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Policy options for advancing seed systems for vegetatively propagated crops in Vietnam

Marcel Gatto, Dung Phuong Le, Grazia Pacillo, Mywish Maredia, Ricardo Labarta, Guy Hareau, and David J. Spielman

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www.rtb.cgiar.org

Contact:
RTB Program Management Unit
International Potato Center (CIP)
Apartado 1558, Lima 12, Perú
rtb@cgiar.org • www.rtb.cgiar.org

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Content

Abstract

Seed systems for vegetatively propagated crops (VPCs) are frequently governed by a regulatory blueprint designed for major cereal crops. This approach tends to disregard the distinct biological characteristics of VPCs, in turn limiting farmers' access to high-quality planting material and increasing the risk of pest and disease transmission. In this paper, we ask what type of regulatory framework is appropriate for improving farmers' access to quality VPC planting material, and what the costs, benefits, risks, and unintended consequences are of alternative regulations. We explore this in the context of cassava and potato in Vietnam through secondary data and document analysis, key informant interviews, and focus group discussions. Findings indicate that despite a regulatory regime that imposes strict rules on the production and trade of planting material for VPCs, the market is largely unregulated due to weak enforcement capacity. In the absence of regulatory enforcement, however, producers and traders of VPC planting material signal quality to farmers through trust, reputation, and long-term relationships. Though effective at a small and localized scale, these informal systems are unlikely to accommodate the plans for rapid expansion of the cassava and potato sectors outlined in the Government of Vietnam's strategy for growth and development. Nor are they likely to prove effective in managing increases in pest and disease pressures that result from cross-border trade, climate change, or other factors. We discuss alternative policy approaches and argue that the most appropriate policy regime requires that a careful balance be struck between a permissive regime at the local level and strict regulatory surveillance and enforcement at the national and regional level.

Keywords: seed systems; vegetatively propagated crops; seed market regulations; seed policy; cassava; potato

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Policy options for advancing seed systems for vegetatively propagated crops in Vietnam

Marcel Gatto,[1] Dung Phuong Le,[2] Grazia Pacillo,[2] Mywish Maredia,[3] Ricardo Labarta,[4] Guy Hareau,[5] and David J. Spielman[6]

1. Introduction

Seed systems are an integral part of agricultural development and efforts to achieve food and nutrition security (Cromwell et al. 1992; Jaffee and Srivastava, 1994; McGuire and Sperling, 2016). In many developing countries the policies and regulations governing seed system and markets are changing rapidly, driven by growth, development, and trade concerns (Spielman and Kennedy, 2016). Increasing attention is being given to the role of seed systems and markets in accelerating the use of improved genetic material and quality seed to increase agricultural productivity growth and incomes from agricultural commodities (Evenson and Gollin, 2003; Walker and Alwang, 2015).

But prevailing narratives around these issues in developing countries tend to focus primarily on the role of formal (i.e. regulated) seed systems for major cereal crops in achieving such outcomes. While this may be appropriate in certain contexts, it overlooks the importance of informal (i.e. unregulated) seed systems for a wide range of crops and countries (Almekinders and Louwaars, 2002; Louwaars and de Boef, 2012; Westengen and Brysting, 2014). Many vegetatively propagated crops (VPCs) fall into this category: informal seed systems are the main channel through which farmers access improved varieties and quality planting material.[7] But many governments and development partners overlook the potential returns to investing in strengthening informal seed production, multiplication, and distribution systems of VPCs (Almekinders et al., 2019; Almekinders, Louwaars and De Bruijn, 1994). This view persists even despite the fact that the informal system in which farmers produce their own seed, exchange/share seed with other farmers, or locally purchase seed from traders and vendors, is the dominant system of seed supply in most developing countries (De Boef et al.,

[1] Corresponding author, m.gatto@cgiar.org. International Potato Center, Bac Tu Liem, Hanoi, Vietnam
[2] International Center for Tropical Agriculture, Bac Tu Liem, Hanoi, Vietnam
[3] Department of Agricultural, Food, and Resource Economics, Michigan State University, East Lansing, USA
[4] International Center for Tropical Agriculture, Palmira, Colombia
[5] International Potato Center, Lima, Peru.
[6] International Food Policy Research Institute, Washington, DC, USA.
[7] Throughout this paper, we use the term "seed" and "planting material" interchangeably, although we recognize that the former refers to material produced from sexual reproduction in a flowering plant, whereas the latter refers to materials produced from either sexual or asexual reproduction. In this paper, we focus on asexual plant parts used for propagation such as cuttings, buddings, stems, roots, tubers, and other plant propagation materials that are asexually, clonally, or vegetatively produced.

2010; Lipper et al., 2010; Poudel et al., 2015; Abizaid et al., 2016). Instead, informal systems are still perceived to be inefficient, closed, weak, and easily eradicated by commercialization and regulation (Coomes et al., 2015).

However, this does not mean that the informal VPC seed systems operate in isolation from the formal sector: the distinction between "formal" and "informal" seed systems is, at best a short-hand way of thinking about the issues. In fact, the integration of informal and formal seed systems represents an important topic for consideration among policymakers, seed businesses, and entrepreneurs (Louwaars and de Boef, 2012). This means that there are opportunities to develop hybrid systems that exploit the linkages between informal system actors—farmers, local seed producers/entrepreneurs, and traders—and formal system actors from the research, extension, and regulatory bodies. Crop- and country-specific differences in how an informal system operates and integrates with the formal sector is especially important for VPC seed systems given the susceptibility of VPCs to pests and diseases and the need for good practices in the production and distribution of planting material.

A key aspect of informal VPC seed systems is the role of decentralized and localized systems in which farmers are the main producers, and are actively engaged in multiplication and distribution of seeds through exchange or sale, typically within limited geographic areas (Jones et al., 2001; Ndjeunga, 2002; Hirpa et al., 2010; Sperling and McGuire, 2010; Witcombe et al., 2010; Tin et al., 2011; Singh et al., 2013; Tadesse et al., 2016). Another distinctive feature of the informal seed system is that seed is a by-product of thousands/millions of farm enterprises that are focused on the production of crop output for consumption. It is thus difficult to monitor and regulate the production and sale of a product that is not the intended output of an enterprise. In the absence of any formal institutions to guarantee the provision of high-quality seed, trust and reputation are critical to these informal systems (Fafchamps and Minten, 2001; Cadilhon et al., 2003; Aji, 2016).[8]

Several recent studies suggest a growing interest in how these issues play out in VPC seed systems. Studies on seed systems for potato in Ethiopia (Hirpa et al., 2010) and Vietnam (Batt et al., 2000), and cassava in Vietnam (Le et al., 2019) and the global context (Delaquis et al., 2018), highlight the complexities of informal VPC seed systems and their role in efforts to increase productivity growth and rural livelihoods. Other studies draw attention to the epidemiological risks associated with VPCs and VPC seed systems and the urgent need to give similar attention to these issues (e.g., Pautasso and Jeger, 2014; Buddenhagen et al., 2017). But a review by Almekinders et al. (2019) concludes that more systematic and interdisciplinary research is required to understand (1) fictive versus effective farmer demand for quality seed, (2) issues associated with establishing decentralized multipliers, and (3) regulatory frameworks to enhance access and availability of quality seed.

[8] Batt et al. (2000) is an exception stressing the importance of trust between farmers and private potato seed producers.

In fact, we are unaware of any documented analysis of regulatory frameworks for VPC seed systems. This is the gap our study aims to address. Specifically, we ask what type of quality assurance systems are effective in increasing the access, availability, and quality of VPC planting material among small-scale, resource-poor farmers in developing countries. To better understand these issues, we examine the market for cassava and potato seed in Vietnam.

In Vietnam, many of the issues associated with the formal seed system are well articulated with respect to major food crops, e.g., rice and maize (Nielsen, 2003; Than Ha et al., 2004). But for Vietnam's main VPCs, cassava and potato, the narrative is largely unwritten. This may be because of the unique biological, social, and economic characteristics of VPCs—characteristics that make it challenging to both design and implement seed system policies and regulations for these crops. Yet they are important to the country's agricultural development and economic growth agenda and deserve attention of researchers and policy makers.

We argue that seed policy frameworks—the laws, rules, regulations, and guidelines that govern both the genetic improvement of crops and the production and exchange of planting material—are weakly adapted to the unique requirements of VPCs. This absence of effective policy and regulation may, in fact, limit farmers' access to planting material of superior genetic and physical quality, thereby increasing the risk of pest and disease transmission and reducing expected gains in productivity for VPCs. However, we also recognize that a formal quality assurance system that relies on certified seed production, inspection, and distribution may not be entirely appropriate or feasible to this context, at least not in the short run.

In this paper, we provide a brief account of the country's policy and regulatory framework for VPC seed systems from its earliest point and explore the drivers of change in recent years. We then analyze the suitability of existing policies and regulations governing the VPC sector, with a focus on the diversity of seed providers and farmer typologies in the cassava and potato sectors. We then discuss the trade-offs and unintended consequences associated with the current policy framework in Vietnam and explore the viability of alternative frameworks to improve farmers' access to quality VPC planting material.

2. Materials and methods

We draw on data from two distinct sources: (1) secondary data and document analysis, including public policy and legal documents, government statistics, and project reports; and (2) key informant interviews and focus group discussions. Each is described in detail below.

Secondary data and analysis on Vietnam's cassava and potato seed systems is limited. We mainly draw on government documents including national agriculture sector development strategies, cassava and potato sector development strategies, and seed regulatory directives, law documents, statutes, rules, guidelines, and standards. Finally, we use secondary sources such as the government's various sources of economic and agricultural statistics and project descriptions from development partners, international organizations, and non-governmental organizations to provide further descriptive insights into Vietnam's cassava and potato seed systems.

The second data source is a series of key informant interviews (KIIs) and focus group discussions (FGDs) conducted with seed systems actors. The KIIs and FGDs were conducted in 2017 using semi-structured interview guides that were developed for each category of actor as part of a larger cross-country project on seed systems and markets for VPCs.[9] The interview guides covered topics that ranged from basic stakeholder details to quality assurance standards and practices, to viewpoints on the effectiveness of current policies and regulations. Where just one or two respondents were present, discussions were conducted as KIIs, and where a larger number of respondents were present, they were conducted at FGDs. The difference pertains primarily to how the discussion is managed and how information is presented, discussed, validated, refuted, and revised by participants and the interviewer. A larger group (i.e., FGDs) often allow for more iterative processes and a single respondent (i.e., KIIs) allow for greater depth in the inquiry.

[9] See https://doi.org/10.7910/DVN/MSIMRE

Table 1. Actors, locations, and number of individuals interviewed

Actor category	Location	No. of	
		Organizations	Individuals
Policymakers, advisors, and regulators	Hanoi, Dalat, Tay Ninh	5	17
Public research agencies, institutes, centers, and stations	Hanoi, Dalat, Dong Nai	5	13
Individual and small-scale seed entrepreneurs	Hanoi, Dong Nai, Tay Ninh, Dalat	6	7
Private companies	Hochiminh City	1	1
Industry associations	Hanoi	1	1
Total		**18**	**39**

KIIs and FGDs lasted between 1.5 and 2 hours. Almost all interviews were exclusively held in Vietnamese by using professional translation services, where possible. But despite the high level of professionalism, the interviews could not always go into the desired depth due to back and forth translation and a lack of mutual understanding of specific concepts due to the use of specific jargon. In these cases, we conducted a second round of follow-up questions with a small number of actors for clarification purposes. All interviews were anonymized[10] and uploaded to a publicly accessible repository (see footnote 3). A total of 18 KIIs and FGDs were conducted in 2017 with 39 individuals across 18 different types of stakeholders in the cassava and potato seed sector (Table 1).

[10] Approval for this study was received from the Institution Review Board of the International Food Policy Research Institute (IRB# 00007490; FWA# 00005121)

3. Conceptual framework

VPCs are a distinct class of commodities with unique biological, social, and economic characteristics that vary considerably by crop, country, and market. These attributes pose significant policy and programmatic challenges to increasing smallholder farmers' access to and availability of quality planting material as a means of increasing VPC yield, output, and value in many developing countries (Almekinders et al., 2019). In this section we discuss these key challenges of vegetatively propagated crops.

Consider the reproductive biology of VPCs as a starting point for understanding the need for distinct seed policies and regulations for VPCs. Typically, VPCs are clonally propagated, that is, they are reproduced using tubers, roots, stems, vines, buds, or cuttings as planting material, resulting in plants that exhibit or express identical genetic traits from generation to generation. Clonal propagation offers several advantages including low-cost and often rapid production of planting material of identical genotypes. However, the quality of clonally propagated planting material tends to degenerate over time with the build-up of pests and disease on or in the material itself.

Relatedly, clonal propagation materials differ between crops. Planting material used for potato (seed potato) is essentially the same plant part as the commodity itself (ware potato). Seed potato is distinguishable from ware potato upon visual inspection only by size, although such inspection does not necessarily allow for assessment of the quality of the seed potato, for example, whether it is free from pests or diseases, whether its moisture content is appropriate for storage or planting, or whether it will, in fact germinate once planted. Cassava planting material, on the other hand, takes the form of a stem cutting that is distinct from the primary commodity, which is the cassava root. Both seed potato and cassava stems are perishable forms of planting material that require distinct storage and preparation practices that differ considerably from cereals.

These characteristics have significant implications for the economics of VPC and the exchange of planting materials through market and non-market mechanisms. In economic terms, VPC planting materials (and, for that matter, most other types and classes of seed) are what are described as "credence" goods: their genetic and physical quality is unobservable by farmers at purchase, thereby making it difficult to assess their utility. A farmer's inability to assess quality can, in turn, introduce information asymmetries that reduce the efficiencies expected from market exchanges. This "lemons market" (Akerlof, 1970) characterization of seed exchanges has been well-documented across a number of crops, and not just VPCs. For example, Stevenson et al. (2017) and Bold et al. (2017) explore the effects of asymmetric information in maize seed markets in Uganda, as does Ma et al. (2017) for transgenic cotton in Pakistan. In a similar vein, studies have found a high rate of error among farmers in the identification of cassava varieties in Vietnam (Le et al. 2019), Ghana (Maredia et al. 2016), and Colombia (Floro et al. 2017) when their beliefs were cross-checked against DNA fingerprinting.

Adding to these challenges is the fact that VPC planting materials are also bulky and have a short dormancy (Hirpa et al., 2010; Dryer et al., 201; Legg et al., 2014). Bulkiness tends to impede a buyer's ability to spot damaged or

degenerated planting material, while slow dormancy imposes a constraint on the point in time within which an exchange must take place. These characteristics potentially impose costs of exchange associated with the timeliness of delivery, the manner in which they are stored and packaged, or the means by which they are transported. When these costs are combined with the credence goods nature of VPC planting material and the information asymmetries present in VPC seed markets, problematic exchanges and market inefficiencies become characteristic features of the challenges surrounding VPC seed system. As a result, high-quality seed is not available, and farmers continue to plant low-quality seed, which impacts the productivity of VPCs.

Where market imperfections persist, social and economic institutions often emerge to facilitate exchanges. In the context of VPC seed markets, repeated transactions and mutual trust between buyers and sellers, along with the preservation of product identity and reputational integrity of the buyer, often emerge as key institutions facilitating such transactions. Prior literature on the role of these institutions in rural market settings is rich, particularly where transactions are frequently undertaken without formal legal contracts but established by personalized relationships enforced by mutual trust and reputation (Minten and Fafchamps, 2001; Lyon, 2000). In the absence of formal institutions which provide reliable information, in many countries, trust and reputation are the essence of how quality is assured.

Finally, the availability and price of high-quality VPC planting material are determined by a wide variety of other factors including demand for the commodity itself, the price of complements (e.g., fertilizer), the price of substitutes (own-saved or farmer-to-farmer exchanged seed), the specific preferences of the farmer, and the cost of seed production for the seller. Of particular note, but often ignored, is the role of traders, agriprocessors, and other actors further down the value chain in supplying farmers with new varieties and quality seed for VPCs. For example, farmers might purchase or receive new planting material at the time they bring their product to the agriprocessor, and might receive inputs, credit, agronomic recommendations, and other information to improve the quality of the feedstock they subsequently bring to the agriprocessor. Such is the case in some contexts for sugarcane, pineapple, and several roots and tubers where production is closely linked to agriprocessing operations (Suzuki et al., 2011; Le et al., 2019). This demand-driven structure of production is rapidly gaining attention in the study of technical change and economic growth in developing-country agriculture (Reardon and Timmer, 2012).

In summary, VPC seed markets are complex, potentially requiring policy and regulatory attention that cannot be found through applications of policies and regulations designed for cereal seed system. In the next sections, we examine this argument further with an emphasis on cassava stems and seed potato in Vietnam. Much of these concepts underlying VPC seed systems boil down to the analysis of actors and exchanges of planting materials, and the ability of policy to shape both the incentives facing such actors and the nature of exchanges between them. Dalton et al. (2011) provide a useful characterization of seed types and seed channels, highlighting the archetypical role of “formal” and “informal” markets, and non-market channels in both “formal” and “informal” seed system (Table 2).

Table 2. Types of channels and seed types

Channels		Seed	
		Formal	**Informal**
Market	**Formal**	A. Certified, improved or purified seed sold in an input supply shop, via extension programs or licensed distributors. Production, multiplication, and sale is regulated by government.	D. Sale of recycled farm-saved seeds or landraces in a setting where sale of informal seed is explicitly permitted, or alternatively where this is not the case, but prohibitions on non-certified seed sale or other deterring regulations are not enforced and the public widely recognizes this.
	Informal	B. Sale of certified improved seed via non-regulated marketing outlets, like a market trader buying seed in bulk and repackaging it and dividing into smaller packages.	E. Sale of non-certified seed in transactions where seed is not explicitly recognized as a product. Separability of seed from grain/ware may not be explicit. Sale in market not recognized by national law or widely acknowledged by public as a source of seed.
Non-market exchange		C. Occurs frequently in the form of free distribution of seed by government, NGOs and other international organizations to promote VPCs or after climatic shocks.	F. Acquisition of seed through non-market exchanges. This includes farmer saved seed, gift from community members, friends or family.

Source: Authors, adapted from Dalton et al. (2011).

Against this backdrop, the key question asked in many studies of seed system policies is whether they are appropriate to improving farmers' access to better seed in terms of both genetic and physical quality, and whether such access is provided in a timely manner and at prices that are affordable and appropriate. In addressing this question, seed policy analyses must identify the full range of actors, the different interests and practices among such actors, the role of policy at various administrative levels, and the alternative policy options that are both appropriate and feasible given crop and country context (Spielman and Kennedy, 2016; Spielman and Smale, 2017). This implies that the identification of risks, tradeoffs, and unintended consequences are also central to the analysis.

4. Overview of cassava and potato sectors in Vietnam

4.1 Importance of cassava and potato in the national and international context

Neither cassava nor potato figure prominently in Vietnam's discourse on agriculture, rural development, or food security. While both are referenced in the country's growth and development strategy, the targets set for their expansion are far more modest than those set for other food staple and high-value export crops. In Vietnam, the total area for cassava and potatoes combined is about 600,000 ha whereas rice alone is planted to an area of close to 8 million ha in 2016 (FAOSTAT, 2018). Moreover, Vietnam is not a particularly well-established producer of either crop in terms of yields relative to other countries. Compared with a selection of major cassava and potato-producing countries, there is a clear yield gap in Vietnam which is more pronounced for potato than cassava (Figure 1).

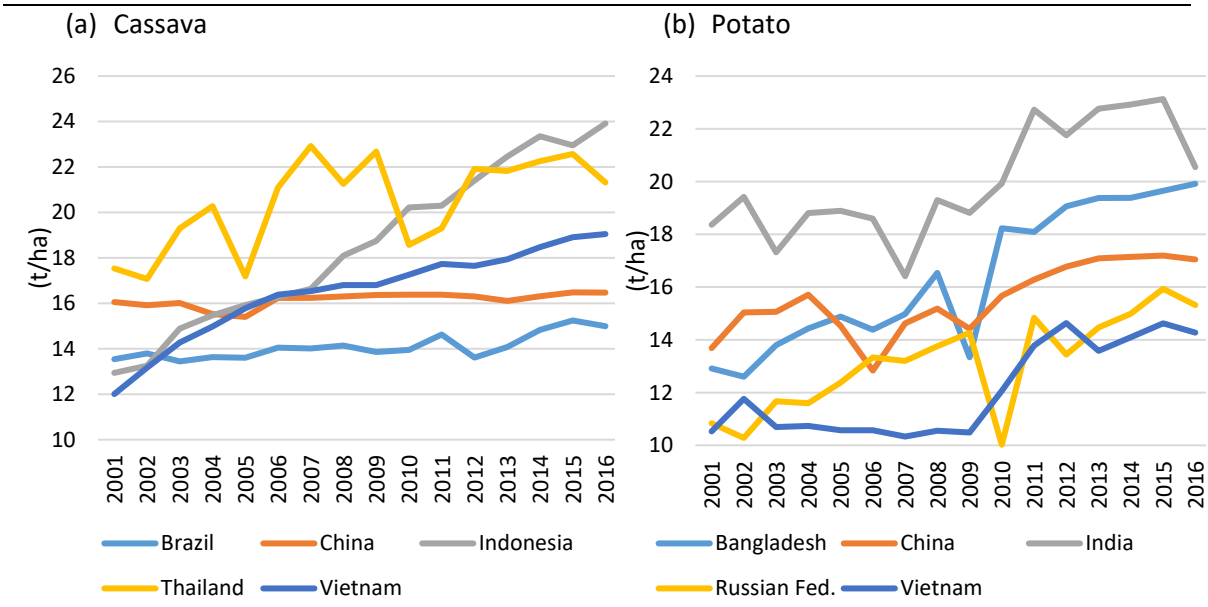

Figure 1. Cassava and potato yields, Vietnam, 2001-2016
Source: FAOSTAT (2018)

Cassava is primarily an industrial crop in Vietnam. During the past decade, it has gained economic importance as cassava cultivation, production, and yield have increased considerably. Between 2000 and 2016, cassava cultivation area expanded by a factor of 2.4 from about 237,000 to 580,000 ha, while production increased more than eightfold, from around 2 million tons to some 11 million tons, indicating a more than doubling of yields from about 8 to 19 tons per ha (Figure 2a). The introduction of high-yielding varieties as a result of research and collaboration in cassava breeding since early 1990s, has played a substantial role in raising cassava yields (Le et al., 2017) contributing to its economic success.

Cassava is now the third most important export crop in the country. About 70% of total production is exported in the form of starch or chips used as an input for food processing, animal feed, pharmaceuticals, and industrial alcohol creating a more than 700 million USD market in 2016 (Figure 2b). China is by far the largest buyer importing 88% of total Vietnamese cassava starch exports. Other countries, such as Indonesia (3.4%), Philippines (2.0%), and Malaysia (1.9%) import only a fraction of total starch exports (ITC, 2018). Only 30% of total cassava production is used domestically which is complemented by cassava starch imports which take a value of about 9 million USD in 2016 (Figure 2b).

Despite the importance of cassava as an industrial crop, a striking 90% of cassava growers obtained their first planting material from the informal system, in which farmer-saved seed was the most common source of planting material in 2016. In addition, farmers reported declining yields over time as the main reason for dis-adopting varieties (Le et al., 2019).

Potato is mainly a cash crop, cultivated for two main markets: fresh and processing. In 2015, about 80% of total production served the fresh market, while 20% of production went to the processing industry. Between 1975 and 2016, total area rapidly increased from some 20,000 to 105,000 ha in only 4 years (1975-1979), but then fell just as rapidly to some 23,000 ha between 1980 and 1985.[11] Since then potato area has been stagnant at the 20,000 ha mark (FAOSTAT, 2018). This trend is confirmed by the total production which was about 300,000 tons in 2016 (Figure 2a). Currently, 85% of potato cultivation occurs in the Red River Delta region, with smaller pockets found in the Northern and Central Provinces (Gatto et al., 2018).

Whereas Vietnam is a net exporter of cassava, it is a net importer of potatoes. This is due mainly to Vietnam's current inability to produce potatoes all year round and potato production is mainly confined to the winter months. Potato imports have been rapidly increasing 24-fold from 1,574 to 39,700 tons between 2001 and 2016 (ITC, 2018) suggesting for an increasing demand, domestic potato production is unable to meet. In 2016, total imports had a value of 17.4 million USD (Figure 2c) of which about 85% of originated from China whose proximity to Vietnam certainly contributes to this large influx. Other countries, such as Germany (8.5%), Australia (3.9%), and Republic of Korea (1.8%) are only marginally important as sources of imported potato (ITC, 2018). Potato exports in 2016 had only the value of 440,000 USD (Figure 2c) representing only 0.38% of total production (ITC, 2018).

[11] The rapid rise of potato area was the result of the government's post-war recovery plan to boost food security by diversifying diets with starchy crops, such as sweet potato, cassava, potato, etc. (Fuglie et al., 2001, p. 2) and the introduction of earlier maturing rice varieties which allowed for the cultivation of potatoes after rice in the winter season (Tung, 2000). A lack of quality seed, which led average yields to fall below 7 t/ha, made potato production economically unviable which, in turn, resulted in a rapid fall of potato area (Fuglie et al., 2001, p.2).

Seed potatoes, officially imported into Vietnam are included in the total figures. Breaking these down reveals that 3,650 tons (or 9.2% of total potato imports) of seed potato were imported in 2016. Germany's share of seed potato imports is the highest (1,630 tons or 45%), followed by Republic of Korea (17.8%), Australia (16.0%), China (13.5%), Netherlands (4.2%), and Canada (3.6%) (Figure 2d). A share of the imported seed is likely subjected to further multiplication domestically, and the remainder is directly used in farmers' fields to produce potatoes.[12]

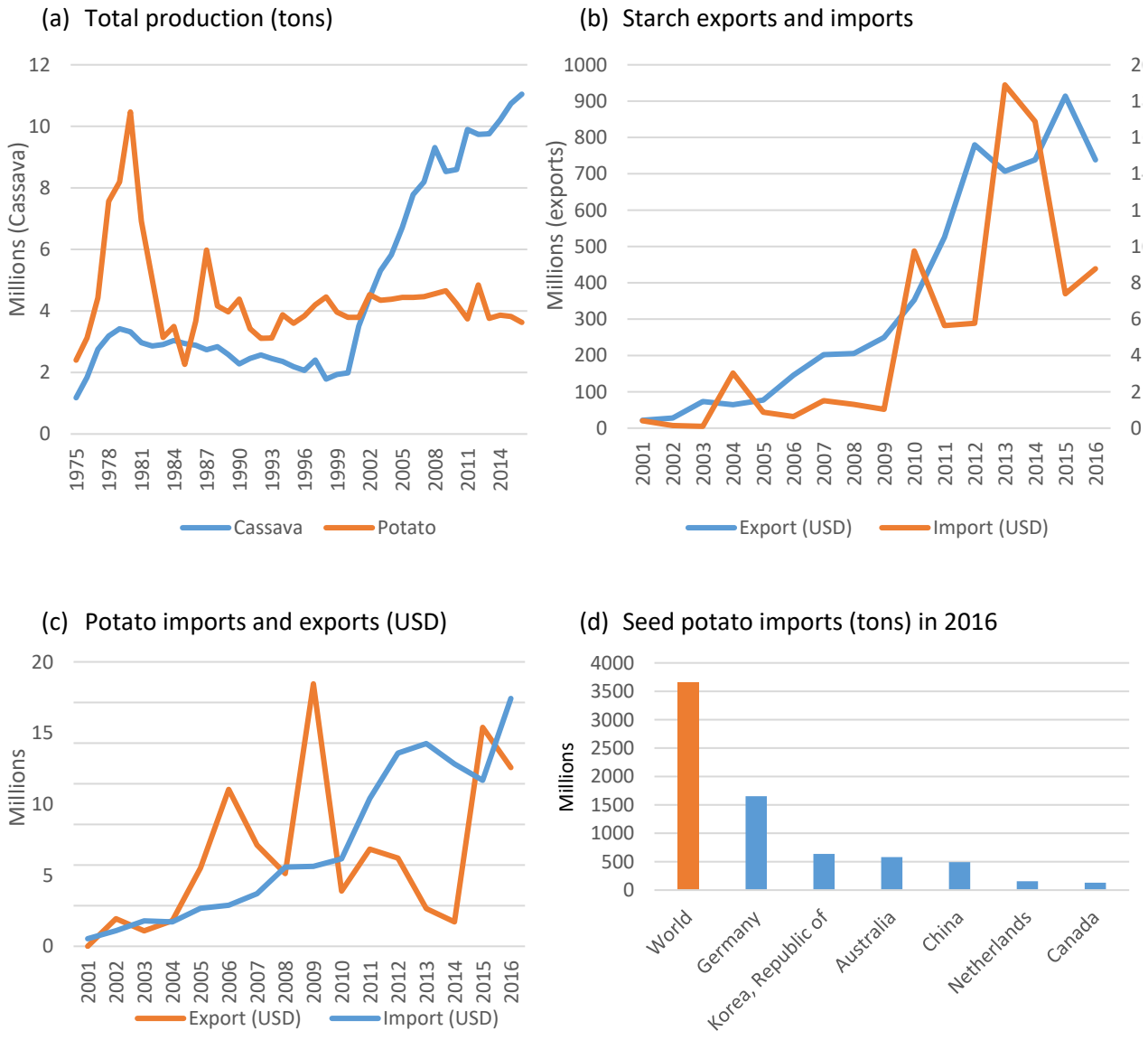

Figure 2. Cassava and potato production, imports and exports in Vietnam
Notes: in (c) import values refer to left axis. Sources: FAOSTAT (2018) and ITC (2018).

[12] Unfortunately, we do not know the exact ratio of imported seed used for multiplication and seed directly used in farmer fields. Thus, we are unable to estimate the total seed supply from international sources. In one of our KIIs, it was estimated that seed produced by national agricultural systems serves 20-30% of total potato production area.

Despite Vietnamese farmers' great appreciation for varieties from Germany and other countries, it is striking that seed potato imports from China was only 491 tons in 2016, especially given its dominance in total potato imports (33,555 tons). Looking at imports from China over time reveals a similar picture: while total potato imports rapidly increased from 1,292 to 33,555 tons between 2001 and 2016, seed potato imports remain at stagnant low levels (Figure 3). There may be various reasons that the China-Vietnam seed potato market has not developed. The issues mentioned earlier on non-separability between ware and seed potato and potatoes being credence goods are facts undoubtedly playing a key role here.

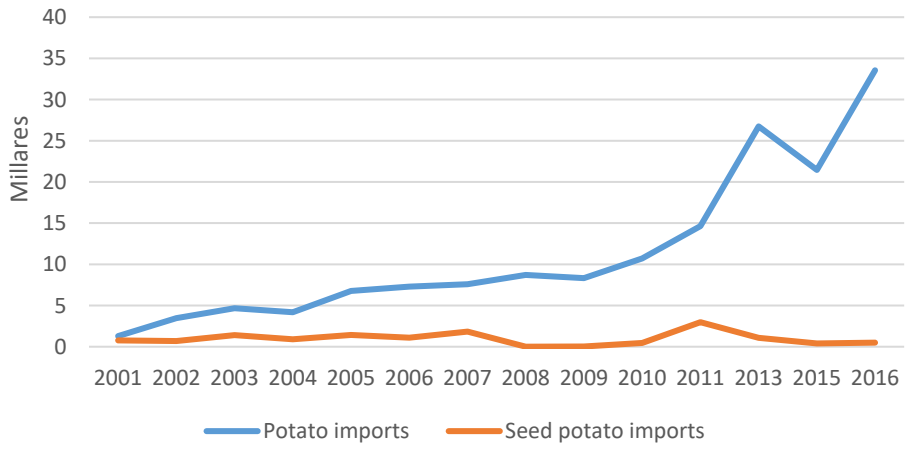

Figure 3. Total potato imports and seed potato imports from China (in *tons) between 2001-2016*
Notes: year 2012 and 2014 are missing. Source: ITC (2018)

4.2 Vietnam's seed laws and regulations

Vietnam's laws and regulations governing the formal market for seed have evolved in recent decades, with a strong emphasis on key cereal crops. In this section, we summarize the key components of various policy and legal documents and briefly discuss the main implications for VPCs. A brief chronological overview of released legal documents is presented in Table 3, and a summary of these legal documents with implications for regulating the production and exchange of VPC seeds can be found in Supplementary Material A.

Seed laws and regulation governing all the crops, including VPCs were first formulated in 1996 with Decree No. 07/1996/ND-CP, which focused mainly on management of plant varieties to improve yields, quality, and rapid multiplication. The decree recognizes four seed grades local, breeder/author, foundation, and certified/commercial, of which certified seed is the only grade that could be legally traded in the market. The corresponding article reads:

> *All acts of producing and trading fake seeds, seeds of poor quality, mixed seeds, seeds with pest or disease germs or seeds which have not been certified, are strictly forbidden (Article 13, Decree 7/1996).*

Production of certified seed requires a license, and production activities must be conducted in accordance with the license and subject to quality control by the Ministry of Agricultural and Rural Development (MARD) (Article

14, Decree 7/1996). However, MARD has not promulgated any guidelines specifying procedures and requirements for obtaining a license. As a result, the production of VPC seed without a license is reportedly commonplace (Trinh et al., 2016).

Table 3. Chronology of seed laws and regulations in Vietnam

Time	Legislation
1996	Decree No. 07/1996/ND-CP on the Management of plant varieties
2001	Decree No. 13/2001/ND-CP on the protection of new plant varieties
2004	Ordinance on Plant Varieties (2004)
2008	Decision 35/2008/QĐ-BNN (MARD) on the management of seed production at farm level
2010	Decree No. 88/2010/ND-CP on the implementation of Law on intellectual property
2011	QCVN 01-61 2011/BNNPTNT (cassava) and QCVN 01-59: 2011/BNNPTNT (potato)
2011	Circular No. 79/2011/BNNPTNT on certification and announcement of plant seed quality conforming with technical regulations
2013	Circular No. 16/2013/TT-BNNPTNT on the protection of plant variety rights
2013	Decree No. 187/2013/ND-CP on Commercial Law regarding the international trade
2015	Circular No. 28/2015/TT-BNNPTNT issuing the List of Protected Plant
2018	Law on Crop Production

In 2004, an ordinance on plant varieties came into effect which set the framework for seed quality standards and stipulated that seed producers bear the responsibility for assuring seed quality (Article 42, Ordinance on Plant Varieties, 2004). But rather than defining quality standards, this ordinance places a strong emphasis on the necessary, mostly physical, conditions to achieve its objectives of regulation of conservation of plant genetic resources, breeding and protection of new varieties, and seed production, trading and quality.

The mandatory quality standards (including pest and disease thresholds) for cassava and potato are prescribed through technical regulations QCVN 01-60: 2011/BNNPTNT and QCVN 01-52: 2011/BNNPTNT, respectively. The procedures and guidelines needed to announce conformity with quality standards are promulgated through Circular No. 79/2011/BNNPTNT. The successful announcement results in receiving a certificate on conformity with quality standards. The outcome of this process is certified seeds which can be legally traded and exchanged for commercial purposes (Article 12, circular No. 79/2011/BNNPTNT). The Circular further describes the responsibilities of MARD and its (sub) departments in the certification process. For instance, the Department of Crop Production is responsible for designation, accreditation, and management of operations such as plant variety testing laboratories and quality certification organizations (Article 19, circular No. 79/2011/BNNPTNT). For all crops, this is the National Center for Plant Testing (NCPT).

The strong focus on the formal sector is also inherent to other decrees. For example, decree No. 187/2013/ND-CP intends to regulate international trade of goods and specifies import permits and certificates for plant varieties which hold risk of pest and disease transmission required for adequate plant quarantine follow-up. In addition, decrees No. 13/2001/ND-CP and No. 88/2010/ND-CP regulate the intellectual property rights and obligations of new plant varieties.

While these various ordinances, decrees, and regulations are essential to the formal seed system, it is widely accepted that informal seed markets are quite vibrant across many crops in Vietnam, including VPCs. To that end, MARD issued Decision 35/2008/QĐ-BNN in 2008 to better regulate the management of smallholder seed and seed production (Tin et al., 2011). Under the decision, farmers were allowed to collect, store, preserve, use, and distribute local plant varieties and genetic resources. In addition, farmers were made eligible for government grants and other forms of financial support for their seed production activities. This decision was MARD's first step towards recognizing the importance of the informal sector. Note, however, that current policy still precludes farmers from participating in the commercial trade and exchange of farmer-saved and farmer-produced seed in the absence of the licensing and certification, as farmers' limited technical capacities and restricted access to early generation material pose considerable barriers for certified seed production (Lua et al., 2015). That said, there is little if any enforcement of this preclusion at the local level, so farmers naturally engage in commercial seed exchanges with fellow farmers.

A new version of the law on crop production recently took effect in November 2018, through which MARD intends to reduce the time and cost of existing procedures to register new plant varieties. This will be achieved by a reduction in administrative procedures, a reduction in the number of agro-ecological zones required for testing new varieties from five to three, and other procedural changes. The requirements for varietal traits to be eligible for release will also be changed: whereas new varieties were required to have clear yield advantages of 15% over existing varieties, the new law relaxes this requirement in exchange for introducing varieties that exhibit high resistance and tolerance levels to various biotic and abiotic stresses.

In addition, through the new law on crop production, MARD intends to facilitate the registration of local varieties which have been used for production in Vietnam for a long time and commonly cultivated varieties informally crossing borders with Vietnam. In doing so, MARD intends to legalize the production of a more diverse set of varieties and thus attempts to better meet farmers' demands and preferences. Farmers are expected to benefit from this because they can access high-quality planting material of their preferred variety. Seed producers are also expected to benefit because they can offer preferred varieties through the formal sector.

Throughout the past two decades the laws and its rules and regulations have evolved considerably covering many crops, including cassava and potato. In most cases, these regulations provide a 'one size fits all' solution and government resources mainly flow to strengthening and regulating the formal seed systems of key crops, most of which are cereals. Although, technical regulations for cassava and potato on quality standards for seed production exist, they are consistently ignored as we show in the findings section of this paper.

4.3 Seed system actors and VPC seed supply chain

Various seed systems actors can be found in the Vietnamese cassava and potato sectors. At the national level, the Ministry of Agriculture and Rural Development (MARD) supports and oversees the seed sector through its

Plant Protection Department (PPD) which is mandated to control and contain plant pests and diseases, especially in the case of outbreaks, and is charged with phytosanitary inspection of imported seeds and other seed pathology issues and its Department of Crop Production (DCP) which mandate is varietal development and seed production. DCP is supported by the National Center for Plant Testing (NCPT) which is responsible for seed certification and the national research institutes. For cassava this is the Experimental Center of Agriculture Hung Loc Research Institute and the Root Crop Research and Development Center (RCRDC). For potato the RCRDC is also important in addition to the Potato, Vegetables, and Flower Research Center (PVFC). The National Agricultural Extension Center (NAEC) under MARD is responsible for technology transfer in all areas of agriculture and crops, including cassava and potato. Other agricultural extension centers are the Provincial Agricultural Extension Centers (PAEC) together with Sub-Department of Crop Production and Plant Protection (PPSD) tend to be much more engaged and involved in cassava and potato varietal testing, seed production and multiplication. Seed entrepreneurs consist of traders, private small-scale multipliers, and farmer cooperatives within the potato sector. In the cassava sector this group mainly consists of cassava farmers partly acting as traders who play an important role in both input (i.e., collection, transportation, and distribution of planting materials) and output (i.e., root) supply chains. See Supplementary Materials B for a detailed description of the various actors' roles and mandates.

4.4 The VPC seed supply chain

Both formal and informal, market and non-market channels play a role in the cassava and potato seed value chains. However, the formal seed system for cassava and potato is of only marginal importance when we consider the scale of the informal seed sector. Based on information shared by several key informants, and in the absence of official figures, our educated guess is that the informal seed sector accounts for between 80% and 90% of the cassava stems planted and potatoes cultivated each (i.e., Category D, E, F in Table 2). As described before, in informal seed systems farmers produce their own seed, exchange/share seed with other farmers (either through market or non-market exchanges), or locally purchase seed from traders and vendors. It is locally organized, and farmers, groups and cooperatives carry out activities like seed selection from own food production, and seed exchange and supply, generally at lower price that formal channels would offer. In the case of cassava, however, the nature and reach of these informal networks might differ depending on how long and how intensively cassava has been produced in the area. The results of a recent social network study in Vietnam and Cambodia shows that, despite being often localized and self-organized, cassava informal seed networks can be of different levels of complexity in terms of reach, institutional arrangements and interconnectedness over different scales and locations. Seed exchanges in high-intensity production sites, such as Tay Ninh in Southern Vietnam, are, for example, much more commercialized; seed flows occur beyond local (commune) level (e.g., at inter-provincial, or even, international level); and more sophisticated "farmers-traders" annual seed sales and replacement systems have been developed (Delaquis et al., 2018).

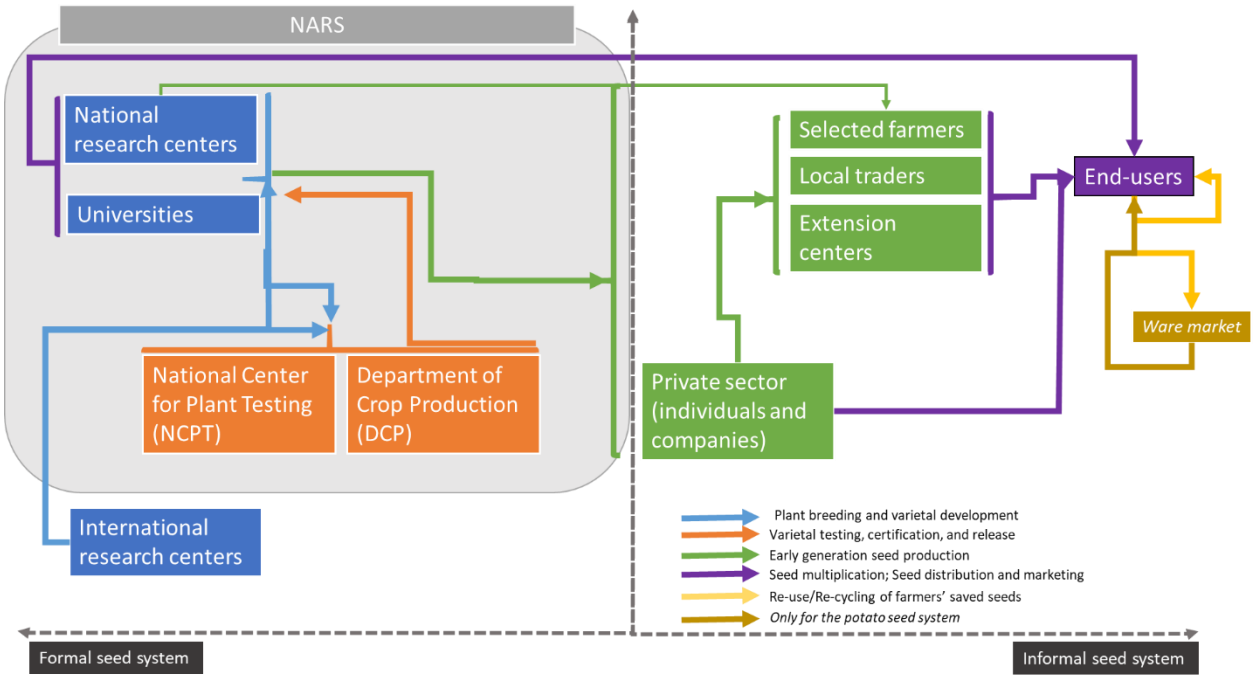

Figure 4. Seed system value chain for vegetatively propagated crops in Vietnam
Source: compiled by authors

Despite the importance of cassava for economic development, policies on quality assurance do not go beyond technical standards and pest/disease thresholds; there is very little certified seed available in the markets as there is no effective certification systems in place. The same holds for potato. For both the crops, most of the seed produced and traded is not certified. Ware potato is frequently exchanged informally with fellow farmers as seed (Category E in Table 2) while cassava farmers generally purchase planting material from other farmers, traders, or starch factories (Category F in Table 2). In rare cases, cassava farmers receive free high-quality planting material from research institutes and extension agents, for example in response to a climatic shock, such as a typhoon (Category C in Table 2).

Other sources of potato seed are manifold but relatively of minor importance in overall potato planting area. Farmers can access high quality certified seed imported from overseas, generally from Germany or the Netherlands. Imports are facilitated by government research institutes and private companies which directly sell certified seed to farmers or multiply first and sell the next generation seed to farmers at a slightly lower price (Category A in Table 2). Another important seed source is domestically produced seed from government research stations and universities which produce NCS from own stock of in-vitro material. Through special cutting technique, seed is rapidly multiplied and sold to farmers for further multiplication or ware potato production (Category A in Table 2). Some family businesses in Dalat area have also specialized in the cutting technique and produce NCS which, however, is not regulated by the government (Category E in Table 2). The 'Chinese potatoes' is an inexpensive alternative to domestically available seed but of questionable quality. In this case, seed enters Vietnam through informal ways usually as ware potatoes which is much more cost-

efficient than seed imports because they avoid high costs of certification and obtaining import permits. These 'Chinese potatoes' are mostly sold to farmers through Vietnamese potato traders (Category E in Table 2).

In sum, the informal seed system dominates for both crops. But regulations are few and ineffective, resulting in planting materials of unknown quality. In contrast, the formal system is governed by stricter rules and regulations, however, it represents only a fraction of the total seed system and its efficacy is questionable, as we discuss below.

5. Findings

Several key findings emerge from our review and assessment of Vietnam's seed system for cassava and potato, with implications for emerging policy reforms.

5.1 VPCs are of nominal importance in Vietnam

A clear finding from our review and assessment based on the KIIs and FGDs was that cassava and potato are relatively low-priority crops. Cassava's use for industrial purposes mean that it is generally perceived as irrelevant to national food security agenda—even despite the income it generates for cassava farmers, and potato's negligible area under cultivation means that it attracts little attention from policymakers. While public subsidies for seed potato have been rolled out in the past, there is no indication that the crop or its associated seed system will receive significant attention or investment under the government's broad strategy for growth and development, or under the seed policy reforms that are currently under preparation.

5.2 But some level of regulation exists for VPC seed systems

Quality standards and procedures for the domestic production and sale of VPC planting materials do exist under the DCP. However, regulations are not actively enforced, and seed inspections are not regularly conducted. When domestic seed producers do seek to produce certified planting material, inspectors visit infrequently and only perform ad hoc visual inspections. Only research stations and universities seem to be engaged in high-quality seed production, although their production capacity is quite limited. PVFC estimated that NARS' annual potato seed production is somewhere between 6,300 and 9,450 tons, which serves 20-30% of total potato area[13]. By all accounts, quality assurance systems for VPC seed in Vietnam are only nominally implemented.

In contrast, the seed quarantine system that governs the formal, cross-border trade in VPC planting material is more proactive. VPC planting material that enters Vietnam through formal channels must be in compliance with the various phytosanitary requirements placed on imports. At border checkpoints, imported seed undergoes visual inspections, documentation checking, and registration of intended destination of the seed lot. This process aims to ensure not only that quality seed is imported into Vietnam, but that any outbreaks of pest or disease can be traced back to the source seed lot, and thus monitored and contained.

5.3 There is demonstrated capacity for disease surveillance and containment

Since informal channels are the main sources of cassava and potato planting materials in Vietnam, it is prone to the risk of seed-borne disease outbreaks. The Government of Vietnam has demonstrated considerable capacity in identifying, isolating, and containing outbreaks of VPC pests and diseases, through Provincial Extension Centers and the Sub-Department of Crop Production and Plant Protection. This was demonstrated by the 'potato seed crisis of 2011' that was thought to have a clear link with imported Chinese potatoes, the

[13] Based on 2016 total potato area of about 21,000ha (FAOSTAT, 2018) and a seed requirement of 1.5t/ha.

cassava mosaic virus outbreak in 2017, and the mealy bug outbreak in 2012 that was thought to have originated from Laos. These seed related disease outbreaks and response by the government are briefly described in Supplementary Materials B.

5.4 The informal trade of VPC seed dominates the market

Not surprisingly, the defining driver of these outbreaks has been the informal, cross-border trade in cassava and potato planting material. While farmers obtain planting material for cassava and potato through many different informal channels—with farmer-saved seed and farmer-to-farmer exchanges likely being the most significant channels—it is the informal cross-border trade in planting material that was cited as the most prone to disease outbreaks. Potato farmers, particularly those living near Vietnam's borders with China, seem to regularly obtain planting material that is imported through unofficial channels. The planting material rarely arrives as packaged and labeled seed potato; rather, they are imported simply as small ware potato. In the case of cassava, the planting material is either informally imported from Cambodia but also commonly purchased by Vietnamese traders and transported to neighboring provinces in Cambodia.

Local authorities responsible for monitoring and protecting crop health in rural Vietnam appear powerless to deal with these illegal flows of planting materials. And where they do take action, it is often reactive—well after the initial damage has been done as illustrated in the three examples described in the previous bullet point.

5.5 Aspirations for a more effective VPC seed system exist

Many of the government officials and public scientists interviewed for this study openly recognized that the VPC seed system is well outside their control, and that efforts to bring the system under government control were unrealistic. Quite simply, few expect farmers to only use certified planting materials for cassava or potato. Reductions in public funding for research along with limited land, infrastructure, and technical capacity have left research stations poorly equipped to produce and distribute clean seed. That said, these same financial pressures have led research centers into the business of early generation seed production as a source of revenue, trading on the trust and reputation that the stations have built among farmers. In addition to multiplying seed for distribution by the government, research stations increasingly produce seed for private companies. In some cases, these research stations have even introduced production techniques that are more efficient or less costly than those of their private competitors.

5.6 There is growth in the market for seed potato, but less so in the cassava stem market

In Vietnam, demand-side signals and vertical integration are influencing the market for quality seed potato. In particular, foreign companies that use potato in its food product lines are providing farmers with high-quality planting material. These materials originate from proprietary varieties bred outside of Vietnam, and are duly registered under the Government of Vietnam's plant variety protection authority, tested at public research stations, and multiplied by farmers working under contract with the company for use either as seed for other farmers, or as ware for chip processing. This vertical integration allows the company to control the quality of both seed and ware production, protect its intellectual property, and ensure a consistent supply of potato to

its agro-processing operation. However, because both potato and seed potato production in Vietnam falls short of the company's requirements: a six- to seven-fold increase above the current annual production of 15,000 tons is required for this vertically integrated supply chain to be profitable, requiring investments in tissue culture laboratories, cold storage systems, aeroponics, transportation, and logistics. Thus, for now, the company also sources seed and processing potatoes from other countries (i.e., Germany, Netherlands) to meet its requirements.

Turning to cassava, there is little indication that starch factories are willing to play a similar role in the market. This is because, product quality purchased from farmers is not a major concern of starch factory owners. Thus generally neither improved varieties nor quality planting materials are provided to farmers by starch factories through either direct or indirect channels.

5.7 Cooperatives and traders may be key entry points for VPC seed system improvement

Farmer cooperatives are a central element in agricultural production in Vietnam. In VPC seed systems, they can potentially play a role in assuring the quality of planting material through self-regulating mechanisms such as trust and reputation, or commercial mechanisms such as internal contract arrangements. Farmers using seed provided by their cooperatives benefit from an internal arrangement in which the cooperative guarantees farmers to buy their entire ware production, irrespective of its quality, as was the case for potatoes. Though this form of collective action is ineffective in assuring quality per se, i.e. increasing access to improved planting material, it is effective in shifting individual production risks associated with the unobservability of the quality of seed to the collective group.

6. Discussion

Policies and regulations designed to improve access to high-quality seed and planting material in Vietnam have evolved considerably in past decades. However, the regulatory framework is relatively more focused on economically important cereal crops and seed systems for those crops. This implies that there is relatively limited financial resources and technical expertise allocated to the implementation and enforcement of a similar regulatory framework for VPCs. But even if resources were allocated to implementation and enforcement of a VPC regulatory framework, it is unclear how effective that might be given the limits of the regulations themselves. As they are written, the regulations do not fully address the biological characteristics of VPCs and the social and economic realities of farmers who cultivate them in Vietnam. Nor do they create opportunities for the kinds of institutional or technological innovation necessary to regulate VPC seed systems.

Existing rules and regulations render much of the VPC planting material produced in Vietnam's formal sector - material produced by government research stations, universities, or local seed producers - as *de jure* illegal. This is because the material is simply not certified. As a result, seed is produced and distributed with a reputational signal of quality rather than an official indication of quality. That reputation signal is typically associated with the use of early-generation material in the seed production process, which is (imperfectly) correlated with a relatively lower pest and disease risk than other sources of seed. Those other sources of seed include farmers' own-saved seed, seed that is locally produced and exchanged, or ware that is supplied through cross-border trade and used as seed.

The fact that VPC seed originating from Vietnam's formal sector accounts for less than 5% of all VPC seed indicates the limits not only of the sector, but of the capacity to govern, manage, and regulate the sector. But that does mean that the broader system can continue to depend primarily on signals such as trust between buyers and sellers, or the reputational integrity of sellers, to indicate quality of planting material. The approach may have strong historical precedence and sociocultural roots, but it is arguably an insufficient means of advancing Vietnam's national plans to scale up quality seed use, reduce exposure to pests and diseases, and adapt to climate change.

Efforts to address this problem of effective regulation often raises the question of how to allocate more resources for seed certification or an alternate quality assurance system. But that strategy may itself be limited if current administrative structures are maintained. Simply put, MARD delegates the responsibility for certifying seed for all crops to just one institute—the NCPT—without the requisite administrative, infrastructural, and technical investments needed to ensure success. It is unreasonable to assume that a single central regulatory agency can effectively inspect, monitor, and certify the production of all planting material for all crops across a country as diverse as Vietnam.

Implicitly, the government already recognizes this and pursues a more relaxed and realistic approach to regulating VPCs. After all, the government contends with many competing priorities, and VPCs such as cassava and potato fall low on its list relative to higher-value crops and cereal staples. There are also limits on what can be done in light of the flow of uncertified planting material from neighboring countries. As a result, seed value chain actors operate with little or no regulatory oversight and rely on their own strategies to signal quality to prospective buyers in the absence of strict enforcements. What is the likely outcome of continuing this unregulated approach? And if it proves ineffective in meeting the demand for quality VPC planting material in the future, then will a stricter regulatory regime be a more effective alternative? We explore this in further detail below.

6.1 The status-quo approach

The continuation of the status-quo approach implies that the government allows the trade in uncertified seed to continue, with the possible exception of seed imported through border points where phytosanitary inspection and quarantine are feasible. This means that the government's primary regulatory instrument is reactive damage control, such as monitoring pest and disease outbreaks, destroying infected and quarantined cropping areas, and continuing inspections after outbreaks. This also means maintaining minimal investment levels on more preventive measures such as seed certification or more sophisticated quality assurance systems.

For government, the consequence of this low-cost regulatory approach is continued large-scale reliance on the informal market and a small-scale contribution from the formal sector. At best, this approach limits the scope for growth of cassava and potato seed systems and their contribution to wider agriculture sector growth. At worst, this approach may also (a) limit farmers' access to new traits that address the changing demand of agro-processers and consumers, or the changing biotic and abiotic stress patterns associated with climate change, and (b) encourage continued importation of uncertified seed and associated seed-borne pests and diseases from neighboring countries. And to the extent that the government views VPC planting material as a sector for export promotion, this low-cost regulatory approach provides little incentive for development of an export-oriented seed production system that could serve neighboring countries' seed requirements in addition to domestic requirements.

Furthermore, this kind of regulatory approach relies heavily on the support of farmers as frontline monitoring and reporting agents of pest and disease incidents. Over the long run, there is a question of whether farmers are disincentivized from reporting incidents when such incidents may be directly (and knowingly) related to their practice of sourcing seed from informal sources—a practice that is legally prohibited and punishable by fines, and when it results in the large scale destruction of the crop and enforcement of other quarantine measures. In sum, the status-quo approach may minimize regulatory costs but also limit access to quality planting material and maintain—if not increase—the risks associated with pests and diseases. The current approach may be ill-suited to Vietnam's changing economy or the agri-food systems within which its farmers operate, and may ultimately reduce farmers' access to important varietal traits and quality planting material.

6.2 A strict mandatory certification approach

An obvious alternative to the status quo is a much stricter approach to quality assurance: mandatory certification of planting material and rigorous enforcement of the regulatory framework. The implementation of such an approach is likely to be extremely costly to government relative to its current level of expenditures on the VPC seed system. For example, there are non-trivial costs in expanding Vietnam's inspection, testing, and certification infrastructure, as well as expanding its pest, disease, and market monitoring and surveillance systems. It also implies the need for increased capacity to enforce the regulation of criminalizing the production and sale of all non-certified seed products in the seed system.

Furthermore, given the availability of near-perfect substitutes to certified seed—own-saved seed or locally exchanged seed that cannot be reasonably barred from use in cultivation—it is possible that many farmers will choose not to purchase certified seed if a significant share of the costs of certification are passed on to them. This implies that seed producers may have to bear the additional costs of certification. Higher production costs may reduce incumbents' capacity to invest in new expansion projects, limit new entrants into the market, concentrate the market around the already small number of producers, or shift the supply channel from domestic seed production to imported seed.

The outcomes of such changes in the market for VPC planting material in Vietnam are difficult to predict. But without a demonstrated path to profitability through new and innovative product lines or economies of scale in production, it is possible that a more concentrated market will slow the rate of growth in the market for quality VPC planting material. The possibility of this outcome seems far more likely in the case of cassava, where there are few signs of innovation: relatively few new varieties are entering the market, no new stem packaging systems are on the horizon, and there are no signals from the starch industry on quality requirements that might encourage farmers to be more discerning in their choice of planting material. In the case of potatoes, new private entrants from the Netherlands offering new potato varieties for agro-processing might allow for the simultaneous emergence of a rigorous seed potato certification system and growth in the seed potato market. However, this might be limited to certain geographies where investors are actively engaging contract farmers, and where the terms of those contracts might address seed potato quality issues more effectively than a strict regulatory system could.

Moreover, it is not necessarily the case that mandatory certification will lead to reductions in pest and disease risks. Seed certification may be a necessary but insufficient condition to addressing pest and disease risk. Concomitant investment in the education and training of farmers on best practices in the use of quality planting material is equally important, as is the recognition that changes in regulatory institutions, seed producer strategies, and farmer management practices all take a long time to change. Until such time, the near-perfect substitutability of own-saved and locally exchanged seed will likely affect the viability of such a transition process.

6.3 The middle-road approach

An alternative to the two approaches described above integrates key elements of each. The first element in this approach is for the government to effectively formalize the informal (and illegal) trade in uncertified seed. The most effective way of doing this is to introduce multiple quality classes beyond the standard "certified" class. This requires revising the strict regulations set forth in the 2004 Seed Ordinance by formally recognizing the role of farmer-saved seed and establishing parameters for farmer-produced seed. For guidance on quality declared seed standards and protocols for vegetatively propagated crops, see FAO (2006).

Another element in this approach is to realign roles and responsibilities for VPC seed production between the public and private sectors in Vietnam. With multiple quality classes and standards in place, it is feasible for MARD to withdraw from production of certified VPC seed and reallocate its resources to its crop improvement programs, early generation seed production, regulatory oversight functions, and capacity development efforts across the seed system. Key to this is strengthening the technical and entrepreneurial capacity of farmers to produce and market quality seed, and capitalizing on the collective capabilities found in Vietnam's rural cooperatives and farmer organizations. A realignment of MARD's public investment strategy focus on three additional elements, all of which are contingent on official recognition of the contribution made by VPCs to Vietnam's agricultural sector and wider economy.

First, MARD, working in partnership with private seed providers, may want to explore strategies to address the fundamental issue of information asymmetries between seed buyers and sellers described earlier. This is an area of both regulatory and technological innovation that holds considerable promise. On the regulatory side, and in conjunction with the introduction of multiple seed quality classes, MARD may consider the introduction and enforcement of truthful labeling rules. Truthful labeling is designed to provide buyers with information on variety name and origin, purity and germination rates, and other information that can help buyers choose the appropriate product for their specific needs (Tripp and Pal, 2001; Roy, 2014). Importantly, truthful labeling requires that farmers be able to seek legal recourse in the event of mislabeled seed. Where legal recourse channels are costly, reliance on truthful labeling may be inappropriate. But when combined with a quality assurance system that allows for multiple seed quality classes, it can potentially reduce information asymmetries and allow seed producers to differentiate their products on quality as well as price.

On the technology side, there are several emerging information technologies that might be worth experimenting with. Product traceability systems, for example, could allow farmers to validate the authenticity and quality of a seed package via a simple text message or a smartphone app. The technological options range from barcoded scratchcards on seed packages to blockchain technologies to store digitally unalterable information used in a market exchange (Ashour et al., 2014; Lin et al., 2017). These same systems can be used to monitor similar variables along the seed supply chain (Ge et al., 2017).

Second, MARD may want to pursue a strategy aimed at reducing the production costs of quality VPC planting material to encourage development and growth of the market. Although some farmers may be willing to pay a premium price for higher quality seed—even the highest-quality imported certified seed—most farmers are likely far less willing to pay the premium. As such, MARD's investments in domestic VPC seed production might focus on cost-reduction strategies such as improving both the quantity and quality of early generation seed that is used as a production input by private seed producers. This requires investment in early generation seed production facilities at research stations and universities. It also requires support to small- and medium-scale enterprises, cooperatives, and farmers organizations, through business development and financial service provision, training on production techniques, and ready access to in-vitro material.

Investment incentives and regulations might also be used to attract foreign crop-science and seed companies to produce seed in-country rather than import their varieties, although this is partly dependent on foreign investors' confidence in the strength of Vietnam's varietal registration and plant variety protection laws. Potentially, this strategy can also address problem posed by the cross-border trade in ware that is used as seed: by providing farmers with access to a wider range of varieties and better quality-assured planting material at affordable prices, it may be possible to successfully compete the cross-border trade out of existence. An even longer-term strategy could build on this to transform Vietnam into a VPC seed production hub for Asia (similar to Thailand's strategy for maize). In the long run, these types of investments are likely to be a more cost-effective means of increasing farmers' access to quality VPC planting material than the current subsidy program for imported certified seed mentioned earlier.

Third, MARD may want to shift its approach to pest and disease management in VPC crops from reactive to preventive. Ideally, part of this approach will result from formalizing the informal market with multiple seed classes, increased investment in early generation seed production, and greater support to small- and medium-scale seed producers. But at much higher level, MARD may have to minimize the use of its primary strategy of quarantining and destroying infected crops in response to reported pest or disease incidences. Instead, it may want to rely on the use of more and better qualified inspectors making frequent visits to *a priori* identified hot spots, as well as closer surveillance of both seed and ware potato at points of sale.

7. Conclusion

This paper reviewed the current seed system for potato and cassava in Vietnam, and investigated alternative public policies and regulations aimed at improving Vietnamese farmers' access to quality planting material. These two crops represent vegetatively propagated crops—a broad class of crops for which seed systems differ dramatically from cereal crops due to both reproductive biology, sociocultural, and economic factors. Drawing on the analysis of secondary data, review of documents, key informant interviews, and focus group discussions, the paper provides a description of the policy landscape's evolution in recent decades, the key actors in that landscape, and the differential effects that this landscape has on stakeholders in the agriculture sector.

We discuss three alternative policy options to support growth in Vietnam's VPC seed system: a business-as-usual regime that relies on minimal government involvement and regulation; an intensive regulatory regime that involves mandatory seed certification and strong enforcement; and a regime that draws on elements of both. The hallmarks of this third regime are (a) the recognition and introduction of seed classes other than certified, (b) a realignment of MARD's roles and responsibilities in the seed system to a more upstream and oversight function, (c) a public investment strategy that aims to reduce VPC seed production costs in Vietnam and make seed producers more competitive both domestically and regionally, and (d) a more preventive approach to pest and disease management for VPCs.

The timing of this study is fortuitous, although the new seed system regulations that came into effect in 2018 do not account for the uniqueness of VPCs and are largely silent on many of the issues raised in this study. However, these new regulations do open the door to closer consideration of VPC-specific requirements as the rules, guidelines, and procedures are detailed during the coming years in order to implement the new regulations. In the context of Vietnam's implementation of its Action Plan for Zero Hunger in Vietnam by 2025,[14] following the United Nations' 2012 Zero Hunger Initiative,[15] more effective policies and regulations for VPC seed systems could contribute to increasing access to nutritious foods and to the diversification of diets throughout the country. But achieving these ambitious goals will require policymakers to first recognize the distinct realities of VPCs, the sensitivity of the VPC seed system to these realities, and the influence that policy and regulation play in making VPCs a valuable part of both the Vietnamese diet and the national economy.

[14] http://www.un.org.vn/en/fao-agencypresscenter1-96/4946-viet-nam-commits-to-achieve-zerohunger-in-viet-nam-by-2025.html (Accessed November 2018)
[15] http://www.un.org/en/zerohunger/challenge.shtml (Accessed November 2018)

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Supplementary Material A – Overview of legal documents regulating production and exchange of seed and implications for VPCs

Legislation	Purpose	Implications for VPCs
Decree No. 07/1996/ND-CP on the Management of plant varieties	- Provides definition of seed grades - Regulates seed production and announcing quality of seed	- Deems production and trade of non-certified seed is unlawful
Decree No. 13/2001/ND-CP on the protection of new plant varieties	- Protects and facilitates the property right of organizations and individuals that select, create or have the legitimate right to inherit new plant varieties	- Newly registered varieties can receive "Protection Title" to be compensated for rights of use.
Ordinance on Plant Varieties (2004)	- Regulates conservation of plant genetic resources, protection of new plant varieties, and seed production, trading and quality	- Seed producers bear responsibility of conforming with quality standards which is done through certification. - Quality standards are defined in regulations QCVN
Decision 35/2008/QĐ-BNN (MARD) on the management of seed production at farm level	- Legalizes and supports farmers, farmers' groups, clubs and cooperatives who can do breeding, selection, seed production for household use and seed exchange.	- Recognizes informal sector and farmer-saved seed. - Trade still forbidden in absence of certification. - Supports farmers to produce farmer-saved seed but not on commercial production.
Decree No. 88/2010/ND-CP on the implementation of Law on intellectual property Circular No. 16/2013/TT-BNNPTNT on the protection of plant variety rights	- Guide the implementation of the regulations on plant variety rights	
QCVN 01-61: 2011/BNNPTNT (cassava) and QCVN 01-59: 2011/BNNPTNT (potato)	- Prescribes technical standards required for commercial seed production	- Prescribes technical standards required for commercial seed production for cassava and potato
Circular No. 79/2011/BNNPTNT on certification and announcement of plant seed quality conforming with technical regulations	- Provides regulations on the certification and announcement of plant seed quality - Defines responsibilities in the process of seed quality announcement	- Crop Production Department is responsible for accrediting and management of certification organizations.
Decree No. 187/2013/ND-CP on Commercial Law regarding the international trade	- Regulates import and export activities of goods, including plant seeds.	- Import permits and trial permits required for good imports which hold risk of pest dissemination.
Circular No. 28/2015/TT-BNNPTNT issuing the List of Protected Plant	- Provides list of plants protected by Law on intellectual property.	- Cassava, Potato and Sweet Potato are on the list.

Law on Crop Production (2018)	- Regulates the plant varieties/seed, fertilizer, cultivation, land use, preservation, processing, trade and product quality in crop production - Reduces requirements for trials and testing. - Facilitates registration of important varieties used for long time	- Increases cost-effectiveness of varietal registration. - Quicker registration and release of varieties without clear yield advantage but important resistances. - Legalizes production of local and preferred varieties; increases diversity

Supplementary Material B – Description of seed sector actors

Government research institutes

Cassava: Two main national research institutes are responsible for the cassava breeding and varietal development in Vietnam: the Root Crop Research and Development Center (RCRDC) and the Experimental Center of Agriculture Hung Loc Research Institute. These institutes fall under MARD and the Vietnam Academy of Agricultural Sciences (VAAS), and are members of the wider cassava breeding network which includes other national universities (for e.g., Thai Nguyen University of Agriculture and Forestry; Ho Chi Minh City (HCMC) University of Agriculture and Forestry). The RCRDC is one of the research centers of the Field Crop Research Institute (FCRI) in VAAS and it mainly operates in three locations: Hanoi, Hai Duong and Lao Cai.The Hung Loc experimental center is one of the five research centers under the Institute of Agricultural Science of South Vietnam and it is located in the Dong Nai province, 60 km south of HCMC.

The main functions of these government research institutes in the formal cassava seed system are: a) to conduct breeding research to develop varieties for high yield, early maturity, good quality, high dry mater and high adaptability to different agro-ecologies; b) early generation seed multiplication; c) conduct research on the development of integrated and sustainable cropping systems; and d) capacity building for extension centers and farmers. At provincial level, the government is responsible for providing capacity building, technical and financial support to those farmers that are actively engaged in the plant genetic resource conservation, development and utilization, crop improvement, seed production and supply.

Research and seed multiplication is mostly carried out via the national varietal breeding program, which aims to maintain and develop new varieties for specific areas: South East, Central Highland, Central South Coastal, and mountainous areas in the North Vietnam (e.g., Yen Bai). In collaboration with international research institutes and foreign universities, these breeding activities have resulted in the introduction and dissemination of the following high yielding varieties: KM94, SA2112, BK, HLS11, HLS10, KM419, and KM140. In addition, the RCDRC has also been working on the breeding and dissemination of other common varieties, such as KM60, KM98-7 and Sa06.

Production trials and varietal preliminary assessment pre-registration are usually carried out using the farmer participatory approach, which gives farmers access to clean planting materials of new varieties for free, should they prefer these varieties to the ones they currently use. In some case, planting materials can be provided for sale, although prices are heavily subsidised and well below market levels. This serves as an important non-market channel of dissemination of quality planting materials of new cassava varieties to farmers. Several NGO programs have also been implemented to support farmers' capacity building using a participatory plant breeding approach (Tin et al., 2011).

The multiplication of seed or planting materials is carried out for those varieties that have already been registered within the official channels (e.g., NCPT, DARD, MARD Scientific committee, etc). Research centers use

different techniques to multiply planting materials, for example, quick multiplication techniques for cassava (used by RCRDC) and growing more densely at 12,500 trees per ha (used by Hung Loc). Strict monitoring and control protocols for pest and disease, including "tree rotation", are carried out throughout the multiplication process. In addition, the Hung Loc center is currently implementing a program funded by JICA, which aims at producing pest and disease-free planting materials sufficient to cover 10,000 ha, using in-vitro multiplication, isolated planting, and daily inspections.

While the RCRDC tends to mostly interact with extension centers and directly with farmers involved in trials who usually access these resources free of charge, Hung Loc research center seems to have taken a more commercialized approach in their supply of planting materials in the cassava seed systems. In fact, planting materials obtained via Hung Loc research breeding and seed multiplication activities are mostly sold. The average price is 1000-1500 VND (or 0.043 – 0.065 USD[16]) per stake each containing 8 to 10 planting materials. Its main customers are starch factories located in Gia Lai, Phu Yen, Tay Ninh (e.g., Hung Duy factories), local extension centers, traders (in Dong Nai) and, sporadically, to farmers. Specific product requirements and arrangement are negotiated and agreed in formal contractual arrangement between the research center and its customers.

Potato: There are two main government-funded research stations. For the northern regions there is the Root Crop Research and Development Center (RCRDC) and in the South is the Potato, Vegetables, and Flower Research Center (PVFC). Among other, a key mandate of both these centers is to provide access to high quality seed. This objective is achieved through two main activities. First, they multiply certified seed imported from other countries (e.g., Germany and the Netherlands) in their facilities of research stations and sell the next generation seed as planting material to farmers. Imported seed is usually of basic or pre-basic quality and adheres to strict rules and regulations set by the government. Second, they produce seed from in-vitro material and do multiplication thereof applying cutting edge techniques (Van Minh et al., 1990). Seed production and multiplication follows the guidelines developed by PPD. In addition, both institutes have also developed their own protocols for quality assurance. In the case of RCRDC these are mainly based on visual inspections of diseases, tuber shape and color. In the case of PVFC, they apply more advanced techniques and kits developed and provided by the International Potato Center for virus testing. In future, although not mandatory within the country's regulatory framework and despite lacking financial support from the government, PVFC intends to invest in more advanced testing machinery and laboratory equipment from the USA, with the goal of producing high quality potato seeds.

Agricultural Extension Centers

NAEC, in collaboration with national research institutes and national universities, provides information and capacity building for local extensionists and key farmers on the new varieties, technical guidelines, and trainings on the sustainable farming practices. Overall, its role in the VPC seed system seems quite limited. Even in its

[16] At the time of the interview 1 USD equaled 23,049 VND.

main activities of capacity building and technical support, it does not have any structural role in the production or promulgation of quality planting materials.

Provincial Agricultural Extension Centers (PAEC) together with Sub-Department of Crop Production and Plant Protection (PPSD) tend to be much more engaged and involved in cassava and potato varietal testing, seed production and multiplication. For example, in Tay Ninh, PAEC and the PPSD have been playing an active role in conducting cassava varietal testing, production trials, promoting varietal diversification for industrial processing,[17] and in transferring technical know-how to farmers via capacity building activities and provision of free inputs, including planting materials. For this purpose, both PAEC and PPSD have built strong relationship with the national research institutes, such as Hung Loc, and universities, such as HCM University of Agriculture and Forestry and the Institute of Agricultural Science in Southern Vietnam. In addition, aside for planting materials testing and dissemination, farmers do rely on PAEC's and PPSD's expertise and support in pest and disease detection and control. Disease outbreaks have become recurrent events in which government interventions are increasingly needed.

Seed entrepreneurs

Cassava: Traders play an important role in the cassava sector both in the input (i.e., collection, transportation, and distribution of planting materials) and output (i.e., root) supply chains. These are mostly cassava farmers who engage with research centers, farmers and processing companies using basic marketing infrastructure and linkages. They function as intermediaries between the production and processing level of the cassava value chain. On the input supply side, traders source their planting materials from the national research institutes, such as Hung Loc Research Center. Planting materials are then multiplied and sold to local farmers, often at lower price (usually 700 – 1000 VND per tree) than the one offered by the research institute (i.e., 1000-1500 VND per tree)[18].

Their customers are usually one-time customers, mainly farmers from neighboring areas, who buy small quantities of planting materials and then multiply it themselves and reuse them for several generations. However, in some regions, such as Luong Son and Phan Thiet, own seed multiplication by farmers is often complicated due to the long gap between the harvest and planting time. As such they tend to buy planting materials more often than the average cassava farmers in the country.

[17] PAEC and PPSD supports the provincial government in the implementation of cassava projects funded through the provincial budget. For example, in 2016-2018 the Tay Ninh PAEC lead the "Strengthening the Effectiveness of Cassava Production in Tay Ninh" project, which includes activities such as varietal testing, production trials and selection of suitable varieties for local production.

[18] During our study, it was mentioned that often traders tend to mix the planting materials, which might have an effect on the value of the final produce for sale.

Usually, customers assess the quality of the planting materials directly by observing the plants and roots on the traders' farm, and only acquire those that, from visual inspection, are considered of highest quality. However, the focus of quality assessment and demand for planting material by farmers is mostly defined by the starch content of the roots. Good quality is considered equivalent to highly starchy roots, and farmers tend correlate that trait with planting materials that have a high density of buds, good shape, and correct aging.

Overall, the role of traders in the cassava seed system varies across production areas, but they seem to play a pivotal function in granting access to planting materials to the farmers. As such they have a substantial influence on the quality of planting materials delivered to the end users. However, due to infrequent nature of their sale transactions, there seems to be less incentive for these actors in improving the quality of the planting materials supplied, unless it positively affects customers' perception of the starch content of the plant.

Potato: This group of seed system actors consists of traders, private small-scale multipliers, and farmer cooperatives. Individual traders generally import smaller batches of seed from overseas, the bulk is imported from China (i.e. Hubei, Mongolia, Shandong, Sichuan, Yunnan) for further multiplication and marketing in Vietnam. PPD requires documentation certifying that imported seed is disease-free. Before seed crosses the border, PPD also takes samples for further testing in laboratories and seed destination is registered allowing for effective monitoring in case of outbreak. Once seed enters Vietnam, no further follow-up inspections take place, even though imported seed is also further multiplied domestically before it reaches farmers. In the absence of formal certification at the end user level, trust and reputation of seed sellers are critical in the functioning of seed markets. To maintain its reputation, a trader has to come up with its own methods to assure quality of seed. For example, one of the traders interviewed for this study used a 'switching technique', whereby locations of seed production were rotated across vast geographies to keep the disease and pest pressure low.

The current system in Vietnam jointly with the specific biology of potatoes provides incentive for fraudulent behavior. In addition to entering the country as ware at official border checkpoints (i.e. non-separability), potatoes may enter Vietnam through multiple unofficial points of entry. Once ware/seed potatoes are imported, traders can multiply, repack, and relabel potatoes without any form of scrutiny by local authorities.[19]

In some parts of the country, esp. in the Dalat region, individual seed producers also engage in producing and distributing seed of non-certified material in alternative classes and at alternative standards such as quality declared seed, which we henceforth refer to as non-certified seed (NCS). NCS is mainly produced using apical root cutting techniques and in-vitro material. Guidelines for seed production are followed and very infrequently inspectors visit, but only for visual inspections. These types of seed producers are located closer to the PVFC and at considerable distance from the border with China. The reduced costs of accessing in-vitro material and the

[19] For example, during one of our interviews, we observed the repacking of potatoes taking place in the storage halls. We were not allowed to further inspect the label tags on potato bags kept in cold store to get a better idea on variety name, place of origin, etc.

reduced availability of 'Chinese potatoes' are two advantages in favor of this types of potato seed producer found in the Dalat region.

Farmer cooperatives are another type of seed entrepreneurs engaged in potato seed production and distribution. They purchase imported certified seed mainly from RCRDC for use as planting material to produce ware potatoes. However, a smaller share is also used for seed potato production which is sold to cooperative members. Smaller tubers from ware productions are also stored for planting in the next season. Quality of seed used by cooperatives is generally assured by mainly using certified imported seed. However, seed multiplied by cooperatives for sale to members is not inspected by local authorities and does not undergo any quality check.

For potato, a number of private individuals with connections to the national research centers are also engaged in early generation seed production and seed multiplication. Other than the individual entrepreneurs, traders, and cooperatives, private seed companies that directly involve in seed multiplication and commercialization of seed potato do not exist in Vietnam.

Supplementary Material C – Pest and disease outbreaks examples

Potato seed crisis of 2011

In 2011, potato producing farmers in Bac Ninh province and other provinces in the Red River Delta reported to local authorities that their seed was of low quality and infected with disease. This prompted the local government to gather a team of inspectors - usually experts in detecting viruses and diseases in cereal crops but trained to detect stresses in vegetatively propagated crops - who were sent to visit affected farms. However, other than doing visual inspections and hold discussions with farmers, inspectors were powerless in confining the spread of 'Chinese potatoes.' Very few seed sellers were convicted and fees were charged.

The local government in Bac Ninh reacted by introducing a subsidy on imported potato seed in 2012. In the 3-year program farmers received 75% of the total acquisition costs of imported certified seed for ware potatoes from developed countries. Most of the imported seed was from Germany or the Netherlands. After the program ended in 2015, the local government introduced a similar program in 2016 in which imported seed was subsidized by 50% for another 5 years until 2020. An obvious question of this reaction by the government is that why imported certified seed was subsidized instead of domestically produced seed. One reason could be that research stations indirectly benefited as well because of their involvement in the multiplication of imported seed. When the subsidy program expires in 2020 and imported certified seed will become expensive again, most farmers are likely to revert back to informal seed sources if NCS supply remains limited.

Cassava Mosaic Virus outbreak in 2017 and Cassava Mealy Bug outbreak in 2012

In July 2017, a Cassava Mosaic Virus outbreak was announced in Tay Ninh and a Steering Committee led by the Provincial Vice President was established. The PPSD asked the district and community authorities to advise farmers to destroy the infected cassava fields and to use pesticide for whitefly. Videos, guidelines, in-field and financial support for destroying infected plants were provided to farmers in the area. Farmers were also advised to not use the planting materials from outbreak area even from what looked like healthy plants. Farmers were recommended to plant variety KM94 in the subsequent season, because it was more tolerant to CMV compared to other varieties.

Notwithstanding the comprehensive official institutional response, the measures taken were not perceived as adequate in mitigating and containing the spread of the disease. More specifically, the compensation for destroying cassava field was 1-2 million VND (or 40-85 USD) per ha for food crops and 2-4 million VND (or 85-170 USD) per ha for industrial crops, was considerably lower than the retail market price, had the farmers harvested it and sold it to local traders. As a consequence, some farmers did indeed continue their cassava cultivation and managed to access premium prices from their buyers, due to the shortage of supply in the neighboring area. Similarly, very few farmers adopted the recommended crop rotation during the outbreak.

The case of cassava mealy bug outbreak in 2012 provides a demonstration of the government's surveillance and containment power and infrastructure. Farmers initially reported incidences of cassava mealybug in the border

regions mainly to Laos. Upon this initial suspicion, affected cassava samples were collected by the Sub-Department of Crop Production & Plant Protection of Tay Ninh (PPSD) and sent for laboratory testing. The provincial PPD first evaluated the possibility of managing the pest through conventional control methods while also assessing the risk and hazard associated with the outbreak. When conventional control methods failed, the area was quarantined, the standing crops were destroyed, and all movements of cassava stems from the affected area were banned.

CGIAR RESEARCH PROGRAM ON Roots, Tubers and Bananas

The CGIAR Research Program on Roots, Tubers and Bananas (RTB) is a partnership collaboration led by the International Potato Center implemented jointly with Bioversity International, the International Center for Tropical Agriculture (CIAT), the International Institute of Tropical Agriculture (IITA), and the Centre de Coopération Internationale en Recherche Agronomique pour le Développement (CIRAD), that includes a growing number of research and development partners. RTB brings together research on its mandate crops: bananas and plantains, cassava, potato, sweetpotato, yams, and minor roots and tubers, to improve nutrition and food security and foster greater gender equity especially among some of the world's poorest and most vulnerable populations.

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