Journal of Applied Biosciences 210: 22212 – 22233
ISSN 1997-5902

Towards an Efficient Management of the Biological Invasions with Special Focus on the Benin's Phytosanitary Legislation: Review

Mahoutin Sonagnon Kindomissi*[1,2], Elie Ayitondji Dannon[1,2], Eric Adossou[3], Gualbert Houéménou[4]

[1]Université Nationale des Sciences, Technologies, Ingénierie et Mathématiques (UNSTIM), École Normale Supérieure de Natitingou, BP 72 Natitingou, Bénin; k.mahouson13@gmail.com*,

[2]International Institute of Tropical Agriculture (IITA) 08 B.P. 0932. Tri Postal. Cotonou, Bénin; *edannon@gmail.com*

[3] Service Protection des Végétaux et Contrôle Phytosanitaire (SPVCP), Direction de la Production Végétale (DPV) 01 BP 58 Porto-Novo, Ministère de l'Agriculture, de l'Elevage et de la Pêche (MAEP), Bénin ; *ericadossou2@yahoo.fr* ;

[4]École Polytechnique d'Abomey- Calavi, Laboratoire de Recherche en Biologie Appliquée, Unité de Recherche sur les Invasions Biologiques, Université d'Abomey- Calavi (UAC), 01 BP 2009, Cotonou, Benin ; *gualbert.houemenou@gmail.com*

* Correspondence: E-mail address: k.mahouson13@gmail.com (M. Kindomissi).

Orcid address: https:// orcid.org/0009-0002-7476-8170

Current adress : Port Environmental Monitoring Platform (EMPP), Autonomous Port of Cotonou, | Bvd de la Marina | 01 BP 927, Cotonou, Benin

Submitted 11/06/2025, Published online on 31/07/2025 in the https://www.m.elewa.org/Journals/journal-of-applied-biosciences https://doi.org/10.35759/JABs.210.4

ABSTRACT

Invasive alien insects pose a serious challenge to agriculture in Benin, threatening the food security, biodiversity, and socio-economic resilience of the country. Global trade of plants and plant products has inadvertently spread pests, causing significant crop and post-harvest losses. To overcome such issues, a robust phytosanitary legal framework is therefore essential for risk prevention and management. This review critically examines the relevance and effectiveness of Benin's regulatory measures in the context of international plant health standards. This study analysis, aligned with international standards, reveals the strengths and weaknesses of Benin's plant health legislation. It provides a technical-scientific analysis of Benin's phytosanitary legislation in the light of International Standards and Phytosanitary Measures. Our analysis reveals the strengths and weaknesses of various frameworks in optimizing interventions. Key priorities for enhancing resilience in Beninese agriculture include strengthening institutional capacity, improving early detection and surveillance systems, and implementing integrated pest management strategies.

Keywords: phytosanitary policy and governance, legal regulation, invasive species, biosecurity, international standards, agricultural development, Benin.

INTRODUCTION

Plant pests and diseases remain among the most persistent and damaging constraints on global agricultural productivity, biodiversity conservation and food system stability. According to the Food and Agriculture Organization of the United Nations (FAO), these biotic threats are responsible for the loss of 40% of global agricultural yields each year, undermining both rural livelihoods and international efforts towards sustainable development (FAO, 2022). Despite the existence of **international regulatory frameworks** such as the International Plant Protection Convention (IPPC), effective management of transboundary pests remains a major challenge, particularly in developing countries where surveillance systems, regulatory infrastructure and technical capacity are often inadequate. In this context, **phytosanitary legislation** is the cornerstone of **phytosanitary governance**. It provides the legal basis for pest surveillance, early warning systems, pest risk analysis, import controls and rapid reaction mechanisms. However, the mere existence of legislation is not enough. Current research highlights the need for national legal frameworks not only to align with international standards for phytosanitary measures (ISPMs), but also to incorporate dynamic, science-based risk assessment tools and institutional capacity building (Mumford and Burgman, 2020; IPPC, 2021). The designation of 2020 as the International Year of Plant Health (IYPH) by the FAO was a pivotal moment, renewing global attention on the fundamental role of phytosanitary systems in achieving several UN Sustainable Development Goals (SDG), including SDG 2 (Zero Hunger) and SDG 15 (Life on Earth) (FAO, 2020). One of the central messages of this initiative was the urgent need to strengthen national legislative and institutional frameworks to stem the rising tide of invasive alien species, a problem exacerbated by intensifying global trade, climate variability and insufficient biosecurity at borders. In regions such as sub-Saharan Africa, where ecosystems are both rich in biodiversity and highly sensitive to biological invasions, strengthening phytosanitary legislation is not just a regulatory obligation, but a strategic imperative. It is essential to preserve agricultural productivity, secure environmental sustainability and protect the food sovereignty of vulnerable populations. This phytosanitary legislation is useful in overcoming problems induced by crop pests' diseases at different levels (local, national or international). It provides administrative and technical facilities for carrying out phytosanitary activities with appropriate means to manage pests and diseases for protecting consumers through quality products promotion. In this period of globalization, the ever-increasing volume of trade increased the risk of biological invasions, and insects on stored foodstuffs are emerging as major vectors. According to the Inter-governmental Platform on Biodiversity and Ecosystem Services (IPBES), ''biological invasion'' is defined as ''a process involving the transport of a native species outside its natural range, intentionally or unintentionally, by human activities to new areas where it can become established, spread and ultimately have a negative impact on nature, nature's contributions to humans and the quality of life (IPBES, 2023). The IPPC Secretariat revealed that around 40% of agricultural yield losses were caused by exotic pests, resulting in annual economic losses estimated at 220 billion dollars. Moreover, these pests were not only a threat to food security but also a test of phytosanitary standards (IPPC, 2021). The risks and damage caused by invasive species can be considerable, especially in unstable island ecosystems (Wittenberg and Cock, 2001). From 1970 to the present day, biological invasions have cost the economy of Sub-Saharan Africa (SSA) between 18.2 and 80 billion dollars, mainly through a small

number of insect species, notably *Chilo partellus* (spotted stem borer), *Tuta absoluta* (tomato leaf miner) and *Spodoptera frugiperda* (autumn armyworm) (Diagne *et al.,* 2021). The latter species, first recorded in Benin in 2016 (Goergen *et al., 2016*), has invaded Africa and spread rapidly to 21 countries causing devastating damage to maize, with crop losses estimated at 3 billion dollars a year (Stokstad, 2017). While smallholder farmers have always faced significant crop losses due to native crop pests, the impact of this invasive pest highlighted the need for developing effective and sustainable pest management methods. In the literature, several studies have addressed the phytosanitary risk management framework induced by the trade movement of products, in this case those related to horticulture (van Klinken *et al.,* 2020), but which are also applicable to all commodities and to phytosanitary risk management horticulture (van Klinken *et al.,* 2023). In Benin, the agricultural sector employs around 70% of the working population and contributes almost 23% to the formation of the Gross Domestic Product (GDP) (INSAE, 2017). It provides around 75% of export earnings and 15% of government revenue. The agriculture sector is recognized as an important sector because it helps to ensure food sovereignty and food and nutritional security. Given the socio-environmental challenges posed by biological invasions, the monitoring and management of invasive species at entry points such as ports, airports and land borders has been identified as a priority by major international organizations (Adamjy *et al.,* 2020). In response to the societal challenges raised by bio-invasions, several international conventions were proposed by the United Nations' specialized agencies. These legal instruments were the basis for any initiative in this direction and even a source of motivation and action for the scientific community, economic and political decision-makers. A key reference point was the International Plant Protection Convention (IPPC) of the Food and Agriculture Organization of the United Nations (FAO), which consisted of agriculture and food sectors. The IPPC develops International Standards for Phytosanitary Measures (ISPMs) (FAO, 1997) and gives concrete recommendations for their implementation in order to guarantee food security and to reduce the threat posed by Invasive Alien Species (IAS) to agriculture and plant biodiversity (Schrader and Unger, 2003). There was also the International Health Regulations formalized in 2005 by the World Health Organization, devoting a large number of sections to the management of IAS at national points of entry, including seaports. In particular, the IHR requires governments to implement active surveillance and management of IAS in seaports and within a 400 meters radius around them. Of course, states can transfer their responsibility and obligation to local stakeholders, such as port authorities, through national regulations and procedures (Formenty *et al.,* 2005). In addition to the international conventions ratified by Benin, which remain supranational standards, the country also adopted several laws/orders to implement its national phytosanitary policy. The Seaport of Cotonou in Benin is one of the main driving forces behind socio-economic development. For example, the Seaport received a total of 1,000 to 2,000 ships each year, and the cumulative amount of goods imported and exported averages 11 million tons, with imports dominating (SOBEMAP, 2024). The Seaport activities account for 90% of Benin's international trade and generate up to 60% of its GDP. They also make a significant contribution to the country's customs revenue (80%-90%) and tax revenue (40%-50%) (SOBEMAP, 2024). Very interesting, the Seaport of Cotonou now has a Port Environmental Monitoring Platform (PPSE in French) with huge expertise and laboratory for monitoring and supporting the management of invasive species (rodents,

insect pests of stocks, mosquitoes, plankton) imported/exported via maritime transport (Adamjy *et al.,* 2024). The plant health legislative framework plays a key role in regulating biological flows and preventing the risks of invasion. However, structural and operational issues persist, hampering the effectiveness of surveillance and intervention strategies.

OBJECTIVES

The current review aims to:

1. analyse the relevance of the phytosanitary legislative framework in the management of invasive alien insects in Benin,
2. assess the effectiveness of existing measures for overcome the present phytosanitary threats and;
3. propose strategic recommendations to strengthen biosecurity and improve the integrated management of Invasive Alien Species.

This article studies the international management of the threats posed by biological invasions in Benin, through its International Seaport of Cotonou, under the prism of phytosanitary legislation. (Section 2) examines the international regulatory framework governing Invasive Alien Species (IAS), with particular emphasis on the normative instruments established by the International Plant Protection Convention (IPPC), the World Health Organization (WHO), the Convention on Biological Diversity (CBD) and the World Trade Organization (WTO). With this global framework in place, Section 3 reviews Benin's national phytosanitary legislation, which serves as the legal and scientific basis for the present study. Section 4 then details the methodological framework underpinning technical and analytical study. Next, section 5 examines the ambiguities in the definition of quarantine pests and assesses their ramifications for the coherence and enforceability of existing regulations. Finally, section 6 critically assesses the institutional responses mobilized at the Seaport level, while exposing the structural and operational constraints on effective phytosanitary governance.

INTERNATIONAL LEGAL FRAMEWORK ON INVASIVE SPECIES

Biological invasions are a dynamic, spatio-temporal phenomenon with numerous side effects on the environment, biodiversity, the economy, food stocks and global health (IPPC, 2005). In view of societal challenges scale raised by biological invasions, several international conventions were adopted and remained a motivation/action source for scientific decision-makers. The International Plant Protection Convention (IPPC) of the Food and Agriculture Organization of the United Nations (FAO) provided International Standards for Phytosanitary Measures (ISPMs) and concrete recommendations for ensuring reduction of threat induced by Invasive Alien Species (IAS) to agriculture and biodiversity, and the Convention on Biological Diversity (CDB, 1992). There was also the International Health Regulations (IHR), formalized in 2005 by the World Health Organization (IHR/WHO, 2005), and the SPS Agreement of World Trade Organization (WTO, 1994).

The International Plant Protection Convention (IPPC)

Adopted in 1951 under the auspices of the Food and Agriculture Organization of the United Nations (FAO), the IPPC is the cornerstone of the international phytosanitary legal regime, its aim to secure coordinated and effective action to preventing and controlling the introduction and spread of plant pests in international trade (FAO,2005). The convention provides International Standards for Phytosanitary Measures (ISPMs), which

guide the member countries in aligning their national legislation with global standards. For example, ISPM 3: guidelines for the export, shipment, import and release of biological control agents and other beneficial organisms (IPPC, 2005) and ISPM 11 (Phytosanitary risk analysis for quarantine pests) (IPPC, 2013) are directly linked to preventing the spread of IAS through trade. These standards emphasize scientific risk analysis, transparency and preventive action.

Convention on Biological Diversity (CBD)

Adopted in 1992, the CBD addresses IAS explicitly in Article 8(h), and this clause obliges contracting parties to "prevent the introduction of, control or eradicate alien species that threaten ecosystems, habitats or species (CDB, 1992). The "Aichi Biodiversity Goals", in particular Goal 9, further strengthen this mandate by calling for identified IAS and their pathways to be managed or eradicated by 2020, a deadline which most countries, and particularly Benin, despite its efforts with the implementation of the PPSE, have not yet met. The CBD also encourages national strategies, ecosystem-based approaches and capacity building for the implementation of effective IAS management programs.

International Health Regulations (IHR)

Adopted in 2005 by the World Health Organization (WHO), the International Health Regulations (IHR), though primarily focused on public health, include essential requirements for the surveillance of IAS (IHR/WHO, 2005). Article 22(c) stipulates that the national authorities must monitor the disinfection and disinsectisation of cargo, ships and containers, particularly at points of entry such as seaports and airports. In the case of invasive insects, this imposes an obligation on states to monitor and control biological contaminants which may accompany goods or packing materials. It also warrants stricter sanitary protocols within 400-meter perimeters around ports, reinforcing national biosecurity systems (Formenty *et al.,* 2005).

World Trade Organization (WTO): SPS Agreement

The WTO Agreement on the application of Sanitary and Phytosanitary Measures (SPS Agreement) fixes the legal limits governing the implementation by member states of protective measures, including those relating to plant pests and diseases (WTO, 1994). In the hypothesis that this agreement authorizes countries to set higher levels of protection than international standards, it requires that these be scientifically justified and non-discriminatory. Importantly, the SPS agreement incentives the use of both IPPC and Codex Alimentarius standards (FAO and WHO, 1999), thereby promoting a harmonized legal framework while protecting developing countries from retaliatory trade measures due to phytosanitary restrictions.

THE LEGAL FRAMEWORK OF PHYTOSANITARY REGULATIONS IN BENIN: THE BASIS OF OUR SCIENTIFIC APPROACH

In the framework of the management of biological invasions, Benin has made laudable efforts to align its phytosanitary system with international obligations, particularly in response to the increasing threats posed by Invasive Alien Insects (IAI). Anchored in a body of legislation initiated at the beginning of the era of the country's democratic renewal, the phytosanitary legal framework of the Republic of Benin has progressively evolved, combining

statutory laws and administrative decrees to regulate plant health protection. At the heart of the national legal architecture are Law No. 91-004 of February 11, 1991 (MDR, 1991), and decree No. 92-258 of September 18, 1992, which constitute the legislative foundation of phytosanitary governance in the country (MDR, 1992).

Foundational Legislation: Law N° 91-004 and its Implementing Decree

Law No.91-004 constitutes the legal framework for the sanitary protection of plants and plant products in Benin. The principal goal of this regulation is expressly outlined in Article 1 in the following terms: to prevent the introduction and spread of harmful organisms that threaten agricultural productivity and ecological integrity. The law authorizes the Minister of Agriculture to prohibit importation of infested products and to take any technical measures deemed necessary to deal with phytosanitary risks (MDR, 1991). Decree No. 92-258 completes the law by detailing surveillance, inspection and quarantine procedures (MDR, 1992). By illustration, under article 14, any person with knowledge of the presence of a quarantine pest is under a legal obligation to report it to the competent authorities, namely the Plant Protection and Phytosanitary Control Service (SPVCP), which is part of the Plant Production Department (MAEP, 2005).

Key Sectoral Orders and Complementary Instruments

In order to manage biological invasions in Benin, several ministerial decrees were subsequently adopted to reinforce the phytosanitary system. These legal instruments are indicative of the growing consciousness of the multiple facets of phytosanitary risks by the authorities in Benin. They include:

1. Order No128/MDR/MF/DC/CC/CP of 1995 prohibits the import of pests listed in its annex, and grants discretionary powers to the Ministry of Agriculture in the face of emerging threats (MDR, 1995).

2 Order No 064/MAEP/DC/SGM/DAF/ CJ/DPV/SA/065SGG21 of 2021 establishes a dynamic list of quarantine pests and regulated non-quarantine pests, which will be updated periodically and published online (MAEP, 2021).

3 Order No 033/MCVDD/DC/SGM/ DGEC/SA025/SGG17 of 2017 governs the disposal of spoiled agricultural products, an often neglected yet crucial issue in preventing reinfestation by pests in storage (MCVDD, 2017).

4 Institutional actors such as the Directorate for Plant Protection (DPV) and the Centre for Plant Quarantine and Fumigation (CQVF) ensure phytosanitary control and fumigation operations. However, they remain fragmented, with limited cross-referencing and no centralised database or digital platform for enforcement and traceability.

Institutional framework for plant protection and capacity

At the institutional level, the Benin 's National Plant Protection Organization (NPP0) officially designated as ''Service de la Protection des Végétaux et du Contrôle Phytosanitaire'' (SPVCP), is legally mandated to ensure plant health surveillance, coordinate interventions, and enforce phytosanitary measures (MAEP, 2005). The SPVCP operates under ''Direction de la Production Vegetable (DPV) and is structured into three technical divisions: inspections, pesticide management, and alerts/interventions. Despite its legal mandate, the SPVCP faces critical limitations:

1 It lacks a dedicated quarantine laboratory and modern diagnostic tools;

2 It depends heavily on external expertise, notably from International Institute of Tropical Agriculture (IITA) and Institut

National des Recherches Agricoles du Bénin (INRAB);

3 The staffing capacity and funding are inadequate for proactive surveillance, particularly at major entry points such as the Seaport of Cotonou.

METHODS

This study adopts a normative and comparative legal methodology aimed at evaluating the capacity of Benin's phytosanitary legislation to effectively address the growing threat of Invasive Alien Species (IAS), particularly insect pests introduced through international trade. We systematically analyse the instruments of phytosanitary legislation in force in Benin in comparison with international standards and conventions (e.g. the IPPC's ISPMs especially ISPM 6 (Surveillance) (IPPC, 2018), ISPM 8 (Pest Status Determination) (IPPC, 2021), and ISPM 20 (Pest Risk Analysis) (IPPC, 2017 et 2023), the Convention on Biological Diversity, and the International Health Regulations to evaluate how well the national framework addresses the risks of biological invasions. The assessment focused on identifying strengths and gaps in the legislation (for example, whether risk assessment procedures or ecosystem approaches are mandated) and on determining whether legal requirements are consistent with recommended international practices. Tables were used to summarise key provisions of the principal laws, and narrative analysis was developed to interpret these findings. In order to test the adequacy and adaptability of Benin's framework, this study engages in a comparative analysis of several countries that exemplify strong institutional and legal responses to biological invasions.

Table 1: Sample of legislative and regulatory texts concerning biological invasions

Legal tools	Law provisions regarding biological invasions
Legal references indexing biological invasions in Benin	
Law 91-004 of February 11, 1991, on phytosanitary regulations in the Republic of Benin.	Title 1, Article 1: - The sanitary protection of plants and plant products through the prevention and control of harmful organisms both at the level of their introduction and of their propagation on the National Territory with a view to safeguarding and guaranteeing a satisfactory environment (...).
	Title 3 - Article 25 - The importation of plants and plant products contaminated by quarantine pests is prohibited, as is the importation of quarantine pests, whether isolated or not. In the event of imminent danger of introduction or spread of any harmful organism not classified as a quarantine pest, the Minister responsible for Agriculture may prohibit its importation and take any additional technical measures deemed necessary.
Decree 92-258 of September 18, 1992, setting out the application of the law of February 11, 1991, **on phytosanitary regulations in the Republic of Benin.**	Article l4: Any natural person or legal entity discovering or having knowledge of the existence of a quarantine pest or an organism classified as a plague should: -inform the Plant Protection Service through the intermediary of extension agents and departmental inspections of the Plant Protection Service.
Interministerial Order 1995 No. 128/MDR/MF/ DC/CC/CP on phytosanitary control of plants and plant products for import or export.	Article 2: The importation into the national territory of the harmful organisms listed in Annex I is prohibited, whether they occur in an isolated state or on plants or any products mentioned in this same annex. In the event of imminent danger of introduction or spread of any harmful organism not listed in Annex 1, the Minister in charge of Agriculture may prohibit its importation and take any additional technical measures deemed necessary.
Law 98-030 of February 12, 1999, **on the framework law on the environment in the Republic of Benin.**	Article 51 - In addition to the provisions of international conventions, treaties and agreements on the protection of biological diversity, (fauna and flora) ratified by the Republic of Benin, the following are laid down by laws and regulations: - (...) The conditions governing the introduction, whatever their origin, of any species which may harm species already in existence or their habitats.
Order 2017 N°033/MCVDD/DC/ SGM/DGEC/SA025/SGG17 defining procedures for the disposal of spoiled products	Article 5: Any unusable food product removed from stock and identified as such is quarantined in a secure area, where it is held until it is disposed of.
Law N°. 2021 No. 064/MAEP/DC/SGM/ DAF/CJ/DPV/SA/065SGG21 establishing lists of regulated pests in the Republic of Benin.	Article 5 Paragraph 1. The lists of quarantine pests and regulated non-quarantine pests are neither exhaustive nor definitive. They are updated whenever necessary. Paragraph 2. The lists of quarantine pests and regulated non-quarantine pests are published on the Government's platform and on the website of the International Plant Protection Convention (IPPC).
Legal references indexing biological invasions at Community level	
Revised ECOWAS Treaty, 1993	Article 29 of the Revised ECOWAS Treaty emphasizes the commitment of Member States to environmental protection, stating that they shall "protect, preserve and enhance the environment and the natural resources of the region". This provision underpins regional efforts to address environmental challenges, including invasive species.

Regulation C/REG.4/05/2008: Harmonization of Rules Governing Quality Control, Certification, and Marketing of Plant Seeds and Seedlings in the ECOWAS Region.	This regulation aims to standardize seed quality control across member states, indirectly addressing IAS through phytosanitary measures. Article 69: Mandates that seeds certified by an authorized agency in one member state are recognized across all ECOWAS countries. This facilitates regional seed trade but necessitates stringent phytosanitary controls to prevent the spread of IAS through seeds. Article 78: Phytosanitary Certificate: Mandates that all seed imports and exports be accompanied by a phytosanitary certificate issued by the national plant protection authority of the exporting country. This certificate ensures that the seeds are free from pests and diseases that could harm agriculture or ecosystems.
Regulation N°007/2007/CM/UEMOA on plant, animal and food safety in UEMOA.	Prevent the introduction and control the spread of harmful organisms and plant pests.
	International legal references on biological invasions
Convention on Biological Diversity (CBD), 1992	Article 8h - Preventing the introduction of, controlling or eradicating exotic species that threaten ecosystems, habitats or species. Regulation aimed at establishing a single sanitary territory within the Union, with a view to protecting plant resources, preventing the introduction and controlling the spread of harmful organisms and plant pests, and facilitating intra- and extra-Community trade in plants and plant products.
International Health Regulations (IHR), World Health Organization (WHO), 2005	Article 22 c - The competent authorities shall supervise the deratting, disinfection, disinsectisation or decontamination of baggage, cargo, containers, means of transport, goods, postal parcels and human remains or the sanitary measures applied to persons, in accordance with these Regulations
World Trade Organization (WTO), Agreement on the Application of Sanitary and Phytosanitary Measures (SPS), 1994	Marrakesh Agreement Establishing the WTO, Annex 1A, Article 3.1-To harmonize sanitary and phytosanitary measures on as wide a basis as possible, Members shall base their sanitary or phytosanitary measures on international standards, guidelines or recommendations, where they exist, except as otherwise provided for in this Agreement, and in particular in paragraph 3.
The International Plant Protection Convention (IPPC), 1951	-International Standards for Phytosanitary Measures (ISPM) N°3 provides Guidelines for the export, shipment, import and release of biological control agents and other beneficial; -International Standards for Phytosanitary Measures (ISPM) Number 11 provides directives Phytosanitary risk analysis for quarantine pests.

Order 1995 No. 128/MDR/MF/DC/CC/CP

An analysis of Law No. 128/MDR/MF/DC/CC/CP of 1995 on phytosanitary control of plants and plant products for import or export (MDR, 1995) compared with international standards such as the Convention on Biological Diversity (CDB, 1992) and the International Health Regulations (IHR, 2005) has revealed its strengths, weaknesses in preventing the risks of biological invasions (Table 2).

Table 2: Strengths and weaknesses in 1995 Order No. 128/MDR/MF/DC/CC/CP

Strengths	Weaknesses
Clear normative structure: the decree provides explicit guidelines for phytosanitary inspection at entry and exit points.	Lack of ecosystem integration: the decree focuses primarily on protecting economic crops, without considering the potential impacts on natural ecosystems and biodiversity
Commitment to biosafety: recognition of the importance of protecting national agricultural biodiversity.	Lack of risk assessment protocols: contrary to CBD recommendations, the decree does not include a scientific methodology for risk assessment of introducing invasive species via seaports, airports and borders.
Responsibility of the players: clarification of the roles of inspectors and economic operators.	Insufficient updating of monitoring tools: Modern techniques, such as genetic monitoring or the use of international databases (IPPC, CABI), are not mentioned.

Recommendations for improving Order No. 128/MDR/MF/DC/CC/CP

The following suggestions were proposed to improve the above order:

1 Integrate an ecosystem approach: Recognize the global threats of invasive species on all ecosystems, beyond agricultural crops;

2 adopt modern risk assessment protocols: Incorporate scientific tools to rapidly identify unknown organisms;

3 provide for post-import measures: Include regular inspections of storage sites and environments close to areas of entry;

4 regularly update the text: Ensure periodic revision of the regulatory framework to include scientific and technological advances.

Order 2021 N° 064/MAEP/DC/SGM/DAF/CJ/DPV/SA/065SGG21

Comparison of Order Law 2021 No. 064/MAEP/DC/SGM/DAF/CJ/DPV/SA/065S GG21 (MAEP, 2021) with international standards such as the Convention on Biological Diversity (CBD, 1992) and the International Health Regulations (IHR/WHO, 2005) revealed the following strengths, weaknesses and in terms of preventing and fighting the risks of biological invasion (Table 3).

Table 3: Strengths and weaknesses in Order 2021 N° 064/MAEP/DC/SGM/DAF/CJ/DPV/SA/065SGG21

Strengths	Weaknesses
Clear conceptual clarification: the law provides details on the categories of regulated pests	International standards (ISPM 6 and ISPM 8) insist on robust monitoring systems to detect and report pests. Beninese law, in turn, lacks specific provisions concerning the frequency, methodology or responsibilities of monitoring. Furthermore, there are no explicit provisions for monitoring high-risk sea or land cargoes, despite Benin being a strategic point for regional trade.

Recommendations for improving Order 2021 N° 064

In order to overcome the weaknesses of this Order it is important to:

1. Integrate an ecosystem approach: recognise the global threats of invasive species on all ecosystems, beyond agricultural crops;
2. adopt modern risk assessment protocols: incorporate scientific tools to rapidly identify unknown organisms;
3. provide for post-importation measures: include regular inspections of storage sites and environments close to areas of entry;
4. regularly update the text: ensure that the regulatory framework is periodically revised to include scientific and technological advances;
5. update pest lists with more recent data (PPSE data) on bioinvasions in Benin.

Order 2017 N°033/MCVDD/DC/SGM/DGEC/SA025/SGG17 versus international standards

Analysis of Order 2017 N°033/MCVDD/DC/SGM/DGEC/SA025/SGG17 defining the modalities for the elimination of spoiled products compared with international standards such as the Convention on Biological Diversity and the International Health Regulations (IHR, 2005) revealed its strengths, weaknesses in preventing bio-invasion risks (Table 4)

Table 4: Strengths and weaknesses for 2017 N°033/MCVDD/DC/SGM/DGEC/SA025/SGG17

Strengths	Weaknesses
A salutary piece of legislation: The law aims to regulate the disposal of spoiled products in Benin, providing a framework for damage management procedures to avoid environmental and health impacts	When a food product is declared unusable, i.e. out-of-date, damaged or non-conforming (Article 1 of the present law), the legislator makes no express mention of the time that should elapse between the declaration by a sworn official and the implementation of the disposal procedure covered by this law. As a direct consequence of this, we find that damage and even customs seizures have been stored for years in warehouses, which are favourable biotopes for the reinfestation of apparently healthy goods by stock insects.

Recommendations for improving Order 2017 N°033/MCVDD/DC/SGM/DGEC/SA025/SGG17

From this analysis, it could be suggested to:

1. facilitate the prompt removal and management of spoiled food products at the Seaport.
2. set up a digital tracking platform to document each stage, from identification of spoiled products to their disposal. This includes the delivery of certificates of safe destruction.
3. raise awareness among stakeholders (importers in particular) of the need to comply with removal formalities quickly enough to limit recurrent customs seizures in port warehouses.

QUARANTINE PESTS: A DEFINITION THAT DEPENDS ON EACH

The definition of a **quarantine pest** varies from one legal text to another. Several ambiguities remain within the national texts. For instance, although Benin's legislation recognizes quarantine and regulated pests, definitional ambiguities persist. The concept of "quarantine pest," for instance, is variably articulated across legislative texts, leading to potential inconsistencies in classification and enforcement. Thus, it may be a potential pest of economic losses not present in the target country but actively controlled (Table 5). In the order 2021 064/MAEP/DC/SGM/DAF/CJ/DPV/SA/065SGG21 the list of quarantine or non-quarantine pest species was provided (MAEP, 2021) (Annexe1).

Table 5: Definitions of quarantine pest according to different order

Definition of quarantine pest according to each legislation	
Law 91-004 of February 11, 1991, on phytosanitary regulations in the Republic of Benin, defined in Title I, Chapter II, Article 3	Quarantine pest as a pest of potential importance to the national economy that is not yet present in the country but is not widely distributed and is actively fighting
Law 2021 No. 064/MAEP/DC/SGM/DAF/CJ/DPV/SA/065SGG21 on the list of harmful organisms, Article 2	The following definitions apply Regulated' pest: Quarantine pest or regulated non-quarantine pest -Quarantine pest: Pest of potential importance to the economy of the threatened area and not yet present in that area, or present but not widely distributed and subject to official control.

Impact of quarantine or non-quarantine species in Benin

Quarantine or non-quarantine species induce heavy impact on agriculture, food security and biodiversity in Benin. For instance, the recent reported invasive species *Spodoptera frugiperda* cause huge losses in maize production and remains a major threat for food security in Benin. Likewise, *Tuta absoluta* occurred in tomato since 2017 and cause severe losses in Tomatoes. According to Eilenberg *et al* (2011) several control options were available to manage such pests including:

1. Integrated Pest Management (IPM): implementing IPM combines cultural, biological, mechanical, and chemical control methods to manage pest populations sustainably. This approach emphasizes monitoring pest levels, setting action thresholds, and using a combination of control techniques to minimize environmental impact;

2. Biological Control Agents: utilizing natural predators, parasitoids, or pathogens can help control pest populations. For instance, introducing parasitoid wasps that target specific pests can reduce their numbers without harming non-target species.
3. Preventive Cultural Practices: adopting farming practices such as crop rotation, intercropping, and the use of pest-resistant crop varieties can reduce pest establishment and proliferation. Maintaining field hygiene by removing plant debris and practicing proper sanitation also helps in minimizing pest habitats.
4. Monitoring and Early Detection: regular field inspections and the use of pest traps can aid in early detection of pest infestations. Timely identification allows for prompt intervention, preventing the spread and minimizing damage.
5. Farmer Education and Training: educating farmers about pest identification, monitoring techniques, and management strategies enhances community involvement and promotes the adoption of best practices.
6. Collaboration and Research: engaging with agricultural research institutions and neighbouring countries facilitates the sharing of knowledge, resources, and technologies, strengthening regional pest management efforts.

The response flow chart in the event of an alert for a new species

The Organisation Nationale de la Protection des Végétaux du Bénin (ONPV) was created within the framework of the IPPC and in Benin this regalian mission is devolved to the Direction de la Production Végétale (DPV). The DPV is governed by Decree 92/258 of 18 September 1992 (MDR, 1992) setting out the conditions for applying Law 91-004 of 11 February 1991 (MDR, 1991) on plant health legislation in Benin. Article 18 clearly defines the missions and responsibilities of the Plant Protection Service. These are: phytosanitary surveillance of the territory; control of pesticides; phytosanitary protection of crops and stocks of agricultural products. From an organizational point of view, the SPVCP comprises: at central level, three (3) divisions, namely: Division Gestion Produits et Matériels Phytosanitaires (DGPMP), Division ''Inspections Phytosanitaires'' (DIP) and ''Division Alertes et Interventions Phytosanitaires'' (DAIP). In this area, the DPV, representing the NPPO, does not have an adequate technical framework, a quarantine laboratory or the state-of-the-art equipment needed to successfully implement its Plant Health Policy in the face of the challenges posed by Invasive Alien Species. In operational terms, the DPV does not yet have full autonomy and currently relies on the expertise of IITA and INRAB to identify IAS. Therefore, when a search leads to the detection of a new species, it must inform national and international public opinion about the interception of the said species while respecting the following official mechanism:

1. Officially refer the matter to the NPPO through the Ministry of Agriculture, Livestock and Fisheries (MAEP), which will instruct the Plant Production Department (DPV), the technical institution to:
2. Carry out surveys to confirm or rule out the presence of the pest (checking);
3. Increase the frequency of inspections to determine the extent of the threat posed by this pest;
4. Use international (IITA) and national (INRAB) scientific staffs to confirm the information;
5. Inform the various contracting parties to the International Plant Protection Convention (IPPC);
6. To make an official declaration of the presence of this pest in the country;
7. Inform the Secretariat of the International Plant Protection Convention

(IPPC) and publish the information on its portal;

8. Inform the CPIA-UA (Inter-African Phytosanitary Council of the African Union - Regional Organisation of the IPPC);

9. Determine its status: quarantine pest or not;

10. In the case of a quarantine pest, i.e. one introduced into the country via importation, appropriate measures are taken to initiate active control, and in the long term, alternatives to the molecules must be found to avoid the phenomenon of resistance.

Institutional responses for phytosanitary risks in the Cotonou seaport

Recognizing the risk of Invasive Alien Species, national authorities have developed a Port Environmental Monitoring Platform (PPSE) at Cotonou (Adamjy *et al.,* 2024). Operational since 2021, the PPSE brings together technical actors including the SPVCP, the Centre de Quarantaine Végétale et Fumigation, and port authorities to coordinate surveillance and intervention against biological invasions. The platform includes laboratory facilities and diagnostic capacity for the identification of pest organisms in real time. This initiative, while promising, remains limited in scope. Surveillance is often reactive, triggered by visible infestations or customs alerts, rather than guided by a proactive risk-based model. The coverage of monitoring also remains constrained to primary cargo zones, leaving secondary storage facilities and surrounding ecological corridors largely unmonitored. Moreover, while the PPSE benefits from international technical support, its activities have not yet been fully integrated into Benin's national regulatory framework, reducing its legal authority and budgetary autonomy (DPV, 2023).

CONSTRAINTS TO THE IMPLEMENTATION OF PLANT HEALTH POLICY IN BENIN

The main constraints to be overcome and the shortcomings to be corrected if Benin's plant health policy is to be effective include the population's lack of knowledge of the existing laws and regulations, and their violation by certain actors who rely on political interference to escape sanctions, as well as the lack of qualified personnel and an appropriate technical framework (DPV, 2014). Managing invasions requires a rapid and coordinated response, based on a robust phytosanitary regulatory framework adapted to new ecological and commercial dynamics. However, by analysing current practices, it is imperative to adopt a proactive approach, integrating science, technology and public policy to minimize the risks of introducing invasive species. Institutional capacity building and regional cooperation must be at the heart of this approach, ensuring effective monitoring and response. Efficient management relies on multi-sectoral collaboration, involving local and international stakeholders to consolidate an adaptive and resilient management system. However, Benin's phytosanitary legislation in its current state is not sufficiently equipped to deal with the complexity of the challenges posed by biological invasions, including a lack of public awareness and government commitment (Adamjy *et al.,* 2020). Early detection of is a crucial step in implementing an efficient plant health policy. Early detection, i.e. active surveillance involving regular spotting in specific areas of interest (Brockerhoff *et al.,* 2010; Rassati *et al.,* 2015a) is essential because it is beneficial from two points of view: reducing eradication costs and increasing the probability of success (Mehta *et al.,* 2007). One of the main difficulties lies in the fact that Invasive Alien Species are generally rare in the early stages of introduction, but are already

widespread when the associated damage is first observed. It is therefore essential to carry out surveillance near potential points of entry (ports, airports, etc.) and in sensitive areas. Central authorities will therefore need to devote significant resources to implementing these measures. However, although a comprehensive monitoring system would greatly improve their ability to respond quickly to introductions of Invasive Alien Species, central authorities would need to have significant resources and enforcement in place to control ports of entry as well as, for example, nurseries and other potential channels through which IAS could spread. Today, to improve the effectiveness of phytosanitary management, developing countries are moving towards surveillance and early detection systems that considerably improve their ability to react quickly to the threat of the introduction of Invasive Alien Species, such as acoustic early detection probes. Furthermore, a comparative study of biological invasion management strategies in Benin compared with other countries that have robust biosecurity systems in place shows gaps in management at Benin level. Among developed nations, United States (Jarrad *et al.,* 2011) have integrated biovigilance and biocontrol strategies into their plant health policies. New Zealand, under its Biosecurity Act 1993 (New Zealand Parliament, 1993), operates a risk-based border management system, with mandatory declarations, proactive surveillance, and public awareness campaigns. The country integrates ecological science with customs and trade operations. Australia (Anderson *et al.,* 2017) is globally recognized for its science-based Biosecurity Act 2015 (Government of Australia, 2015), which consolidates pest and disease management under a single regulatory umbrella. Its early warning system includes real-time digital monitoring, risk zoning, and community-based surveillance, with strict phytosanitary controls at all points of entry. The Australian model notably incorporates advanced pest risk analysis tools and stakeholder consultation mechanisms to ensure compliance and transparency. In Africa, countries such as Kenya (Keshavamurthy, 2021), South Africa (Shabangu, 2024) and Morocco (Kingdom of Morocco, 2011) have advanced regulatory systems, where the management of agricultural pests is based on strong institutional synergy and effective biomonitoring mechanisms. Distinctly, the South Africa has developed a comprehensive Plant Health (Phytosanitary) Policy embedded in the country's environmental law framework. It integrates cross-sectoral coordination, pest risk assessment, and biosecurity surveillance mechanisms. It National Plant Protection Organisation (NPPO) maintains a centralized database for pest reporting, and its border control strategy includes both post-entry quarantine and emergency response protocols (RSA, 2014). The Kenya, under the Kenya Plant Health Inspectorate Service (KEPHIS), operates a robust bio surveillance and certification system, backed by the Plant Protection Act Cap. 324 and recent reforms aligned with the IPPC (KEPHIS) 2012; Government of Kenya, 2020), KEPHIS oversees pest diagnosis, quarantine, and enforcement, with strong collaboration between agricultural, trade, and customs authorities. The Morocco has implemented a regional traceability system using the TRACES platform, enabling digital import-export certification and phytosanitary alerts among Mediterranean and European partners (Kingdom of Morocco, 2011). Benin could draw on these experiences for phytosanitary surveillance at the Seaport of Cotonou, a key entry point for the introduction of Invasive Alien Species into the country. To enrich the legal analysis, the research also draws upon grey literature, including technical reports from the Port Environmental Monitoring Platform of Cotonou, internal policy documents from the Plant Production

Department (DPV), and pest alert records from the International Institute of Tropical Agriculture (IITA). In addition, an efficient plant health policy depends on the operational capabilities of the agents. Knowledge of the prevention, management and control of plant pests and diseases is therefore important in overcoming their introduction and spread within the country. Pests and diseases of plants of economic importance have affected agriculture and horticulture in terms of food production, food safety and trade over the last decade (Flood, 2010). Effective plant health management is a key factor in supporting food security as well as national and international trade, as shown by the study conducted in Uganda (Danielsen & Matsiko, 2016). Plant pests and diseases have a significant impact on food availability and security (Oerke, 2006). One important research has confirmed that the introduction of quarantine pests can have major trade consequences for trading partners (Pimentel, 2003). In Africa, many countries have been found to have difficulties in understanding and implementing international plant health requirements due to a lack of necessary resources and/or relevant capacity (Chinappen, 2011). For his part, the researcher Flood (Flood, 2010) conducted a study on society's perceptions of the importance of phytosanitary measures and concluded that phytosanitary issues are not given the priority they should be, particularly regarding the impact of pests and diseases on crop losses. The negative impact caused by pests and diseases of economically important plants can ultimately have consequences for farmers (RSA, 2014). Therefore, it is important that extension agents and/or agricultural advisors in the Agricultural Development Pole (PDA) have relevant knowledge of phytosanitary issues to be able to assist and advise farmers appropriately. Relevant national/international requirements for the control and management of plant pests and diseases for food production and safety as well as trade are the World Trade Organization Agreement on the Application of Sanitary and Phytosanitary Measures (WTO-SPS Agreement) as well as the International Plant Protection Convention (IPPC) (FAO, 2011; RSA, 2014). Finally, it should be noted that one of the constraints hampering the effectiveness of the Plant Health Policy is the length of time it takes to recognize a newly introduced species. Official recognition of the presence of harmful organisms often lags behind their detection by several years, allowing them to spread before eradication measures can be taken (Landeras *et al.* 2005; Brasier 2008). Synergy of action and real-time communication between researchers and the Direction de la Production Végétale are therefore needed so that a new species that has been detected and verified can be communicated to update the list of regulated pests in Benin.

CONCLUSION AND PERSPECTIVES

A review of Benin's phytosanitary legislative framework reveals significant progress in regulating biological flows, but also critical flaws limiting the effectiveness of biological invasion management. While progressive for its time, this legislative framework has aged. It lacks express reference to international instruments such as the IPPC, the CBD, or the SPS Agreement. The absence of embedded risk analysis tools, ecosystem-based approaches, or explicit obligations regarding post-border surveillance illustrates a need for legislative modernization. The lack of a reinforced surveillance system, the poor harmonization of sectoral policies and the failure to apply international standards compromise the fight against Invasive Alien Species and expose the agricultural sector to increased risks. To overcome these shortcomings, it is essential to adopt an integrated approach, combining institutional strengthening, biovigilance and technological

innovation. Improving phytosanitary inspection protocols at points of entry, implementing early detection tools and encouraging sustainable strategies such as biocontrol are major levers for action. In addition, closer cooperation with international bodies such as the IPPC and the FAO could help bring Benin into line with best practice in terms of biosecurity. Ultimately, the efficient management of biological invasions through the prism of plant health legislation requires proactive and adaptive governance, integrating the scientific, regulatory and socio-economic dimensions. By modernizing the legal framework and increasing the commitment of stakeholders, Benin could significantly reduce the negative impacts of Invasive Alien Species on its agriculture and biodiversity, thereby ensuring greater resilience in the face of the phytosanitary challenges of the 21st century. Based on the gaps revealed by the technical-scientific review of the regulatory framework for phytosanitary protection in Benin, this study will develop recommendations aimed at strengthening phytosanitary governance in Benin. These will include:

1. Strengthening the regulatory framework to better anticipate and respond to biological invasions by invasive alien insects;
2. Establish a national training programme for inspectors and quarantine officers in collaboration with international partners (e.g. FAO, EPPO);
3. Promote regional harmonization of phytosanitary standards within ECOWAS and UEMOA;
4. Enhance public-private partnerships for risk awareness, rapid reporting, and compliance incentives.
5. Improving surveillance and control systems at borders and within the country;
6. Integrating sustainable solutions, such as biocontrol and biovigilance, to reduce the impact of IAS on Beninese agriculture;
7. Equip the Plant Quarantine and Fumigation Centre with quality computer equipment;
8. Provide the centre with a high-speed Internet connection;
9. Facilitate the rapid removal and management of spoiled food products at the Cotonou Seaport;
10. Set up a digital tracking platform to document every stage, from the identification of spoiled products to their disposal. This includes issuing certificates of safe destruction;
11. Raise awareness among stakeholders (importers in particular) of the need to comply with removal formalities quickly enough to limit the number of customs seizures in port warehouses.

By 2030, Benin should have an operational and efficient national framework for the sustainable health protection of plants and plant products, with harmonized prevention and control mechanisms that are effective and safe for the user, the consumer and the environment, thus contributing to food security and the fight against poverty'.

ACKNOWLEDGEMENTS

Mahoutin Kindomissi was supported by the doctoral fellowship with PASPort/PPSE project, funded by Enabel (Belgian Agency for International Cooperation) under subsidy agreement BEN1803811-10103 and the technical support of French National Research Institute for Sustainable Development (IRD). The authors would like to thank the Cotonou Seaport authorities for the implementation of the Port Environmental Monitoring Platform. Grateful acknowledgements are due to the Plant Protection and Phytosanitary Control Service (SPVCP) for providing valuable documentation on Benin's phytosanitary regulatory framework.

REFERENCES

Adamjy T, Dobigny G, Aholou S, Mourlon M, 2020. La gouvernance des risques liés aux invasions biologiques. L'exemple du Bénin. Dans Sciences Eaux & Territoires 2020/5 (Numéro hors-série), 1-12.

Adamjy T, Tchabi A, Gauthier P, Houemenou G, Goergen G, Gouriveau F, Badou S, Dossou HJ, Etougbetche J, Lokossou, AS, Missihoun AA, Kindomissi M, Ouinsou FT, Ali Mamam H, Bagan TAA, Faton L, Abotsi Y, Akanni-Ediko R, Aikpon R, Akodogbo H, Dannon E, Corbel H, and Dobigny G, 2024. Maritime Trade and Biological Invasions Management: A Seaport Platform of Environmental Surveillance in Cotonou, Benin, as a Pilot Multi-Stakeholder Initiative," Cities and the Environment (CATE): Vol. 17: Iss. 2, Article 1. DOI: 10.15365/cate.2024.170201 Available at: https://digitalcommons.lmu.edu/cate/vol17/iss2/1

Anderson, C.; Low-Choy, S.; Whittle, P.; Taylor, S.; Gambley, C.; Smith, L.; Gillespie P., Locker, H., Davis, R., Dominiak Bernie. **2017**. Australian plant biosecurity surveillance systems. .Crop Protection 100 : 8-20. https://doi.org/10.5281/zenodo.10056589.

Arrêté interministériel N°128/MDR/MF/DC/CC/CP du 7 mars 1995 relatif au contrôle phytosanitaire à l'importation et à l'exportation

Arrêté N° 064/MAEP/DC/SGM/CJ/DPV /SA/065SGG21, 2021 portant listes des organismes nuisibles de quarantaine et des organismes nuisibles règlementés non de quarantaine en République du Bénin, pp 1-13 pages.

Brasier CM, 2008. The biosecurity threat to the UK and global environment from international trade in plants Plant. Plant Pathology (2008) 57, 792–808. https://doi: 10.1111/j.1365-3059.2008.01886.

Brockerhoff EG, Liebhold AM, Richardson B, Suckling DM, 2010. Eradication of invasive forest insects: concepts, methods, costs and benefits. NZ J Forest Sci 40(Suppl): S117–S135

Chinappen M, 2011. Proposal for Phytosanitary Capacity building strategy in Africa. Technical report. 14 September 2011, pp1-62.

Convention on Biological Diversity (CBD), 1992. Opened for signature 5 June 1992, 1760 UNTS 79 (entered into force 29 December 1993), Art 8(h).

Danielsen S, Matsiko FB, 2016. Using a plant health system framework to assess plant clinic performance in Uganda. Food Security. 2016 ;8(2) :345–59. https:// doi.org/10.1007/s12571-015-0546-6

Diagne C, Turbelin AJ, Moodley D, Novoa A, Leroy B *et al*. 2021. The economic costs of biological invasions in Africa : a growing but neglected threat? NeoBiota 2021, 67, pp.11 51. 10.3897/neobiota.67.59132. hal-03410320. HAL Ids: hal-03410320 https://hal.science/hal 03410320v1

Direction de la Production Végétale (DPV), 2014. Politique Phytosanitaire de la République du Benin, pp 1-56

Direction de la Production Végétale (DPV), 2023. Rapport Annuel du SPVCP, Ministère de l'Agriculture de l'Elevage et de la Peche (MAEP), Communication interne sur la plateforme PPSE, 2024

Eilenberg J, Hajek A, and Lomer C, 2001. Suggestions for unifying the

terminology in biological control. Bio-Control 46: 387–400, 2001

FAO (Food and Agricultural Organization of United Nations), 1997. International Plant Protection Convention (CIPV) (revised in 2022). www.ippc.int

FAO (Food and Agricultural Organization of United Nations), 2011. International Plant Protection Convention (IPPC), 1997. New Revised Text (NRT). Food and Agriculture Organisation of the United Nations, Rome, Italy.

FAO (Food and Agricultural Organization of United Nations), 2020. International Year of Plant Health 2020 Final Report. Accessed on: https://openknowledge.fao.org/items/f237d92e-96d4-4aa6-a4a8-3561b3bdfc65

FAO (Food and Agricultural Organization of United Nations), 2022. Plant pests and diseases: a growing threat to food security. Available at: https://www.fao.org/plant-production-protection/about/en (consulté le 29 mai 2025).

FAO (Food and Agricultural Organization of United Nations),, International Standards for Phytosanitary Measures No. 6, 8 and 20 IPPC, FAO. **2005**. Accessed 28 April 2025.

FAO and WHO (Food and Agriculture Organization of the United Nations and World Health Organization), 1999. Guidelines for the Production, Processing, Labelling and Marketing of Organically Produced Foods FAO/WHO Codex Alimentarius Commission

Flood J, 2010. The importance of plant health to food security. Ambio 2016, 45 (Suppl. 2): S223–S234. https://dOI 10.1007/s13280-015-0748-3

Formenty P, Roth C, Gonzalez-Martin F, Grein TRM, Drury P, Kindhauser MK, Rodier G, 2005. Emergent pathogens, international surveillance and international health regulations. Médecine et maladies infectieuses 36 (2006) 9–15. https://dOI: 10.1016/j.medmal.2005.06.009.

Goergen, G, Kumar PL, Sankung SB, Togola A, Tamò M, 2016. First Report of Outbreaks of the Fall Armyworm Spodoptera frugiperda (J E Smith) (Lepidoptera, Noctuidae), a New Alien Invasive Pest in West and Central Africa. PLoS ONE 11(10): e0165632. https://doi.org/10.1371/journal.pone.0165632

Government of Australia, Biosecurity Act 2015. Cth, Act No. 61 of 2015.

Government of Kenya, 2020**.** KEPHIS Strategic Plan 2020–2025.

Institut National de la Statistique et de l'Analyse Economique (INSAE), 2017**.** État des lieux de l'emploi au Bénin, Août 2017, pp 1-52 12

International Plant Protection Convention (IPPC), 2005. ISPM 3: Guidelines for the export, shipment, import and release of biological control agents and other beneficial organisms (Second edition, adopted in 2005). Rome: Food and Agriculture Organization of the United Nations (FAO). Available at: https://www.ippc.int/en/publications/11080/

International Plant Protection Convention (IPPC), 2013. ISPM No. 11: Pest risk analysis for quarantine pests including analysis of environmental risks and living modified organisms. Rome: FAO. available at: https://www.ippc.int/en/publications/639/

International Plant Protection Convention (IPPC), 2021. Scientifc 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.

FAO on behalf of the IPPC Secretariat. https://doi.org/10.4060/cb4769 en ISBN 978 928 92 4 158041 0 (NLM classification: WA 32.1)

International Plant Protection Convention (IPPC), IPPC/FAO, 2021. Reorganization and revision of pest risk analysis standards. Accessed on: https://assets.ippc.int/static/media/files/publication/en/2021/11/Spec_72Reorganization_PRA_En_2021-11-24.pdf

International Plant Protection Convention IPPC, FAO 2023. Normes Internantionales et Mesures Phytosanitaires No 20: Directives pour un système phytosanitaire de réglementation des importations, adoptée en 2004, révisée en 2017 et 2023.

International Plant Protection Convention NIMP 8: Détermination de la situation d'un organisme nuisible dans une zone (adoptée en 1998, révisé en 2021)

International Plant Protection Convention, FAO 1998. Normes Internantionales et Mesures Phytosanitaires No 8: Détermination de la situation d'un organisme nuisible dans une zone (adoptée en 1998, révisé en 2021).

International Plant Protection Convention, FAO, 1997. Normes Internantionales et Mesures Phytosanitaires No 6 : Surveillance (adoptée en 1997, révisée en 2018)

International Plant Protection Convention, NIMP 20: Directives pour un système phytosanitaire de réglementation des importations (adoptée en 2004, révisée en 2017 et 2023)

IPBES, 2023. Thematic Assessment Report on Invasive Alien Species and their Control of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services, Bonn, Germany, IPBES Secretariat, Doi:10.5281/zenodo.7430682.

Jarrad, F.C.; Barrett, S.; Murray, J. et al. **2011**. Ecological aspects of biosecurity surveillance design for the detection of multiple invasive animal species. Biol Invasions 13, 803–818 https://doi.org/10.1007/s10530-010-9870-0.

Kenya Plant Health Inspectorate Service (KEPHIS) **2012**. Plant Protection Act, Cap. 324 (Revised 2012).

Keshavamurthy R., Thumbi., SM., Charles, L.E. (2021) Digital Biosurveillance for Zoonotic Disease Detection in Kenya. Pathogens 2021, 10(7), 783. https://doi.org/10.3390/pathogens10070783

Landeras, E.; Garcia, P.; Fernández, Y.; Braña, M.; Fernández-Alonso, O.; Méndez-Lodos, S.; Pérez-Sierra A.; Leon M., Abad-Campos P., Berbegal M. et al. **2005.** Outbreak of Pitch Canker Caused by Fusarium circinatum on Pinus spp. in Northern Spain. Plant Dis. 2005, 89, 1015. Published Online :6 Mar 2007 https://doi.org/10.1094/PD-89-1015A

Law No. 29-05 on the Protection of Wild Flora and Fauna Species and the Control of Their Trade, promulgated by Dahir No. 1-11-01 of 21 February, 2011, Official Bulletin No. 5928, 3 March 2011, Kingdom of Morocco.

Law No. 29-05 on the Protection of Wild Flora and Fauna Species and the Control of Their Trade, promulgated by Dahir No. 1-11-01 of 21 February 2011, Official Bulletin No. 5928, 3 March 2011, Kingdom of Morocco.

Mehta SV, Haight RG, Homans FR, Polaskya S, Venettec RC, 2007. Optimal detection and control strategies for invasive species management. Ecol Econ 61: 237–245. https://doi.org/10.1016/j.ecolecon.2006.10.024

Ministère du Cadre de Vie et du Développement Durable (MCVDD), 2017. Arrêté 2017 N°033/MCVDD/DC/SGM/DGEC/SA 025/SGG17 définissant les modalités d'éliminations des produits avariés du Ministère du Cadre de Vie et du Développement Durable (MCVDD), République du Bénin, 5 pages

Ministère du Développement Rural (MDR), 1991. Loi n°91-004 du 11février 1991 portant règlementation phytosanitaires en République du Bénin, pp 1-12

Ministère du Développement Rural (MDR), 1992. Decret N'92-258 du 18 Septembre 1992 fixant les modalités d'application de la Loi N'91-004 du 11 Février 1991 portant règlementation phytosanitaire " en République du Bénin, pp 1-13.

Mumford JD, Burgman MA, 2020. Risk Assessment for Invasive Species. In: Invasive Species: Risk Assessment and Management. Taylor & Francis. DOI: 10.4324/9781351131599-21

New Zealand Parliament, 1993. Biosecurity Act 1993 No. 95. Wellington: New Zealand Government.

NIMP 6 Surveillance (adoptée en 1997, révisée en 2018).

Oerke EC, 2006. Crop Losses to Pests. Journal of Agricultural Science, 144, 31-43. https://dx.doi.org/10.1017/S00218596 05005708.

Order No. 3541/MAEP/D-CAB/SGM /DRH/DAGRI/SA of 29 November 2005.

Pimentel D, 2003. Plant pathogens and quarantines and the implication for global trade and world food. In: Loebenstein, G., Thottappilly, G. (eds) Virus and Virus-like Diseases of Major Crops in Developing Countries. Springer, Dordrecht. https://doi.org/10.1007/978-94-007-0791-7_4

Rassati D, Faccoli M, Petrucco Toffolo E, Battisti A, Marini L, 2015 a. Improving the early detection of a lien wood-boring beetles in ports and surrounding forests. Journal of Applied Ecology 52(1): 50–58. https://doi.org/10.1111/1365-2664.12347

Republic of South Africa (RSA), 2014. Plant Health (Phytosanitary) Policy of South Africa. Department of Agriculture, Forestry and Fisheries (DAFF). Pretoria: Government Gazette No.38102.

Schrader G, Unger JG, 2003. Plant quarantine as a measure against invasive alien species: the framework of the International Plant Protection Convention and the plant health regulations in the European Union. Biological Invasions 5: 357–364, 2003.

Shabangu, FR, 2024. Efficacy and biases In inspections for biosecurity threats In South Africa, , Master of Science in Environmental Management, University of Pretoria, South Africa February 2024, URI: DOI http://hdl.handle.net/2263/ 94718.

Statistics and Economic Studies Service, SOBEMAP, 2024. See the Government Program "Revealing Benin", https://beninrevele.bj/projects/port/

Stokstad E, 2017. The fall armyworm has invaded more than 20 sub-Saharan countries. sciencemag.org. 5 MAY 2017 VOL 356 ISSUE 6337. Downloaded from https://www.science.org at International Institute of Tropical Agriculture on April 07, 2025 9

van Klinken RD, Fiedler K, Kingham L, *et al,* 2020. A risk framework for using systems approaches to manage horticultural biosecurity risks for

market access. Crop Prot 129 :104994. https://doi.org/10.1016/j.cropro.2019. 104994 10

van Klinken, RD, Hill MP, Kingham L, Collins K, 2023. A menu of measures to manage trade-related plant pest risks, and a review of methods for demonstrating measure efficacy. Biol Invasions 2023 25 :1227–1248 https://doi.org/10.1007/s10530-022-02977-2

Wittenberg R, Cock MJW, 2001. Invasive alien species: a toolkit of best prevention and management practices. Pages xvii-228. CAB International, Wallington, Oxon. 6.

World Health Organization, International Health Regulations, 2005. 2nd edition, WHO, Geneva, ISBN 9789241580410, article 22(c).

WTO, 1994. Agreement on the Application of Sanitary and Phytosanitary Measures, April 15, 1994, Marrakesh Agreement Establishing the WTO, Annex 1A, Art 3.1