




CASE STUDY



Horizon scanning of invasive plant pests endangering Zimbabwe's agricultural sector based on insights from neighbouring countries

Nhamo Mudada^{1,2,*}, Georgina K. Mwaramba³, Dumisani Kutwayo³, Nyamande Mapope¹, Brighton M. Mvumi⁴, and Wonder Ngezimana^{1,5}

Abstract

Background: Zimbabwe's agricultural sector faces an imminent threat from 73 invasive plant pests currently established in neighbouring countries, with the highest risk of entry stemming from travellers and their luggage, a new horizon scan reveals. **Methods:** The Centre for Agriculture and Bioscience International (CABI) Horizon Scanning Tool (HST), one of the modules used to focus pest threats for specific geographical areas, was employed to scan threats to Zimbabwe's plant biosecurity. The likelihood of pest entry and establishment was determined using the procedure for pest risk analysis described by CABI and Food and Agriculture Organisation. The European and Mediterranean Plant Protection Organization method for likelihood of entry and the likelihood of establishment were ranked on a scale of 1 (very unlikely) to 5 (very likely). Pest rating was done by the selected pest risk analysis experts from the Plant Health Authorities in Zimbabwe. Descriptive statistics were mostly used to analyse the threats. Diversity indices were included to bring a new dimension to pest risk analysis where these indices capture meaningful ecological patterns relevant to threats of invasive pest invasion to the country. **Results:** There were 29 plant pests, 58 invertebrates, 17 fungi/chromista, 4 bacteria, 5 viruses, and one vertebrate pest-threat species recorded in Zimbabwe's neighbours, whilst 1,163 pest threats were present in SADC and 16,651 were found globally. The HST revealed more invertebrate pest threat organisms to Zimbabwe's plant biosecurity than the other pest organisms. Zimbabwe's neighbours had 50% invertebrate threats; SADC had 43% whilst the global scan revealed 47%. More threats were from South Africa (87%) than the other three neighbours (13%). Of the identified pest threats from the Zimbabwe's four neighbours, 73 (64%) pest species had entry and establishment score of 3 (moderately likely or more). These 73 pest species comprised of 3 (4%) bacteria, 9 (12%) fungi, 46 (63%) invertebrates, 11 (15%) weeds/plants, and 4 (5%) viruses. Of the identified pest threats from the Zimbabwe's four neighbours, 73 (64%) pest species had entry and establishment score of 3 (moderately likely or more). These 73 pest species comprised of 3 (4%) bacteria, 9 (12%) fungi, 46 (63%) invertebrates, 11 (15%) weeds/plants, and 4 (5%) viruses. *Dysmicoccus brevipes* (score 5), *Polyphagotarsonemus latus* (4), *Aleurothrixus floccosus* (4), *Aonidiella orientalis* (4), *Ceratitis rosa* (4), *Phoracantha recurva* (4), *Erysiphe platani*, *Fusarium oxysporum f. sp. cubense* (4), *Candidatus phytoplasma palmarum* (4), *Amaranthus retroflexus* (4), *Solanum torvum* (4), and Maize Chlorotic Mottle Virus (4) were amongst the major threats Zimbabwe's plant biosecurity faces. Simpson diversity index revealed that Zimbabwe's neighbours had moderate pest threat diversity (1-D = 0.62). The invertebrates (51%), dominated the pest threats present in the neighbours. SADC (1-D = 0.66) had higher diversity with plants (40%) and invertebrates (43%). The Shannon diversity index (H') revealed a gradient pattern where global diversity (H' = 1.63) was the highest, then SADC (H' = 1.41), and lastly, the Zimbabwe's neighbours (H' = 1.37). **Conclusions:** This study provides the first systematic horizon scan and prioritization of invasive pest threats for Zimbabwe, offering a critical evidence base for proactive biosecurity policy and resource allocation.

Affiliations: ¹Department of Crop Science, Faculty of Plant & Animal Sciences and Technology, Marondera University of Agricultural Sciences and Technology, P.O. Box 35, Marondera, Zimbabwe; ²Agricultural Advisory and Rural Development Services, P.O. Box 143, Mutare, Zimbabwe; ³Agricultural Research, Innovation and Specialist Services, P.O. Box CY550, Causeway, Harare, Zimbabwe; ⁴Department of Agricultural and Biosystems Engineering, Faculty of Agriculture Environment and Food Systems, University of Zimbabwe, P.O. Box MP167, Mt Pleasant, Harare, Zimbabwe; ⁵Department of Plant Production Sciences and Technology, Faculty of Agriculture Environment and Food Systems, University of Zimbabwe, P.O. Box MP167, Mt Pleasant, Harare, Zimbabwe

*Corresponding Author: Nhamo Mudada. Email: mudadan@gmail.com

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One Health impact statement

Invasive plant pest species are serious concerns regarding the substantial crop losses, which threatens the global food and feed security systems, negatively impacting livelihoods of the population in sub-Saharan Africa and beyond. Invasive pest species disrupt ecosystems, reduce biodiversity, and degrade natural habitats, which are critical for overall health of people, plants, and animals, and this requires a unified approach to plant biosecurity. Early warning systems especially horizon scanning of invasive pest threats pave way for the prevention, early detection, and rapid response to curb their spread, and allows for multi-stakeholder collaboration in the development of strategies that minimize negative impacts of invasive plant pest invasions.

Keywords: plant pest threats, pest risk analysis, plant-pest-pathways, diversity index, plant biosecurity protection, pest disaster preparedness

Introduction

Zimbabwe's agricultural sector faces imminent threats from invasive plant pests currently established in neighbouring countries, with risk of entry stemming from the pest-pathways such as debris and waste associated with human activities (DWP); people and their luggage/equipment (PLP); and food contaminants (FCP), all exacerbated by anthropogenic behaviours linked to smuggling and the use of non-official entry points (Mudada *et al.*, 2022). Despite the existence of strategies to protect plants against pests in plant-pest-pathways, it remains critical to focus on understanding pest threats within the trading environment, especially for purposes of pest disaster preparedness (Venter *et al.*, 2021). Estimation of pest threats can be done through models that can forecast the likelihood of pest entry, establishment, and spread. The Centre for Agriculture and Bioscience International (CABI) horizon scanning and pest risk analysis (PRA) tools are some of the modules that are used to forecast pest threats for specific geography areas (CABI, 2021a, 2021b).

A variety of plant-pest-pathways found in cross-border traffic exists in Zimbabwe and the Southern Africa region (Mbekeani, 2013; Mudada *et al.*, 2022; Tshikhudo *et al.*, 2025). 'Pest-pathways' are means by which pests are passed from one area to another (IPPC Secretariat, 2016a). They can also be referred to as 'prospects resulting in the translocation of pests across geographical areas, including aspects of the vectors involved, features of the original and recipient environments, and the nature and timing of what exactly is moved' (Ministry for Primary Industries, 2020).

Zimbabwe and the SADC region experience natural or anthropogenic plant-pest-pathways (FAO, 2007). Human-aided pest movement through cross-border trading is one of the ways in which transboundary pest movement is exacerbated. Over 500,000 pest species have been introduced across borders through pest-pathways found in cross-border traffic (Tshikhudo *et al.*, 2025). Africa loses over US\$65.58 billion yearly due to invasive alien pest species, causing about 2.5% losses in Gross Domestic Product (GDP) for the African states (Eschen *et al.*, 2021).

In 2016 and 2017, new races of pathogens and strains of insects were recorded in Zimbabwe and other Southern African countries (CABI, 2016; FAO, 2017). New races of Potato Virus Y (PVY) suspected to have been introduced through seed potato imports were recorded in Zimbabwe (Dimbi *et al.*, 2017; Plant Quarantine Services Institute, 2017). This new PVY race was suspected to have reduced the 2017 annual tobacco production from 202 million kilograms to 189 million kilograms harvested in 2016 (TIMB, 2017). Within the same period, some Southern African countries' crops were attacked by equally damaging *Spodoptera frugiperda* (J. E. Smith, 1797), *Tuta absoluta* (Meyrick, 1917), and *Phenacoccus solenopsis* (Tinsley, 1898) (FAO, 2017; Plant Quarantine Services Institute, 2017; Tambo *et al.*, 2021). Such pest invasions, associated with breaking down of physical barriers from pest geographical areas of origin, are strongly linked to anthropogenic behaviours such as deliberate introduction and globe-travel (Black and Bartlett, 2020; Jansen and De La Cruz Bekema, 2023). For instance, in Zimbabwe, the accidental introduction of *T. absoluta*

was suspected to have been caused by the smuggling of tomato fruits (Tengeru variety) from Zambia to Chinhoyi, Mashonaland West Province in July 2016 (Anonymous, 2016). The introduction of *T. absoluta*, *S. frugiperda*, and Foc TR4 affected Mozambique with half a million plants being infected within 3 years (Snyder & Hansen, 1940). The accidental introduction of *Fusarium oxysporum pv cubense tropical race 4* (Foc TR4) to Mozambique was suspected to have been aided by contaminated farm protective clothing from Philippines (IPPC Secretariat, 2013; Dita *et al.*, 2018). These new pest introductions were associated with cross-border traffic (CABI, 2020).

Consequently, the best way to protect plants from pests is through pest exclusion, a function of plant quarantine regulations (Webber, 2010; Mudada *et al.*, 2022). This is the basis for the International Plant Protection Convention (IPPC) and the World Trade Organisation (WTO) Sanitary and Phytosanitary Standards (SPS) (IPPC Secretariat, 2016b).

The above cited series of invasions by pests indicate the possibilities of the existence of significant pest threats in neighbouring areas of Zimbabwe. Previous studies reported how invasive pest species were transmitted from one country to another (Forestry Research, 2021; Mudada *et al.*, 2022; Kadzamira *et al.*, 2023; Hulme, 2024; CABI, 2025b). Whilst there are many plant-pest-pathways existing in Zimbabwe and the Southern African Development Community (SADC) region, this study focused on human-aided plant pest pathways that are associated with deliberately introductions in the form of bio-terrorism and bio-weapons (Forestry Research, 2021; Tshikhudo *et al.*, 2021; Zhang *et al.*, 2022). The pathways studied were: debris and waste associated with human activities (DWP); people and their luggage/equipment (PLP); and food contaminants (FCP), which are exacerbated by anthropogenic behaviours linked to smuggling and the use of non-official entry points (Mudada *et al.*, 2022). This study therefore aimed to identify and characterize the invasive plant pests currently absent from Zimbabwe but present in its neighbouring countries (Botswana, Mozambique, South Africa, and Zambia) that pose the greatest plant biosecurity risk, with a focus on their associated pathways. Thus, this study provides the first systematic horizon scan and prioritization of invasive pest threats for Zimbabwe, offering a critical evidence base for proactive biosecurity policy and resource allocation.

Methods

The study design followed a Predictive, Geospatial Risk Assessment using a systematic horizon scanning methodology (systematic review and analysis of geospatial pest data). This study was a desktop study that applied a formalized analytical framework to existing spatial pest databases to model and rank the likelihood of future invasive pest introductions into a Zimbabwe based on proximity and the established presence in the neighbouring regions. The CABI scanning horizon tool was used to examine the invasive plant pests threatening Zimbabwe from her four neighbouring countries, with the SADC region as the buffer zone (CABI, 2025b). The study method was adapted from Tshikhudo *et al.* (2025). The geographical origin of danger

included all the four Zimbabwe neighbouring countries whilst the other SADC member states were acting as pest buffers (CABI, 2021c, 2021b). The scan considered Botswana, Mozambique, South Africa, and Zambia as the neighbouring geographic areas to Zimbabwe amongst the other 16 SADC member states, which are shown in Fig. 1. The horizon scanning of the invasive pest species threatening Zimbabwe from her neighbours was conducted on the 11th of June 2025.

DESCRIPTION OF THE CABI HORIZON SCANNING TOOL USED FOR THE PEST THREAT SCANNING

The Horizon Scanning Tool (HST) is one of the innovative online decision tools launched by CABI in 2018 (Kadzamira *et al.*, 2023). Roy *et al.* (2014) further defined the HST as 'a rapid process for screening invasive species and pest risks based on a systematic study of possible future risks, leading to non-native species being prioritized for further inquiry'. The tool is used to model a decision that includes forecasting animal and plant pest threats, chiefly those affecting plant defence and biosecurity and was used to solve essential resource equations regarding the war against plant health fears. The HST is a 'systematic user-friendly process for identifying and prioritisation of potential invasive species and plant pest threats for further inquiry for specific geographical areas' (Oronje, 2025).

With HST, users select the 'area at risk' that does not currently have an invasive pest species presence record; the select potential 'source areas' where species are present and act as points of entry to the 'area at risk' and then the HST scans for the pest threats (CABI, 2021a). For this scanning, the geographical area at risk was Zimbabwe and the potential sources of threats were her neighbouring countries (Botswana, Mozambique, South Africa and Botswana). The pest database queried by HST is the CABI own databases which are the Invasive Species compendium (ISC) and Crop Protection Compendium (CPC) (CABI, 2025b). It also queries the European and Mediterranean Plant Protection Organization (EPPO), United States Department of Agriculture's Germplasm Resources Information Network (USDA's GRIN), and the Food

and Agriculture Organisation (FAO) databases to scan for invasive species (CABI, 2025b). The tool also incorporates climate matching (Köppen-Geiger) and trade data from the UN Comtrade database (Kottek *et al.*, 2006). The scan results are a list of plant pest species identified using the taxonomic classification presented as output in CSV or XLSX format (CABI, 2021b, 2025b). The CABI HST enhances the pest threats by focusing on habitats, pest-pathways, at risk plant hosts, endangered plant parts in the trading of plants and plants products, and associated negative impacts of the pests apart from the organism types scanned (Hutchinson, 2023). The framework of HST was integrated with the International Standards for Phytosanitary Measures (ISPMs) developed and adopted by the International Plant Protection Convention (IPPC) (Roy *et al.*, 2014).

PEST PATHWAYS SCANNED

The horizon scanning queried three natures of pest-pathways that are mainly associated with human-aided cross-border traffic across SADC. These were DWP, PLP, and FCP. These pathways are often neglected at ports of entry yet they are mostly found amongst cross-border traffic. These three pathways are normally excluded in cross-border plant pest pathway screening as low risk and they are also often smuggled across borders through unofficial crossing points.

PESTS ORGANISM SCANNED

The pest organisms scanned were plants, bacteria, viruses, protozoa, fungi/chromista, vertebrates, invertebrates, and diseases of unknown aetiology. Pests of potential deleterious sway were gauged on the country's agricultural systems with focus on trade restrictions to plants and plant products. The identified threats were listed according to their organism type. The scanned pest-organisms were climate-matched to Zimbabwe's climatic condition for the purposes of likelihood of their establishment (Fig. 2). As shown in Fig. 2, the climate-matched geographical area modelled for Zimbabwe included the hot arid desert; the humid subtropical (monsoon-influenced); the steppe (semi-arid, hot); the subtropical highland (warm); and the tropical savannah (wet) climates.

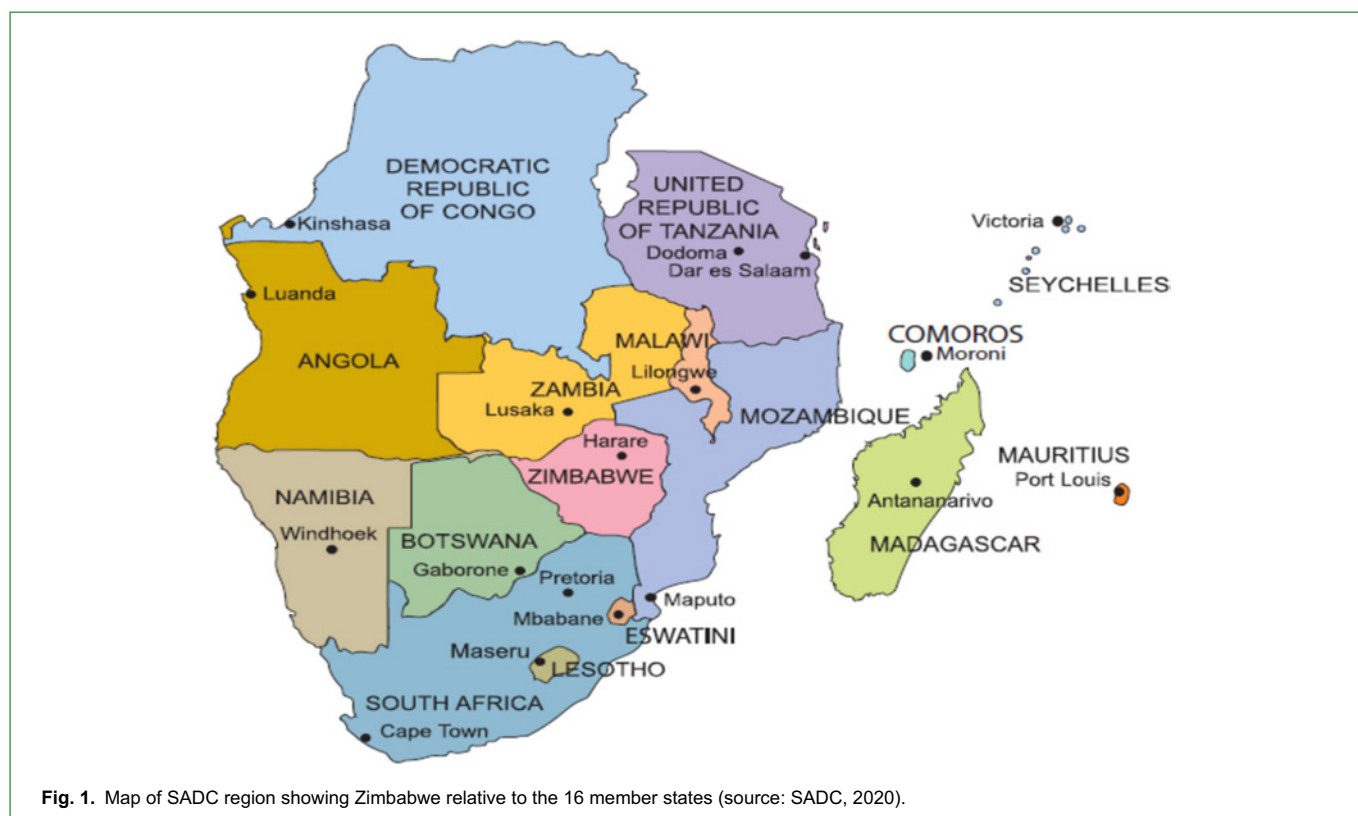


Fig. 1. Map of SADC region showing Zimbabwe relative to the 16 member states (source: SADC, 2020).

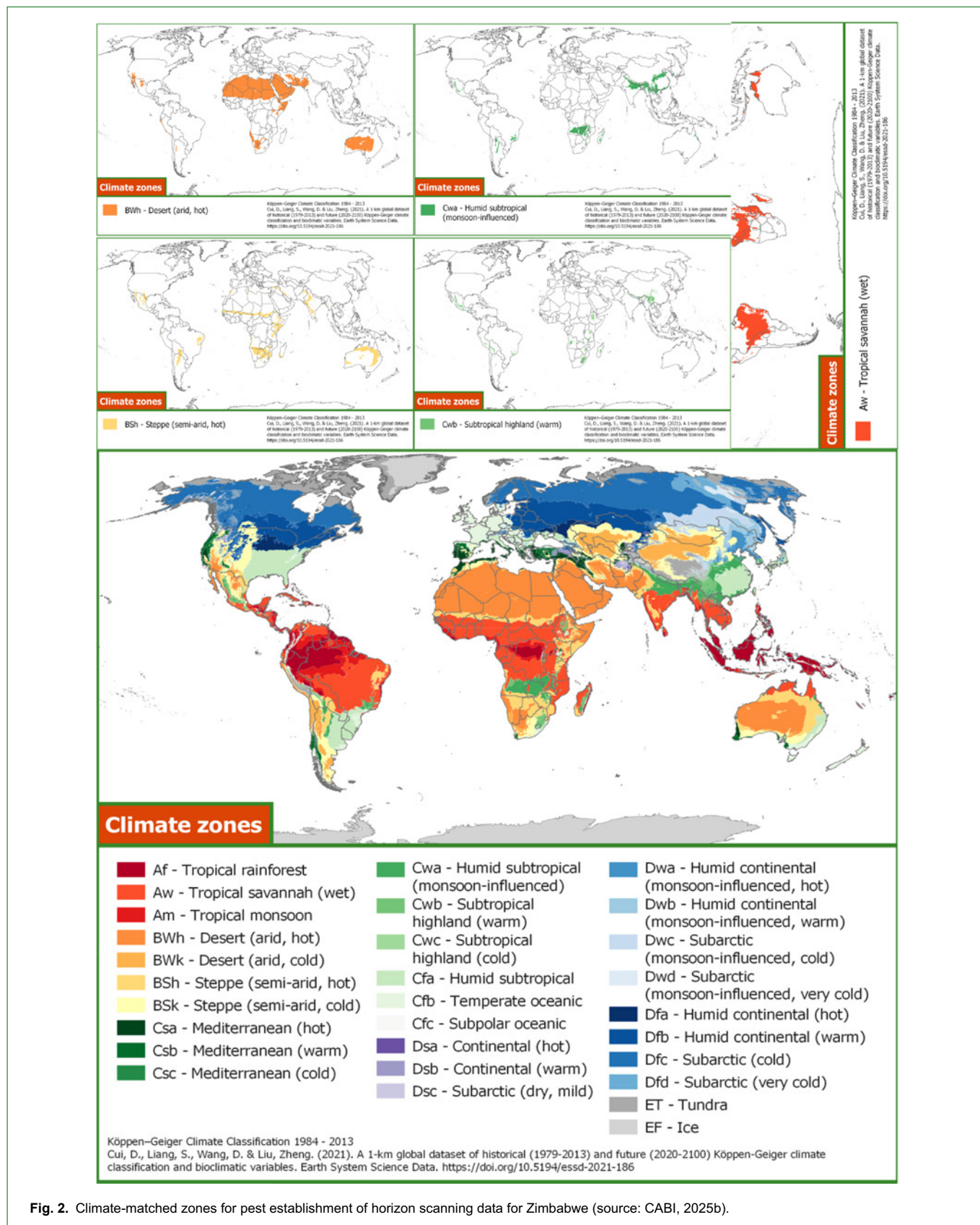


Fig. 2. Climate-matched zones for pest establishment of horizon scanning data for Zimbabwe (source: CABI, 2025b).

LIKELIHOOD OF PEST ESTABLISHMENT IN ZIMBABWE

The likelihood of pest entry and establishment was determined using the procedure for pest risk analysis described by FAO (2007) and CABI (2025a). The EPPO method for likelihood of entry and

the likelihood of establishment were ranked on a scale of 1 (very unlikely) to 5 (very likely) also as described by Tshikhudo *et al.* (2025). These scores were provided by the selected pest risk analysis experts from the Plant Health Authorities in Zimbabwe. The key factors and scoring guidance for assessing the likelihood

of pest entry were score 1 (very unlikely) with the key consideration for entry that no viable pathways or pathways are effectively blocked by prohibitions and rigorous inspections (e.g., a regulated quarantine pest with a prohibited pathway); 2 (unlikely) with key consideration for entry that pathways exist but are infrequent, pest association with the pathway is low, and/or some basic mitigations (e.g. visual inspections, standard treatments) were in place; 3 (moderately likely) with key consideration for entry that established pathways with a clear link to the pest, some natural or human-assisted movement is possible and mitigations may be inconsistent or only partially effective; 4 (likely) with key consideration for entry that frequent and viable pathways (e.g., high-volume trade in a susceptible commodity), pest is known to be associated with the pathway, and opportunities for transfer to a host are high; and 5 (very likely) with key consideration for entry that very high volume of movement along multiple, unobstructed pathways, pest is commonly associated with the commodity or pathway, and transfer to hosts is almost certain.

The key factors and scoring guidance for assessing the likelihood of pest establishment were: score 1 (very unlikely) with key consideration for establishment, assessment that the environment (climate, habitat) is wholly unsuitable, essential hosts or breeding sites are absent, and the pest cannot complete its life cycle; 2 (unlikely) with key consideration for entry that suitable conditions are rare and fragmented, hosts are limited, and survival and reproduction possible but unlikely to be sustained; 3 (moderately likely) with key consideration for entry that environment is suitable in some areas, hosts are available, and the pest can likely survive and reproduce, potentially forming local populations; 4 (likely) with the key consideration for entry that environment is widely suitable, abundant and the widespread hosts are present, and few biotic or abiotic barriers exist to prevent persistent populations, and 5 (very likely) with key consideration for entry that conditions are highly favourable across the risk assessment area, hosts are ubiquitous, and the pest is highly adaptable and expected to thrive and perpetuate. The overall probability of introduction was often determined by the lower between score between the Entry and Establishment scores, as both are required for a successful introduction.

The CABI PRA tool was launched in 2014 as a decision-making tool that provides scientific pest data from the CABI Crop Protection Compendium (CPC) to support the use of phytosanitary measures for reducing threats of the ingress of new exotic pests into new territories (CABI, 2025c). The outcome of the HST queries comprised comprehensive pest information, including complete taxonomic classification (with scientific names); organism type; invasiveness status; documented presence records (correlated with current and projected climatic conditions); host species; associated habitats; plant parts traded; associated pest pathways; and recorded impact outcomes (Roy *et al.*, 2014; Kadzimir *et al.*, 2023; Tshikhudo *et al.*, 2025; CABI, 2025b).

DATA ANALYSIS

The Microsoft Excel and SPSS vs. 25 were used for Exploratory Data Analysis (EDA) (Komorowski *et al.*, 2016). A descriptive statistical analysis of the organism threats, including the Coefficient of Variation percentage (CV %), confidence interval (CI), and standard error (SE) were computed using Microsoft Excel. A Chi-square test (χ^2) was employed to evaluate the differences in the number of pest organisms across pest-pathways categories.

Simpson's diversity index (1-D) was calculated to understand the diversity of pest organism threatening Zimbabwe agriculture system. Simpson's diversity index was calculated using the following formula:

$$D = \sum_{i=1}^S \left(\frac{n_i}{N} \right)^2 \quad \text{and} \quad \text{Simpson's diversity} = 1-D$$

Where: n_i = count of pest threats for organism type i , N = total pest threats in the region, and S = number of organism types.

The Simpson's diversity index (specifically, the (1-D)) quantifies ecological dominance and evenness of pest threats across the regions scanned (Somerfield *et al.*, 2008). Shannon index (H') was also computed to measure the ecological diversity by quantifying two things: richness (number of different species (or pest types) present) and evenness (how evenly individuals are distributed amongst those species) simultaneously. Shannon index (H') was calculated using the following formula:

$$H' = -\sum_{i=1}^S (p_i \cdot \ln p_i)$$

Where p_i is the proportion of each species; \ln = natural logarithm (can also use \log_2 or \log_{10}); S = total number of species.

The key to using diversity indices brings a new dimension to pest risk analysis where these indices, even when applied to high-level categories, capture meaningful ecological patterns relevant to invasion risk (threats of invasive pest invasion to the country). Simpson's and Shannon's indices are commonly used in invasion biology to quantify community structure and at coarse resolution; they can reveal important properties like dominance patterns and resource heterogeneity that influence invasion susceptibility enabling comparative risk prioritization. I should emphasize that whilst species-level data is ideal, high-level application provides actionable insights for screening-level analysis bridging ecological theory and practical risk assessment needs.

Applying Simpson's and Shannon's biodiversity indices to high-level taxonomic categories (like 'Invertebrates' or 'Plants') in pest risk analysis serves specific practical purposes to screen for community-level (area at risk) vulnerability and prioritize risk at a pathway scale. It allows analysts to use available, coarse data to make initial, resource-efficient judgments about which (ecosystems, regions matched to area with risk), or import pathways (pathways with risk) might be most susceptible to invasion, guiding where to focus deeper, species-level investigations.

When comparing multiple regions (areas with risk) and trade pathways (risk pest pathways), these indices provide a standardized, quantitative metric for ranking pest-pathways with persistently low diversity. For instance, pathway or area with high dominance of a specific organism group might be prioritized for enhanced inspection or stricter phytosanitary measures. However, the major limitation in using diversity indices is the loss of species-specific risk information. These indices are complementary to, not a replacement for, species-level pest risk analysis (PRA). In this study on invasive plant pests threatening Zimbabwe's plant biosecurity, we applied these indices to help identify the pest organisms overwhelmingly dominant, signalling a key risk neighbours (area with risk) and guiding for a further, more granular analysis.

Results

PREVALENCE OF PEST ORGANISMS REVEALED BY THE CABI HST

The scanning horizon tool revealed that there were a total of 114 invasive plant pest species currently absent in Zimbabwe but present in Zimbabwe's four neighbouring countries (Botswana, Mozambique, South Africa, and Zambia) (Table 1). There were 29 plants, 58 invertebrates, 17 fungi/chromista, four bacteria, five viruses, and one vertebrate species recorded. Globally, 16,651 pest threats were present and 1,163 found in the SADC region but absent in Zimbabwe. The scanning tools revealed that there were more invertebrate pest organism proportions that threaten Zimbabwe's plant biosecurity across the scanned three geographic regions (Fig. 2), than the other pests' organisms. Zimbabwe's four neighbours (Fig. 1) had 50% proportions of invertebrate's pests; SADC had 43.42%, whilst global scan revealed 47.14% proportion. The HST scan results showed that there were more pest threat organisms in South Africa (87%) than the other three neighbours (13%) (Table 2).

Table 1. Plant pest organism threats currently absent in Zimbabwe but present in her four neighbours, SADC, and the world as revealed by the Centre for Agriculture and Bioscience International (CABI) Horizon Scanning Tool (HST).

Organism type	Total pest threats present in the Zimbabwe's four neighbours		Total pest threat present in SADC		Total pest threat present globally	
	Pest threats present in Zimbabwe's neighbours	Proportion (%)	Count SADC	Proportion (%) SADC	Count global	Proportion (%) global
Bacteria	4	3.51	41	3.53	352	2.11
Fungi/chromista	17	14.91	104	8.94	1,879	11.28
Invertebrates	58	50.88	505	43.42	7,850	47.14
Plants	29	25.44	468	40.24	5,032	30.22
Vertebrates	1	0.88	9	0.77	541	3.25
Virus	5	4.39	36	3.10	778	4.67
Protozoa	0	0	–	0	38	0.23
Diseases of unknown aetiology	0	0	–	0	13	0.08
Unknown	0	0	–	0	168	1.01
Grand total	114	100.00	1,163	100.00	16,651	100.00

CABI HST = Centre for Agriculture and Bioscience International (CABI) Horizon Scanning Tool (HST); SADC = Southern African Development Community; GLOBAL = all the world geographical areas.

Table 2. The distribution of pest threats currently absent in Zimbabwe's but recorded in the neighbouring countries as revealed by the Centre for Agriculture and Bioscience International (CABI) Horizon Scanning Tool (HST).

Organism type	Mozambique	South Africa	Zambia	Botswana	Total pests recorded
Bacteria	1	2	1	0	4
Fungi/chromista	3	15	2	0	17
Invertebrates	10	52	7	1	58
Plants	4	26	5	1	29
Vertebrates	0	1	0	0	1
Virus	3	3	2	0	4
Total pest threats recorded	21	99	17	2	114
Frequency (%)	18.42	86.84	14.91	1.75	100.00

Of the identified pest threats from the Zimbabwe's four neighbours, 73 (64%) pest species had entry and establishment score of 3 (moderately likely or more). These 73 pest species comprised of 3 (4%) bacteria, 9 (12%) fungi, 46 (63%) invertebrates, 11 (15%) weeds/plants, and 4 (5%) viruses.

A Chi-square test to analyse differences in pest organism distribution across pathways was not significant [$\chi^2 \approx 4.27$ and $df = 10$, p -value = 0.93]; hence, the distribution of different invasive organism types across the pathways (Debris/Waste, Food Contaminant, People/Luggage) was likely due to random variation, not a systematic association (Table 3). Descriptive statistics revealed that the organisms with the highest variability were bacteria (CV = 16%) followed by viruses (CV = 13%). The group "Plants" (CV = 4%), were the most stable pest organisms threatening Zimbabwe.

The Shannon diversity analysis showed that the global diversity index ($H' = 1.63$) was the highest, then SADC ($H' = 1.41$), and lastly, the Zimbabwe's neighbours ($H' = 1.37$) (Table 9). Invertebrates and plants dominated pest threat organisms across all the scales

constituting 50–80% of threats. The evenness (J') was the lowest globally ($J' = 0.51$). The highest was on the SADC ($J' = 0.55$), suggesting localized dominance of invertebrates (50.88%). The Richness index (S) was the same for SADC ($S = 6$) and Zimbabwe's neighbours ($S = 6$) and higher at the global level ($S = 9$). The difference was attributed to the presence of protozoa and the disease of an unknown aetiology at the global level. Invertebrates contributed most to H' index across the scales (0.34–0.35) and the plants showed high evenness in SADC (40.24% of pest threats). The protozoa and diseases of unknown aetiology were only noted at the global level. Protozoa and the diseases of unknown origin contributed 0% to neighbours and SADC.

The horizon screening model revealed that the pest pathway categorized as PLP had the highest potential (104) to carry invasive pest organism into Zimbabwe. The second highest potential pest-pathway was the FCP, which was attributed to 94 pest organisms, and lastly, the pathway categorized DWP which had a potential to translocate 93 pest organism forms within the Zimbabwe's four neighbours (Tables 3–9).

Table 3. Count data of pathway segregation of the invasive pest threats absent in Zimbabwe but present in Botswana, Mozambique, South Africa, and Zambia.

Organism type	Debris/waste	Food contaminant	People/luggage	Mean	Standard deviation	Coefficient of variation (%)	Key insights
Invertebrates	42	44	52	46	5.29	12	Highest risk in all pathways, especially luggage
Plants	28	26	27	27	1	4	Consistent high risk across all pathways
Fungi/chromista	15	15	17	15.67	1.15	7	Moderate risk, slightly elevated in luggage
Viruses	4	5	4	4.33	0.58	13	Low but notable presence in food
Bacteria	3	4	4	3.67	0.58	16	Minimal risk across pathways
Vertebrates	1	–	–	1	–	–	Negligible risk

($\chi^2 \approx 4.27$ and $df = 10$, p -value = 0.93).

Table 4. The list of invasive bacteria pest threats absent in Zimbabwe but revealed to be present in Botswana, Mozambique, South Africa, and Zambia using the Centre for Agriculture and Bioscience International (CABI) Horizon Scanning Tool (HST).

Preferred scientific name	Order	Number of hosts affected	Neighbours with pest record	Probable pathway	Likelihood of entry	Likelihood of establishment	Overall risk rating
<i>Candidatus Phytoplasma palmae</i> (Firrao et al., 2004)	Acholeplasmatales	52	1 (Mozambique)	DWP, FCPP, PLP	4	5	4
<i>Curtobacterium flaccumfaciens</i> pv. <i>Flaccumfaciens</i> (Hedges, 1922; Collins and Jones, 1984)	Actinomycetales	14	1 (Zambia)	DWP, PLP	3	4	3
<i>Pseudomonas savastanoi</i> pv. <i>savastanoi</i> (Janse, 1982; Gardan et al., 1992)	Pseudomonadales	9	1 (South Africa)	DWP, FCP, PLP	3	2	2
<i>Xanthomonas axonopodis</i> pv. <i>Manihotis</i> (Dowson, 1939)	Xanthomonadales	2	1 (South Africa)	DWP, FCP, PLP	3	3	3

DWP = debris and waste associated with human activities; FCP = food contaminant; PLP = people and their luggage. Source: CABI (2025a, 2025b, 2025c). Key to score: 1 = very unlikely; 2 = unlikely; 3 = moderately likely; 4 = likely and 5 = very likely (Schrader, n.d.).

BACTERIAL INVASIVE PESTS' THREATS ABSENT IN ZIMBABWE BUT PRESENT IN HER FOUR NEIGHBOURING COUNTRIES

There were four bacteria invasive pest species from orders revealed by the SHT that were found present in the Zimbabwe's four neighbouring countries during this modelling (Table 4). *Candidatus phytoplasma palme* that affects a wide host range (52 hosts) of plants was found to be associated with all the three pest pathways scanned. The four fungi listed from the scan were all found in at least one neighbouring country. The overall pest entry and establishment score ranged from 2 to 4 where *Candidatus Phytoplasma palmae* had the highest threat of invading Zimbabwe from the invasive bacteria pests list revealed by HTS. Three (75%) of the listed pest threats had an overall entry and the establishment score of 3 (moderately likely) = or higher.

FUNGI/CHROMISTA INVASIVE PEST THREATS ABSENT IN ZIMBABWE BUT PRESENT IN HER FOUR NEIGHBOURING COUNTRIES

There were 17 fungi/chromista invasive pests' organisms distributed across nine orders from Zimbabwe's four neighbouring countries as revealed by the HST (Table 6). Erysiphales and Hypocreales had the highest pest species that were three pest species each, whilst the rest order has either one or two pests' species. The HST singled out the PLP as the only probable pathway for *Phytophthora*

cambivora (Petri) Buisman, (1927) and *Pucciniastrum minimum* (Schw.) Arth. (blueberry leaf rust). *Seiridium cardinal* (W.W. Wagener) B. Sutton & I.A.S. Gibson, was found to be moved through two pathways excluding DWP. *Phytophthora cambivora* had the highest host range (60), whilst both *Oidium anacardii* F. Noack and *Peronospora belbahrii* Thines had only one host. *O. anacardii* was revealed to be recorded in three of the neighbours to Zimbabwe. *Fusarium oxysporum* f. sp. *cubense* had an overall score of 4 (likely) making a serious threat to the country based on EPPO standard. *Erysiphe platani* had the highest overall score of entry and establishment (4). Though *Oidium anacardii* had a likely (4) of entry, its overall probability of being a menace was unlikely (1) due to low probability of establishment (1 = unlikely). Nine of the seventeen (9/17 = 53%), had overall entry and the establishment of 3 (moderately likely) or higher. *Dysmicoccus brevipes* had an overall entry and the establishment score of 5 (very likely) which make it an outstanding invasive pest threat to the country. Of critical highlight was the *Fusarium oxysporum* f. sp. *cubense* (score 4 = likely), a pest that threatens the banana production industry in the eastern highlands of Zimbabwe.

INVERTEBRATE INVASIVE PEST THREATS ABSENT IN ZIMBABWE BUT PRESENT IN HER FOUR NEIGHBOURING COUNTRIES

There were 59 invertebrate invasive pest organisms distributed across nine orders, which were revealed by the HST from the four

Table 5. The list of invasive fungi/chromista pest threats absent in Zimbabwe but revealed to be present in Botswana, Mozambique, South Africa, and Zambia using the Centre for Agriculture and Bioscience International (CABI) Horizon Scanning Tool (HST)

Preferred scientific name	Order	Number of hosts affected	Neighbours with pest record	Probable pathway	Likelihood of entry	Likelihood of establishment	Overall risk rating
<i>Cyclaneusma minus</i>	Marthamyceatales	25	1 (South Africa)	DWP, FCP, PLP	3	4	3
<i>Diaporthe eres</i>	Diaporthales	23	1 (South Africa)	DWP, FCP, PLP	3	4	3
<i>Erysiphe platani</i>	Erysiphales	5	1 (South Africa)	DWP, FCP, PLP	3	2	2
<i>Fusarium oxysporum f. sp. cubense</i>	Hypocreales	22	2 (Mozambique, South Africa)	DWP, FCP, PLP	4	4	4
<i>Gibberella circinata</i>	Hypocreales	48	1 (South Africa)	DWP, FCP, PLP	3	5	3
<i>Gibberella indica</i>	Hypocreales	5	1 (Mozambique)	DWP, FCP, PLP	3	2	2
<i>Leptographium procerum</i>	Ophiostomatales	21	1 (South Africa)	DWP, FCP, PLP	3	4	3
<i>Magnaporthe oryzae Triticum pathotype</i>	Magnaporthales	12	1 (Zambia)	DWP, FCP, PLP	3	3	3
<i>Neofusicoccum mangiferae</i>	Botryosphaeriales	12	1 (South Africa)	DWP, FCP, PLP	3	3	3
<i>Oidium anacardii</i>	Erysiphales	1	3 (Mozambique, South Africa, Zambia)	DWP, FCP, PLP	4	1	1
<i>Peronospora belbahrii</i>	Peronosporales	1	1 (South Africa)	DWP, FCP, PLP	3	1	1
<i>Phyllactinia guttata</i>	Erysiphales	17	1 (South Africa)	DWP, FCP, PLP	3	3	3
<i>Phytophthora cambivora</i>	Peronosporales	60	1 (South Africa)	PLP	2	5	2
<i>Puccinia horiana</i>	Pucciniales	11	1 (South Africa)	DWP, FCP, PLP	3	3	3
<i>Pucciniastrum minimum</i>	Pucciniales	11	1 (South Africa)	PLP	2	3	2
<i>Seiridium cardinale</i>	Xylariales	35	1 (South Africa)	FCP, PLP	3	4	3
<i>Synchytrium endobioticum</i>	Chytridiales	8	1 (South Africa)	DWP, FCP, PLP	3	2	2

DWP = debris and waste associated with human activities; FCP = food contaminant; PLP = people and their luggage; CABI HST = Centre for Agriculture and Bioscience International (CABI) Horizon Scanning Tool (HST). Source: CABI (2025a, 2025b, 2025c); key to score: 1 = very unlikely; 2 = unlikely; 3 = moderately likely; 4 = likely and 5 = very likely (Schrader, n.d.).

neighbouring countries to Zimbabwe (Table 6). The HST revealed that Hemiptera order had the highest number which had 14, whilst the least was the order Blattodea that had two. Forty-six of 59 (78%) vertebrates listed had an overall entry and establishment score of 3 (moderately likely) or higher. *Dysmicoccus brevipes* (score 5), *Polyphagotarsonemus latus* (4), *Aleurothrix floccosus* (4), *Aonidiella orientalis* (4), *Ceratitidis rosa* (4), and *Phoracantha recurva* (4) are some of the invertebrate pests threats the country should watch.

INVASIVE PLANT PEST THREATS ABSENT IN ZIMBABWE BUT PRESENT IN HER FOUR NEIGHBOURING COUNTRIES

There were 29 plant invasive pest organisms distributed across 12 orders which were revealed by the HST from the four neighbouring countries to Zimbabwe (Table 7). Of importance on these pest organism is the record of *Hydrilla verticillata* in the three neighbouring countries of Zimbabwe which has no host to attack. *Convolvulus arvensis* under the poacea family had a wider host range of 31 than all the other plants listed as the potential invasive species reported to be present in Zimbabwe's three neighbouring countries. Table 7 also shows the orders of the invasive plant species reported in the four Zimbabwe's neighbours. Eleven (38%) of the listed pest threats from weeds had score of 3 or higher. *Amaranthus retroflexus* and *Solanum torvum* with overall score of 4 apiece were some of the weeds watch against.

VERTEBRATE INVASIVE PEST THREATS ABSENT IN ZIMBABWE BUT PRESENT IN HER FOUR NEIGHBOURING COUNTRIES

There was one vertebrate's invasive pests' organism belonging to the order rodentia which was revealed by the HST from the four neighbouring countries to Zimbabwe. This pest was reported in one neighbouring country to Zimbabwe, the Republic of South Africa and it is likely to be found in DWP. Its likelihood of entry in the studied pest pathways score was 1 (unlikely), and with an establishment score of 5 (very likely) making it of low risk with an overall entry and establishment score of 1.

VIRUS INVASIVE PEST THREATS ABSENT IN ZIMBABWE BUT PRESENT IN HER FOUR NEIGHBOURING COUNTRIES

There were five virus invasive pests' organisms that were revealed by the HST from the four neighbouring countries to Zimbabwe (Table 8). East African cassava mosaic virus was reported in three Zimbabwe neighbours by the HST. Of critical importance is the report of the devastating Maize Chlorotic Mottle Virus (MCMV) associated with Maize Lethal Necrosis for maize and other cereals. Grapevine virus A had the highest number of host plant species. Four of the five viruses listed (80%) had overall entry and the establishment score of 3 or higher. Maize Chlorotic Mottle Virus had an overall establishment of 4 placing it as a serious threat to enter the country.

Table 6. The list of invasive invertebrate pest threats absent in Zimbabwe but present in Botswana, Mozambique, South Africa, and Zambia using the Centre for Agriculture and Bioscience International (CABI) Horizon Scanning Tool (HST).

Preferred scientific name	Order	Number of hosts affected	Neighbours with pest record	Probable pathway	Likelihood of entry	Likelihood of establishment	Overall risk rating.
<i>Aceria guerreronis</i>	Prostigmata	4	1 (Mozambique)	DWP, FCP, PLP	3	2	2
<i>Aleurocanthus woglumi</i>	Hemiptera	108	1 (South Africa)	DWP, FCP, PLP	3	5	3
<i>Aleurodicus dispersus</i>	Hemiptera	258	1 (Mozambique)	PLP	2	5	2
<i>Aleurothrix floccosus</i>	Hemiptera	21	2 (South Africa, Zambia)	DWP, FCP, PLP	4	4	4
<i>Aonidiella orientalis</i>	Hemiptera	74	2 (South Africa, Zambia)	DWP, FCP, PLP	4	5	4
<i>Aphelenchoides ritzemabosi</i>	Rhabditida	60	1 (South Africa)	PLP	2	5	2
<i>Aspidiella hartii</i>	Hemiptera	10	1 (Zambia)	DWP	2	3	2
<i>Bactrocera cucurbitae</i>	Diptera	101	1 (Mozambique)	FCP	3	5	3
<i>Bactrocera oleae</i>	Diptera	3	1 (South Africa)	PLP	2	1	1
<i>Bemisia tabaci (MED)</i>	Hemiptera	117	1 (South Africa)	DWP, FCP, PLP	3	5	3
<i>Blattella germanica</i>	Blattodea	1	2 (Botswana, South Africa)	DWP, FCP, PLP	4	1	1
<i>Brevipalpus lewisi</i>	Prostigmata	9	1 (South Africa)	DWP, FCP, PLP	3	2	2
<i>Bruchophagus roddi</i>	Hymenoptera	7	1 (South Africa)	DWP, FCP, PLP	3	2	2
<i>Callosobruchus maculatus</i>	Coleoptera	24	1 (Zambia)	DWP, FCP, PLP	3	4	3
<i>Ceratitidis rosa</i>	Diptera	35	2 (Mozambique, South Africa)	FCP	4	5	4
<i>Ceroplastes rubens</i>	Hemiptera	306	1 (South Africa)	FCP	3	5	3
<i>Coccidohystrix insolita</i>	Hemiptera	41	1 (South Africa)	DWP, FCP, PLP	3	5	3
<i>Coptotermes curvignathus</i>	Blattodea	24	1 (South Africa)	DWP, FCP, PLP	3	4	3
<i>Corythucha ciliata</i>	Hemiptera	5	1 (South Africa)	DWP, FCP, PLP	3	2	2
<i>Ctenarytaina eucalypti</i>	Hemiptera	9	1 (South Africa)	DWP, FCP, PLP	3	2	2
<i>Daraba laisalis</i>	Lepidoptera	2	1 (South Africa)	DWP, FCP, PLP	3	1	1
<i>Deroceras reticulatum</i>	Stylommatophora	16	1 (South Africa)	DWP, FCP, PLP	3	3	3
<i>Ditylenchus africanus</i>	Rhabditida	19	2 (Mozambique, South Africa)	PLP	4	3	3
<i>Ditylenchus dipsaci</i>	Rhabditida	127	1 (South Africa)	PLP	2	5	2
<i>Dysmicoccus brevipes</i>	Hemiptera	86	3 (Mozambique, South Africa, Zambia)	DWP, FCP, PLP	5	5	5
<i>Epichoristodes acerbella</i>	Lepidoptera	19	1 (South Africa)	DWP, FCP, PLP	3	3	3
<i>Euwallacea piceus</i>	Coleoptera	19	1 (South Africa)	DWP, FCP, PLP	3	3	3
<i>Grapholita molesta</i>	Lepidoptera	18	1 (South Africa)	DWP, FCP, PLP	3	3	3
<i>Hylurgus ligniperda</i>	Coleoptera	14	1 (South Africa)	DWP, FCP, PLP	3	3	3
<i>Leptoglossus occidentalis</i>	Hemiptera	22	1 (South Africa)	DWP, FCP, PLP	3	4	3
<i>Meloidogyne acronea</i>	Rhabditida	18	1 (South Africa) ¹	PLP	3	3	3
<i>Meloidogyne chitwoodi</i>	Rhabditida	18	2 (Mozambique, South Africa)	PLP	4	3	3
<i>Meloidogyne fallax</i>	Rhabditida	18	1 (South Africa)	PLP	3	3	3

Continued

Table 6. Continued.

Preferred scientific name	Order	Number of hosts affected	Neighbours with pest record	Probable pathway	Likelihood of entry	Likelihood of establishment	Overall risk rating.
<i>Meloidogyne graminicola</i>	Rhabditida	58	1 (South Africa)	PLP	3	5	3
<i>Meloidogyne mayaguensis</i>	Rhabditida	13	1 (South Africa)	PLP	3	3	3
<i>Milax gagates</i>	Stylommatophora	1	1 (South Africa)	DWP, FCP, PLP	3	1	1
<i>Monomorium destructor</i>	Hymenoptera	1	2 (Mozambique, South Africa)	DWP, FCP, PLP	4	1	1
<i>Ophelimus maskelli</i>	Hymenoptera	3	1 (South Africa)	DWP, FCP, PLP	3	1	1
<i>Orseolia oryzivora</i>	Diptera	2	1 (Zambia)	DWP, FCP, PLP	3	1	1
<i>Orthotomicus erosus</i>	Coleoptera	32	1 (South Africa)	DWP, FCP, PLP	3	5	3
<i>Paracoccus marginatus</i>	Hemiptera	188	1 (South Africa)	PLP	2	5	2
<i>Paratrechina longicornis</i>	Hymenoptera	4	1 (South Africa)	PLP	2	2	2
<i>Phlyctinus callosus</i>	Coleoptera	18	1 (South Africa)	DWP, FCP, PLP	3	3	3
<i>Phoracantha recurva</i>	Coleoptera	32	2 (South Africa, Zambia)	DWP, FCP, PLP	4	5	4
<i>Pieris brassicae</i>	Lepidoptera	37	1 (South Africa)	DWP, FCP, PLP	3	5	3
<i>Polyphagotarsonemus latus</i>	Prostigmata	37	2 (Mozambique, South Africa)	DWP, FCP, PLP	4	5	4
<i>Pratylenchus bolivianus</i>	Rhabditida	1	1 (South Africa)	DWP, FCP, PLP	3	1	1
<i>Pyrhalta luteola</i>	Coleoptera	11	1 (South Africa)	FCP	3	3	3
<i>Raoiella indica</i>	Prostigmata	116	1 (South Africa)	DWP	2	5	2
<i>Scyphophorus acupunctatus</i>	Coleoptera	10	1 (South Africa)	DWP, FCP, PLP	3	3	3
<i>Siphoninus phillyreae</i>	Hemiptera	15	1 (South Africa)	DWP, FCP, PLP	3	3	3
<i>Sirex noctilio</i>	Hymenoptera	27	1 (South Africa)	DWP, FCP, PLP	3	4	3
<i>Sitophilus granarius</i>	Coleoptera	17	1 (South Africa)	DWP, FCP, PLP	3	3	3
<i>Sitophilus oryzae</i>	Coleoptera	21	1 (South Africa)	DWP, FCP, PLP	3	4	3
<i>Xyleborinus saxesenii</i>	Coleoptera	43	1 (South Africa)	DWP, FCP, PLP	3	5	3
<i>Xyleborus similis</i>	Coleoptera	24	1 (South Africa)	DWP, FCP, PLP	3	4	3
<i>Xylosandrus crassiusculus</i>	Coleoptera	52	1 (South Africa)	DWP, FCP, PLP	3	5	3
<i>Zonitoides arboreus</i>	Stylommatophora	0	1 (South Africa)	DWP, FCP, PLP	3	1	1

DWP = debris and waste associated with human activities; FCP = food contaminant; PLP = people and their luggage; CABI HST = Centre for Agriculture and Bioscience International (CABI) Horizon Scanning Tool (HST). Source: CABI (2025a, 2025b, 2025c), key to score: 1 = very unlikely; 2 = unlikely; 3 = moderately likely; 4 = likely and 5 = very likely (Schrader, n.d.).

Discussion

This study scanned the threats of invasive plant pest species present in four neighbouring countries but not present in Zimbabwe that are likely conveyed via DWP, PLP, and FCP pathways using the HST. There were 114 plant pest threats associated with the three aforementioned pathways that will likely impact Zimbabwean agriculture negatively. The presence of pest threats such as MCMV indicates a serious plant biosecurity threat to the Zimbabwe's cereal food production sector (Kimani *et al.*, 2024). Other pests identified by the HST included *Dysmicoccus brevipes*, *Polyphagotarsonemus latus*, *Aleurothrixus floccosus*, *Aonidiella orientalis*, *Ceratitidis rosa*, *Phoracantha recurva*, *Erysiphe platani*, *Fusarium oxysporum f. sp. cubense*, *Candidatus Phytoplasma*

palmae, *Amaranthus retroflexus*, and *Solanum torvum*. These threats require proactive planning to protect the plant biosecurity challenges that could be imminent.

HST equips countries with evidence-based decision-making capacity regarding pathway management in plant biosecurity (Webber, 2010). Biosecurity considers the importance of protecting nations from transboundary pests that are brought about by the cross-border movement of people, goods, and commodities which act as the pathways of pest movement (Waage and Mumford, 2008; Department of Primary Industries, 2019). This scanning horizon tool has not only reported pest threats for plant host, but the pests that could impact the availability of agricultural water. The scan reported the presence of *H. verticillata*, a weed

Table 7. The list of invasive weeds/plants pest threats absent in Zimbabwe but reported in Botswana, Mozambique, South Africa, and Zambia using the Centre for Agriculture and Bioscience International (CABI) Horizon Scanning Tool (HST).

Preferred scientific name	Order	Number of hosts affected	Neighbours with pest record	Probable pathway	Likelihood of entry	Likelihood of establishment	Overall risk rating
<i>Amaranthus deflexus</i>	Caryophyllales	3	1 (South Africa)	DWP, FCP, PLP	3	5	3
<i>Amaranthus retroflexus</i>	Caryophyllales	34	2 (Botswana and Zambia)	DWP, FCP, PLP	4	5	4
<i>Atriplex muelleri</i>	Caryophyllales	1	1 (South Africa)	DWP, FCP, PLP	3	1	1
<i>Convolvulus arvensis</i>	Solanales	31	1 (South Africa)	DWP, FCP, PLP	3	5	3
<i>Cyperus cyperoides</i>	Poales	1	1 (South Africa)	DWP, FCP, PLP	3	1	1
<i>Elymus repens</i>	Poales	26	1 (South Africa)	DWP, FCP, PLP	3	4	3
<i>Erodium cicutarium</i>	Geraniales	3	1 (South Africa)	DWP, FCP, PLP	3	1	1
<i>Ficus carica</i>	Rosales	1	1 (South Africa)	DWP, FCP, PLP	3	1	1
<i>Glandularia aristigera</i>	Lamiales	1	1 (South Africa)	DWP, FCP, PLP	3	1	1
<i>Hydrilla verticillata</i>	Alismatales	0	3 (Mozambique, South Africa, Zambia)	DWP, FCP, PLP	5	2	2
<i>Leersia hexandra</i>	Poales	5	2 (Botswana, South Africa)	DWP, FCP, PLP	4	2	2
<i>Ludwigia peruviana</i>	Myrtales	1	1 (South Africa)	DWP, FCP, PLP	3	1	1
<i>Melastoma malabathricum</i>	Myrtales	6	1 (South Africa)	DWP, FCP, PLP	3	2	2
<i>Nassella neesiana</i>	Poales	0	1 (South Africa)	DWP, FCP, PLP	3	2	2
<i>Nassella tenuissima</i>	Poales	0	1 (South Africa)	DWP, FCP, PLP	3	2	2
<i>Nopalea cochenillifera</i>	Caryophyllales	0	2 (Mozambique, South Africa)	DWP	4	2	2
<i>Opuntia dillenii</i>	Caryophyllales	1	1 (South Africa)	DWP, FCP, PLP	3	1	1
<i>Oxalis pes-caprae</i>	Oxalidales	5	1 (South Africa)	DWP, FCP, PLP	3	2	2
<i>Passiflora foetida</i>	Malpighiales	17	2 (Mozambique, South Africa)	DWP, FCP, PLP	4	3	3
<i>Poa trivialis</i>	Poales	1	1 (South Africa)	DWP, FCP, PLP	3	1	1
<i>Polygonum hydropiper</i>	Caryophyllales	21	1 (South Africa)	DWP, FCP, PLP	3	4	3
<i>Polygonum nepalense</i>	Caryophyllales	10	1 (South Africa)	DWP, FCP, PLP	3	3	3
<i>Solanum rostratum</i>	Solanales	1	1 (South Africa)	PLP	2	1	1
<i>Solanum torvum</i>	Solanales	110	2 (South Africa, Zambia)	DWP, FCP, PLP	4	5	4
<i>Stachytarpheta jamaicensis</i>	Lamiales	15	2 (South Africa, Zambia)	DWP, FCP, PLP	4	3	3
<i>Synedrella nodiflora</i>	Asterales	28	1 (Zambia)	DWP, FCP, PLP	3	4	3
<i>Talinum paniculatum</i>	Caryophyllales	3	1 (South Africa)	DWP, FCP, PLP	3	1	1
<i>Thlaspi arvense</i>	Brassicales	26	1 (South Africa)	DWP, FCP, PLP	3	4	3
<i>Tropaeolum majus</i>	Brassicales	1	1 (South Africa)	DWP	3	1	1

DWP = debris and waste associated with human activities; FCP = food contaminant; PLP = people and their luggage. Source: CABI (2025a, 2025b, 2025c), key to score: 1 = very unlikely; 2 = unlikely; 3 = moderately likely; 4 = likely; and 5 = very likely (Schrader, n.d.).

capable of spreading by vegetative propagules fragments that take advantages of its floatation mechanism on water bodies as a secondary means of translocation (Velez-Gavilan, 2024). There were 116 pest threats reported in Zimbabwe's neighbours where unofficial exchange of planting material takes place due to porous borders and cross-border kinship.

The pest pathways studied in this study are subjects for use by smugglers and non-official crossings points. This is likely to negatively impact the biosecurity of the country, especially given the porous borders between Zimbabwe and her neighbours (Nyoni, 2022). People and their luggage were associated with the highest pests' threats of 104, whilst food contaminants and debris

Table 8. The list of virus pest threats absent in Zimbabwe but recorded in Botswana, Mozambique, South Africa, and Zambia using the Centre for Agriculture and Bioscience International (CABI) Horizon Scanning Tool (HST).

Preferred scientific name	Order	Number of hosts affected	Neighbours with pest record	Probable pathway	Likelihood of entry	Likelihood of establishment	Overall risk rating
<i>Grapevine virus A</i>	Tymovirales	11	1 (South Africa)	DWP, FCP, PLP	3	3	3
<i>East African cassava mosaic virus</i>	Geplafuvirales	9	3 (Mozambique, South Africa, Zambia)	FCP	4	2	2
<i>Maize Chlorotic Mottle Virus (Machlomovirus zaeae)</i>	Machlomovirus	8	1 (Mozambique)	DWP, FCP, PLP	4	5	4
<i>Cassava brown streak viruses</i>	Patatavirales	3	2 (Mozambique, Zambia)	DWP, FCP, PLP	4	3	3
<i>Tomato curly stunt virus</i>	Geplafuvirales	1	1 (South Africa)	DWP, FCP, PLP	3	4	3

DWP = debris and waste associated with human activities; FCP = food contaminant; PLP = people and their luggage. Source: CABI (2025a, 2025b, 2025c), key to score: 1 = very unlikely; 2 = unlikely; 3 = moderately likely; 4 = likely; and 5 = very likely (Schrader, n.d.).

Table 9. Shannon diversity index (H') for pest threats at different geographic scales (Zimbabwe's neighbours, SADC, and globally).

Organism type	Neighbours ($H' = 1.37$)	SADC ($H' = 1.41$)	Global ($H' = 1.63$)
Bacteria	0.12 (3.51%)	0.13 (3.53%)	0.08 (2.11%)
Fungi/chromista	0.27 (14.91%)	0.21 (8.94%)	0.24 (11.28%)
Invertebrates	0.35 (50.88%)	0.35 (43.42%)	0.34 (47.14%)
Plants	0.36 (25.44%)	0.37 (40.24%)	0.34 (30.22%)
Vertebrates	0.01 (0.88%)	0.01 (0.77%)	0.04 (3.25%)
Virus	0.06 (4.39%)	0.05 (3.10%)	0.06 (4.67%)
Protozoa	–	–	0.002 (0.23%)
Unknown aetiology	–	–	0.0003 (0.08%)
Unknown	–	–	0.004 (1.01%)
Total H' (bits)	1.37	1.41	1.63
Richness (S)	6	6	9
Evenness (J')	0.53	0.55	0.51

and waste associated with human activities were associated with 94 and 93 pest threats, respectively. The pest pathways scanned did not have significant differences of pests carried on them. Similarly, from its findings, the Department of Primary Industries (2019) reported that pest propagules can carry anything with them without much a choice as long as that organism can find a seat in the medium. In such situations of high pest threats, pest monitoring mechanisms call for highly specific and rapid diagnosis systems that provide for efficient customs clearing and that thoroughly screen out pest threats (Augustin *et al.*, 2012). Such procedures must have minimal inconveniences to the cross-border traffic for both goods and passengers whilst at the same time providing for due diligence of cross-border traffic quarantine inspections. From the evaluation of the use and impact of the CABI's decision support tools for biosecurity, Kadzamira *et al.* (2023) found that the HST had since undergone enrichments to strengthen its technological design and content to meet the user needs, increasing the tools' value as a resource in pest risk decision support mechanisms, providing a sterling advantage over manual pest scanning systems used prior to this development.

The existence of pest threats in the Zimbabwe's neighbours provide countries with intelligence to remain vigilant given the

free movement of pest-pathways across borders given brought by trade agreements such as the African Continental Free Trade Area (AfCFTA) (Youm *et al.*, 2011). The AfCFTA allows a free movement of travellers as they market their goods across African continent. The threats of new pest invasions need to be guaranteed by allowing sovereignty of member states on phytosanitary regulations in order to protect plant biosecurity. The advent of AfCFTA threatens the continent with increased risk of pest invasions due to frequent and diverse trade that opens up the heightened opportunities for pests to hitchhike on goods and packaging pest pathways exacerbating the risk of entry of invasive species (Epanchin-Niell *et al.*, 2021). This may lead to significant negative biosecurity impacts such as agricultural losses, damage to biodiversity, and increased costs for pest management within the member states (Margolis and Shogren, 2004).

In order to avert such threats, robust phytosanitary measures, such as strengthened risk assessments systems, pest management including fumigation, and trade restrictions of high-risk species, should be implemented to balance trade benefits and biosecurity concerns (Epanchin-Niell *et al.*, 2021). For instance, the clear dominance of the PLP pathway should lead to the immediate need to enhance surveillance at official border posts and to launch public

awareness campaigns targeted at travellers. Such robust measures should not be limited to ACFTA but to all free trade areas that might lead to proliferation of new pests in new environments. Free trade areas are also associated with high trade volume that provides more pathways for pest movement (Padhiyar and Thakar, 2022).

CONCLUSIONS

The study found significant invasive plant pest threats endangering Zimbabwe's agriculture sector from her neighbouring countries. There were 29 plant pests, 58 invertebrates, 17 fungi/chromista, 4 bacteria, 5 viruses, and one vertebrate pest threat species recorded in Zimbabwe's neighbours. At SADC level 1,163 pest threats were present, whilst 16,651 threats were found globally. More threats were from South Africa (87%) than the rest of Zimbabwe's neighbours (13%). The invertebrates (51%) dominated the pest threats present in the neighbours. SADC had a high diversity of plants (40%) and invertebrates (43%). Sixty-three percent (63%) of the listed 73 pests require urgent preparedness to avoid any plant biosecurity challenges to the country in the imminent future. This was the first horizon scanning report of invasive pest species threatening Zimbabwe's agricultural systems and it provided a valuable prioritized list and a hypothesis of pest risk that must now be validated through further, more detailed investigations.

RECOMMENDATIONS

Whilst this study provided a first crucial step in revealing valuable prioritized list of invasive pests threatening Zimbabwe's plant biosecurity from its neighbours, an in-depth analysis of the listed pests is required, possibly through conducting pest risk analysis. The Zimbabwe plant protection authority is strongly recommended to immediately initiate Pest Risk Analyses for pest threats associated with PLP and FCP Tables 4–8, specifically cereal and fruits that constitute major pathways into the country through importation. The country needs to strengthen inspection protocols for passenger luggage, particularly from South Africa given the high diversity of pest threat organism revealed in these studies. Zimbabwe should enhance invertebrate-dominated biosecurity policing from the neighbours and invest in broad-spectrum plant biosecurity systems for the global pest threats. Future research should focus on ground-truthing the pathway associations identified by the HST and developing methods to correct for surveillance bias in cross-border pest risk data.

LIMITATION OF THE STUDY

The use of HST revealed only the invasive pest species recorded in the data bases the HST queries. Any invasive pest threats outside this framework were not recorded. Overall Risk Likelihood of entry and establishment of the identified threats followed the EPPO 'bottleneck' principle, taking the lower score of Entry and Establishment, resulting in some pest threats such as why *Gibberella circinata* (Entry 3, Establishment 5) had an overall score of 3 yet its high establishment potential was constrained by a moderately likely entry. The core EPPO principle is that a pest cannot establish if it does not enter a country, and it cannot cause effect if it does not establish. This means that the overall risk is constrained by the weaker link in the chain. This is exemplified by cassava brown streak viruses, which have a high entry pressure (4) but a very low establishment potential (1), resulting in a final overall rating of 1 (very unlikely).

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CONFLICT OF INTEREST

The authors have no conflicts of interest to declare.

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Not applicable.

AUTHOR CONTRIBUTIONS

All authors contributed significantly to the paper.

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References

- Anonymous (2016) Annual Report 2016. Plant Quarantine Services Institute, Department of Research and Specialist Services, Mazowe, Zimbabwe.
- Augustin, S., Boonham, N., DeKogel, W.J., Donner, P., Faccoli, M. *et al.* (2012) A review of pest surveillance techniques for detecting quarantine pests in Europe. *EPPO Bulletin* 42(3), 515–551. DOI: 10.1111/epp.2600.
- Black, R. and Bartlett, D.M.F. (2020) Biosecurity frameworks for cross-border movement of invasive alien species. *Environmental Science & Policy* 105, 113–119. DOI: 10.1016/j.envsci.2019.12.011.
- CABI (2016) *Fall Armyworm First Report in Zimbabwe*. Centre for Agriculture and Biosciences International (CABI), United Kingdom. DOI: 10.1079/cabicompendium.29810.
- CABI (2020) *Fusarium oxysporum f. Sp. Cubense (Panama Disease of Banana)*. CAB International, Wallingford, UK. [Dataset]. Available at: <https://www.cabi.org/isc/datasheet/24621> (accessed 02 January 2020).
- CABI (2021a) *Invasive Species Compendium online*. CAB International, Wallingford, UK. [Dataset]. (accessed 08 March 2021).
- CABI (2021b) *Scanning Horizon; Online*. CAB International, Wallingford, UK. [Dataset]. Available at: <https://www.cabi.org/online> (accessed 08 March 2021).
- CABI (2025a) *Crop Protection Compendium*. CAB International, Wallingford. [Dataset]. Available at: <https://www.cabi.org/PRA-tool> (accessed 11 June 2025).
- CABI (2025b) *Horizon Scanning Tool*. CAB International, Wallingford, UK. [PEST DATA BASE]. Available at: <https://cabidigitalibrary.org/journal/cabicompendium> (accessed 22 June 2025).
- CABI (2025c) *Pest Risk Analysis Tool*. CAB International, Wallingford, UK. [Dataset]. Available at: <https://www.cabi.org/PRA-tool> (accessed 22 June 2025).
- Department of Primary Industries (2019) *Intergovernmental Agreement on Biosecurity*. Department of Primary Industries, Australia. Available at: www.dpi.nsw.gov.au.
- Dimbi, S., Masukwedza, R. and Garwe, D. (2017) *Failure to Destroy Tobacco Stalks on Time Can Potentially Destroy the Zimbabwean Tobacco Industry!* Tobacco Research Board, Harare. Available at: www.kutsaga.co.zw/downloads/destroystalks.pdf (accessed 17 February 2020).
- Dita, M., Barquero, M., Heck, D., Mizubuti, E.S.G. and Staver, C.P. (2018) Fusarium wilt of banana: Current knowledge on epidemiology and research needs toward sustainable disease management. *Frontiers in Plant Science* 9, 1468. DOI: 10.3389/fpls.2018.01468.
- Epanchin-Niell, R., McAusland, C., Liebhold, A., Mwebaze, P. and Springborn, M.R. (2021) Biological invasions and international trade: Managing a moving target. *Review of Environmental Economics and Policy* 15(1), 180–190. DOI: 10.1086/713025.
- Eschen, R., Beale, T., Bonnin, J.M., Constantine, K.L., Duah, S. *et al.* (2021) Towards estimating the economic cost of invasive alien species to African crop and livestock production. *CABI Agriculture and Bioscience* 2(1), 18. DOI: 10.1186/s43170-021-00038-7.

- Komorowski, M., Marshall, D.C., Salciccioli, J.D., Crutain, Y. (2016). Exploratory data analysis. In: *Secondary Analysis of Electronic Health Records*. Springer, Cham. DOI: 10.1007/978-3-319-43742-2_15.
- FAO (2007) *Pest Risk Analysis (PRA) Training Participant Manual*. Chief, Electronic Publishing Policy and Support Branch, Communication Division, FAO, Rome, Italy.
- FAO (2017) *Fall Army Worm First Report in Zimbabwe*, FAO in Zimbabwe. Available at: <https://www.fao.org/zimbabwe/news/detail-events/en/c/1098239/> [Online post]
- Forestry Research (2021) A pathway approach towards prevention of movement of pests and pathogens with live plants in international trade. In: *Recommendation of a Pathway Approach for Regulation of Plants for Planting. A Concept Paper from the IUFRO Unit on Alien Invasive Species and International Trade*, Forest Research, United Kingdom.
- Hulme, P.E. (2024) Networks of risk: International tourists as a biosecurity pathway into national parks. *Biological Invasions* 26(12), 4317–4330. DOI: 10.1007/s10530-024-03448-6.
- Hutchinson, D. (2023) *Horizon Scanning and Pest Risk Analysis of Prioritized Pests in Bangladesh*. Available at: <https://blog.plantwise.org/2023/03/31/horizon-scanning-and-pest-risk-analysis-of-prioritized-pests-in-bangladesh/> (accessed 21 June 2025).
- IPPC Secretariat (2013) *New Banana Disease Found in Mozambique (Fusarium oxysporum f. Sp. Cubense Tropical Race 4)*. (No. IPPC Official Pest Report No. MOZ-03/2). IPPC, Food and Agriculture Organisation, Rome, Italy.
- IPPC Secretariat (2016a) *International Standards for Phytosanitary Measures ISPM 27 Diagnostic Protocols for Regulated Pests* (ISPM No. 32). FAO on Behalf of the Secretariat of the International Plant Protection Convention (IPPC), Rome, Italy. Available at: https://assets.ippc.int/static/media/files/publication/en/2024/07/ISPM_05_2024_En_Glossary_PostCPM-18_InkAmdts_2024-07-29.pdf
- IPPC Secretariat (2016b) *Phytosanitary Principles for the Protection of Plants and the Application of Phytosanitary Measures in International Trade* (No. 1). FAO on Behalf of the Secretariat of the International Plant Protection Convention (IPPC), Rome, Italy.
- Jansen, K. and De LaCruz Bekema, J. (2023) The control of transboundary plant diseases and the problem of the public good: Lessons from *Fusarium wilt* in banana. *NJAS: Impact in Agricultural and Life Sciences* 95(1), 1–31. DOI: 10.1080/27685241.2023.2261402.
- Kadzamira, M., Charles, L., Hevi, W., Kasoma, C., Ogunmodede, A. and Williams, F. (2023) Assessment of the use of CABI's pest risk decision support tools – Pest risk analysis tool and horizon scanning tool. In: *CABI Working Paper*. Vol. 31, CABI, United Kingdom, 26 pp. DOI: 10.1079/cabicomm-62-8172 (accessed 12 August 2025).
- Kimani, E.N., Micheni, C.M., Muriki, L.G., Kiarie, S.M., Miano, D.W. et al. (2024) Influence of genotypes and crop growth stage at time of infection on seed transmission of *Maize chlorotic mottle virus*. *Archives of Phytopathology and Plant Protection* 57(2), 95–111. DOI: 10.1080/03235408.2024.2331040.
- Kottek, M., Grieser, J., Beck, C., Rudolf, B. and Rubel, F. (2006) World Map of the Köppen-Geiger climate classification updated. *Meteorologische Zeitschrift* 15, 259–263. Available at: <https://koeppen-geiger.vu-wien.ac.at/present.htm> (accessed 22 January 2026).
- Margolis, M. and Shogren, J.F. (2004) *How Trade Politics Affect Invasive Species Control* (No. Discussion Paper 04-07). Resources for the Future, 1616 P Street, NW Washington, D.C. 20036. Available at: <http://www.rff.org> (accessed 30 September 2025).
- Mbekeani, K. (2013) *Regional Integration Policy Papers: Intra-Regional Trade in Southern Africa: Structure, Performance and Challenges Regional* (No. 2). African Development Bank Group: Integration & Trade Department, Tunis – Belvédère (Tunisia).
- Ministry for Primary Industries (2020) *Risk Management Proposal: Amendments to the Import Health Standard for Sea Container from All Countries*, New Zealand. Available at: <https://www.mpi.govt.nz/news-and-resources/publications/> (accessed 06 January 2020).
- Mudada, N., Mapope, N. and Ngezimana, W. (2022) The threat of transboundary plant pathogens to agricultural trade in Southern Africa: A perspective on Zimbabwe's plant biosecurity – A review. *Plant Pathology & Quarantine* 12(1), 1–33. DOI: 10.5943/ppq/12/1/1.
- Nyoni (2022) Smuggled tomatoes flood Zim markets Agriculture. In: *Southern Eye*, Harare, Zimbabwe. Available at: <https://www.newsday.co.zw/southerneye/agriculture/article/200004041/smuggled-tomatoes-flood-zim-markets> (accessed 13 March 2025).
- Oronje, M. (2025) *Horizon Scanning for Climate-driven Pest Threats Can Prevent Biodiversity Loss*. CAB International, Wallingford, UK. Available at: <https://blog.plantwise.org/2025/05/22/horizon-scanning-for-climate-driven-pest-threats-can-prevent-biodiversity-loss/> (accessed 21 June 2025).
- Padhiyar, D.H. and Thakar, P.K. (2022) Global trade and risk of invasive pests. *Agriculture and Food* 04(10): 99–102. Agrifood magazine, India. Available at: www.agrifoodmagazine.co.in (accessed 30 September 2025).
- Plant Quarantine Services Institute (2017) *Annual Report 2017*. [Annual Report]. Plant Quarantine Services Institute, Department of Research and Specialist Services, Mazowe, Zimbabwe.
- Roy, H.E., Peyton, J., Aldridge, D.C., Bantock, T., Blackburn, T.M. et al. (2014) Horizon scanning for invasive alien species with the potential to threaten biodiversity in Great Britain. *Global Change Biology* 20(12), 3859–3871. DOI: 10.1111/gcb.12603.
- Schrader, G. (n.d.) *Adaptation of Regional Pest Risk Assessment to the Revised ISPM 11. Or the EPPO Pest Risk Assessment Scheme*. Food and Agriculture Organization of the United Nations (FAO), Rome, Italy. Available at: <https://www.fao.org/4/y5968e/y5968e0k.htm> (accessed 26 January 2026).
- Somerfield, P.J., Clarke, K.R. and Warwick, R.M. (2008) Simpson Index. In: *Encyclopedia of Ecology*. Elsevier, Oxford, pp. 3252–3255. DOI: 10.1016/B978-008045405-4.00133-6.
- Tambo, J.A., Kansime, M.K., Rwomushana, I., Mugambi, I., Nunda, W. et al. (2021) Impact of fall armyworm invasion on household income and food security in Zimbabwe. *Food and Energy Security* 10(2), 299–312. DOI: 10.1002/fes3.281.
- TIMB (2017) *Zimbabwe Tobacco Industry and Marketing Board (TIMB). Annual Statistics 2017*. Tobacco Industry and Marketing Board, Harare, Zimbabwe, p. 25. Available at: <https://www.timb.co.zw/storage/app/media/Annual%20Stats%20Report/2017%20ANNUAL%20STATISTICAL%20REPORT.pdf> (accessed 31 January 2021).
- Tshikhudo, P.P., Nnzeru, L.R., Rambauli, M., Makhado, R.A. and Mudau, F.N. (2021) Phytosanitary risk associated with illegal importation of pest-infested commodities to the South African agricultural sector, Pretoria, South Africa. *South African Journal of Science* 117(7/8), 1–8. DOI: 10.17159/sajs.2021/8675.
- Tshikhudo, P.P., Simandla, A., Nnzeru, L.R., Gebeyehu, S., Mokwele, J. et al. (2025) Horizon scanning for invasive insects with potential threats to crop production in South Africa. *Discover Sustainability* 6(1), 205. DOI: 10.1007/s43621-025-01010-5.
- Velez-Gavilan, J. (2024) *Hydrilla verticillata (hydrilla)*. CAB International, Wallingford, UK. [Dataset], p. 28170. DOI: 10.1079/cabicompndium.28170.
- Venter, T.S., Robertson, M.P., Saccaggi, D.L. and Faulkner, K.T. (2021) The wheat curl mite *Aceria tosichella*, Prostigmata: Eriophyidae) could establish in South Africa. *African Zoology* 56(1), 17–24. DOI: 10.1080/15627020.2020.1845794.
- Waage, J.K. and Mumford, J.D. (2008) Agricultural biosecurity. *Philosophical Transactions of the Royal Society B: Biological Sciences* 363(1492), 863–876. DOI: 10.1098/rstb.2007.2188.
- Webber, J. (2010) Pest risk analysis and invasion pathways for plant pathogens. *New Zealand Journal of Forestry Science* 40(suppl.), S45–S56.
- Youm, O., Vayssières, J.-F., Togola, A., Robertson, S.P. and Nwile, F.E. (2011) International trade and exotic pests: The risks for biodiversity and African economies. *Outlook on Agriculture* 40(1), 59–70. DOI: 10.5367/oa.2011.0031.
- Zhang, S., Griffiths, J.S., Marchand, G., Bernards, M.A. and Wang, A. (2022) Tomato brown rugose fruit virus: An emerging and rapidly spreading plantv RNA virus that threatens tomato production worldwide. *Molecular Plant Pathology* 23(9), 1262–1277. DOI: 10.1111/mp.13229.