Multilayer Networks Supporting Healthy Potato Seed Systems in Tungurahua, Ecuador

J. Hernandez Nopsa[1*], J. Andrade-Piedra[2], G.A. Forbes[3], P. Kromann[4], S.L. Lei[1], J. Brisbane[1], and K.A. Garrett[1*]

[1]Institute for Sustainable Food Systems, Plant Pathology Department, and Emerging Pathogens Institute, University of Florida, Gainesville, FL, USA,
[2]International Potato Center (CIP), Lima, Peru, [3]CIP, Beijing, China, [4]CIP, Quito, Ecuador. ***Contact information:** nopsa@ufl.edu, karengarrett@ufl.edu**

Introduction

The potato seed system includes social, economic, and agroecological components (e.g., market prices, disease outbreaks, IPM, and seed production) as a set of multilayer networks. Seed and ware potato producers, breeding institutions, technical support, pests, and diseases are part of this complex system. We study networks of communication and seed exchange to understand interconnectivity and impacts on the potato seed system in the Consortium of Small Potato Producers (CONPAPA; Figs. 1 and 2) in Ecuador.

We evaluate the CONPAPA structure as a first step to support improved sampling, IPM, risk assessment for pathogen and pest movement, and farmer decision-making. Identification of key control points that influence the success of seed systems (e.g., farmers, farms, information sources) supports enhancement of the system (e.g., maximizing the distribution of new seed varieties using fewer distribution channels, managing disease outbreaks, and targeting improvement of communication and infrastructure). Resources can be invested in particular nodes to improve practices and to control pest and disease outbreaks, leading to improvements in the seed system. We present preliminary results for CONPAPA as part of an ongoing project to develop general recommendations for improving seed system structure.

Fig. 1. Farmer associated with CONPAPA in Tungurahua harvesting potatoes.

Locations and distance networks of the farms

Fig. 2. Four potato cultivars commonly grown in the Tungurahua region, clockwise from top left: Yana Shungo (native cultivar), Fripapa, Puca Shungo (native cultivar), and Superchola

Pathogen/disease or pest	Percentage farmers reporting
Phytophthora infestans	72
Premnotrypes spp.	59
Phtorimaea operculella, Symmestrichema tangolias, Tecia solanivora	19
Epitrix spp.	13
Spongospora subterranea	16
Erwinia sp.	12
Fusarium spp.	28
Puccinia pittieriana	25
Rhizoctonia solani	6

Fig. 3. Common pests and diseases reported by farmers in Tungurahua, Ecuador, in a 2015 survey.

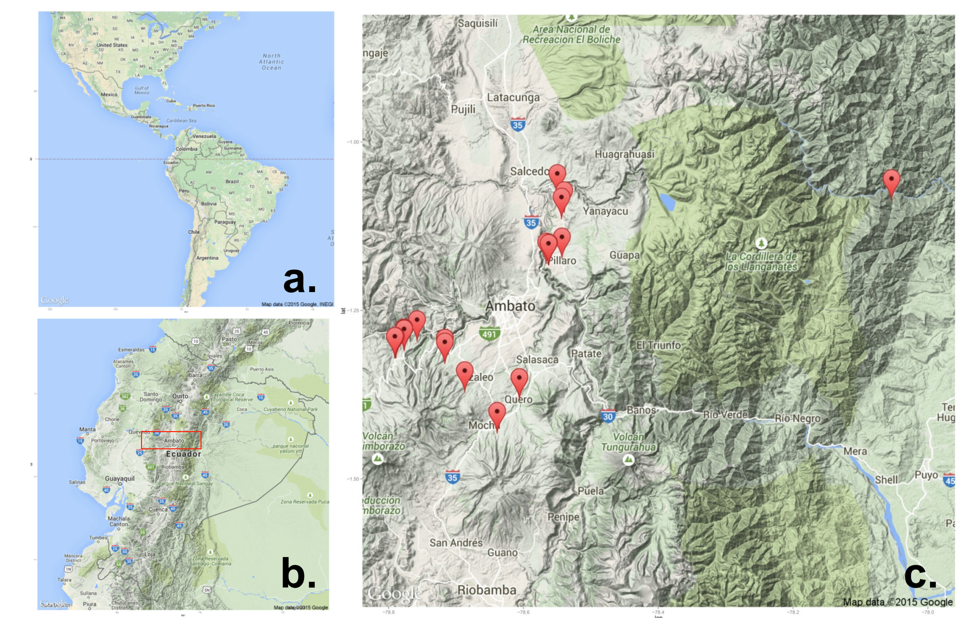

Fig. 4. a) Ecuador in the Americas, b) Ambato, the capital of Tungurahua province, and c) the locations of the farms associated with CONPAPA in Tungurahua.

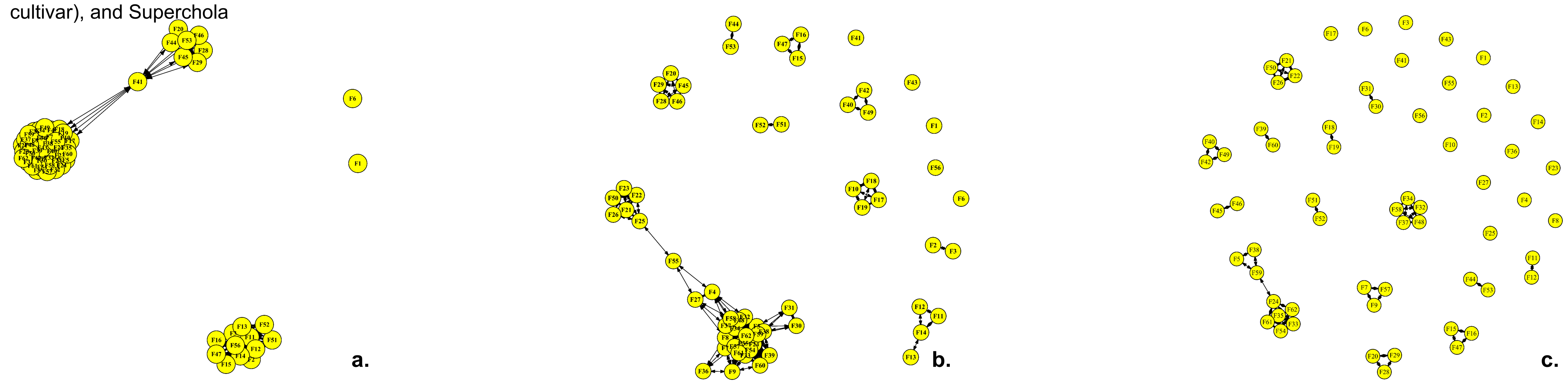

Fig. 5. Networks in which links represent the "overall risk" (averaged across potential pathogen/pest species) of movement due to physical proximity between CONPAPA farms. Risk was approximated by a power law function of the Euclidean distance between farmers' fields. The three networks are scenarios where a) links represent overall risk of movement that ranges from low to high (β=1), b) links represent medium to high risk of movement (β=0.5), and c) links represent strictly high risk of movement (β=0.45).

Methods

We conducted surveys of farmers in CONPAPA, CONPAPA administrative members, and agrochemical suppliers who serve CONPAPA members. Surveys of 48 potato (seed and ware) producers belonging to CONPAPA were conducted in November 2015 in Tungurahua province, Ecuador. Onsite interviews were conducted at the farms. We focused on three types of data from the surveys in this preliminary analysis: i) geographical coordinates of CONPAPA member farms, ii) identification of farmers' sources of information for IPM (e.g., extension agents, CONPAPA technical support, agrochemical dealers, etc.), and iii) sources of planting material.

The distance between potato farms was calculated using the coordinates of the centroid of the potato fields (Fig. 4). The overall risk of pathogen/pest movement was approximated by a function of Euclidean distance between farms (nodes) i and j (d_{ij}) as $d_{ij}^{-\beta}$ using a power law function, where greater β reflects lower likelihood of long-distance dispersal. Depending on the specific pathogen or pest species of interest, "low overall risk" movement may be more or less likely to occur (Fig. 5). The communication network for IPM was approximated based on farmer responses to questions about their sources of information about diagnostics and management. Nodes are farmers and their sources of information such as the CONPAPA technical manager, NGOs, and agrochemical dealers, where links represent information movement among nodes. Analyses were performed in R.

Communication network of potato farmers

Potato seed network

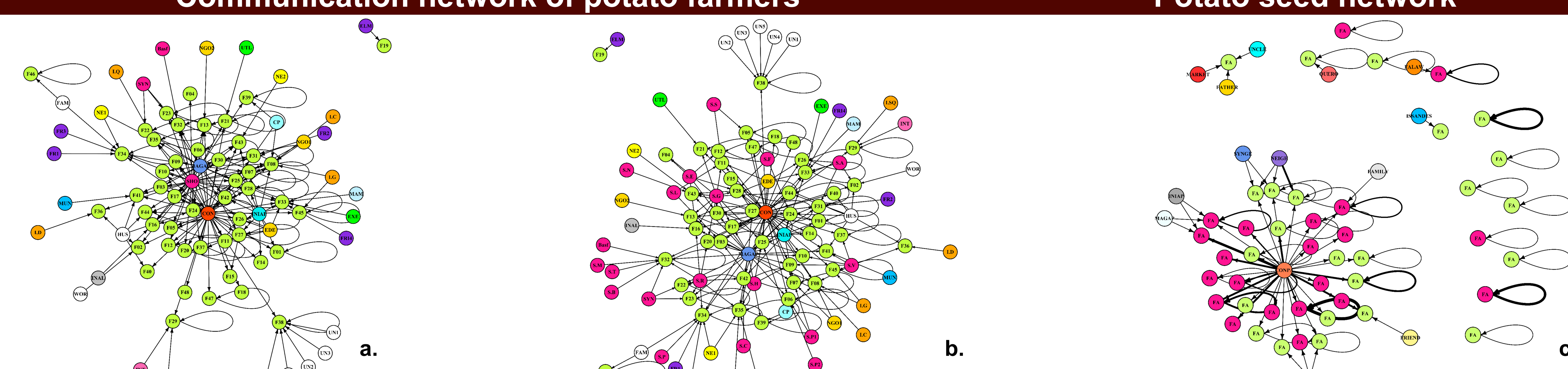

Fig. 6. (a) and (b) Networks representing how information about management of pest and diseases is obtained by 48 farmers (green nodes) associated with CONPAPA. Nodes represent different sources of information for the farmers (pink: agrochemical stores (aggregated in (a), disaggregated in (b)), purple: land owner or farmers friends, orange: CONPAPA, cyan: INIAP, white: husband or worker, light blue: MAGAP (Ecuadorian Ministry of Agriculture), light orange: crop consultant, gold: NGOs, gray: state government, light gray: potato industry, green: local university, pink: agrochemical industry and agrochemical shops, light pink: internet, pale blue: Ministry of the Environment). Links represent the movement of information from information sources to farmers, (c) Seed exchange network: green: ware potato producer, pink: seed and ware potato producer, blue: NGO, cyan: uncle, red: Ambato market, dark orange: father in-law, brown: dealer, light yellow: friend, dark blue: agrochemical industry, purple: neighbor, orange: CONPAPA, gray: family, light yellow: Pillaro Market, white: MAGAP as seed source, dark gray INIAP. Self-loops represent seed produced on-farm, link weights (thickness) represent volume of seed obtained from the source.

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Next stages of analysis

This work is ongoing, as we integrate the different types of networks in scenario analyses to identify key strengths and weaknesses of the CONPAPA system, and more broadly in other similar seed systems. An understanding of network structure can be applied to identify the key network components for pathogen or pest movement through the system. Identification of crucial network nodes such as hubs and bridges for information and seed can be used to strengthen these components. Farm locations suggest that certain farms may act as bridges between others (Fig. 5), though more information will be needed about non-CONPAPA farmers to interpret landscape effects more fully. Agrochemical stores play a substantial role in informing farmers about IPM (Fig. 6a and b), and we are interested to evaluate the quality of advice supplied. Farmers re-using their seed (Fig. 6c) may be subject to increased risk of seed degeneration if on-farm management is not implemented well.