ANALYSIS OF PUBLICLY FUNDED INTELLECTUAL PROPERTY MANAGEMENT TO SUPPORT AGRICULTURAL DEVELOPMENT AND FOOD SECURITY IN LOW- AND MIDDLE-INCOME COUNTRIES

A Capstone Project Thesis

Presented to the Faculty of the Graduate School

of Cornell University

In Partial Fulfillment of the Requirements for the Degree of

Master of Professional Studies | Global Development

by

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May 2024

DISCLAIMER

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ABSTRACT

Technological breakthroughs in agriculture, including agronomy machinery, high-yield disease-resistant crop varieties and relevant smart informational systems, are crucial to consistently enhance food production and quality. The booming of agriculture-related cultivation techniques, large-scale application of machinery, fertilizers, and genetic engineering technologies contributed to the drastic increases in both crop yields and world population. However, the advancement of agricultural technologies remains imbalanced worldwide, leading to food insecurity in v low- and middle-income countries. The existence of patent barriers and licensing systems can hinder the transfer of imperative technologies to assist agriculture growth in developing countries. With support from The United States Agency for International Development (USAID) Innovation Labs, a comprehensive advisory framework on the management and regulation of the US federally funded agriculture technology projects will be created to guide the organization of these intellectual properties and transferal or dissemination of the intellectual properties (IP) to target users from low- and middle-income countries, seeking to improve food and nutritional security. Using literature review, in-person interviews and online survey, this research paper analyzes diverse categories of IP management and modes of patent transfer to provide insights for regulatory and policy reforms. Finally, this research project hopes that our summary finding, and recommendations can address the vital needs of the low- and middle-income countries and maximize the public benefit.

BIOGRAPHICAL SKETCH

Mr. Ziqing Wei finished his high school diploma at Xi'an Tieyi Middle School, Shaanxi, China (2016). He then had been admitted into the Cornell-China Agricultural University Joint Program for his undergraduate education. He graduated from both institutions and finished a Bachelor of Science with Distinction in Research in Plant Sciences major (Summa Laude Cum) at Cornell University, and a Bachelor of Science (Agricultural Sciences category) in Agronomy major at China Agricultural University (2020). He was also introduced into the undergraduate honor society, College of Agriculture and Life Sciences, Cornell University (2019), and the United States National Society for Plant Sciences and Horticulture (Pi Alpha Xi) Cornell University Chapter (2019). He earned CALS Alumni Funds for Research (2019), Cornell University; First Class Scholar Prize (2017), China Agricultural University, and Gold Arowana Scholarship, Wilmar International (2017) to support his undergraduate research projects. His projects at China Agricultural University were selected into the Best Performance Portfolio by Education Commission Office, an office affiliated to Beijing People's Government (2019). Afterwards, he received a Master of Science degree from Cornell Plant Biology graduate program (2023). Now, he is a Master of Professional Studies candidate at Department of Global Development, Cornell University (2024).

TABLE OF CONTENTS

LIST OF ACRONYMS

CGIAR - Consultative Group for International Agricultural Research

FAO - Food and Agricultural Organization, United Nations

FtF - Feed the Future Initiative

IFPRI - International Food Policy Research Institute

IL(s) - Innovation Labs

IITA - International Institute of Tropical Agriculture

ILCI - Innovation Lab for Crop Improvement, Cornell University

IP - Intellectual properties

IRAD - Institute of Agricultural Research for Development

ISRA - Institut Sénégalais de Recherches Agricoles

ISSER - Institute for Statistical, Social, and Economic Research - Ghana

LFSI - L'Aquila Food Security Initiative

NARS - National Agricultural Research Systems

NML - New Markets Lab

ODA - Official development assistance

OPHI - Oxford Poverty and Human Development Initiative

PICS - Purdue Improved Crop Storage

ReNAPRI - Regional Network of Agricultural Policy Research Institutes

R&D - Research and development

SSA - Sub-Saharan Africa

TRL - Technology Readiness Level

USAID - The United States Agency for International Development

LIST OF FIGURES

LIST OF TABLES

Chapter I: Introduction

1.1 BACKGROUND AND RESEARCH OBJECTIVES

This capstone research project aims to investigate the current Intellectual Property (IP) management systems at Innovative Labs (IL) under the USAID Feed the Future initiative (FtF). At this stage of international agricultural aid and technical assistance, multiple stakeholders have invested heavily in providing available technologies to the developing economies and emerging markets in the Global South (Adenle et al. 2019). Main players such as the United States Department of Agriculture, Bill & Melinda Gates Foundation, The World Bank, and International Development Organization have already put more than 10 billion dollars per year to support the local agricultural development in order to fulfill the mission of food security and nutrition enhancement through supporting agricultural research and development (Vorisek and Yu, 2020). However, despite all the investments and aids coming from governments and international organizations around the world, it is still a problem that local agricultural production and development are hindered by the technological barriers due to the current IP protection framework and diverse IP management systems among those entities. Nonetheless, the recognition of technology remains as a crucial component for achieving sustainable development and Sustainable Development Goals, international initiatives aimed at providing technological support for sustainable development transitions in developing countries have not produced the desired outcomes aligned with their specific needs. (Dowd-Uribe 2014; Pandey et al. 2022). Therefore, this research project will address the current limitations of FtF in terms of technological transfer and IP management by studying different strategies from ILs' practices. It will also analyze the plant variety availability, and how does breeder's rights influence the transfer of good-quality crop seeds. Finally, this research project will summarize the relationship between IP protection and commercialization and provide insights into the management of IP partnership and up-scale production.

1.2 USAID FEED THE FUTURE INITIATIVE

Historically, official development assistance (ODA) has played a crucial role in providing support for agricultural development in impoverished nations. The global food price crisis that occurred in 2007-08 prompted international donors to renew their efforts and collaborate in aiding agriculture and ensuring food security. An important example is the L'Aquila Food Security Initiative (LFSI), started by G8 donors from 2009 onwards, that pledged to invest US$22 billion in three years to promote smallholder agriculture in developing countries. The United States, being the largest historical contributor to agriculture globally, enacted Feed the Future (FtF) in line with LFSI. The FtF is under the leadership of USAID, and it is a US$3.5 billion endeavor designed to meet the United States' commitments towards achieving the LFSI goals. (Tumusiime and Cohen, 2017).

USAID's Feed the Future initiative plays a central role in supporting agricultural research and development (R&D) to address food security and sustainable farming practices (FAO, 2021). The initiative focuses on partnerships and collaborations with universities, research institutions, and the private sector to foster innovation. USAID provides funding for research projects that tackle agricultural challenges like crop diseases, pests, and soil degradation. Capacity building programs are implemented to enhance the skills of farmers and agricultural professionals, promoting the adoption of improved practices and technologies. USAID also invests in research facilities and laboratories in partner countries to support local R&D efforts. Overall, USAID's Feed the Future initiative supports R&D in agriculture through partnerships, funding, capacity building, and research infrastructure, aiming to drive innovation and contribute to sustainable food security and economic development (STIP, 2017).

With the aid of FtF, America has helped nineteen low-income countries, including twelve in Sub-Saharan Africa (SSA), to advance their agriculture and enhance food security and nutrition. The US Congress approved continued funding in 2016; however, there is still a need for further funding if we are to tackle issues of poverty and hunger, among other issues. Development stakeholders also attest that for projects and programs to succeed, the implementation approach should also be considered. On the part of the donors, they have recommitted to the principles of ‘country ownership’ from the Paris Declaration on Aid Effectiveness, with an emphasis on inclusive growth and food security through their investments (FAO, 2009; Borter and Malik, 2023).

In the context of current food security and agricultural development initiatives, technology transferal plays a fundamental role in promoting interventions that benefit all individuals or a larger segment within the target population, specifically focusing on heterogeneous smallholder producers in the case of FtF. Using technology provided by local partners is particularly emphasized for lower socio-economic households that lack sufficient resources to access the market, as well as socially marginalized groups, with women farmers being a prominent example (IFPRI, USAID, and OPHI, 2012; Djurfeldt, 2013).

It is widely recognized that women in developing countries face marginalization or exclusion when it comes to accessing and benefiting from innovations and development initiatives. They often encounter barriers in accessing productive resources such as technology and extension services, resulting in relatively lower productivity compared to men (Gardella, 2006). To address this gender disparity and promote technology inclusivity, efforts are being made to enhance women's participation and empowerment in agricultural development programs. These initiatives aim to provide women farmers with equal opportunities, access to resources, and the necessary support to overcome the challenges they face.

Recognizing the importance of technological transfer, stakeholders involved in food security and agricultural development are striving to ensure that interventions are designed and implemented with a focus on reaching marginalized populations, including women farmers. By promoting inclusive practices and addressing the specific needs and constraints faced by these groups, these initiatives can foster equitable and sustainable agricultural development, ultimately leading to improved food security and enhanced overall well-being for all segments of the population (FAO, 2011).

Ascertaining the dynamics of such reforms in beneficiary nations is equally critical as it can help establish whether there is any lack of uniformity between USAID headquarters policies and field practices. Knowledge, technologies, and experiences acquired from the field may also play a pivotal role in shaping and fine-tuning continuous as well as future food security development aid programs. However, only limited external surveys have examined the effectiveness of FtF technological and IP management implementation at the Innovation Lab (IL) level. This study uses qualitative methods to investigate two research questions. First, how, if at all, does FtF's implementation approach foster smooth transferal of the US federally funded intellectual assets or IPs? To begin with, the use of the implementation methodology is expected to contribute to more diverse and sustainable agricultural growth as well as the promotion of food security in rural and national communities. Secondly, the features of federally funded innovations, such as technology category, commercialization potential, and development phase, should be included to present a complete assessment of the projects from FtF ILs. In this article, our goal is to gauge the degree of partnership and IP management framework in IL projects. The conclusions made are based on qualitative analysis of primary and secondary data collected from ten FtF ILs working towards various fields of agricultural technology and food security.

1.3 BACKGROUND OF TECHNOLOGY TRANSFER IN THE UNITED STATES

The 1980 Bayh-Dole Act allowed academic recipients of federal research funding to patent inventions resulting from that funding, in a bid to translate university discoveries into new products and industries, thus maintaining national competitiveness. The proclamation of the Bayh-Dole Act stimulated the increase of federally funded patents nationwide (Fleming et al. 2019). However, the Act does not give grantees complete autonomy, instead stipulating accountability safeguards. These include reporting requirements for not only the patents' existence, but also their licensing, assignment, and practical utilization, as well as retaining a set of rights for the government in the funded work (Rai and Sampat 2012). Despite that this Act provided the university researchers with incentives and meanwhile preserved federal right, many issues and misunderstanding stemmed from it in the practical settings due to the unexplained details and different interpretations by various stakeholders. The U.S. Feed the Future Initiative, which aims at to strengthen the agriculture sectors in the developing countries through hand-in-hand partnership, has encountered patent problems in utilizing government-sponsored intellectual properties. Unfortunately, most of the urgent-needed innovations are unable to be delivered to their targeted users partially owing to the complicated patent protection and owners' right. Furthermore, in the developing markets, the demand for technology and challenges on patents are completely distinct, and usually low return on investment ratio hinders the U.S. institutions' willingness to install their public-funded technologies. Therefore, this project will analyze the problems, and recommend management and commericallization methods to facilitate the distribution of these funded innovations. The organizing structure of the U.S. Feed the Future Initiative involves multiple entities and agencies working together to address global food security and agricultural development. Key components include Lead Agency, Interagency Coordination, Global Program, Country Ownership, Partnerships, and Monitoring and Evaluation (Du et al. 2015). The U.S. Feed the Future Initiative involves coordination among government agencies, collaboration with partner countries and stakeholders, and a focus on evidence-based approaches to achieve sustainable agriculture, improved nutrition, and enhanced food security globally. To address the agriculture and food security issue in each aspect, The U.S. Government's Global Hunger and Food Security Initiative includes different innovation labs, ranging from human nutrition, pathogen control, crops and soils, women empowerment to sustainable intensification, to assist the scientific research and policy implications. The transdisciplinary mode of the structure will promote the understandings and feedback from each other, enlightening a better blueprint for partner countries to develop the agriculture production and food security, ultimately stop the cycle of hunger and poverty (Hayes 2023).

Since the implementation of 1980 Bayh-Dole Act, a lot of research had analyzed this Act, and discussed the possibility of patent transferal under this framework. In a University of Michigan Law School article, Eisenberg 1996 discussed a significant shift in U.S. government policy regarding intellectual property rights in government-funded research. The author highlighted that prior to 1980, federal agencies typically made research results available to the public through government ownership or dedication to the public domain. However, in 1980, two statutes were enacted that promoted a new approach. This approach emphasized the need for private sector involvement and commercial development of research results. According to this vision, public ownership of research results was seen as limiting their potential, while patents and private appropriation were considered necessary for successful commercialization. The new strategy aimed to achieve several goals, including effective transfer and commercial development of research discoveries that might otherwise remain unused. It was also intended to stimulate U.S. industry by providing fresh ideas for innovation.

Besides the academic concerns, several other U.S. government departments discussed the patent transferal issue. NASA established their own standard for funded research innovations in NASA’s Technology Transfer Process (NASA, 2019). It exhibited NASA's efforts to share its inventions and scientific breakthroughs with the public, academia, and private industry. The report highlights the importance of technology transfer and the legislation that governs NASA's role in disseminating information about its activities and results. The report acknowledged that NASA had made significant efforts to improve the awareness of its Technology Transfer Program through enhanced communication and outreach. The introduction of the electronic New Technology Report (e-NTR) and the issuance of a new policy for technology transfer activities have contributed to increased communication, resulting in higher numbers of reports, patent applications, and licenses. However, the report identified poor technology transfer performance at Goddard Space Flight Center compared to other NASA Centers. The lack of adequate controls and collaboration between Goddard's Technology Transfer Office and the Office of Patent Counsel hinders the technology transfer process. This leads to delays in processing New Technology Reports (NTRs) and patent applications, as well as a lower percentage of licenses. Consequently, NASA lacks assurance that commercially viable technologies are effectively reviewed and disseminated for public and private sector benefit. Based on the findings, the report provides several recommendations to improve the effectiveness

and efficiency of NASA's Technology Transfer Program. These recommendations include examining Center-specific operations for potential Agency-wide implementation, completing the implementation of a two-party authentication system, making necessary changes to improve technology transfer processes or personnel at Goddard, and establishing firm completion dates for outstanding action items.
Meanwhile, the U.S. Department of Agriculture, Agricultural Research Service (USDA-ARS) Government Patenting and Technology Transfer report explored the objectives and benefits of patenting government research and examines the effectiveness of ARS's patenting and licensing activities as a means of technology transfer. It emphasized that patents play a crucial role in protecting intellectual property rights and promoting innovation. They incentivize invention and allow for the commercialization of research findings. The government, including federal research agencies like ARS, holds numerous patents on inventions and discoveries resulting from public research, many are left unused. By partnering with the private sector, technologies developed by ARS can be further developed into commercial products, resulting in net social benefits. However, ARS's patenting and licensing activities are primarily focused on technology transfer rather than generating revenue to finance research. Licensing revenue only partially funds ARS's Office of Technology Transfer and represents a small portion of the total budget. The report compares the ARS Office of Technology Transfer with university technology transfer offices and acknowledges the differences in objectives and protocols. The federal government follows specific guidelines to ensure transparency and fairness in licensing arrangements, with preference given to smaller firms. The success of licensing terms and practices is challenging to determine, as it depends on market factors, technology characteristics, and competitive risks. The study also discusses the importance of flexibility in renegotiating license terms and the potential benefits of geographically segmented or co-exclusive licensing arrangements.

In conclusion, from universities to the U.S. government agencies, public-funded projects patents have always been paid to a close attention. On the one hand, all institutions realize that, by sharing the patents with private sectors or commercial development, it is beneficial for all parties, and boosting the innovation and welfare in society. On the other hand, they are clear that the patent transfer might be a double-sided sword in lack of adequate control agenda, poor communication, economic incentives, and social benefit guarantee. Moreover, excessive government restrictions and less potential to gain revenue delay the patent transfer at the same time. In the following sections, we will address the questions mentioned, and bring up our perspectives on effective and helpful patent transfer from agricultural end.

This research project aims to summarize the current development of technology transfer through the Feed the Future Initiative and analyze the transferring mode, IP management and types of technology by interviewing and surveying the Innovation Labs to provide further advice on future policymaking. The research will highlight diverse categories of technologies, and study how these technologies are managed and their relationships with the local partners. Following significant patents are our concentrations to address regarding the technology background and the mode of transferal.

Chapter II: Analysis of Interview Results from Selected Innovation Labs

2.1 METHOD

In this study, a semi-structured interview approach was employed to gather data and gain insights from the participants. Semi-structured interviews offer a flexible yet systematic method of data collection, allowing for both predetermined questions and the opportunity to explore additional topics raised by the participants.

2.2 INTRODUCTION OF SELECTED INNOVATION LABS AND INTERVIEW RESULT SUMMARY

Case 1: IL for Soybean Value Chain Research at the University of Illinois (SIL).
Interviewed on Jan 26, 2024; Surveyed on Apr 1, 2024

Primary mission and technology: The mission of Soybean Innovation Lab is to provide researchers, extensionists, the private sector, non-governmental organizations, and funders operating across the entire value chain the critical information and technology needed for the successful advancement of soybean development in Africa. (Soybean Innovation Lab, 2024).

Partners: A wide range of US universities, including University of Missouri, Iowa State University, University of California, Davis, Mississippi State University, University of Ghana, Cornell University; federal government agencies including USAID, USDA; foreign government agencies such as Ministry of Agriculture, Irrigation and Water Development, Republic of Malawi; non-profit organizations and research institutions like the International Institute of Tropical Agriculture (IITA), National Agricultural Research Systems (NARS), Savanna Agricultural Research Institute, international companies such as BASF chemistry, Dow, Du Pont, Bayer, Corteva, Pyxus, CSIRO and agilis; local private sector partners including Sunseed Oil Company, AgVenture, aWhere, and Phoenix Seeds.

Key products and output to date: the Open-Source Single Plant Thresher; Soybean varieties; Soybean plant disease and pest management; Improved soybean agronomic practices.

IP management: soybean crops, perceived as open-pollinated goods by the public, are susceptible to IP theft. This refers to unauthorized use or commercial sale of someone else's intellectual property, which includes patented seeds or other plant varieties protected under the protection of plant breeder's rights. The prevalence of IP theft or "brown bag seed" in the soybean industry is noted to be common.

In the targeted regions such as Latin America, government involvement in the seed system is strong. The public sector views the distribution of safe seeds and brown bag seeds as a means of distribution rather than considering it as IP theft that needs to be prevented or managed through royalties. This suggests a lack of recognition or enforcement of intellectual property rights in the seed sector.

Moreover, because weak institutions in Latin America and Sub-Saharan Africa are characterized as significant barriers to seed development and private sector engagement, the lack of a viable investment-revenue model deters the involvement of the private sector in developing improved soybean varieties or investing in seed research and distribution.

The soybean variety is bred and owned by the CGIAR center IITA, and this IL is a research partner with IITA working directly on soybean breeding and IP management, such as licensing to companies or producers. IITA licenses to one seed company who then pays a royalty and has 3 years of exclusivity with other negotiated features of the license. Without licensing, the traditional model for seed companies and IITA-soybean varietal release was .08 varieties/country per year since 2000. So essentially there was no adoption or scale up before this IL built an IP management system with IITA and their licensees.

SIL works closely with breeders from the International Institute of Tropical Agriculture (IITA) and National Agricultural Research Systems (NARS) in Africa. The ownership of intellectual property rights (IP) lies with the developers and the organizations employing the breeders. The lab collaborates with these breeders to commercialize and protect new soybean varieties under IP rights. The decision-making process regarding commercialization and IP protection is handled by the lab's IP team.

Innovation: USAID and this IL aim to address the low productivity of agriculture in Africa. However, the issue of intellectual property is consistently intertwined with these efforts. The interview implies that the IP challenges faced in the soybean industry are a concern that USAID seeks to tackle. The lab recognizes the importance of IP management in incentivizing breeders and ensuring the availability of improved varieties to farmers. They are exploring licensing options to protect their materials and establish revenue models. While the traditional system has been that the center gives germplasm out and NARS can take them and claim it as their own. IITA works as a center that gives out the IP - They have been working on a program to license. Moreover, as IITA has a licensing platform, the respondent believes that the presence of a project manager is crucial in the soybean seed management system, yet it is lacking among most public sector actors. Additionally, there is a need for more guidance and legal advice related to IP and relevant contracts. Another aspect to consider is the presence of a lawyer on the licensee side to handle royalties. These are all novel elements that require attention.
Implementing a license management system and ensuring proper tracking is essential to provide guidance and comprehensive information to address the various legal aspects involved in licensing. These competencies, pertaining to licensing, are new and have not been previously dealt with by IITA and the NARS.

Limitations: There are several potential limitations mentioned in the interview. Weak institutions in Latin America and Sub-Saharan Africa pose a significant impediment to seed development and private sector engagement. The lack of resources, working

capital, and competence within the public sector and NARS hinder the establishment of relevant breeding programs. Additionally, IP theft is a prevalent issue, discouraging investors and limiting the commercialization potential of new varieties.
In terms of the revenue reallocation, In the agricultural research sector, it has been observed that each NARS director or breeder has established their own seed companies and is directly transferring the developed plant material to these entities. However, a significant concern arises due to the limited number of players involved in this practice, as even a small-scale operation can have far-reaching implications. Moreover, due to the multilayer management from different institutions, there is a huge internal conflict for the public sector (CGIARs and NARS) about seed as a public and free good versus a licensed product that incentivizes the private sector to scale.

Case 2: IL for Peanut at the University of Georgia.
Interviewed on Dec 19, 2023

Primary mission: The Feed the Future Peanut Innovation Lab applies U.S. science to improve peanut production and use, raise nutrition awareness, and increase food safety in developing countries (Innovation Lab for Peanut, 2024).

Partners: Through the Peanut Innovation Lab and approximately two dozen other Innovation Labs, USAID utilizes the expertise of top U.S. universities and research organizations such as College of Agricultural and Environmental Sciences, University of Georgia and National Agricultural Research Systems (NARS) to solve food production, storage, processing, and marketing challenges that prevent partner countries from producing enough food.

Key products and output to date: Peanut varieties, gender and youth development, school feeding programs.

IP Management: The Innovation Lab for Peanut operates under the University of Georgia's IP policy. The lab does not function as an independent legal entity. The management of non-state funds, including those from USAID, is handled by a research foundation established by the University. The lab is required to abide by USAID's policies on intellectual property management, although they mentioned that these policies are currently vague.

The university, being a public entity, has ownership rights over the breeders' intellectual property. Additionally, the breeders themselves possess rights associated with public-private partnerships for seed development. It is also mentioned that the university has established a research foundation, which may have its own rights associated with intellectual property. The university and associated entities have obtained patents for certain innovations in seed development over the past few years. This suggests a focus on protecting their intellectual property through the patent system.

In the meantime, this IL indicates that private seed ownership, which is financially viable, is scarce. The informal sector dominates the seed market. This suggests that the university's IP system may primarily revolve around public ownership and management of seed varieties. The notion of owning rights to a seed variety is described as recent, as seed varieties were traditionally considered part of the public domain. This implies a shift towards recognizing and asserting intellectual property rights in the seed sector.

In their IP management for peanut projects, the IL preferred free access to innovations rather than strict licensing and/or property rights. The perception is that intellectual property protection could potentially restrict the free flow and utilization of research outputs. This suggests a more open, inclusive approach to sharing and disseminating innovations rather than strict ownership and licensing.

Innovation and Dissemination: The lab's approach is to support national programs in the countries they work with, allowing those programs to manage the innovations developed for their specific countries. The lab does not claim intellectual property rights over plant variations or innovations. The dissemination of innovations is primarily done through the national program partners. The lab emphasizes free access to innovations over licensing and property rights, as there is a perception that intellectual property protection might restrict the free flow and utility of research outputs.

Moreover, they mentioned that a public-private corporation called Georgia Seed Development that operates on a self-funded basis is available to them. This entity manages all royalties from seed production, handles contracting and cash flow, and serves as a facilitator. This arrangement could be an interesting aspect for further research on the university's IP management.

They also emphasize the importance of contemplating the time it takes for crops to develop and how this influences research and funding terms. While benefits are perceived from previous work, the real benefits are projected to materialize once markets for new varieties are effectively created. It is crucial to maintain attractive business models even during the period when crops and new varieties do not generate immediate income.

Limitations:

- Varieties developed in the U.S. may not work in other agro-eocologies due to unique conditions and species.
- Lack of clarity on how intellectual property management should be implemented.
- Limited clarity and detail on intellectual property arrangements with USAID.
- Limited paperwork and formal ownership models, with a preference for informal provision of materials.
- Lack of control over seed markets and challenges in engaging private actors in protecting innovations without burdening cooperation.
- In the meantime, their NARS partners, in addition to the funding provided by the innovation lab, have additional funding sources. Separating ownership rights in terms of property becomes challenging when multiple funding sources are involved. The innovation lab acknowledges its contributing role but has no intention of claiming property rights over the collective efforts.

Case 3: IL for Crop Improvement at Cornell University (ILCI)

Interviewed on Feb 7, 2024; Surveyed on Apr 12, 2024

Technology: This IL's work is advancing plant breeding tools, technologies and methods aimed at delivering staple crops that can increase yields, enhance nutrition, and show greater resistance to pests and diseases. We listen to the voices at National Agricultural Research Institutes and work together to drive advancement in crop improvement. Together we are forming sustainable solutions to reduce hunger on a local and global scale. (ILCI, 2024).

Partners:

- Quisqueya University in Haiti.
- ISRA (Institut Sénégalais de Recherches Agricoles) in Senegal.
- IITA (International Institute of Tropical Agriculture) in Costa Rica.
- CGIAR centers

Key products and output to date: Breeding Analytics Hub, which is a JupyterHub-based platform meant to bring breeding-focused data sets together with analytical packages using R programming language. The platform is based on an open-source, freely available coding environment (JupyterHub), and is non-proprietary, though access is shared with ILCI teams.

IP Management: The lab operates as part of Cornell University, and all applicable laws to Cornell also apply to the lab. The lab has a philosophy of making innovations available in the public domain at no cost. As of current information, there have been no attempts to acquire IP or royalties.

As this IL focuses on providing tools, technologies, methods, and scientific insights to advance crop improvement programs. Their definition of crop improvement encompasses various aspects, including basic biology, entrepreneurial work, seed systems, and digitization of data. These products may not be the end products but represent valuable intellectual property.

The dissemination of technologies to NARS is utilized as an informal process. It is unclear whether this informality reflects a deliberate philosophy or position, or if it is due to the novelty of the program.

Innovation: The program expresses a dedication to open-source inventions, with some tools totally freely available on the market. They also talked about adding value through their own insights and expertise. They focus on supporting national programs, seed systems, and entrepreneurship programs to ensure the effective dissemination and utilization of their innovations. Moreover, they addressed that digitization of their materials and projects is highlighted as a fundamental task and a prerequisite for effective uptake of innovations from other ILs or institutions. It is seen more as a psychological problem rather than a technical one, requiring a transition in research mindset and training.

Limitations: One of the challenges has been to lay USAID´s strategic plan and leadership from the national programs to what our capabilities are. They offer various services, but in some cases what the local programs need is experimental design help, or guidance on data digitization which are fundamental things. To have an effective program in the 21st century you need to digitize it, lose your pen and paper and code it, so there are a lot of things that we are working on with our partners.
It would also be advantageous to generate tangible products through this program and allocate the returns to support the FtF program as open-source goods may also present challenges in terms of commercialization, especially in generating revenues, and protection of innovations. They are actively considering this possibility. Currently, there are no strict processes for IP protection employed in the program. While the program in sub-Saharan Africa and Central America protects varieties, the informality suggests that IP management may be limited or not a primary focus at this stage of this IL's mission. However, it is important to clarify that our program does not have any intention to acquire IP or royalties, which may not be beneficial to establish stable business models and prevent IP abuses. In terms of functionality, the main issue is

fine-tuning the management software to be practical for users and attracting more users within ILCI's international partners.

Case 4: IL focuses on improving nutrition among the nutritionally-at-risk population at Tufts University.

Interviewed on Dec 19, 2023

Primary mission and technology: The lab's goal is to enhance diets and increase the inclusion of nutritional foods for consumers, with a focus on the end-users who consume the food rather than farmers or businesses. The lab's role is to identify innovations in the field of nutrition, coordinate with innovators, and help generate real business models. They act as "angel investors" and promote new ideas, aiming to overcome the lack of business models that hinder the adoption and scaling of innovations. The lab engages with governments, food markets, and regulations to mediate and identify priorities that can lead to the creation of viable business models (Nutrition Innovation Lab, 2024).

Partners: The IL at Tufts University is funded primarily by USAID. The lab collaborates with various partners, including institutions, innovators, entrepreneurs, business leaders, and government agencies such as 1890 universities foundation, Action for enterprise, American Indian higher education consortium, Arizona state university, California State University - San Bernardino, Harvard T.H. Chan School of Public Health, Global alliance for improved nutrition, Hellen Heller international, International Crops Research Institute For the Semi-arid Tropics, International Food Policy Research Institute, John Hopkins Bloomberg School of Public Health, Michigan State University, The National Cooperative Business Association - CLUSA International, Purdue University, The Borlaug Institute for International Agriculture, Tuskegee University, University Of California, Davis; University Of Colorado Anschutz Medical Campus, World Fish Center, World Vegetable Center. Also, local businesses and companies in Bangladesh are involved in their commercialization practices.

Key products and output to date: Building capacity in food and nutrition network for local users, food system transformation studies, urban and rural food system and human health, food value chain research.

IP Management: Regarding IP management, it states that neither the lab nor the IL owns any of the innovations discussed. The innovations come from external sources, and the lab serves as a catalyst coordinator across innovators rather than an innovator itself. The innovations discussed in the interview are not protected by IP rights.
The program works with both the private sector and civil society to gauge the initiatives. Private sector companies interested in improving their food print and businesses involved in procurement and distribution from the public sector are engaged. Partnership with "angel inventors", innovators, entrepreneurs, and business leaders help identify constraints and access to technologies, and license products to enhance the capacity of stakeholders.

Innovation: The program's primary focus is on improving nutrition among the nutritionally-at-risk population, aiming to enhance their access to healthier diets. The end-users are consumers, and the goal is to increase the inclusion of nutrient-dense foods in their diets and focus on consumer impact.
The innovative aspects mentioned revolve around finding ways to improve the dissemination and commercialization of innovations related to food storage, packaging, and improved nutrition. The lab aims to identify technologies that can enhance the availability, affordability, and quality of perishable products. They also work on promoting better standards, control of market access, and trust in markets to overcome barriers to adoption and scale.
Furthermore, the program seeks to identify improvements such as refrigeration, improved packaging, and bio-packaging to address challenges related to food perishability, food loss, and waste. By making it more practical to bring perishable products such as fruits to the market, access to healthier foods can be increased.

Limitations: Potential limitations discussed include challenges related to the cost of doing business, lack of understanding of regulations, opaqueness, lack of transparency, and uncertainty in finding information. This IL highlights the need for better communication and collaboration between the private sector and the government. Additionally, specific limitations mentioned for certain countries include issues with regulatory environments, lack of microfinance support, and constraints in investing and human capacity.

In the context of technology commercialization and dissemination, they mentioned that a U.S.-based company trying to invest in Kenya and facing challenges with the regulatory environment before starting exports. The company seemed to license the use of the technology to a local partner, but this IP management system encountered some difficulties in distributing those goods.

This model also has some ethical considerations regarding its relationship with local governments. Their cooperations touch on the distribution of information about product toxicity. Local governments may be hesitant to disclose such information due to concerns about consumer backlash. In some scenarios, restrictions on the extraction of DNA or the export of biological and blood samples can impede supplementary research due to lack of funding or local processing capabilities.

Case 5: IL for Animal Health at Washington State University.

Interviewed on: Feb 1, 2024

Mission: The Washington State University, Paul G. Allen School for Global Health's NGO, Global Health – Kenya, leads the Feed the Future Innovation Lab for Animal Health to address animal health challenges related to agriculture and food security. Using an interdisciplinary approach, the lab will identify interventions to address livestock diseases, particularly East Coast Fever, and develop capacity in-country in both research training and institutional development for long-term impact. (Feed the Future Innovation Lab for Animal Health, 2024).

Partners: The lab is involved in research and innovation related to animal health, specifically focused on addressing East Coast Fever (ECF) in cattle. The lab collaborates with various partners, both local and international. Local partners include the University of Nairobi in Kenya, where Dr. Thumbi Mwangi, the Lab Director, holds a position. International partners include CGIAR, represented by Dr. Nicholas Svitek, a Senior Scientist, and ILRI (International Livestock Research Institute). This IL also conducts research projects which is in partnership with scientists from the Kenya Agriculture and Livestock Research Organization, and the Kenya Medical Research Institute. They also received their funding from a combination of sources including USAID and FAO.

Key products and output to date: Animal infection disease treatment, diagnostics of East Coast Fever, antibody response in cattle, animal health management, animal health education.

IP Management: The lab's IP management approach is under the management of both ILRI (International Livestock Research Institute) and the university. In the meanwhile, they mentioned that all discoveries made at the lab are the property of ILRI. It appears that obtaining a patent for the test may not be feasible due to its dependence on previously existing publicly available technology. However, there may be potential for patenting the multiplexing and biomarkers components they employed in their current research projects, as these technologies are not yet publicly known. In order to protect these aspects, it would be necessary to maintain them as trade secrets and keep them confidential.
In terms of field tests of their developed technologies, their plan is to test the prototype in the field and observe what the farmers' response and acceptance are. The intended market for the test includes veterinarians, researchers, government labs, and farmers, with a primary focus on providing farmers with information to make decisions regarding cattle treatment. Additionally, there is an interest in exploring the viability of the test as a business idea. The need for patenting is uncertain within the IL, as it may not directly impact farmers but could be beneficial for a potential business. The

consideration of whether to establish a company to move forward with the project is under discussion.

Innovation: The innovations lie in developing new solutions for ECF, including improving the vaccine production process, developing a diagnostic test using CRISPR-Cas technology, attenuating the parasite using recombinant technology and nanotechnology, and studying biomarkers for predicting infection outcomes. These advancements aim to address the challenges associated with diagnosing and treating ECF in a more efficient and cost-effective manner.

Limitations: Limitations include the uncertainty of whether the lab's diagnostic test using CRISPR-Cas technology can be patented due to prior technology being in the public domain. In this case, certain components or elements of the product could potentially be protected through patents. This may include novel reaction methods, primers, specific RNA sequences, or other innovative aspects of the product used in animal health research. Patent protection would grant exclusive rights to the patent holder for a limited period, enabling them to control the commercial use of the patented technology.
There is also a mention of the need to determine the ownership and control of innovations between the lab, ILRI, and the CGIAR center. Additionally, people raised concerns about the impact of intellectual property protection on the dissemination and accessibility of the technology to the end users, particularly farmers.

Case 6: IL at Purdue University. Purdue Improved Crop Storage (PICS)

Surveyed on Apr 5, 2024

Primary mission and technology: Purdue Improved Crop Storage (PICS) bag. The Purdue Improved Crop Storage (PICS) bag is a low-cost, simple, and effective technology for low-resource farmers to help them preserve their dry crops for several months after harvest. These bags prevent crop losses due to insect pests without using insecticides. PICS technology involves storing grain in hermetic triple-layer plastic bags. The bags enable smallholder farmers to store grain for food security and for sale during the lean season when prices are high (PICS, 2024).

Partners: This IL's partners include research grants, university departments (Purdue), public-private partnerships (Local plastic manufacturers and distributors/Ag-input dealers), service provider, local partners, and donor organizations (Bill & Melinda Gates Foundation). During the initial stages of PICS bags development (late 1980s), Purdue also collaborated with various partners in West and Central Africa. These partners included national research institutions such as IRAD (Institute of Agricultural Research for Development) Cameroun and ISRA in Senegal. The partnership was under a project funded by USAID- The Bean-Cowpea Collaboration Research Support Project (CRSP).

Key products and output to date: Improved post-harvest storage crop bags, post-harvest storage management system.

IP Management: The PICS IP is a trademark. The PICS trademark is licensed to plastic manufacturers or distributors. In their commercialization practices, several partners are involved in the commercialization of the PICS bags. These include plastic manufacturers, distributors, and vendors. Distributors or vendors may include Agro-dealers' shops, input suppliers, woven bag dealers, etc.

PICS Global (https://picsglobal.com) is a private social enterprise established in the mid-2010s to oversee the management of the PICS trademark. The company operates by granting licenses for the trademark to manufacturers and distributors across various countries. In each country, the suppliers, including manufacturers and distributors, contribute a small loyalty fee to PICS Global for every bag produced by a plastic manufacturer. These funds are utilized for maintaining trademark registration, promoting technology, and supporting the company's staff.

Training and capacity building programs for farmers and extension agents. This enables them to understand the benefits of hermetic storage and effectively use the PICS bags in their agricultural practices. The project also focuses on awareness campaigns and dissemination of information through various channels to reach a wide audience. It is important to note that PICS is primarily focused on providing practical solutions and technologies to farmers in developing countries rather than seeking commercialization or patent protection.

Innovation: Early, professional IP management system was established, as mentioned above, is a key to maintaining the brand, patent, and managing the technology transfer and license dissemination.

Limitations: One potential limitation of PICS is that hermetic storage, which involves airtight containers, is widely practiced globally. Smallholder farmers use various forms of hermetic storage, such as metal and plastic drums, silos, and jerrycans, to store grains and food items. However, these methods often face challenges related to cost, availability, and scalability. PICS Bag, an innovative solution, stands out due to its flexible design, cost-effectiveness, and scalability. To protect its uniqueness, the PICS brand has been trademarked, which has facilitated its commercialization. Unfortunately, the market is flooded with low-quality or counterfeit hermetic bags, sold at lower prices, posing a risk to customer trust, especially among smallholder farmers. In regions with limited awareness about hermetic bags, farmers may struggle to differentiate between genuine and substandard/fake products. Efforts have been made, particularly in East Africa, to establish hermetic standards to address these issues.

Case 7: IL for Current & Emerging Threats to Crops at Pennsylvania State University

Interviewed on Jan 10, 2024

Primary mission and technology: The Feed the Future Innovation Lab for Current and Emerging Threats to Crops will focus on tackling pests, diseases, and weeds of crops in a climate changed world. A cost-effective, highly efficient integrated global platform to monitor, predict and combat the threats to crops in the context of climate change (Feed the Future Innovation Lab for Current and Emerging Threats to Crops, 2024).

Partners: Government agencies and public sectors including United Nations Food and Agricultural Organization (UN FAO), Consultative Group on International Agricultural Research (CGIAR) and National Agricultural Research Organizations (NAROs). They also host four regional centers, and connect to local partners and private capitals.

Key products and output to date: PlantVillage platform to forecast, manage and advise farmers and researchers about current or emerging threats to crops through crop surveillance, remote sensing, and machine learning.

IP Management: The IL develops knowledge and systems protected by IP. The AI system related to computer vision, which aids farmers in plant diagnosis, is mentioned as an example. In addition to educating farmers, the system also gathers information on specific crops across different geographical locations, creating a comprehensive database. Originally developed for the United Nations (UN), this technology has had a significant economic impact of 1.7 billion units. It was released as a common good, which means it is not open access or open source, but rather a shared resource. If it were openly accessible, the information could be subject to a paywall, limiting the transparency of model usage. The IP rights are owned by Penn State University, as all codes fall under their copyright protection except the algorithm is open source for public test. Licensing is governed by the policies of the Gates Foundation, which provides funding with a focus on humanitarian access. The university retains ownership of the IP, and the PlantVillage name is trademarked. The project is considered a curated public good, and the decision not to open-source it is aimed at preventing misuse by malicious actors and avoiding negative consequences. While the lab does not open-source the technology, it considers it a curated public good rather than a proprietary product.

Innovation: The IL refers to the development and application of novel approaches, technologies, and solutions to address challenges related to crop threats. The lab focuses on leveraging technology, such as the AI system mentioned, to provide farmers with valuable information and support in diagnosing and managing crop-related issues.

Under a public-private model, all plant-related data will be sold and managed by Microsoft. This data will be supplemented with information from companies operating in the carbon market. The argument is made that both the data and algorithms used for farm decision-making should be publicly accessible. The public-private model enables the utilization of the private market while ensuring that the data contributes to a "carbon bank" for environmental purposes.

Traditionally, it has been recognized that the uploaded user works and information to this system should be shared among relevant parties. However, the ownership of such data, whether it belongs to the farmers or governmental authorities, remains uncertain. Additionally, there is a considerable amount of publicly available data, including resources provided by organizations like NASA. Nevertheless, establishing property rights and ownership in relation to this data, particularly within the framework of trademark regulations, continues to pose a challenge and lacks clarity.

Limitations:

- Managing Common Goods: With the increasing availability of knowledge, it tends to be consolidated by larger entities. While there is a wealth of information on farming practices, accessing it has become more challenging over time. The influence of private interests has gradually eroded IP laws, leading to a decrease in the accessibility of knowledge over the years.
- Access to Data: The ownership and sharing of data related to pests, diseases, and transboundary issues are mentioned as areas where uncertainties exist. Ownership of such data is not clearly defined, and there may be legal regulations that determine data sharing.
- Funding Challenges: The lab acknowledges that funding research in this area has been a challenge, with both governments and the public sector falling

short. As a result, the lab is exploring private capital and forming a private company to commercialize their software for carbon markets.

Case 8: IL for Fish at Mississippi State University

Interviewed on Feb 27, 2024

Primary mission: To update an old saying, give a man a fish, and you feed him for a day. Teach his village to farm fish sustainably, and the world moves a step closer to ending hunger. Applying reliable and inclusive provision of nutrient-rich fish and other aquatic foods to relieve poverty and improve nutrition, especially for marginalized communities (Team IWD Home, 2024).

Partners: They collaborate with various stakeholders, including small-scale partners, end consumers, processors, and commercial sponsors. Additionally, they mention a professor in Zambia who collaborated on vaccine development. The IL seeks partnerships with organizations that share the goal of reaching end users and achieving the goal of mutual benefits.

Key products and output to date: Various fish vaccines, fisher livelihood improvement, ocean protection and human health.

IP Management: This IL does not prioritize IP protection for most of their technologies, even if some could potentially be considered patentable. They focus on improving existing technologies, adapting them locally, and making them easily accessible to end users. Their innovations often involve improved practices, social campaigns, and the incorporation of existing technologies into locally acceptable and preferred diets. They prioritize dissemination and adoption of their innovations over IP protection.

Innovation: The IL has a broad understanding of innovation. They consider intellectual assets to go beyond traditional IP and incorporate an extensive range of improvements, including production technologies, inputs, disease control measures, food safety practices, and consumer-targeted technologies. They also emphasize social campaigns and improved practices as part of their innovative approach. Moreover, they are considering that one of the potential solutions was keeping their technologies as a trade secret, but restricting access to the latest generation to recover some of the costs while letting previous versions be freely available as they highly value the experience and feedback from their end-users.

Limitations: The IL faces financial challenges as some innovations, such as modified fishing traps, require many upfront investments. Despite demonstrating improved profitability, the initial cost of adopting these technologies can be a barrier to their dissemination, especially for the target users in developing economies.

Case 9: IL for Food Security, Policy Research, Capacity, and Influence at Michigan State University

Interviewed on Dec 21, 2023

Primary mission: Collaborating to enhance local and regional capabilities in policy research and influence, with the aim of promoting sustainable, inclusive, and healthy transformation of agrifood systems (Innovation Lab for Food Security Policy, Research, Capacity and Influence, 2024).

Partners: Their consortium partners include ReNAPRI (Regional Network of Agricultural Policy Research Institutes), ISSER (Institute for Statistical, Social, and Economic Research - Ghana), IFPRI (International Food Policy Research Institute), and Cornell University. They also established collaborations with institutions, ministries, governments, and research centers in countries such as Uganda, Zambia, and Tanzania, such as University of Ghana.

Key products and output to date: Sustainable intensification, sustainable fertilizers and other subsidy policies, institutional capacity strengthening, developing issues and socio-technical bundling.

IP Management: This IL does not have any innovations subject to IP. Instead, their "innovations" and "IPs" are associated with how they work with and advise their partners, customize assistance, and lead them in pursuing USAID's local goals and agendas.

Innovation: The focus of this IL is not solely on technological innovations but also on producing ideas and approaches that lead to policy change, regulatory impact assessment, institutional capacity strengthening, and facilitating access to finance for local small farmers and businesses. They highlight the importance of disseminating innovations related to policies, regulatory ideas, and decision-making processes.
The focus of this IL's responsibility is not solely on technology, but rather on advancing policies and regulatory ideas for IP management. In Uganda, for instance, they have supported the research on the sugar cane sector. This research identified the need for institutional and regulatory-oriented studies, which were then taken up by the government. They applied the concept of regulatory impact assessment, examining the potential effects of new regulatory structures for the sugarcane industry. This institutional innovation is not subject to IP rights but is aimed at informing decision-making by authorities.

Limitations: This IL suggested that there are some weaknesses in analyzing value chains, financial systems, and access to credit for adopting technologies. The IL member mentioned that relevant policy and regulatory barriers are not the primary hindrances to technology dissemination but rather weaknesses in market behavior, information availability, and infrastructure such as transportation. The IL also suggests that there is a lack of collaboration across different labs and the demand for a more supportive platform to enable the dissemination of federally or university funded technologies under the USAID FtF framework.

Case 10: IL for Horticulture at University of California, Davis

Interviewed on Jan 11,2 024

Primary mission and technology: This IL conducts research throughout the horticultural value chain, focusing on inclusive agricultural-led growth, enhanced resilience, and improved nutrition. Their research portfolio encompasses a wide range of topics and aims to address the diverse challenges and opportunities within the horticulture sector. Their projects and technologies include a series of post-harvest control and monitoring instruments, as well as agronomical techniques (Horticulture Innovation Lab, 2024).

Partners: They have extensive partnerships among all continents. They work with local farmers and private sectors. Also, their partnerships include U.S. universities, international researchers, non-governmental organizations, national agricultural research institutes, and foreign universities in Africa, Asia, and Latin America. Their consortium partners include Florida A&M, Michigan State University, Texas A&M, the World Vegetable Center, Pennsylvania State University, Making Cents International, the Institute for Global Nutrition at UC Davis, Cultivating New Frontiers in Agriculture, and the International Fertilizer Development Center. (Dawson 2018)

Key products and output to date: Enhancing productivity, post-harvest management, and market access of African indigenous vegetables; horticulture production as adaptation to climate change; mitigating soilborne diseases to improve smallholder farmer livelihoods and food security.

IP Management: The IL is interested in understanding how innovations generated by the IL are disseminated to end users and how IP, in a formal sense, plays a role in this dissemination process. The IL acknowledges that there are currently no traditional intellectual property rights or trademark protection in favor of the Innovation Lab. However, due to the partnership with Rutger University, a project in which nutritional profiles of indigenous vegetables were researched was patented. The overall strategy towards IP filing is with whether the research comes up with new varieties. Some of the current innovations will represent a small margin. Also, there are some ethical considerations about making indigenous varieties as patents.

Innovation: The IL explores different scaling pathways for their horticultural innovations, adapting them based on their effectiveness. They emphasize the importance of local-led initiatives, co-designing technologies with end users to ensure applicability, suitability, and economic returns. Responsible innovation transfer and gender considerations are also mentioned as key aspects of their approach.

Limitations:

- One of the concerns is the potential theft of technology and the possibility of others using it with lower quality while using the same name. It is difficult to determine if someone is using the technology without detection, especially when operating under a limited timeframe and resources. Additionally, an entrepreneur program has been implemented, allowing individuals to establish their own businesses related to drying carts. Many of these entrepreneurs have expressed concerns about copyright protection for the program and have taken steps to protect their own ventures. They suggest that ILs should have a higher-level ministry impact to create an enabling environment for the adoption of innovations. Collaborative policy efforts among ILs are also encouraged.
- Access to Research Outputs: Once research is published, it can become expensive and inaccessible, even for universities. This lack of access restricts the dissemination of knowledge and impedes the adoption of innovations.
- Market Relevance: The IL emphasizes the significance of a market that supports and demands the development of varieties and innovations. Without a market that values and utilizes technology, the transfer and adoption of innovations will become limited.

Case 11: IL for Legume Systems Research at Michigan State University.

Interviewed on Dec 22, 2023

Primary mission and technology: The Feed the Future Innovation Lab for Legume Systems Research fosters dynamic, profitable, and environmentally sustainable approaches that contribute to resilience, productivity and better nutrition and economic opportunities. (Feed the Future Innovation Lab for Legume Systems Research, 2024).

Key products and output to date: This IL has funded initiatives in West Africa focused on releasing new crop varieties. Additionally, there is a co-funded project dedicated to developing self-owned applications that assist farmers in the field and facilitate market connections. The lab also produces animation and extension content for farmers, conducts research on fertilizer application best practices and IP strategies, and engages in policy and market-related activities alongside technological advancements.

IP Management: The IL acknowledges that the existing IP policies and dissemination chain have not been effectively structured over time. Their current goal is to identify gaps in the current IP process and develop a more streamlined approach. The IL mentions protection of new varieties through plant variety rights and the pursuit of IP protection by U.S. labs and international entities. However, licensing of technology and negotiation to ensure broader dissemination is highlighted as a gap, while the use of exclusive licenses is considered to capture the value of innovations.

While standard breeding methods cannot be protected, new varieties can be. Breeders are generally familiar with the process of protecting new varieties; however, filing for protection requires significant resources, which may not always be available to NARS. In the IL, the researchers are knowledgeable about the filing process and dedicate themselves to the licensing aspect. The specific variety being developed is in high demand, and there is a possibility of private entities expressing interest in it.

With regard to licensing plant varieties, currently, the general consensus is to pursue exclusive licenses, as private companies in general seek to adopt and promote the developed biological material. Licensing agreements often include language emphasizing the goal of reaching a large number of farmers, although the enforceability of such provisions is tentative. When cooperating with the public sector, valuable ideas are generated, but without a mechanism to capture value, innovation dissemination becomes challenging. Currently, exclusive licenses are considered the most effective means of capturing value from innovations. The exclusive licenses are considered the most effective means of capturing value from innovations.

Innovation: This IL is involved in Development of new varieties through standard varietal development and crop improvement and use self-owned applications to guide farmers and connect with markets. In the meantime, they created animation and extension content for farmers, showing best practices of fertilizer applications and IP strategies.

Limitations and Tech Transfer: According to the lab, the breeders, and National Agricultural Research Systems (NARS) are less comfortable with licensing and negotiations, hindering the dissemination of technologies. It also highlights the lack of business planning and the need for private sector investment in order to reach a broader audience.

From the local breeders' perspective, there is often inadequate support to assist the filing process to NARS. In contrast, however, most laboratories based in the United States are well-knowledgeable in the procedures involved in protecting new crop varieties. Most of the NARS do not have the resources to make the filing for the breeding projects in the Global South region, unless they are linked with a U.S. based lab.

Furthermore, although licensing is an effective way to attract private sector partners, there are some concerns from them when cooperating with the public sector. As valuable ideas are generated, innovation dissemination becomes challenging without a mechanism to capture value. How to effectively address the problems in the licensing process and formalize the exclusive licensing are crucial to further deepening the public-private relationship.

Chapter III: Analysis of Current Technology and Plant Varieties from Feed the Future Initiative Innovation Labs

3.1 INTRODUCTION

Currently, more than 800 million people globally undergo chronic hunger, while 2 billion lack essential micronutrients, stemming significant public health challenges (FAO, 2019). Malnutrition impedes physical and mental development, increases vulnerability to cause-specific diseases, and leads to more neonatal mortalities (Development Initiatives, 2018). Achieving Sustainable Development Goal 2, which aims for zero hunger and improved nutrition for all human beings, necessitates significant renovations in global food systems, where isolated food or agricultural systems are insufficient to address the complicated issues, and agricultural technologies, especially breeding efforts through technology transfer, play a crucial role in the solution (FAO, 2019).

From the perspective of environmental justice, vulnerable populations in Africa and Asia, who are heavily dependent on agriculture production for their livelihoods, position as the frontier of climate-related disasters due to their susceptibility to price and income shocks. Moreover, overdosage of agrochemicals and pest controls not only influence the crop yield but also deteriorate the fragile local ecosystem (Cai et al. 2017). Without the adoption of new technologies through proper IP management system, sustainable agriculture, food security, and malnutrition issues will continue to be faraway ambitions (FAO, 2019).

New breakthroughs in plant breeding technology such as gene-edited crops and marker-assisted breeding have great potential in increasing crop yields, lowering the use of agro-chemicals, and preparing plants to be more resilient to climate changes (Zaidi et al. 2019). However, these new breeding technologies have not been extensively employed in developing countries, even though most of them have been validated to be harmless compared to traditional breeding methods (Qaim 2016). Therefore, plant breeding network is an important mission of USAID, and crucial for understanding the contemporary policies towards public-private partnerships and technological transfer. The following analysis will use the plant variety data from USAID FY 2022 breeding projects to reveal the geographical patterns of variety distribution, and further study the year-crop classification interactions within this project.

3.2 DATA AND METHODS

By implementing the FY 2022 applied or field-tested plant variety dataset from USAID Bureau for Resilience, Environment & Food Security, Center for Ag-Led Growth, this chapter uses descriptive statistics to analyze the patterns of plant variety distribution, species classification and distribution, and yearly output to investigate the possible gaps between plant breeding and transfer of those seeds. The results from this study will further advise the future of breeding work and provide insights into the application and transfer of federally funded breeding projects.

3.3 RESULTS AND DISCUSSION

3.3.1 Geographical Distribution

Table 1. Geographical distribution of applied or field-tested plant varieties in FY 2022

Country	Freq
India	63
Zambia	24
Uganda	14
Bangladesh	12
Haiti	11
Kenya	11
Senegal	11
Ecuador	10
Honduras	10
Nepal	9
Ghana	8
Ethiopia	7
Malawi	7
Nicaragua	6
Nigeria	6
Mozambique	4
Zimbabwe	4
El Salvador	3
Mali	3
South Africa	3
Costa Rica	2
Puerto Rico	2

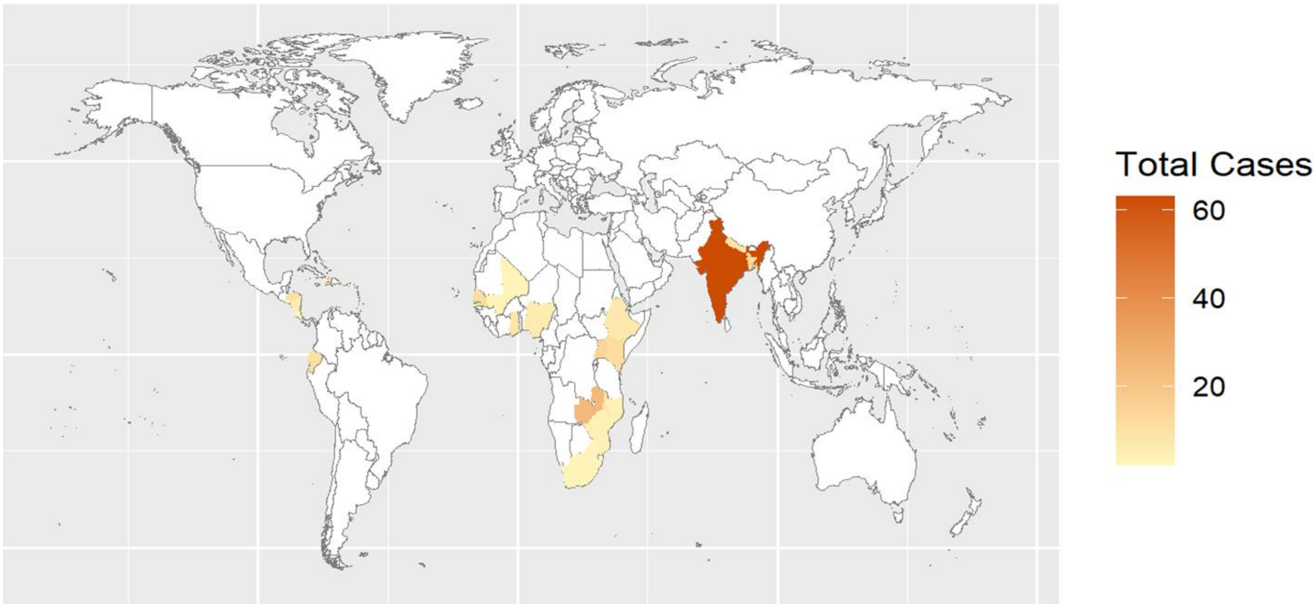

Figure 1. Distribution map of applied or field-tested plant varieties in FY 2022

To study the collection of crop varieties emerging from the USAID ILs and where they are currently being deployed during the fiscal year 2022, the results indicate that India leads the way with 63 varieties that were either applied or field-tested. Zambia comes next with 24 varieties. Uganda follows closely behind with 14 applied or field-tested plant varieties, while Bangladesh made significant progress with 12 varieties of their own. This result indicates the breeding commitment from USAID-funded projects to agricultural development in those regions (Table 1).

In the middle of the pack, it is found that Haiti, Kenya, and Senegal, all of which have 11 applied or field-tested plant varieties. Ecuador and Honduras are not far behind, each boasting 10 varieties. Nepal, with 9 applied or field-tested plant varieties, also made noteworthy contributions to local agricultural development.

The remaining countries on the list have fewer applied or field-tested plant varieties, ranging from 8 to 2. Although their numbers may be lower, their efforts and contributions are still valuable for advancing agricultural research and development. These regions might require further assistance in terms of breeding cooperations. Overall, this data provides valuable insights into how different countries are dedicating resources and efforts to develop and test new plant varieties through the

USAID breeding network. It highlights the prominence of regions such as South Asia, East Africa, Southern Africa, West Africa, and Latin America with Caribbean Islands, where this breeding framework is primarily focused. Moreover, it is noticed that there is some inequality both intra- and inter-countries in the Global South who are targets of current technology transfer framework (Table 1, Figure 1).

3.3.2 Distribution by Crop Type

Table 2. Crop type summary of plant varieties of applied or field-tested plant varieties from USAID IL projects in FY 2022

Cereals	119
Legumes	81
Vegetables	29
Fruits	10

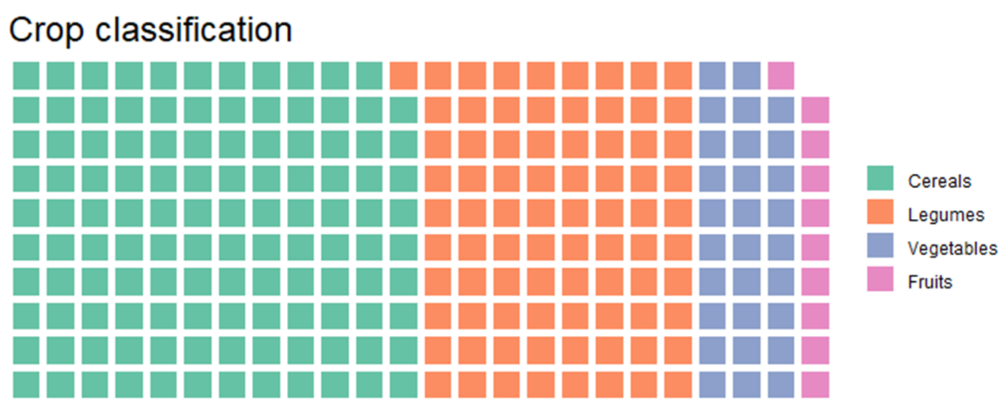

Figure 2. Crop type of plant varieties of applied or field-tested plant varieties from USAID IL projects in FY 2022

Increasing demand for nutritious and affordable diet is highly reliant on agro-biodiversity, which is currently threatened by climate change. As people within developing countries are largely based on plant-derived diets for daily energy and nutrition intake, cultivar nutritional quality and crop variety diversity should be concentrated as well (Dwivedi et al. 2017).

From this analysis of species, the cereals take up 49.8% of the total crop varieties, and legume variety type is 33.9% of total crops. It shows that most of the breeding efforts are put into the categories of cereals or legumes, while vegetables (12.1%) and fruits (4.1%) together only take up 1/6 of the research species. Therefore, it infers that the current work mainly promotes enough energy intake for local residents. However, in the future, there might be huge needs to address the vegetable and fruit varieties so that these breeding programs could not tackle food security issues but also deal with the malnutrition phenomenon among those countries (Table 2, Figure 2).

3.3.3 Temporal Analysis

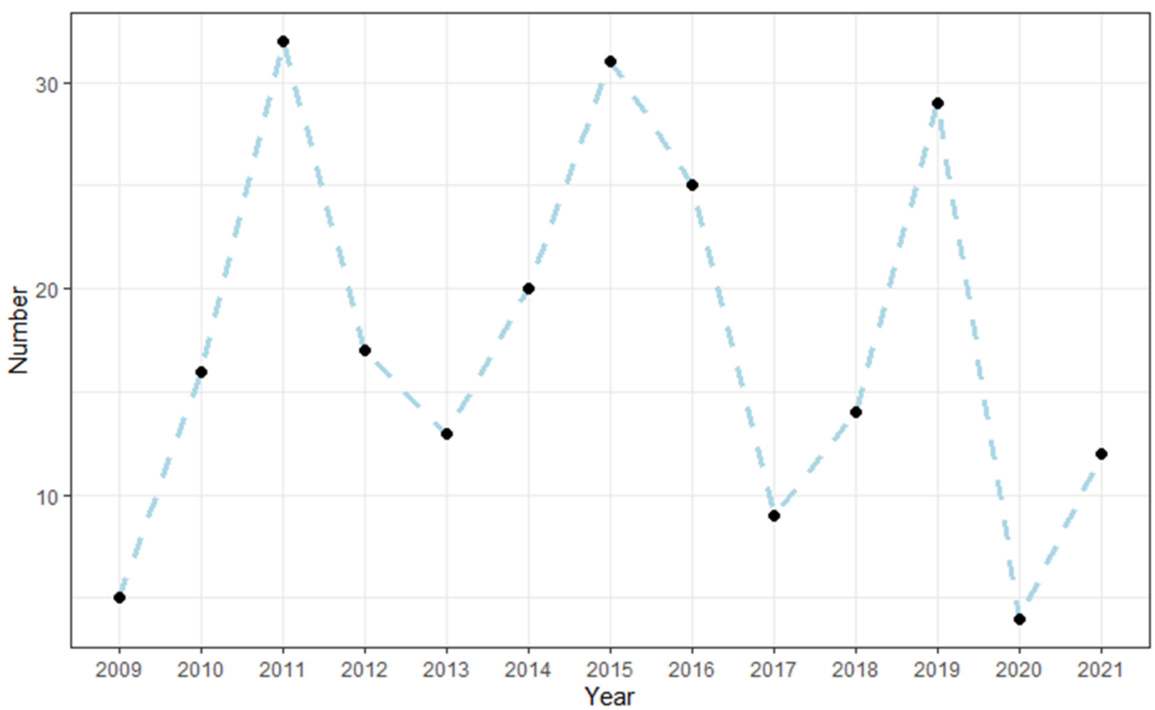

Figure 3. Year of application/field test summary of plant varieties in FY 2022

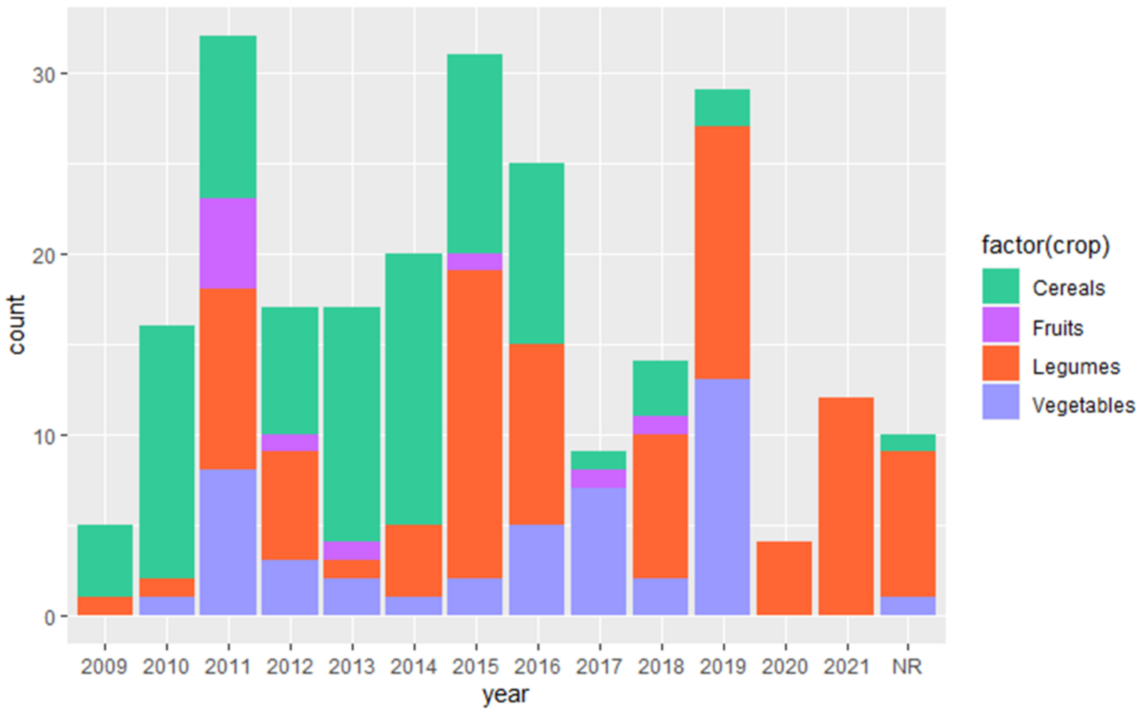

Figure 4. Application year and crop classification summary of plant varieties in FY 2022

From these analyses, it implies that, during the 2010 to 2019 timeframe, there were around 10 – 30 crop varieties being tested each year. The highest output of crop varieties happened in 2011 and 2015 that each of these two years applied or tested more than 30 varieties. However, due to the pandemic in 2020, the applied or tested plant varieties dropped to the lowest point in history. After 2020, it started to restore back to the pre-pandemic level but still needs more time (Figure 3).

The species distribution of all plant varieties also witnessed the impact of COVID-19 pandemic on international agricultural development. Before 2020, most of the years have applied or tested all categories of crop varieties including cereals, fruits, legumes, and vegetables (Figure 4). However, after the pandemic, only legumes were used in the breeding programs. We do not know the exact reasons for this phenomenon yet. However, it is clear that the pandemic has also shifted the breeding focus of this USAID project. Moreover, as mentioned in the last section of this research paper, this shift might be related to the plan of building resilience and capacity in local agricultural systems and partnerships. Therefore, legumes seem to be the best choice as they are more versatile and resilient when encountering drastic climate or societal changes (Araújo et al. 2015).

3.4 SUMMARY

The analysis on crop varieties originated from USAID IL projects in FY 2022 provides insight into geographical distribution, crop types and temporal patterns of those plant varieties. The geographical distribution analysis reveals that India has 63 applied or field-tested varieties from ILs, followed by Zambia with 24, and Uganda with 14. Projects in Bangladesh made significant progress with 12 varieties. Haiti, Kenya, Senegal, Ecuador, Honduras, and Nepal fall in the middle range with 11 to 9 varieties bred from the ILs. Other countries on the list have 8 or fewer varieties from this breeding framework. The analysis emphasizes the breeding commitment of USAID-funded projects in regions like South Asia, East Africa, Southern Africa, West Africa, and Latin America with Caribbean Islands.

In terms of crop types studied in the USAID-funded programs, Cereals and legumes dominate the breeding efforts, while vegetables and fruits receive less focus. The temporal impact of the COVID-19 pandemic is evident, with a decline in variety testing in 2020 (Wamwere-Njoroge et al. 2021). Legumes emerged as a preferred choice, possibly due to their versatility and resilience (Araújo et al. 2015).

To summarize, these findings highlight the current progress of USAID IL-related breeding programs to address food security and malnutrition challenges, and the importance of building resilience and capacity in local agricultural systems.

Chapter IV: Analysis of Technology Development Phases and Conclusion

4.1 TECHNOLOGY CLASSIFICATION

Besides the technology and IL analysis, it is critical to tracK the categories and development stages of the novel or critically enhanced technologies, plant varieties, information systems and related practices through the public or private sector involvement. The research and development (R&D) progress follows the principles of replication, examination, and hypothesis orientation. Hence, it is significant to ensure that the current USAID FtF IL projects are best alternatives available to previous international agricultural aid systems in order to fulfill the sustainable development goals of decreasing poverty, controlling hunger, and addressing the urgent food and nutrition crisis around the world. By implementing technology categorical system and development stage assessment, these novel and crucial enhancements can satisfy the target users' purpose, while allowing the field test and further applications (Feed the Future Initiative, 2023).

As the innovations and invention from ILs range from agricultural mechanics, traditional fertilizers, and new plant varieties to crop surveillance information systems and nutrition policy analyses, it is useful to develop a R&D category system to distinguish the current progress of these novel technologies, which can be classified into different phase of development. This practice can provide U.S. government, research institutions, and private sector partners with valuable scales to estimate the usefulness of their research outputs, and further gives feedback on the ongoing projects. By designing this technology scheme of classification, this research will indicate more insights into the scientific discoveries, research developments, field-testing, and modes of cooperation (Feed the Future Initiative, 2023).

Definition and demonstrative examples of technologies and practices according to technology categories are mainly involving the following three components (Feed the Future Initiative, 2023):

i. **Plant and Animal Improvement Research**: This category contains improvements or discoveries for gene materials (functional sequences including markers) and biological traits that are agriculturally important. Novel or improved biological contents are often associated with traditional or contemporary breeding and bio-engineering methods, such as gene editing approaches like CRISPR-Cas9 for application in plants and animals. Within the research context, this category consists of high-quality, disease-resistant, nutritionally enhanced and/or climate-smart plant varieties, plant gene bank and related information systems, animal disease related gene improvements.

ii. **Production Systems Research**: This category includes multifaceted management or information systems. For instance, PICS provides holistic post-harvest storage management. IL at University of California, Davis invented an integrated crop pest management system. Moreover, Pennsylvania State University's IL filed a patent on their PlantVillage forecasting software which could analyze the crop surveillance data and climate data to provide information regarding the current and future threats to crop growth. All these practices fulfill the needs for sustainable development and become more and more significant in further improving the local agricultural production.

iii. **Social Science and Public Policy Research**: This category often includes research projects on the usefulness of current agricultural policies. These projects have diverse contents regarding the various aspects of socioeconomic factors that could affect the local agricultural development. The current research efforts lie in the breeding technology systems, nutrition and food security policies, local partnership initiatives, public-private cooperations, and commercialization strategies. This category of research represents how institutional technological support can be effectively distributed into local development projects, and studies the influence of changing demographics, social behaviors, and political atmosphere.

Please refer to Table 3 displaying the scores for the technology categories of interviewed FtF ILs.

4.2 STAGES OF TECHNOLOGY DEVELOPMENT

As these novel technologies and practices are assigned to different categories, it is now important to assess their phases of development according to their special characteristics, developing progress and application abilities. They can be distributed into the following four phase of research, development, and uptake (Feed the Future Initiative, 2023):

i. **Phase I: Under research** – In this stage, novel technologies and practices are still under research. The progress of such projects is experiencing the primary developmental stage while only being tested under ideal or controlled circumstances such as in laboratory or greenhouse for biotech-related inventions (e.g. crop varieties). For non-biotech related research, even though they might be examined in the non-indoor settings (such as experimental station testing for animal health research), they are nonetheless considered as testing under controlled conditions. For social science categories, only results could effectively enhance agricultural development using theoretical method or secondary data analysis are included in this phase.

ii. **Phase II: Under field testing** – The field-testing term requires that, for novel technologies and practices, they have been transformed from developing research that improves the technology trait to the testing stage, where the testing will attempt to rebuild the user experience and solve the problems in real applications. This also includes the testing conditions that validate the invention performance through duplication examinations. For biotech related inventions, this applies to the test happening in the confined outside field, allowing the evaluation of real working environment. For the social science category, the research should withstand a randomized controlled trial or quasi-experimental design for establishing the causal-effect relationship, removing spurious alternatives, and validating the significance of research.

iii. **Phase III: Made available for uptake –** In this stage, novel technologies and practices are prepared for the real-world utilization by public or private sectors. This phase of development also requires the sustainable and effective distribution of technology to target users. Although this phase of development does not require a formal technological transfer by public or private sectors, an licensure, certification, or guidelines might be necessary to validate the technology is available for uptake. Moreover, before the actual dissemination to local users, relevant regulatory approvals or legal documents must be met.

iv. **Phase IV: Demonstrated uptake by the public and/or private sector** – In this phase, the uptake and commercialization of novel technologies and practices are independent of U.S. government assistance. A public sector and/or private sector institution have uptake the invention and distributed through their own networks. However, it is worth noticing that this stage of development does not represent uptake of end user or multilateral donor organizations. Under this phase of development, the technologies, methods, or practices are usually disseminated successfully via the sustainable pathways through the public or private sector partnerships. This requires that non-USAID financial support is involved in the distribution process. Meanwhile, the integration of the research outputs should be guided by local regulations and legal requirements. Ultimately, market access should be available and distribution assistance should be provided by local partners.

The full scheme of the specific development phase and detailed technological classification can be accessed in Appendix 1, which is provided by Faith Tarr, General Development Officer, Biotechnology Specialist at Center for Agriculture-Led Growth, USAID Bureau for Resilience, Environment, and Food Security. Please refer to Table 3 showing the scores for the development phase of interviewed FtF ILs.

4.3 DIFFERENT LEVELS/APPROACHES TO PROTECTION OF INTELLECTUAL ASSETS

Intellectual property protection can incentivize innovation and ensure fair competition. However, potential disadvantages include monopoly power and access barriers. Through the analysis of IL IP management, types of technology categories, and development phases, in this section, this study will score the main or most recent inventions or technologies of the interviewed FtF ILs. They have been assigned into the following categories based on Encaoua and Lefouili 2005 and Sunuwar 2024.

i. **High IP protection level (7-10):** Patent, Trademark, Copyright, Trade Secret - If the inventions of IL have been intentionally filed patents, and the IL has organized their own IP management corporation. They will achieve the highest IP protection level.

ii. **Medium IP protection level (4-6):** License (exclusive, semi-exclusive or non-exclusive), Other Contracts, Paywall for Access – In this level of protection, a formal patent has not been filed yet, while the IP management is processed in the form of written agreements.

iii. **Low IP protection level (0-3):** No intention or measures to protect the research output; or sometimes the invention is available in the public domain – Due to funding requirements and/or laboratory's mission, many ILs do not protect their IP, instead, they hope that more end-users can assess and take advantage of their inventions for the public welfare. It will promote the usage of inventions in some way but contain other legal and practical concerns.

Please refer to Table 3 displaying the scores for the development phase of interviewed FtF ILs.

4.4 COMMERCIALIZATION POTENTIAL

Based on the interview contents about technology commercialization progress, the commercialization potential can be assessed through 3 standards, market relevance and size, local buying power and willingness to pay, and existing alternatives, described as following categories (Porter 1979):

i. **High commercialization potential (7-10):** This category refers to the satisfaction of all three criteria stated above. The technology or practice should have high market relevance and appropriate market size to be applied. The relative price to local buying power is acceptable. The innovation should also be useful in addressing urgent food security or nutritional issues within the context of local agricultural development. Ultimately, the current substitution of technology is not available or incapable of completing with the innovation.

ii. **Medium commercialization potential (4-6):** This category refers to the completion of two assessment criteria. The technology or practice should have medium market relevance and market size to be employed. The relative price to local buying power is fair. The innovation is considered to be somewhat useful in addressing food security or nutritional risks in local agricultural development. Moreover, the current substitution of technology might be available or to some degree capable of completing with the innovation due to the incompletion of innovation's operational test.

iii. **Low commercialization potential (0-3):** The category indicates the completion of one or zero criteria in the assessment. The technology or practice has low market relevance and a small market size to be employed. The relative price to local buying power is high, exceeding the willingness to pay. The innovation is not validated to be useful in tackling local food security or nutritional problems. For the alternatives, the substitution of technology is available and qualified of completing with the innovation.

Please refer to Table 3 displaying the scores for the commercialization potential of interviewed FtF ILs.

4.5 SUMMARY AND FUTURE PERSPECTIVES

Table 3. Summary of FtF IL key innovations, category of innovation, phase of development, IP protection strength, and commercialization potential score.

IL Name	Main or Most Recent Innovation	Technology Category	Phase of Development	IP Protection Level	Commercialization Potential
IL for Soybean Value Chain Research at the	Soybean varieties	Plant and Animal Improvement Research	III	Medium, licensing; 5	9

University of Illinois					
IL for Peanut at the University of Georgia	Peanut varieties	Plant and Animal Improvement Research	III	Medium, open pollination 4	5
IL for Crop Improvement at Cornell University	Breeding improvement system	Production Systems Research	II	Low, no protection; 0	5
IL that focuses on improving nutrition among the nutritionally-at-risk population at Tufts University	Nutrition and food policy	Social Science and Public Policy Research	I	Low, no protection; 0	2
IL for Animal Health, located at Washington State University	Animal vaccine	Plant and Animal Improvement Research	II	High, managed by ILRI and university; 9	6
IL lab at Purdue University. Purdue Improved Crop Storage	PICS bags	Production Systems Research	IV	High, patent and trademark, managed by PICS Global; 10	10
IL for Current & Emerging Threats to Crops at Pennsylvania State University	PlantVillage software	Production Systems Research	IV	High, patent and trademark filed; 10	8

IL for Fish at Mississippi State University	Fish vaccine	Plant and Animal Improvement Research	III	Low, no protection; 1	6
IL for Food Security, Policy Research, Capacity, and Influence at Michigan State University	Institutional capacity building	Social Science and Public Policy Research	II	Low, no protection; 1	3
IL for Horticulture, UC Davis	Horticulture production system	Production Systems Research	III	Low, no protection; 2	7
IL for Legume Systems Research at Michigan State University.	Legume varities	Plant and Animal Improvement Research	II	Medium, exclusive licensing; 6	7

For the IP protection and commercialization potential scores, the explanation are as follows: If the patent and trademark have been filed, and directly managed by own IP institutions, a 10/10 score will be given for IP protection (PICS and PlantVillage); if the patent is filed, and owned by university, USAID, NARS or other institutions, a score 9 will be given (Animal vaccines, WSU); Otherwise, if the patent has been filed without additional management efforts, a 7 will be given. For the medium level of protection, exclusive license will get a score of 6 (Legume varieties, MSU), and non-exclusive license will receive a 5 (Soybean varieties, Illinois), while other forms of licensing will be 4. Here, although the peanut lab at Georgia have their IP managed by the university, considering the peanut is open pollinated, it is hard to effectively protect their species when operating in the field conditions. Therefore, a 4/10 will be assigned for this IL. For the low level of IP protection, a 0 will be considered for ILs that do not exercise any form of IP management (Cornell and Tufts). Score of 1 represents most of innovation from the IL do not have any form of IP management, except just one or two projects is using some form of IP protection (Institutional capacity building, MSU and Fish vaccine, Mississippi State). IL at UC Davis received a 2 because they have been considering to file license or patent on some of their innovations. If all the inventions from the IL are currently under consideration of any form of IP protection, the score will be improved to 3 (Table 3).

For the commercialization potential, ILs based in PICS, PSU, MSU Legume, Illinois and UC Davis achieve a high level because they have satisfied all criteria mentioned above. Their score variation is mainly concerned with the development of technology, and existence of current alternatives. Mississippi State, WSU, Georgia, and Cornell received a medium potential rating as they satisfied two of the standards. In the case of Mississippi State and WSU, their technologies are facing the replacement of alternatives from other institutions as some of them have better cost performance, such as the One Health animal vaccines (Beyene et al. 2019). The breeding assistance system investigated by Cornell does not specify the market relevance and target users. The peanut varieties from Georgia does not have a high market relevance given that peanut is not a staple food, which indicates the consumer need will be very limited. Eventually, the ILs from Tufts and MSU Capacity research are considered as low commercial potential because the market size and relevance of application are unknown, while the local willingness to pay is not very high given the current development stage of their innovations (Table 3).

A detailed plot of technology IP protection and commercial potential scoring is depicted in Figure 5.

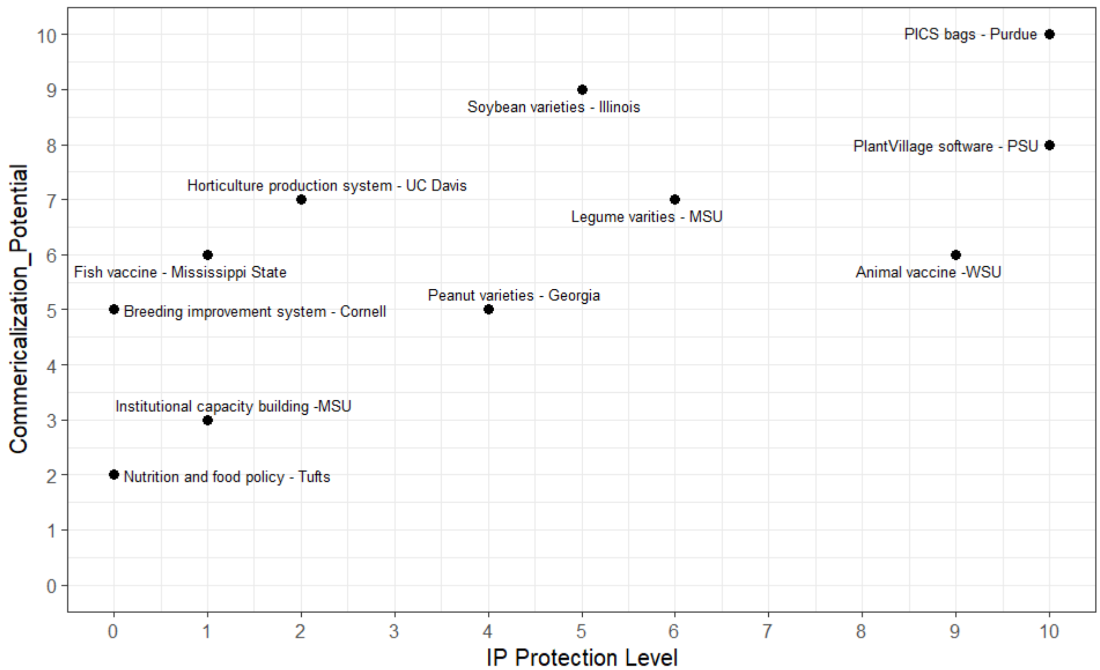

Figure 5. Plot of IP protection strength against commercialization potential score.

4.6 CONCLUSIONS

These ILs, which this research project has interviewed, focus on a range of innovations, including all three categories of technology classification: plant and animal improvement (crop varieties and animal vaccines), production systems research (information system and database), and social science and public policy research (food and nutritional policy). The levels of IP protection vary, with some innovations having high protection through patents and trademarks, while others have no protection, committing to becoming public goods. The phase of development and commercialization potential indicates the progress and maturity of the innovations, with higher scores indicating more advanced stages of commercial development and possibility.

The relationship between IP protection level and current commercialization progress. Indicate that novel technologies or practices, which do not have a high level of IP protection but with high commercialization value, could be the ideal candidates for technological transfer as they are not constrained by the IP management system, such as the horticultural production system, fish vaccines and breeding technology assistance system. Also, the soybean and legume varieties, which are scored 5-6 in the IP protection, have great potential in technology transfer initiatives as they use exclusive or semi-exclusive licenses to manage their inventions. Therefore, if they could find appropriate private sector partners within the target region of agricultural development, a license system will help with both smooth transition of IP and protect the rights of local users and manufacturers (Figure 5).

In the meantime, some technologies or practices that have high commercial potential also exercise stringent IP protection measures, such as PICS bags, animal vaccines and PlantVillage software. Implementation of these technologies often can greatly increase the productivity of local agricultural systems. Despite the existence of current IP barrier, it is surprising that these IL's commercialization progress is not hindered by the patent or trademarks they have. On the contrary, by establishing the high-quality public-private international-local partnership, the application of these innovations has withstood the operational test and produced positive results through the effective transfer and their cooperative mode with local companies (Figure 5).

The biggest controversy about IP protection in international development organizations is free access versus proper IP management, which is existing in the interview and analysis results of this research. The ILs who believe in public welfare theory think that their innovations should be publicly available. Therefore, they tend to not register any forms of IP. The advantages of leaving the innovations in the public domain include promoting the technology use, removing the IP barriers, and making sure that the invention can be equally distributed for the purpose of public good. However, according to our research result, innovations without proper IP protection often encounter problems such as IP theft, IP abuse, reselling of IP, and no economic incentives for local businesses to be involved. Therefore, a licensing permit or at least a formal written agreement might be necessary to restrict the misuse of these IP, which could also help with the commercialization and dissemination of the technology.

On the other hand, stringent IP protection is helpful to establish mutually beneficial business partnerships because of profitability by filing the patent, trademark, or copyright. In the meanwhile, such cooperation will promote the holistic development of local agriculture, and distribution of innovation. Nonetheless, excessive IP protection might fail to achieve the mission of international agricultural development and sustainability due to the high bar of qualification as partners. Moreover, it will add more burdens to the local people economically.

As discussed in the tragedy of the commons, complete market behavior or full government regulation will have negative implications on social justice. In this question of IP management, technology transfer and commercialization, it is possible to find a middle ground as Ostrom did in the environmental conservations (Hardin 1968; Ostrom 1990), which will balance the need for innovation as a public good to boost sustainable development, and the incentives for establishing efficient local partnerships.

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APPENDIX

Appendix 1: Guidance on counting technologies, practices, and approaches by phase of research. This document is adapted from EG.3.2-7 Feed the Future 2023 Update, USAID Bureau for Resilience, Environment, and Food Security.

CATEGORY OF RESEARCH	PHASE OF RESEARCH	TYPE OF TECHNOLOGY, PRACTICE OR APPROACH	WHAT TO COUNT
Plant and Animal Improvement	**Phase I: Under research**	Novel gene with known major effect(s) on specific traits.	Each unique gene or genetic element identified that controls the expression of a specific major function in the plant or animal.
		Transgene or genetic element for improved trait	Each unique transgene or genetic element with a known function in the plant system.
		Tissue-specific gene promoter identified and validated	Each gene promoter with its own unique sequence and function in the plant or animal (but see note below under transformation-ready gene constructs).
		Molecular genetic marker linked to genes controlling specific traits	Each molecular marker identified and linked to a particular gene with a major effect that is related to a specific function/trait (but see note below under transformation-ready gene constructs).
		Transformation-ready gene constructs	Each gene construct capable of being used in transformation can be counted as a separate technology. Note: If a gene and/or promoter are included in a construct for transformation, they should not also be counted separately.
		Quantitative trait locus (QTL) for major effects identified and validated	Mapped and/or phenotyped for desired trait. Each QTL in a specific position on the linkage group and related to a specific trait can be counted as a separate technology. Used in association mapping studies.
		Panel of genes or markers used in association studies	Each single-nucleotide polymorphism (SNP) panel used in association mapping studies.

		Phenotyping and crossing block population	Population of lines or breeds with improved traits to be used in phenotyping and large crossing blocks. Counts are the number of populations (not lines) for further genetic/breeding studies under Phase I.
		Research line with improved trait (introgression, self-pollinate (SP), recombinant inbred line (RIL), and Near Isogenic Line (NIL))	Lines for research: Introgression lines, lines of SP crops, RIL, and NIL with desired specific genes/QTLs/marker loci/traits incorporated in a background phenotype. Includes Multi-Parent Selection (MPS) and mapping populations. The improved trait, the genetic control of the trait, and the genetic background of the lines are important points to consider in counting lines. A group of lines identified for the same trait with the same genetic system and derived from the same parents should be taken as one technology. However, lines identified for a different trait from the same population may be counted as separate technology for further genetic/breeding studies under Phase I.
		Plant line for gene pyramiding	Each group of lines containing the unique gene for pyramiding.
		Inbred, doubled haploid lines (DHLs), hybrid lines with desired traits	Breeding populations: DHLs, inbred lines (hybrid parents), and hybrids with desired traits. This is the last step of Phase I. A group of DHLs identified for the same trait with the same genetic system and derived from the same bi- parents should be taken as one technology. However, DHLs identified for a different trait from the same population should be counted as separate technology. Each inbred line or hybrid with its own features can be counted as a separate technology.
		Plant germplasm accession with specific trait	Each accession identified as a source of gene(s) for a specific

			trait, (e.g., heat, drought, growth, and disease tolerance).
		Animal germplasm accession	Each accession identified as a source of gene(s) for a specific trait (e.g., heat tolerance, disease resistance, and productivity).
		Transgenic line with improved trait	Each transgenic line with its own desirable attribute for further use. Note: Distinct events with the same construct in the same background material do not constitute multiple technologies. Count each construct in a particular background (not each event) as ready for field testing. Last step of Phase I.
		Animal line with specific trait as sources of genes	Count each line with desirable attributes for further use (e.g., heat tolerance and disease resistance and productivity).
	Phase II: Under field testing	Conventional plant genotype or line under field testing	Each new and superior genotype or line over the standard check for a specific trait with field performance data under end-user conditions.
		Breeds or lines with improved traits under field testing	Each new and improved line over the standard check for a specific trait with field performance data under end-user conditions.
		Transgenic line under field testing	Each new and improved transgenic line over the standard check for a specific trait with field performance data under end-user conditions.
		Conventional variety submitted for regulatory approval	Improved conventional variety for which regulatory approval or certification is actively being sought so that it may be commercially released. Last step of Phase II.
		Transgenic variety or breed submitted for regulatory approval	Improved transgenic variety for which regulatory approval or certification is actively being sought so that it may be commercially released. Last step of Phase II.
	Phase III: Made available for uptake	Varieties, cultivars, lines, and breeds	Each variety, improved line, or breed made available for dissemination during the reporting

			year may be counted as a separate technology. To be considered Phase III, the technology must have passed all approvals (e.g., variety registration, certification, and biosafety approvals) such that intermediaries and end-users (e.g., service/input providers and farmers) are able to disseminate or use them legally.
	Phase IV: Demonstrated uptake by the public and/or private sector	Varieties, cultivars, lines, and breeds	Demonstrated uptake includes any support for, or adoption by, the public and/or private sector at any point during the reporting period. Examples include procurement or accessing sources of non-USAID financial support provided through public, private, or public-private agreements (i.e., non-revenue monies from non-donor sources) to disseminate the technology, including—but not limited to—private investments, grants, loans, funds, or government bonds; market introduction; or delivery via public and/or private sectors, such as by agricultural extension agents. This does not include utilization by end-users (i.e., individual customers or farmers) or by donor organizations (i.e., USAID Missions).
Production Systems Research Production	**Phase I: Under research**	N/A	Includes identification of appropriate candidate practices and system components and significant improvements in existing practices, working under idealized conditions.
	Phase II: Under field testing	N/A	New/improved system components or management practices in field testing under end-user conditions.
	Phase III: Made available for uptake	N/A	New/improved system component or formal recommendations ready for dissemination to farmers, including guidance for where the practice is appropriate and other conditions for use. To be considered Phase III, the

			new/improved system component must have passed all required regulatory approvals such that end-users (e.g., service/input providers and farmers) are able to use them legally.
	Phase IV: Demonstrated uptake by the public and/or private sector	N/A	Demonstrated uptake includes any support for, or adoption by, the public and/or private sectors at any point during the reporting period. Examples include institutionalization/incorporation into a host country government's national or subnational guidelines, policies, or other legal frameworks; market introduction; or delivery via public and/or private sectors, such as by agricultural extension agents. This does not include utilization by end-users (i.e., individual customers or farmers) or by donor organizations (i.e., USAID Missions).
Social Science Research	**Phase I: Under research**	N/A	Theoretical, efficacy, or secondary data social science research finding on an innovative approach for use by other researchers. Examples of theoretical research on a specific innovation include a paper outlining the potential positive impacts of smart subsidies on fertilizer take-up or how integrating subsidized index insurance into public safety net programs can increase resilience more cost-effectively than alternatives. Basic research on poverty dynamics or determinants of food security would not be included in Phase I.
	Phase II: Field testing	N/A	Count each approach undergoing an RCT or experimental/quasi-experimental pilot for testing effectiveness or causal impact of the approach. Only the first field test of any given approach should be counted.

	Phase III: Made available for uptake	N/A	Social science research finding on an approach or innovation available for uptake by development programs and the public and private sector. Examples include policy guidelines or recommendations, a formal training with training materials, or evidence-based toolkits. Only the first such instance will be counted per approach or innovation.
	Phase IV: Demonstrated uptake by the public and/or private sector	N/A	Demonstrated uptake includes any support for, or adoption by, the public and/or private sectors at any point during the reporting period. Examples include incorporation/institutionalization into a host country government's national or subnational guidelines, policies, or other legal frameworks; or delivery via public and/or private sectors, such as by agricultural extension agents. This does not include utilization by end-users (i.e., individual customers or farmers) or by donor organizations (i.e., USAID Missions).