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Assessing the Plant Health System of Burundi: What It Is, Who Matters and Why

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Abstract: The concept of a plant health system (PHS) is mainly anchored on experiences from human health where varied sources of knowledge, expertise, and technology are combined to provide healthcare. While diverse human health systems have been proven, little is known about PHS and what is needed to base effective plant healthcare services. A stakeholder analysis was carried out in Burundi. The aim is to understand the system as it is presently and to identify constraints and opportunities. This paper reports on the process and results of this assessment. The initial step in this process was to define PHS and its functions and to evaluate stakeholders' interests and influence. The first step was followed by examining stakeholders' perceptions concerning the sustainability of interventions geared at strengthening PHS functions. The process included a document review and stakeholder workshops. After the stakeholders defined the PHS functions, they proceeded to identify valuable actors. The assessment process highlighted several key challenges, including inadequate skills to serve farmers and insufficient capacity to diagnose pests, as significant impediments to effective PHS performance. Based on the information marshalled here, seven broad interventions are proposed for practitioners to strengthen Burundi's PHS rapidly.

Keywords: plant health system; stakeholder analysis; plant health problems

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1. Introduction

Burundi, a landlocked country in the Great Lakes Region of central-eastern Africa, occupies an area of approximately 27,834 km² [1]. The total population was estimated at 11.89 million in 2020 (463 inhabitants/km²), making it the fourth most densely populated country in Africa [2]. The economy of Burundi is driven mainly by agriculture, with the sector contributing close to 40% of the gross domestic product (GDP), employing 84% of the working population, and providing 95% of the food supply [3–5]. Furthermore, the sector accounts for more than 90% of foreign exchange earnings and is the leading supplier of raw materials for the agro industry. The portion of the country's land area appropriated for agriculture is 73.3%, of which 38.9% is arable land (though prone to erosion and low soil fertility). Average land ownership is 0.27 ha per household, which is well below the 0.90 ha thought as the minimum for economic viability [6].

Agricultural productivity in Burundi is impeded by several constraints, including outbreaks of crop pests and diseases [7], occasional droughts and floods [8,9], limited cash for inputs (fertilizers, plant protection products, productive seeds, and planting materials), land fragmentation [10], inefficient use of the existing water resources [11], lack of cash and credit facilities among smallholder farmers [12], and limited access to research and extension services [8,13].

Despite the challenges mentioned above, there are considerable opportunities to increase farm production and food security. The climatic conditions in most parts of the country favor agriculture [14]. There is usually enough rain, and the countryside is diverse to sustain different crops. The country is endowed with abundant water resources [15] and potential irrigable lands, which are yet underdeveloped. The emergence of farmers' organizations (e.g., the National Confederation of Coffee Growers' association, cooperatives at the colline level, etc.), although still developing, is demonstrating the potential role of farmers' organizations [16]. The government of Burundi has also developed policies in support of agriculture [17,18].

To respond to the challenges impeding agricultural productivity in Burundi, CABI, with funding support from the Embassy of the Netherlands in Bujumbura and Nuffic, is introducing its award-winning Plantwise program in Burundi [19]. Plantwise is a global program led by CABI, which supports farmers to lose less of what they grow to plant health problems. The program has helped millions of farmers in various countries to identify and manage threats posed by pests at the farm level and to minimize crop losses by strengthening in-country plant health systems (PHS) [20].

Plantwise in Burundi will address some of the main challenges in the country's agricultural sector (mainly pests and diseases). The strategies proposed for managing plant health problems include setting up an early-warning system for communicating pest threats and strengthening the capacity of farmers' organizations in pest management [19].

A stakeholder analysis was carried out in 2021 to investigate whether the proposed Plantwise project can achieve its aims of strengthening the PHS of Burundi. The objective is to understand the system as it is presently and to identify challenges and opportunities from the perspective of various actors. Stakeholder analyses are crucial for identifying significant stakeholders and their particular sets of interests, power/policy influence, and roles [21]. In addition, stakeholder analyses allow the exploration of the individual, group, and institutional landscape amongst pertinent stakeholders, their associations, what concerns them the most, and how these could affect the project [22].

The specific objectives of the Plantwise Burundi stakeholder analysis included: (1) to examine the PHS of Burundi; (2) to evaluate and map stakeholders' interests and influence concerning the functions of the PHS; (3) to assess stakeholders' perceptions concerning the success and sustainability of the proposed project's broad work areas. This paper reports on the process and results of this stakeholder analysis.

2. Methods

The analysis of the PHS of Burundi and its key stakeholders, undertaken from March to December 2021, was structured in four major phases: (i) a document review, (ii) a stakeholder workshop, (iii) a needs assessment workshop, and (iv) a stakeholder forum meeting.

2.1. Document Review

The assessment partially understood Burundi's plant health system and functioning through a literature review. Information on contextual influences is often available in grey literature [23,24]. Where the assessors could not obtain information from the CAB Abstracts database, a search of the grey literature was carried out in March 2021 within the open-access collections on Google™ (Menlo Park, CA, USA). The target of the search was contemporary reports on Burundi focusing on institutional structures, politics and organizational culture, development partners' influences, and local and international strategies. Additionally, the investigators obtained key statistics relating to Burundi within the databases FAOSTAT, a widely used database in peer-reviewed literature as the base for many global agriculture perspectives analyses [25], and the World Bank Open Data, an open-access collection on global development data. The investigators used universal terms associated with agriculture to search for country-specific reports. These terms were: food security, plant health, crop protection, crop production, agricultural extension, farmer advisory services, and agricultural policy. From the documents retrieved, the

investigators searched reference lists for other sources. A total of 15 documents were included: (1) original research and research reviews (n = 10); (2) government policy (n = 3); and (3) international organizations strategic plans (n = 2). The assessors present these documents in Table 1.

Table 1. Key documents reviewed on the contextual influences of the plant health system of Burundi.

Documents reviewed
Government policy
Republique du Burundi Portant Organisation Du Ministere De L'environment, De L'agrculture et de L'elevage; Burundi, 2020
Republique du Burundi Plan National de Developpement Du Burundi—PND Burundi 2018–2027; 2018
Republique du Burundi Vision Burundi 2025; 2011
Original research and reviews
Bamber, P.; Gereffi, G. Burundi in the Agribusiness Global Value Chain: Skills for Private Sector Development; 2014
IFPRI Burundi: Recent Developments in Public Agricultural Research; 2011
Niragira, S. Feasibility Study for the Development of Public-Private Seed Delivery Systems in Burundi; 2020;
Chauvin, N.D.; Mulangu, F.; Porto, G. Food Production and Consumption Trends in Sub-Saharan Africa: Prospects for the Transformation of the Agricultural Sector; 2012
Curtis, M. Improving African Agriculture Spending: Budget Analysis of Burundi, Ghana, Zambia, Kenya and Sierra Leone; 2013
Ludgate, N.S.; Tata, J.S. Integrating Gender and Nutrition within Agricultural Extension Services: Burundi Landscape Analysis; 2015
Niragira, S.; Ndikumana, D.; Muvunyi, R.; Nzigamasabo, D.; Nduwimana, A. Situational Analysis of Food Safety Control Systems in Burundi; 2020
Kinuthia, R.; Kiptot, E.; Nkurunzinza, C. The Extension System in Burundi: Kayanza Province, Muruta Commune; 2016
FAO FAOSTAT Database on Agriculture. Available online: https://www.fao.org/faostat/en/#data
The World Bank Burundi Available online: https://data.worldbank.org/country/BI
International organizations strategic plans
IFAD Republic of Burundi: Country Strategic Opportunities Programme (2022–2027); 2022
WFP Burundi Interim Country Strategic Plan (2018–2020); 2018

However, policy documents and institutional frameworks do not always mirror the reality on the ground. Consequently, the document review only served as a basis for understanding the system. At the same time, the workshops were essential for gaining a deeper understanding of Burundi's overall plant health system.

2.2. Stakeholder Workshop

The investigators convened stakeholders in March for a 2-day stakeholder workshop. The participants numbering 25 were identified based on document review, snowball technique where stakeholders identified additional stakeholders, and the result of brainstorming amongst the project team members to determine: (i) groups of stakeholders and how they could be affected by the project's interventions, (ii) who are the individuals expected to be the direct beneficiaries of the project interventions, and (iii) the potential impact of the project interventions on stakeholders, including their numbers. The investigators then prioritized the following groups of stakeholders: The Ministry of Environment, Agriculture, and Livestock (MINEAGRIE), institutions of higher learning, provincial leadership, development partners, non-governmental organization (NGOs), international organizations, farmer associations and cooperatives, agricultural input supply, and other private sector players.

The workshop focused on: defining the PHS of Burundi; stakeholder roles, responsibilities, and mandates in delivering PHS functions; nature of interactions between stakeholders; and policies, politics, and institutions that influence those interactions.

Based on the functions described in the literature [26], the PHS functions of Burundi were examined and defined through quick brainstorming and group discussions. After the investigators delimited the functions, they identified the activities/roles involved per each function and the stakeholders carrying out those activities/roles. After identifying stakeholders and their actions, the investigators assessed how much interest and influence each stakeholder has regarding PHS functions. The investigators requested the participants to draw a box/circle in flipcharts in the middle with the name of the PHS function [26]. Investigators asked participants around the PHS function to draw a circle for each stakeholder involved, with the explanation that the length from the central function ought to show the interest that the stakeholder has in the process, and the size of the circle ought to show the influence that a stakeholder has on the PHS function. The closer the stakeholder circle is to the central function, the higher their interest level in the process. The larger the stakeholder circle, the more influence the stakeholder wields.

The assessors discussed the findings in plenary to highlight points of departure, the things that stand out, associations, and stakeholders who appeared isolated. Afterward, critical stakeholders—stakeholders with high interest and a significant influence (larger circles close to the center)—were identified for each PHS function. Identification of essential stakeholders was made by reviewing the diagrams drawn by participants for each function and deciding where the stakeholders fall within the following categories [26]:

- High interest, significant influence—critical
- High interest, low influence—important
- Low interest, significant influence—optional
- Low interest, low influence—irrelevant

Finally, the participants focused on how the different stakeholders identified above interact with each other within the PHS as a whole and explored the strengths and weaknesses of the critical stakeholder interactions.

2.3. Needs Assessment Workshop

The investigators undertook in June a 1-day needs assessment workshop. The aim of the workshop, which was an extension of the stakeholder workshop conducted in March, was to examine the strengths, weaknesses, and needs of the diverse functions of the PHS of Burundi and identify opportunities for interventions. The needs assessment workshop involved 15 in-country experts drawn from the same organizations, earlier engaged in the stakeholder workshop. As a kick-off to the meeting, the investigators presented an overview of the PHS functions. Subsequently, for each PHS function, the participants discussed the country's strengths and weaknesses regarding the same. Afterward, the researchers engaged the participants to discuss and agree by consensus on fundamental needs (gaps) that the project can realistically address within the available time and resources.

2.4. Stakeholder Forum Meeting

The researchers assembled influential stakeholders of the PHS of Burundi in a national forum conducted in November and attended by 28 representatives from the same organizations involved in the stakeholder and needs assessment workshops. In the course of the meeting, findings from the stakeholder and needs assessment workshops were presented by researchers and validated by participants—meaning the participants compared results, identified areas of commonality and divergence, and determined how best to move forward. The workshop included presentations, work within small groups, a section on questions and answers, and a plenary discussion.

3. Results

3.1. Policy and Institutional Framework of the Plant Health System of Burundi

In tandem with the country's Vision 2025, the ambition of the government of Burundi is to transform the country into an emerging country by 2040 through, among others, reduction in poverty, reduction of population pressure and improvement of agricultural development, and increase in the country's GDP. Coupled with Vision 2025, the country's National Development Plan (NDP) (2018–2027) aims to fundamentally change the country's economy, with the modernization of agriculture and attainment of food self-sufficiency at the heart of this objective. Within the framework of NDP, the government of Burundi in April 2021 adopted the National Program for the Capitalization of Peace, Social Stability, and the Promotion of Economic Growth (NPCP-SS-PEG) [6]. In addition, the MINEAGRIE produced an environmental, agricultural, and livestock policy (DOPEAE) (2020–2027). Other relevant national policies/strategies include: (i) multisectoral strategic plan for food security and nutrition (2019–2023); (ii) national action plan (2017–2021) for implementation of United Nations Security Council resolution 1325 for women, peace, and security; (iii) national gender policy (2012–2025); (iv) action plan for youth employment (2021–2024); (v) national health development plan (2021–2025); (vi) investment code (2008); (vii) national road map for strengthening food systems; (viii) national employment policy (2016–2025); and (ix) national strategy for financial inclusion [6].

In terms of institutional arrangement, the Ministry of Environment, Agriculture, and Livestock (MINEAGRIE) essentially coordinates agriculture in Burundi by overseeing agricultural development programs in the country and developing agricultural policies [6,18]. The ministry comprises seven general directorates (Figure 1): (i) the General Directorate of Agricultural and Livestock Planning—which supports the development of projects and programs within the sector; (ii) the General Directorate of Mobilization for Self-Development and Agricultural Extension (DGMAVAE)—develops methods and approaches to extension and designs and organizes training for various officials; (iii) the General Directorate of Agriculture—promotes the development of the agricultural sector, including seed, and policy formulation; (iv) the General Directorate of Livestock—promotes the development of the livestock sector; (v) the General Directorate of Land use planning, irrigation, and protection of land assets; (vi) the General Directorate of Environment, Water Resources and Sanitation; and (vii) the General Directorate of Human Resources. Additionally, MINEAGRIE oversees various national institutions, including Institut des Sciences Agronomiques du Burundi (ISABU)—responsible for agricultural research; Centre National de Technologie Alimentaire (CNTA)—supports food processing technical innovations; and Autorité de Régulation de la Filière Café au Burundi (ARFIC)—regulatory authority for coffee [18].

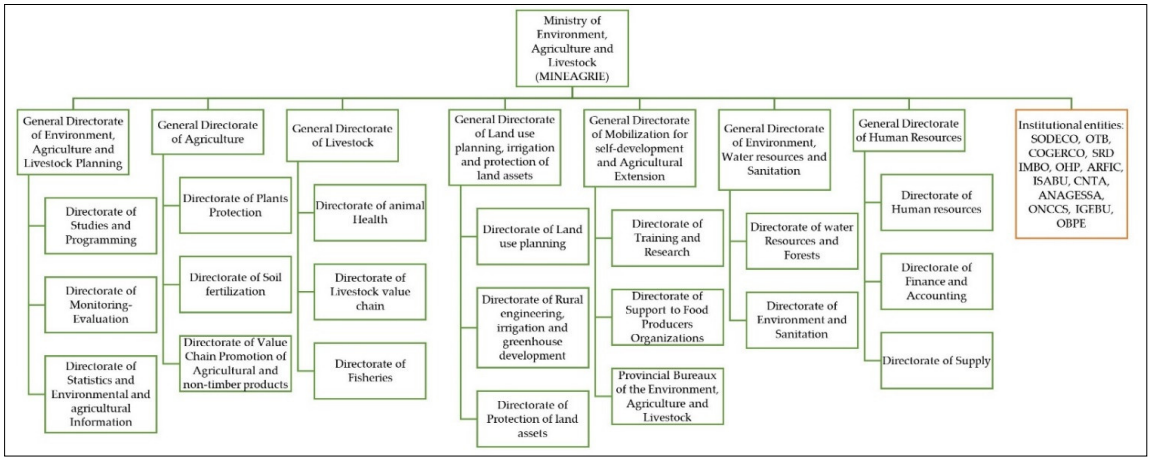

Figure 1. Structure of the Ministry of Environment, Agriculture, and Livestock of Burundi (MINEAGRIE).

3.2. Functions of the Plant Health System of Burundi

The concept of PHS is based on lessons and experiences from human health, where varied sources of knowledge, expertise, and technology are combined to provide healthcare [27]. In human health, in an attempt to advance a universal understanding of what a health system is and the basis for health system strengthening, the World Health Organization (WHO) defined, based on functions, a discrete number of "building blocks" making up the system [28].

While diverse human health systems have been advanced, proven, and studied over time, little is known regarding PHS and what is needed to base effective plant healthcare services. A step towards addressing this gap is a need to identify and define the structure and functioning of a PHS. However, such functions would not represent a 'universal truth' as a country's perspective on things sways them.

During the discussions at the stakeholder workshop, the participants confirmed that the PHS functions pre-defined in [26] (namely advisory services, information management, diagnostic services, policy and regulation, input supply, and research and technology development) were accurate and appropriate for Burundi. In addition, the participants highlighted two more PHS functions (crop production and agricultural training), bringing the total number of identified PHS functions for Burundi to eight (8):

1. Farmer advisory (extension) services. A complete set of institutions facilitating and supporting individuals engaged in agricultural production to solve problems and access skills, information, and technologies to enhance their livelihoods.
2. Plant health information management. Structures and approaches for availing plant health information to diverse actors at various levels.
3. Diagnostic services. Expertise and facilities required for identifying plant health problems, including pests, diseases, nutrient deficiencies, and soil health problems
4. Research and technology development. Process of invention and innovation to establish better practices and to implement technology as an added value
5. Agricultural input supply. Provision of agricultural inputs (seeds, fertilizer, pest control products, etc.)
6. Policy, regulation, and control. The mechanism through which government can manage the sector to achieve sustainable outcomes
7. Crop production. The process of growing crops for subsistence and commercial purposes
8. Agricultural training. Developing skills and knowledge relating to agriculture.

While looking at the PHS, one should consider the system in terms of its functions (e.g., service delivery, training, research, etc.) and, more crucially, its interrelations.

3.3. Stakeholders Involved in the Functions of the Plant Health System of Burundi

Stakeholders can be defined as individuals and organizations concerned with a particular activity owing to their participation in generating, consuming, regulating, managing, or evaluating the same [29]. While looking at the PHS of Burundi, one should include the institutional or supply side of the PHS and the individuals making up the system (population). In a progressive view, the population is not an extraneous recipient of the system; it is an integral part of it. This understanding of the population is because, when it comes to plant health, persons play at least two roles: (i) as farmers with specific needs requiring care; and (ii) as consumers with expectations.

After the investigators defined the PHS functions, they identified twenty (20) stakeholders to be helpful to engage when it comes to various PHS functions (Table 2). Most of the stakeholders were from the government sector (65%), followed by NGOs/International agencies/development partners/civil society (15%), farmers/farmers associations/farmers cooperatives, academia, consumers, and the private sector—all at 5% each. The researchers provide the interactions between the stakeholders in Figure 2.

Table 2. Importance of stakeholders in each function of the plant health system of Burundi according to 68 participants involved in three workshops.

Critical to Engage	Important to Engage	Optional to Engage
Farmer advisory (extension) services - General Directorate of Mobilization for Self-Development and Agricultural Extension (DGMAVAE) - Bureau Provinciale de L'Environnement, de l'Agriculture et de l'Elevage (BPEAE) - Directorate of Plant Protection (DPV) - Institut des Sciences Agronomiques du Burundi (ISABU)	- Agricultural input suppliers - Farmers, farmer associations & cooperatives - NGOs - Institutions of higher learning - Ministry of Finance - Office National de Contrôle et de Certification des Semences (ONCCS)	- Consumers
Plant health information management - Communication unit of Ministry of Environment, Agriculture and Livestock (MINEAGRIE) - Department of Statistical and Agricultural Information (DSIA)	- Institut de Statistiques et d'etudes Economiques du Burundi (ISTEEBU) - NGOs, international organizations, development partners (e.g., FAO) - ISABU - Institutions of higher learning - BPEAE - Agricultural input suppliers - Ministry of Finance	- Farmers, farmer associations, and cooperatives
Diagnostic services - ISABU - DPV - Farmers, farmer associations, and cooperatives - BPEAE - DGMAVAE	- Institutions of higher learning - Agricultural input suppliers - ONCCS - Ministry of Finance	- NGOs, international organizations, development partners
Research and technology development - ISABU - DPV	- NGOs, International Organization, Development Partners - Farmers, farmer associations & cooperatives - Institutions of higher learning - BPEAE - Ministry of Finance	- Agricultural input suppliers - Consumers
Agricultural input supply - Agricultural input suppliers - Collectif des Compagnies et Coopératives de Production des Semences du Burundi (COPROSEBU) - DPV	- Farmers, farmer associations, and cooperatives - BPEAE - ONCCS - Ministry of Finance	- ISABU - NGOs, international organizations, development partners (e.g., FAO) - Institutions of higher learning
Policy, regulation and control - Cabinet of MINEAGRIE - DPV	- National assembly - NGOs, international organizations, development partners (e.g., FAO, IPPC) - BPEAE - Agricultural input suppliers - Farmers, farmer associations, and cooperatives - ISABU	- Ministry of Finance - Institutions of higher learning
Crop production - Farmers, farmer associations, and cooperatives - General Directorate of Agriculture	- Agricultural input suppliers - Institutions of higher learning - Consumers	

		- NGOs, international organizations, development partners - ISABU	
Agricultural training			
- Institutions of higher learning - Ministry of Education		- BPEAE - Farmers, farmers association, and cooperatives - DPV - Agricultural input suppliers	- NGOs, International organization, development partners (e.g., IFDC, INADES, IFAD) - Ministry of Finance - ISABU

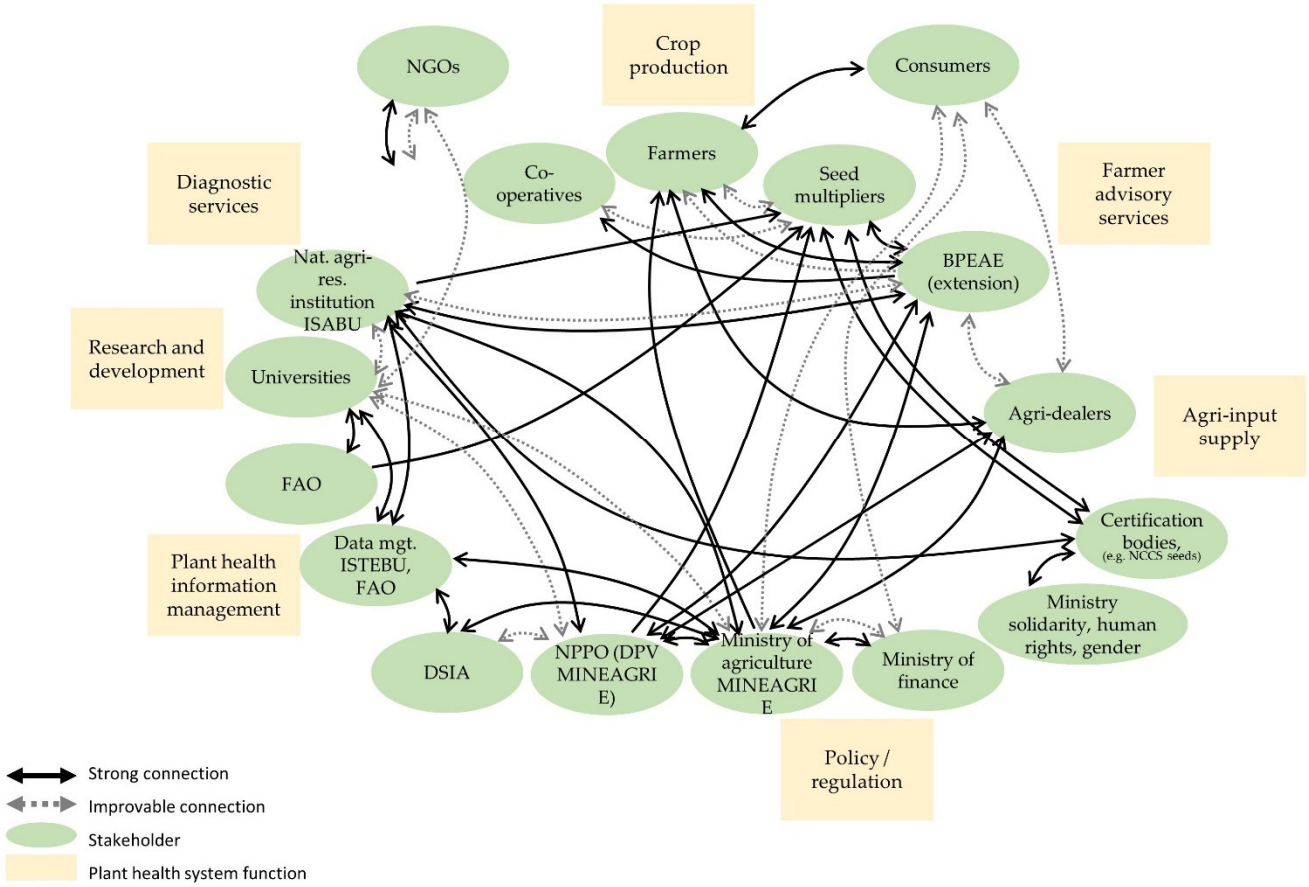

Figure 2. Interactions among stakeholders in the plant health system of Burundi identified by 68 participants involved in three workshops.

The government of Burundi plays a significant role in the PHS of the country (Table 3). It sets policies and standards, supports plant health services research, passes laws and regulations, and provides technical assistance and resources to local PHS. In addition, the government helps to finance plant health services, provides protection against international plant health threats, undertakes surveillance to establish status and plant health needs, and supports international efforts towards better plant health (Table 3).

Table 3. Role of plant health system stakeholders in each function of the plant health system of Burundi according to 68 participants involved in three workshops.

Key Actors	Role
Farmer advisory (extension) services	
(a) General Directorate of Mobilization for Self-Development and Agricultural Extension (DGMAVAE)	- Promotion of extension service delivery - Coordination of extension services nationally
(b) Bureau Provinciale de L'Environnement, de l'Agriculture et de l'Elevage (BPEAE)	- Coordination of extension activities in the provinces
(c) Institut des Sciences Agronomiques du Burundi (ISABU)	- Provision of agricultural extension services
(d) Farmers, farmers association and cooperatives	- Direct beneficiary of agricultural advisory services
Plant health information management	
(a) Department of Statistical and Agricultural Information (DSIA)	- Collection, analysis, and dissemination of agricultural statistical information
(b) Communication unit of Ministry of Environment, Agriculture and Livestock (MINEAGRIE)	- Posting media updates and engaging the public on agricultural matters
Diagnostic services	
(a) ISABU	- Soil analyses and plant health problems diagnostics
(b) DPV	- Diagnosis of plant health problems on samples brought by farmers
(c) Farmers, farmers association, and cooperatives	- Monitoring and reporting of plant health problems
Research and technology development	
(a) ISABU	- Main agricultural research agency in Burundi - Application of the research findings, technologies, and innovations
(b) Office National de Contrôle et de Certification des Semences (ONCCS)	- Research
(c) Institutions of higher learning (e.g., universities)	- Research
Agricultural input supply	
(a) DPV	- Quality assurance of agricultural inputs
(b) ISABU	- Seed variety development
(c) ONCCS	- Seed certification
(d) Collectif des Compagnies et Coopératives de Production des Semences du Burundi (COPROSEBU)	- National seed trade association - Seed production and processing - Seed production
(e) Agri-input supply and other private sector players	- Linking farmers with other actors in the agricultural input supply chain - Providing farmers with farm inputs (pesticides, seeds, fertilizer, and tools)
Policy, regulation, and control	
(a) Cabinet of MINEAGRIE	- Policy formulation
(b) DPV	- Plant protection regulation - Enforcement of sanitary and phytosanitary measures - Liaison office for International Plant Protection Convention (IPPC)
(c) Confédération des Associations des Producteurs Agricoles pour le Développement (CAPAD)	- Lobbying and advocacy for pro-farmer policies.
Crop production	
(a) MINEAGRIE	- Policy formulation, coordination, and mobilization of funds

(b) General Directorate of Agriculture	- Provision of the basics for the population's food needs - Adoption of new farming technologies,
(c) Farmers associations and cooperatives	- Suppliers of agricultural credit and inputs to their members - Seed production and processing
Agricultural training	
(a) Institutions of higher learning	- Education, training
(b) Ministry of Education	- Education, training
(c) CAPAD	- Training and provision of extension services to farmers

Currently, the primary government body responsible for Burundi plant health is MINEAGRIE. Other ministries also have agencies with responsibilities related to plant health, such as the Institute of Statistics and Economic Studies of Burundi (ISTEEBU) in the Ministry of Finance, Budget, and Economic Planification (MFBPE); technical colleges and universities in the Ministry of Education and Vocational and Professional Training; and the Ministry of National Solidarity, Human Rights, and Gender. Besides state actors, non-state actors are involved in the PHS of Burundi, including development partners, international agencies, NGOs, civil society, academia, and the private sector (Table 3).

Of the 20 stakeholders identified to be helpful to engage when it comes to various PHS functions, 13 were categorized as being critical (Table 4)—stakeholders with high interest and a significant influence: agricultural input suppliers; BPEAE; Cabinet of MINEAGRIE; Communication unit of MINEAGRIE; COPROSEBU; General Directorate of Agriculture; DGMAVAE; DPV; DSIA; farmers, farmers associations, and cooperatives; institutions of higher learning; ISABU; and Ministry of Education.

Table 4. Critical to engage stakeholders in the plant health system (PHS) of Burundi.

Stakeholder	**PHS Function**							
	AIS	**AT**	**CP**	**DS**	**FAS**	**PHIM**	**PRC**	**RTD**
(1) Agricultural input suppliers	x							
(2) Bureau Provinciale de L'Environnement, de l'Agriculture et de l'Elevage (BPEAE)				x	x			
(3) Cabinet of Ministry of Environment, Agriculture and Livestock (MINEAGRIE)							x	
(4) Communication unit of MINEAGRIE						x		
(5) Le Collectif des Compagnies et Coopératives de Production des Semences du Burundi (COPROSEBU)	x							
(6) General Directorate of Mobilization for Self-Development and Agricultural Extension				x	x			
(7) Directorate of Plant Protection	x			x	x		x	x
(8) Department of Statistical and Agricultural Information (DSIA)						x		
(9) Farmers, Farmers associations, and cooperatives			x	x				
(10) Institutions of higher learning		x						

Stakeholder	PHS Function							
	AIS	**AT**	**CP**	**DS**	**FAS**	**PHIM**	**PRC**	**RTD**
(11) Institut des Sciences Agronomiques du Burundi (ISABU)				x	x			x
(12) Ministry of Education and Vocational and Professional Training		x						
(13) General Directorate of Agriculture			x					

AIS = Agricultural input supply; AT = Agricultural training; CP = Crop production; DS = Diagnostic services; FAS = Farmer advisory (extension) services; PHIM = Plant health information management; PRC = Policy, regulation, and control; and RTD = Research and technology development; and Key: x = involvement in a PHS function.

3.3.1. Agricultural Input Supply

Agricultural input suppliers play a significant role in the distribution system, linking farmers to products, particularly in areas not easily accessible. The input segment is concentrated by stakeholders in the private sector (agricultural input suppliers), public sector (DPV), and civil society (COPROSEBU and CAPAD) (Figure 3a). ISABU mainly controls the country's formal market for seed production. In terms of quantity and quality, the seed supply is considered inadequate for the requirements to increase yields and improve nutritional content and drought and pest resistance in the agricultural sector [30]. ONCCS is responsible for regulating the industry, improving the quality of seeds sold within the country, and facilitating the importation of foreign seeds to satisfy the local requirements for improved seed varieties [31].

Though available, mineral fertilizers and pest control products tend to be expensive due to inadequate competition and high costs associated with transportation. In addition, the available large pack sizes tend to be inappropriate for smallholders with limited needs due to their relatively low land areas and who are compelled to carry the products back to their farm by bicycle or on foot [8,30].

3.3.2. Crop Production

Agricultural production is mainly handled by smallholder farmers in Burundi (Figure 3b). Many are subsistence farmers, and many others are smallholder commercial farmers [6]. Smallholder farmers typically produce a varied range of commodities in limited quantities to manage risks for household food supplies and complement this with production for cash. These crops grown by smallholder farmers include roots and tubers, fresh fruit and vegetables, pulses, and cereals. Other smallholders may produce palm fruit. Production is generally anchored on traditional farming—manual, hand-hoe powered, minimal use of inputs, and limited irrigation and water management techniques.

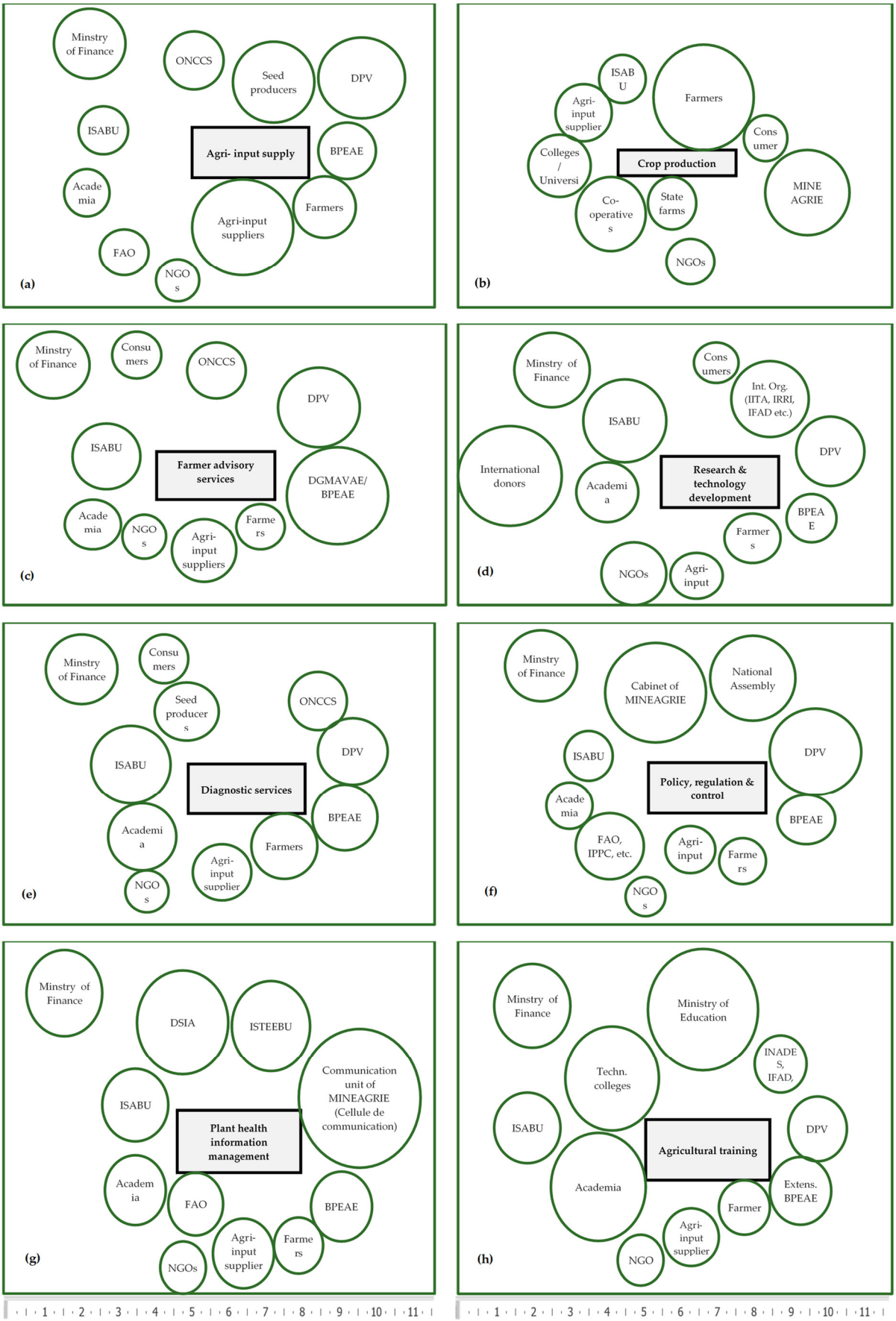

Figure 3. Schematic arrangement of interest (proximate to function) and influence (size of circle) of stakeholders in a plant health system's (PHS) functions. A ruler is included for scale.

There are only a few medium size producers (primarily producing fresh fruit and vegetables and cereals) and large commercial farms, mainly for export commodities like coffee, palm fruit, and vegetables [30]. Cooperatives are relatively less developed, but the government highly encourages their establishment, and their numbers have increased over time. State farms hardly exist. Nevertheless, Burundi can produce most of its food needs internally.

In 2020, roots and tubers, fresh fruit and vegetables, pulses, and cereals accounted for approximately 92% of the total crop production in Burundi [32]. Roots and tubers accounted for the largest share at 51% of production value, followed by fresh fruit and vegetables (22%), pulses (6%), and cereal production (6%) [32].

3.3.3. Farmer Advisory Services

Agricultural technical assistance is provided principally by BPEAE's extension workers, as well as through an assortment of programs by donor agencies and development partners and a small number of private sector contract farming schemes (Figure 3c). By 2020, Burundi had 1030 extension officers, of which BPEAE employed 996, while the remaining 34 were used by seed producers [31]. The ratio of extension officers to agricultural households stood at 1:3929 in 2017.

As noted above, the deployment of private extension service providers has primarily been low. Notwithstanding, a previous report observed that their performance might have been better compared to that of their counterparts in the public sector [30].

3.3.4. Research and Technology Development

Various public, international, and private organizations and institutions of higher learning undertake research in the agricultural sector (Figure 3d). Research and development are mainly focused on crop production and food technologies. In terms of crops, among the most researched crops include vegetables, rice, potatoes, and fruits.

Actors in the public sector include ISABU, the Agronomic and Zootechnique Research Institute (IRAZ), and the National Centre on Food Technologies (CNTA). The country's leading research center is ISABU accounting for most of Burundi's research capacity and investments. IRAZ supports food security through animal science and agriculture research, while CNTA focuses on developing and adapting processing and storage technologies [27]. Institutions of higher learning, such as the University of Burundi and the University of Ngozi, have departments specifically dedicated to research. Private sector investment in research and development is minimal. Besides local institutions, various international organizations, including IITA and IRRI, undertake applied research in Burundi.

3.3.5. Diagnostic Services

Diagnostics is mainly implemented by ISABU and the universities and certification bodies such as ONCCS (Figure 3e). Moreover, laboratories and institutions outside Burundi play a role. As for field diagnostics, the extension workers under BPEAE and farmers are key players and, to a small extent, the agricultural input supplier.

3.3.6. Policy, Regulation, and Control

The MINEAGRIE is responsible for developing rules relating to agriculture, as well as preparing agricultural policies. When it comes to the formulation of regulations, the cabinet of MINEAGRIE is critical in the decision-making process (Figure 3f). On the other hand, when it comes to agricultural policies, the national assembly plays an integral role. Some regulations are also adopted from international protocols, guidance, and agreements. Therefore, for example, FAO and IPPC influence regulations. DPV usually handles forecasting and warning systems under MINEAGRIE.

3.3.7. Plant Health Information Management

Agricultural data management seems less emphasized in Burundi, and linkages may need improvements. This low emphasis is, despite the existence of a department within MINEAGRIE (DSIA), meant to spearhead initiatives relating to agricultural data, and coupled with this is the existence of ISTEEBU (Institut de Statistiques et d'études économiques du Burundi) (Figure 3g). Some NGOs, such as AUXFIN, are capturing agricultural and farmer data and may be able to implement monitoring and quality assurance activities.

3.3.8. Agricultural Training

Agricultural training in Burundi has been chiefly driven by development partners through collaboration with MINEAGRIE's programs and involving a few private sector players who provide technical support. The partners who have supported agricultural training in the past include the World Bank and the French and Belgian cooperation agencies, the EU, IFAD, and FAO, as well as a raft of international and local NGOs (Figure 3h). Agricultural training programs have concentrated mainly on technical, administrative, and literacy issues to support the sector's development.

Formal training in agriculture is provided at high school and undergraduate levels. The agricultural training and educational institutions include the Faculty of Agronomy at the University of Ngozi and the Faculty of Agronomy and Bio-Engineering (FABI) at the University of Burundi; and the Institut Technique Agricole du Burundi (ITAB).

3.4. Strengths, Weaknesses, and Opportunities of the Functions of the Plant Health System of Burundi

Through discussions with stakeholders, the researchers identified the strengths and weaknesses of the PHS of Burundi. Additionally, the investigators undertook a comprehensive analysis of relevant secondary literature.

Across the PHS functions of Burundi, some significant weaknesses identified include low productivity, lack of adequate skills to serve farmers effectively, and inadequate capacity to diagnose pests.

Researchers have identified low agricultural productivity as a critical impediment to food security and fiscal development in post-conflict Burundi [7,8,33]. With the increasing population [34], poor yields have meant that the amount of food produced does not match the population, resulting in a constant food shortfall in the country.

The twin challenges of unpredictable smallholder agricultural production and the reality that most agricultural land is presently under production require that further growth emanates from product and process upgrades that aim for sustainable intensification [30]. These upgrades can include bench terraces on sloping land for enhanced hillside agriculture [35], adoption of minimum tillage and other improved land preparation methods [36], low-cost technologies on micro-fertilization [37,38], and small-scale irrigation schemes [39]. Additional upgrades include the safe use and handling of pesticides and the prioritization and promotion of integrated pest management techniques [40,41].

Adopting the above upgrades at the farm level requires strategic support and investment by government and development partners to stimulate demand and uptake by smallholders. Technical and financial support by government and development partners is necessary, particularly for upgrades whose returns on investment in the short term are negative.

Lack of adequate skills. As the agricultural sector of Burundi adapts to the upgrades above, development skills capacities for farmers and farmers' advisors on, among others, effective and practical methods of managing plant health problems is required.

In the short term, to complement formal education programs, the country can consult international experts from organizations such as CABI, IITA, FAO, and IFAD about developing suitable training programs. Besides developing the training programs and

curricula, the country should seek opportunities for institutionalizing this training at the ITAB and university levels and in other institutions of higher learning [42–44].

Inadequate capacity to diagnose pests. Crop pests diminish the quality and yield of agricultural production [45]. They reduce food security at various levels (household, national and global) and are attributed to considerable economic losses, particularly in food-deficit regions with rapid population growth and often with emerging or re-emerging pests [46].

A scarcity of diagnostic service for plant health problems remains a critical contributing factor to plant health burden in resource-poor settings. Opportunities exist in Burundi for:

- Enhancing the capacity of agricultural extension workers to increase field-level detection of plant health problems.
- Supplementing the existing laboratory infrastructure with additional equipment and skilled personnel to enable the diagnosis of a broad spectrum of plant health problems
- Sharing and integrating plant health information sources in support of early warning systems
- Promoting innovations in surveillance and control that do not require and/or can lessen the physical presence of plant health practitioners

Notwithstanding the constraints above, the country has numerous crucial factors favoring the development of an enhanced PHS. For instance, the country is endowed with a good climate and geographical conditions that favor agricultural production, with several cropping seasons. In addition, the country enjoys competitive labor costs and is strategically placed to export in the region through Lake Tanganyika. However, the country must confront its fundamental weaknesses to take advantage of these opportunities. An analysis of the country's strengths and weaknesses is presented in Table 5.

Table 5. Strengths and weaknesses of each plant health system function of Burundi (n = 68 participants involved in three workshops).

Strengths	Weaknesses
Agricultural input supply	
	- Weak demand from producers
	- Lack of technical knowledge
- Availability of raw materials	- Lack of financial resources
- Minimal or no cost in seed production in the informal sector	- Market distortions from subsidy program
	- Scarcity of locally available organic fertilizer and mulch
- Availability of seed in the informal sector is assured	- Inadequate competition
	- High transportation cost
	- Minimal use of external inputs
	- Poor quality seed
Crop production	

	- Production based on traditional farming methods - Pests and diseases - Cooperatives and contract farming schemes are not well organized
- Good climate for crop production - Available arable land - Comparatively low labour costs - Significant involvement of women in production - Improved crop varieties/breeds	- Limited access to finance - Unclear land tenure system coupled with scarcity of land and an increasing population - Poor rural transportation infrastructure - Soil degradation - Majority of land that is cultivatable is already under production
Research and technology development	
- Existence of a national agricultural research system - Experience in collaborative research	- Shortage of human resource - Limited budget
Farmer advisory services	
- Decentralized and well-defined extension system - Available workforce of extension agents - Presence of farmers organizations, NGOs, and projects providing alternative extension service providers	- Many extension agents lack the requisite skills to effectively serve farmers either due to lack of practical skills or limited experience in the sector - Government extension staff are often poorly motivated due to low wages - Budgetary constraints limiting the hiring of more extension workers - Low literacy rates among farmers - Reluctance by trained agronomists to live or work in the rural areas
Plant health information management	
- Existence of institutions mandated to manage plant health information	- Lack of data science approach
Diagnostic services	
- Knowledge sharing platforms - Strong collaboration with experts outside the country	- Limited capacity to identify and isolate pests - Lack of equipment and infrastructure - inadequate capacity to prevent, detect and respond to new and emerging plant health problems
Policy, regulation and control	
- Extensive agricultural strategies detailing the vision and priority interventions	- Bureaucracy (e.g., overly centralized systems for planning and management) - Poor interdependencies between PHS and program investments - Inadequate regulation of agricultural inputs sector, improper industry practices - Underdeveloped sanitary and phytosanitary system
Agricultural training	

- Existence of agricultural vocational training institutes for training and producing middle-level skilled extension personnel	- Fast growing enrolment and inadequate facilities, equipment, and teaching staff - Training programs for universities are broad and focus on theoretical knowledge and lack training in applied and practical skills - Lack of resources - Discrepancy between the needs of the private sector and the skills provided by formal education schools - Lack of a clear mechanism for institutionalizing knowledge transfer and provision of adequate scale for reaching the fragmented production base. - Women not targeted in agricultural trainings

In terms of crucial needs (gaps) that the proposed project can realistically address, within the available time and resources, the participants, through consensus, identified the following:

- Management of linkages among stakeholders in plant health
- Training qualified staff in field diagnosis principles and giving farmers practical and effective plant health management recommendations. Also relevant are other training, including IPM/biocontrol, and the development of extension materials, e.g., pest management decision guides (PMDGs) and fact sheets for farmers.
- Operation of plant clinics and associated activities such as delivery of advice to farmers through complementary extension campaigns (such as plant health rallies and mass extension campaigns).
- Training of plant health practitioners in data management—processes involved in the collection and processing of plant clinic data.
- Setting up of ICT-based systems to support information sharing.
- Monitoring, evaluation, and learning to assess and document outcomes and impact of project interventions.
- Prioritization and addressing some of the vital gender-based constraints in agriculture

In light of the identified needs (gaps), seven broad interventions are proposed to help rapidly strengthen the PHS of Burundi:

1. Promotion of a comprehensive approach to plant health governance. Plant health policies, operational processes, planning, and budgeting ought to be linked to the attainment of the relevant Sustainable Development Goals (SDGs), specifically SDG 2 (End hunger, achieve food security and improved nutrition, and promote sustainable agriculture). Means of firming accountability and mechanisms for engaging stakeholders, including alternative sectors, communities, external partners, civil society, private sector players, and academia, should be explored.
2. Provision of adequate, skilled, and well-distributed plant health practitioners. Staff cadres need to be streamlined following the requirements for essential services, and this needs to be mirrored in staffing standards, norms, conditions, and certification. Training curricula and programs need to be responsive to new and emerging priorities. The government and development partners should channel investments towards training programs (both pre-service and in-service) to ensure the personnel mirror both present and future plant health needs.
3. Building of an efficient agricultural advisory service delivery mechanism. The agricultural advisory service delivery mechanism needs to be rationalized at all levels (national and local) to reflect the country's priorities.
4. Provision of sufficient plant health equipment and infrastructure. The concerned entities should establish operational procedures and standards for critical plant health infrastructure. They should also develop medium-term and long-term plans for

investment (including their maintenance and disposal) of plant health equipment and expansion of fixed infrastructure.

5. Provision of good-quality, affordable critical pest control products, diagnostics, and other agricultural inputs. To be implemented through a well-regulated procurement and supply system. The government must revise regulations and policies to enhance the capacity for judicious use of pest control products and other agricultural inputs, including during emergencies. The national plant protection organization should improve surveillance systems for monitoring new and emerging plant health problems, adverse effects, pesticide quality, and resistance.
6. Strengthening of plant health information systems and surveillance. The stakeholders should establish data coordination apparatuses to interlace information systems for research, surveys, surveillance, and critical statistics to support integration and lessen fragmentation. The capacity for data analysis and sharing should be prioritized, especially at the local level. Additionally, the stakeholders should scale up innovative approaches for data collection and use. Finally, the stakeholders should prioritize the engagement of the research community for the generation and usage of evidence emanating from research for decision-making.
7. Provision of sustainable financing for plant health. The government should do this by establishing mechanisms for mobilizing additional sustainable domestic resources while sourcing more external resources for plant health. The country should strengthen accountability systems, public financial management, and institutional arrangement.

4. Conclusions

Functional plant health systems have been integral in mitigating the movement of non-native organisms, pests, and diseases within and between countries through trade. In some countries, such as Cuba [47], Venezuela [48], and Burundi, practitioners know little about the plant health system and other support systems. Efforts are underway in many regions to strengthen plant health systems through collaboration, including regulatory frameworks [49].

The accumulated experience of agroecological initiatives in thousands of small- and medium-scale farms in developing countries [47,48] is essential in defining national policies to support sustainable agriculture. In this regard, a vital aspect of the plant health systems is their pest and disease monitoring system that covers the most economically important crops in the country [49], providing pest thresholds to farmers and the importance of identifying possible interrelationships with biophysical components such as climate, soil, or agronomic management [48].

To facilitate the development of future trade partnerships between countries, agencies need to understand the organizational structure and diagnostic capacity of the plant health system of these countries, identify potential synergies between country systems, and identify steps toward cooperation. The results of this study fill this critical gap by presenting a descriptive analysis of the plant health system in Burundi. An understanding of plant health systems will be crucial for the regional economic and environmental stability of a relationship between countries.

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