakers to design policy control measures with respect to female farmers.

Findings from this study might be useful for organizations like Food and Agriculture Organisation (FAO), International Plant Protection Convention (IPPC), Food Safety Authority (FSA), and national governments on designing pest control programs targeted at female farmers. The insights from this study can be extremely valuable for policymakers to facilitate policies to reduce the impacts of pests and address gender differences at the farm, regional and national levels.

4 Conclusions

This study for the first time assessed the gendered perception of the change in prevalence of pests and existing pest management practices under irrigation schemes. Our study results show that both male and female farmers were aware of trends of pests under climate change. Female participants perceived a higher increase in prevalence of cutworms, red spider mites, maize grain weevils, and termites, while male participants have a distinct perception of the higher increase in prevalence of FAW, bollworms, and whiteflies. Participants in this study reported a rising number of aphids, cutworms, FAW, red spider mites, bollworms, whiteflies, and termites and a decrease in maize grain weevils. Perception of the change in prevalence of pests shapes the behavior of farmers towards changing pest trends and pest management practices of farmers. Policymakers and researchers are recommended to acknowledge the gendered perception of the change in prevalence of pests in policy formulation. Based on the study findings, perception of the change in prevalence of pests helps researchers understand the awareness of scheme farmers about the impacts of climate change in Zimbabwe and the region. Further, this study has implications for pest management practices and food security. It recommends surveillance and monitoring of pests, integrated pest management practices, interdisciplinary approaches to managing pests, crop insurance, and building pest management capacity for farmers must be pursued by extension services and research organizations.

Acknowledgements The authors acknowledge AGRITEX Management in the Midlands Province for their support on logistical arrangements and providing technical information about the three schemes during the study. We would also like to thank the extension workers and farmers in Exchange, Insukamini, and Ruchanyu irrigation schemes for their patience in responding to the questionnaire. We also acknowledge the enumerators who worked diligently during the survey period.

Authors' contributions Conceptualization, L.M.; methodology, L.M. and R.M.; investigation, L.M. and R.M.; writing – original draft, L.M.; writing –review & editing, L.M.; R.M; and P.L.M.; funding acquisition, P.L.M.; resources, P.L.M.; supervision, R.M. and P.L.M.

Funding This study was funded by South Africa's National Research Foundation (NRF), grant number 86893.

Data availability The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request, in anonymized format, or except the parts revealing personal information about farmers.

Code availability Available upon request to the corresponding author

Declarations

Ethics approval Ethics was approved by the Institutional Review Board of University of KwaZulu-Natal (HSSREC/00003196/2021).

Consent to participate Informed consent was obtained from all participants involved in the study.

Consent for publication Not applicable.

Conflict of interest The authors declare no competing interests.

Open Access This article is licensed under a Creative Commons Attribution 4.0 International License, which permits use, sharing, adaptation, distribution and reproduction in any medium or format, as long as you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons licence, and indicate if changes were made. The images or other third party material in this article are included in the article's Creative Commons licence, unless indicated otherwise in a credit line to the material. If material is not included in the article's Creative Commons licence and your intended use is not permitted by statutory regulation or exceeds the permitted use, you will need to obtain permission directly from the copyright holder. To view a copy of this licence, visit http://creativecommons.org/licenses/by/4.0/ .

References

Akter S, Erskine W, Branco LV, Agostinho OF, Imron J, Spyckerelle L (2016) Gender in crop production in Timor-Leste. In ACIAR: Australian Centre for International Agricultural Research (ACIAR) Proceedings Series 146:158–164

Andrew NR, Hill SJ (2017) Effect of climate change on insect pest management. In *Environmental pest management: challenges for agronomists, ecologists, economists and policymakers*, edited by Eric Wajnberg Moshe Coll, 197:195–223

Atreya K (2007) Pesticide use knowledge and practices: a gender differences in Nepal. *Environ Res* 104(2):305–311. https://doi.org/10.1016/j.envres.2007.01.001

Awudzi GK, Adu-Acheampong R, Avicor SW, Bukari Y, Yeboah MA, Boateng EKO, Ahadzi SK (2021) Farmers' knowledge and perception of cocoa insect pests and damage and the implications for pest management on cocoa in Ghana. J Plant Protec Res:145-155-145-155. https://doi.org/10.24425/jppr.2021.137022.

Badstue L, Petesch P, Farnworth CR, Roeven L, Hailemariam M (2020) Women farmers and agricultural innovation: marital status and normative expectations in rural Ethiopia. *Sustainability* 12(23):9847. https://doi.org/10.3390/su12239847

Barzman M, Bàrberi P, Birch ANE, Boonekamp P, Dachbrodt-Saaydeh S, Graf B, Hommel B, Jensen JE, Kiss J, Kudsk P (2015) Eight principles of integrated pest management. *'Agron. Sustain Dev* 35(4):1199–1215. https://doi.org/10.1007/s13593-015-0327-9

Baudron F, Zaman-Allah MA, Chaipa I, Chari, and Chinwada P (2019). Understanding the factors influencing fall armyworm (Spodoptera frugiperda JE Smith) damage in African smallholder maize fields and quantifying its impact on yield. A case study in Eastern Zimbabwe. *Crop Prot* 120:141-150. https://doi.org/10.1016/j.cropro.2019.01.028.

Bernstein D (2018) *Essentials of psychology*. Cengage learning, Boston, USA

Biber-Freudenberger L, Ziemacki J, Tonnang HEZ, Borgemeister C (2016) Future risks of pest species under changing climatic conditions. *PloS one* 11(4):e0153237. https://doi.org/10.1371/journal.pone.0153237

Biswas RK, Kabir E, Khan HTA (2019) Causes of urban migration in Bangladesh: evidence from the urban health survey. *Popul Res Policy Rev* 38(4):593–614. https://doi.org/10.1007/s11113-019-09532-3

Bjorkman C, Niemela P (2015) Climate Change and Insect Pests. Wallingford, UK: CABI

Cairns JE, Sonder K, Zaidi PH, Verhulst N, Mahuku G, Babu B, Nair SK, Das B, Govaerts B, Vinayan MT (2012) Maize production in a changing climate: impacts, adaptation, and mitigation strategies. *Advanc Agron* 114:1–58. https://doi.org/10.1016/B978-0-12-394275-3.00006-7

Carvalho FP (2017) Pesticides, environment, and food safety. *Food Energy Secur* 6(2):48–60. https://doi.org/10.1002/fes3.108

Ch M (2013) Potential impact of climate change in sugarcane and mitigation strategies in Zimbabwe. *Afr J Agr Res* 8(23):2814–2818. https://doi.org/10.5897/AJAR2013.7083

Chanza N, Chigona A, Nyahuye A, Mataera-Chanza L, Mundoga T, Nondo N (2019) Diagnosing barriers to climate change adaptation at community level: reflections from Silobela, Zimbabwe. *GeoJ* 84(3):771–783. https://doi.org/10.1007/s10708-018-9890-3

Charamba V, Thomas B, Charamba B (2017) Relative importance analysis of the factors influencing maize productivity at Olushandja and Etunda irrigation Schemes of Namibia: a secondary analysis of data from farm household survey. *Int Scie Tech J Nam*:033-047. http://repository.unam.edu.na/handle/11070/2193. Accessed on 10 June 2022

Chazovachii B (2012) The impact of small scale irrigation schemes on rural livelihoods: the case of Panganai irrigation scheme Bikita District Zimbabwe. *J Sustain Deve Afric* 14(4):217–231

Choithani C, van Duijne RJ, Nijman J (2021) Changing livelihoods at India's rural–urban transition. *World Dev* 146:105617. https://doi.org/10.1016/j.worlddev.2021.105617

Dhanush D, Bett BK, Boone RB, Grace D, Kinyangi J, Lindahl JF, Mohan CV, Villegas JR, Robinson TP, and Rosenstock TS (2015) Impact of climate change on African agriculture: focus on pests and diseases.CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS). CGIAR. www.ccafs.cgair.org. Accessed on 25 June 2022

Dilling L, Daly ME, Travis WR, Wilhelmi OV, Klein RA (2015) The dynamics of vulnerability: why adapting to climate variability will not always prepare us for climate change. *Wires Clim Change* 6(4): 413–425. https://doi.org/10.1002/wcc.341

Edmonds RL (2013) General strategies of forest disease management. In *Infectious Forest Diseases. CAB International, Wallingford, UK: CAB International*, 29-49

Eschen R, Britton K, Brockerhoff E, Burgess T, Dalley V, Epanchin-Niell RS, Gupta K, Hardy GESTJ, Huang Y, Kenis M (2015) International variation in phytosanitary legislation and regulations governing importation of plants for planting. *Environ Scie Policy* 51:228–237. https://doi.org/10.1016/j.envsci.2015.04.021

FAO (2008) Climate related transboundary pests and diseases. Food and Agriculture Organization (FAO), Rome

FAO (2010) Gender dimensions of agricultural and rural employment: differentiated pathways out of poverty Status, trends and gaps. FAO, Rome

FAO (2017) National gender profile of agriculture and rural livelihoods - Zimbabwe: Country gender assessment series. FAO, Harare

Fu X, Akter S (2016) The impact of mobile phone technology on agricultural extension services delivery: Evidence from India. *J Devel Stud* 52(11):1561–1576. https://doi.org/10.1080/00220388.2016.1146700

GFFW (2015) Keeping Food On The Table In Sub-Saharan Africa." Global Fund for Women, accessed 01/10/2021. https://www.globalfundforwomen.org/latest/article/keeping-food-on-the-table-in-sub-saharan-africa/

Gornall J, Betts R, Burke E, Clark R, Camp J, Willett K, Wiltshire A (2010) Implications of climate change for agricultural productivity in the early twenty-first century. *Philos Transac Royal Socie B: Bio Sci* 365(1554):2973–2989

GoZ (2020) Accelerated irrigation rehabilitation and development plan 2021 - 2025. edited by Agriculture Ministry of Lands, Water and Rural Resettlement. Government Printers. Harare. Government Printers

Gregory PJ, Johnson SN, Newton AC, Ingram JSI (2009) Integrating pests and pathogens into the climate change/food security debate. *J Expe Bot* 60(10):2827–2838. https://doi.org/10.1093/jxb/erp080

Gullino ML, Albajes R, Al-Jboory I, Angelotti F, Chakraborty S, Garrett KA, Hurley BP, Juroszek P, Makkouk K (2021) Scientific review of the impact of climate change on plant pests-A global challenge to prevent and mitigate plant pest risks in agriculture, forestry and ecosystems. https://doi.org/10.4060/cb4769en

Heeb L, Jenner E, Cock MJW (2019) Climate-smart pest management: building resilience of farms and landscapes to changing pest threats. *J Pest Scie* 92(3):951–969. https://doi.org/10.1007/s10340-019-01083-y

Huyer S, Nyasimi M. (2017) Climate-smart agriculture manual for agriculture education in Zimbabwe. Retrieved from https://cgspace.cgiar.org/handle/10568/89632. accessed on 10 June 2022

Jactel H, Desprez-Loustau M, Battisti A, Brockerhoff E, Santini A, Stenlid J, Björkman C, Branco M, Dehnen-Schmutz K, Douma JC (2020) Pathologists and entomologists must join forces against forest pest and pathogen invasions. *NeoBiota* 58:107–127. https://doi.org/10.3897/neobiota.58.54389

Juroszek P, Racca P, Link S, Farhumand J, Kleinhenz B (2020) Overview on the review articles published during the past 30 years relating to the potential climate change effects on plant pathogens and crop disease risks. *Plant Pathol* 69(2):179–193. https://doi.org/10.1111/ppa.13119

Karuppaiah V, Sujayanad GK (2012) Impact of climate change on population dynamics of insect pests. Insects. https://doi.org/10.3390/2Finsects12050440

Katsaruware-Chapoto RD, Mafongoya PL, Gubba A (2017) Farmer knowledge of climate change impacts and adaptation strategies in the management of vegetable insect pests in Zimbabwe. *J Agric Sci* 9(12):194. https://doi.org/10.5539/jas.v9n12p194

Kawarazuka N, Damtew E, Mayanja S, Okonya JS, Rietveld A, Slavchevska V, Teeken B (2020) A gender perspective on pest and disease management from the cases of roots, tubers and bananas in Asia and sub-Saharan Africa. *Front Agrono* 2:7. https://doi.org/10.3389/fagro.2020.00007

Kutywayo D, Chemura A, Kusena W, Chidoko P, Mahoya C (2013) The impact of climate change on the potential distribution of agricultural pests: the case of the coffee white stem borer (Monochamus leuconotus P.) in Zimbabwe. PLoS One 8(8):e73432. https://doi.org/10.1371/journal.pone.0073432

Machingura F, Nicolai S (2018) Contextualising the SDGs to leave no one behind in health A case study from Zimbabwe. ODI, London

Mafongoya PL, Gubba A, Moodley V, Chapoto D, Kisten L, Phophi M (2019) Climate Change and Rapidly Evolving Pests and Diseases in Southern Africa. In New Frontiers in Natural Resources Management in Africa, Springer, Cham. 41–57

Matsa M (2012) Crop diversity measurement at Dufuya gardens and Insukamini irrigation scheme in Lower Gweru communal lands. *J* Environ Scie Engin B 1. 673–681

Matthews S (2017) Smallholder irrigation-Recipe for success: exploring the tools farmers need to succeed. Water Wheel 16(1):16–18. https://doi.org/10.10520/EJC-56569d4ea

Mazuru N (2019) Chapter nine climate change in Zimbabwe: challenges and prospects for rural women in Bikita District. In *Necroclimatism in a Spectral World (Dis) order?: Rain Petitioning, Climate and Weather Engineering in 21st Century Africa 255*

Mclaughlin C, Tarasuk V, Kreiger V (2003) An examination of at-home food preparation activity among low-income, food-insecure women. *J Am Diete Assoc* 103(11):1506–1512

Mhembwe S, Chiunya N, Dube E (2019) The contribution of small-scale rural irrigation schemes towards food security of smallholder farmers in Zimbabwe. J Disas Risk Stud 11(1):1–11. https://doi.org/10.4102/2Fjamba.v11i1.674

Milfont TL, Duckitt J, Wagner C (2010) A cross-cultural test of the value–attitude–behavior hierarchy. *J Appl Soc Psychol* 40(11): 2791–2813. https://doi.org/10.1111/j.1559-1816.2010.00681.x

Mkenda PA, Ndakidemi PA, Stevenson PC, Arnold SEJ, Darbyshire I, Belmain SR, Priebe J, Johnson AC, Tumbo J, Gurr GM (2020) Knowledge gaps among smallholder farmers hinder adoption of conservation biological control. *Biocontrol Sci Techn* 30(3):256–277. https://doi.org/10.1080/09583157.2019.1707169

Mohammed SAR (2019) Participation of Female Farmers in Water Management in Rahad Irrigation Project. *Eur J Soc Sci* 58(4):317–321

MoHCC (2017) National health strategy 2016–2020: equity and quality of health – leaving no one behind. MoHCC, Harare

Munkvold GP, Gullino ML (2020) Seed and propagative material. In *Integrated pest and disease management in greenhouse crops*, edited by Ramon Albajes Maria Lodovica Gullino, Philippe C. Nicot, 331. Springer Nature, Italy

Nagoshi RN, Meagher RL, Hay-Roe M (2012) Inferring the annual migration patterns of fall armyworm (Lepidoptera: Noctuidae) in the United States from mitochondrial haplotypes. *Ecol Evol* 2(7):1458–1467. https://doi.org/10.1002/ece3.268

Nhemachena C, Nhamo L, Matchaya G, Nhemachena CR, Muchara B, Karuaihe ST, Mpandeli S (2020) Climate change impacts on water and agriculture sectors in Southern Africa: threats and opportunities for sustainable development. *Water* 12(10):2673. https://doi.org/10.3390/w12102673

Nyamayevu D, Sun W, Chinopfukutwa GL (2015) An assessment of the reliability and adequacy of irrigation water in small holder irrigation schemes. Int J Sci Eng Res 6:14-19

Raney T, Anríquez G, Croppenstedt A, Gerosa S, Lowder SK, Matuschke I, Skoet J (2011) The role of women in agriculture. edited by Agricultural Development Economics Division. FAO, Rome

Savari M, Sheykhi H, Amghani MS (2020) The role of educational channels in the motivating of rural women to improve household food security. *One Health* 10:100150. https://doi.org/10.1016/j.onehlt.2020.100150

Savary S, Willocquet L, Pethybridge SJ, Esker P, McRoberts N, Nelson A (2019) The global burden of pathogens and pests on major food crops. *Nat Ecol Evol* 3(3):430–439. https://doi.org/10.1038/s41559-018-0793-y

Scherm H (2004) Climate change: can we predict the impacts on plant pathology and pest management? *Can J Plant Pathol* 26(3):267–273. https://doi.org/10.1080/07060660409507143

Scott NR, Chen H, Cui H (2018) Nanotechnology applications and implications of agrochemicals toward sustainable agriculture and food systems. J Agric Food Chem 66, 26:6451–6456. https://doi.org/10.1021/acs.jafc.8b00964

Sharaunga S, Mudhara M (2021) Analysis of Livelihood strategies for reducing poverty among rural women's households: a case study of KwaZulu-Natal, South Africa. *J Inte Dev* 33(1):127–150. https://doi.org/10.1002/jid.3516

Shaw MW, Osborne TM (2011) Geographic distribution of plant pathogens in response to climate change. *Plant Pathol* 60(1):31–43. https://doi.org/10.1111/j.1365-3059.2010.02407.x

Shrestha S (2019) Effects of climate change in agricultural insect pest. Acta Sci Agric 3:74–80. https://doi.org/10.31080/ASAG.2019.03.0727

SIRP (2017) Smallholder irrigation revitalisation program participatory rapid appraisal for exchange irrigation project midlands province Zimbabwe. SIRP, Harare, Zimbabwe

Sisay B, Simiyu J, Mendesil E, Likhayo P, Ayalew G, Mohamed S, Subramanian S, Tefera T (2019) Fall armyworm, Spodoptera frugiperda infestations in East Africa: Assessment of damage and parasitism. *Insects* 10(7):195. https://doi.org/10.3390/insects10070195

Sithanantham S, Seif AA, Ssennyonga J, Matoka C, Mutero C (2002) Integrated pest management (IPM) issues in irrigated agriculture: current initiatives and future needs to promote IPM adoption by smallholder farmers in Eastern Africa. The Changing Face of Irrigation in Kenya: Opportunities for Anticipating Changes in Eastern and Southern Africa. pp 231–261

Thomas JE, Wood TA, Gullino ML, Ortu G (2017) Diagnostic tools for plant biosecurity. In *Practical Tools for plant and food biosecurity*, edited by James P. Stack Maria Lodovica Gullino, Jacqueline Fletcher, John D. Mumford, 209-226. Springer, The Netherlands

Tibugari H, Jowah P, Mandumbu R, Karavina C (2012) Tackling diamondback moth Plutella xylostella (L.) resistance: a review on the current research on vegetable integrated pest management in Zimbabwe. *Arch Phytopath Plant Prot* 45(20):2445–2453. https://doi.org/10.1080/03235408.2012.729015

Van der Fels-Klerx HJ, Liu C, Battilani P (2016) Modelling climate change impacts on mycotoxin contamination. *World Mycotoxin J* 9(5):717–726. https://doi.org/10.3920/WMJ2016.2066

Wang W, Jin J, He R, Gong H (2017) Gender differences in pesticide use knowledge, risk awareness and practices in Chinese farmers. *Sci Total Environ* 590:22–28. https://doi.org/10.1016/j.scitotenv.2017.03.053

Whyte KP (2014) Indigenous women, climate change impacts, and collective action. *Hypatia* 29(3):599–616. https://doi.org/10.1111/hypa.12089

Xie H, You L, Wielgosz B, Ringler C (2014) Estimating the potential for expanding smallholder irrigation in Sub-Saharan Africa. *Agr Water Manage* 131:183–193. https://doi.org/10.1016/j.agwat.2013.08.011