Microorganism-Based Innovation Process: Agricultural Bio-Inputs in Cambodia

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Abbreviations and Acronyms

AC	Agricultural Cooperative
ADG	Agile Development Group
ALiSEA	Agroecology Learning Alliance in South-East Asia
ASSET	Agroecology and Safe Food System Transitions
AVSF	Agronome et Vétérinaires Sans Frontières
BoD	Board Of Director
CA	Conservative Agriculture
Cam-GAP	Cambodia-Good Agricultural Practices
CARDI	Cambodian Agricultural Research and Development Institute
CASIC	Cambodia Conservation Agriculture and Sustainable Intensification Consortium
CF	Contract Farming
CIRD	Cambodia Institute for Research and Rural Development
COrAA	Cambodian Organic Agriculture Association
DCA	DanChurchAid in Cambodia
DALRM	Department of Agricultural Land Resources Management
EU	European Union
FAEC	Federation of Farmer Associations Promoting Family Agricultural Enterprise in Cambodia
FGD	Focus Group Discussion
FNN	Farmer and Nature Net
GAP	Good Agricultural Practice
GDA	General Directorate of Agriculture
ITC	Institute of Technology of Cambodia
Kg	Kilogram
L	Liter
MAFF	Ministry of Agriculture, Forestry and Fisheries
NKA	Neary Khmer Association
NSDP	National Strategic Development Plans
PMUAC	Preah Vihear Mean Chey Union of Agricultural Cooperatives
R&D	Research and Development
RUA	Royal University of Agriculture
SEDP	Socio Economic Development Plan
SSLA	Sustainable Soil for Life Association (SSLA)
NUBB	National University of Battambang
USD	US Dollar

Executive Summary

This report provides an overview of the current state of bio-inputs in Cambodia, as well as some insights from innovation perspectives. It is primarily to evaluate the current state of the bio-inputs in Cambodia, identify key challenges and opportunities, and propose future pathways for sustainable agricultural development.

We have gathered insights from surveys and forums, engaging stakeholders including Non-Governmental Organizations (NGOs), agricultural cooperatives (ACs), researchers, enterprises, and farmers to focus on technical aspects, value chains, and policy support. The overarching aim is to contribute for agroecological transition from chemical to natural and safe agricultural production. By identifying barriers, current statuses, and desired futures, we have crafted action plans for the next five years to realize these goals.

Our empirical data, including forum discussions and surveys, reveal that unclear policies and limited production factors severely constrain biotechnological research and technologies in Cambodia. This leads to low demand and perpetuates a cycle of underdevelopment and under-innovation in bio-inputs. As quality and effectiveness of the bio-inputs are critical for farmers, one of the ways to improve its quality for agriculture is to foster research and development activities that involve local producers, agricultural communities, researchers, and private companies. These actors can collaborate to identify the best sources of biological inputs, including imported products, and to facilitate their trade and distribution. By promoting the commercial production and use of agricultural biological inputs, they can also contribute to the sustainability and productivity of the agricultural sector.

Stakeholders aim to break this cycle by focusing on various aspects. Farmers prioritize cost reduction and market access, NGOs emphasize certification, research, development, and awareness-raising, while enterprises seek favorable policies and practical business models. Institutions focus on infrastructure development and awareness-raising.

These efforts translate into pathways that initiate from the demand side to trigger the supply side. This entails raising consumer and farmer awareness, followed by entering high-value or modern markets practical for farmers. Leveraging traditional knowledge alongside modern technologies like Trichoderma shows promise, as seen in successful business models commercializing bio-inputs.

A possible way to address these challenges is to involve external expertise in the design and implementation of experiments that can test and validate new practices of innovative bio-inputs. These experts can include researchers, suppliers, facilitators, or other actors who can provide technical assistance, financial resources, or institutional support for the experiments. By engaging these experts, the farmers can access more information and guidance, as well as benefit from more favorable conditions (such as funding, mandates, or exemptions) that can facilitate the adoption and innovation of bio-inputs.

Through the forums with key actors and stakeholders, we have secured experimental spaces to enhance product effectiveness. This planning process reflects stakeholders' dedication to agricultural input innovation. Researchers and NGOs have called for more clarity and coherence in the policy frameworks that govern the bio-input sector, as well as more incentives and support for the producers and users of these products.

In conclusion, this research underscores the critical role of planning, where stakeholders are poised to act through existing platforms and connections. With committed human resources at national and international levels, scaling up further is feasible. This progress is due to well-planned projects and free technology initiatives, highlighting the potential for innovative research.

Introduction

Agroecological transition is a process of transforming agricultural systems to enhance their sustainability, resilience, and productivity, while minimizing their negative impacts on the environment and society [1]. Agricultural systems depended on internal resources, recycling of organic matter, built-in biological control mechanisms, and rainfall patterns to provide essential ecosystem services, such as nutrient cycling, pest control, soil health, and water regulation [2]. According to Côte et al. 2022 [3], bio-technical levers for agroecological transition of tropical agriculture was identified as necessary for mobilizing complementarity among crop species to optimize natural resource use. In other word, agroecological transition in Cambodia could easily shift to affordable non-chemical inputs by leveraging the biodiversity in the tropical region. This agricultural bio-inputs such as compost, biofertilizers, biopesticides, and inoculants could alternatively improve soil fertility, crop quality, and yield while reducing the dependence on synthetic chemicals and potentially achieving sustainable agricultural development and building new agro-industrial capacities for sustained agro-industrial growth [4].

In the last 5 decades, Cambodia agriculture has transitioned from a low input-farming system to more intensified agriculture, but AE is momentum. In the Khmer Rouge regime in 1970s, collective farming and nature-based agricultural production focusing on rice paddy production were promoted. After the regime collapsed in 1979, farmers continued to practice low-input farming, using local seeds, animal manure, and traditional knowledge. In the last 15 years, there have been different efforts to promote AE among smallholder farmers, including the promotion of bio-inputs. For instance, many of the development projects including the governmental projects such AIMS[1], ASPIRE[2], and CASDP[3] supporting the farmers to access to the agricultural bio-input production and applications [5]. However, the sustainable practices usually remained constrained by different factors such mineral fertilizer, lack of technologies, climate change and variability remained neglect by either producer especially smallholder farmers [6]. According to the second regional workshop of CASIC in 2021, ongoing research, along with the refinement and development of appropriate for bio-products, remains a top priority.

Different literatures emphasize on the needs for the concerted efforts among the different stakeholders in commercializing of agricultural bio-inputs giving access to smallholder farmers toward the agroecological transition[7][8]. However, these stakeholders hardly know each other. In addition, these innovations have not been adequately documented or made visible to current and potential initiatives. There is a lack of systematic data and evidence on the performance, benefits, and challenges of agroecological systems in Cambodia, which hinders their scaling up and adoption by other farmers and stakeholders. Moreover, there is a need for more awareness, capacity building, and policy support for agroecology through access to appropriate inputs including bio-inputs, as well as stronger collaboration and coordination among different actors, such as the government, the private sector, the civil society, the research institutions, and the development partners.

This study aims to characterize and analyze the agricultural bio-input innovation based on micro-organisms in Cambodia, to identify the main locks and levers; and pathways to scale up the production and application.

[1] AIMS - Accelerating Inclusive Markets for Smallholders
[2] ASPIRE - Agriculture Services Programme for Innovation Resilience and Extension
[3] CASDP - Cambodia Agricultural Sector Diversification Project

Methodology

To have a comprehensive understanding of how various elements interact and collectively influence the innovation process, this study was inspired by various research methods such as i) exploring the emergence trajectory in terms of the macro-institutional variables that govern it; ii) using a characterization approach for the stakeholder system involved in this process at different phases; iii) an ex-ante evaluation of the impacts. This approach is summarized in the following figure.

The approach relies in a conceptual basis that combine the ‘spiral of innovation”, which describing and evaluating the stages of which the innovation was and the Impress approach which consolidating the findings and continuing to analyze in participatory manner about the pathway of the future development of bio-inputs in Cambodia.

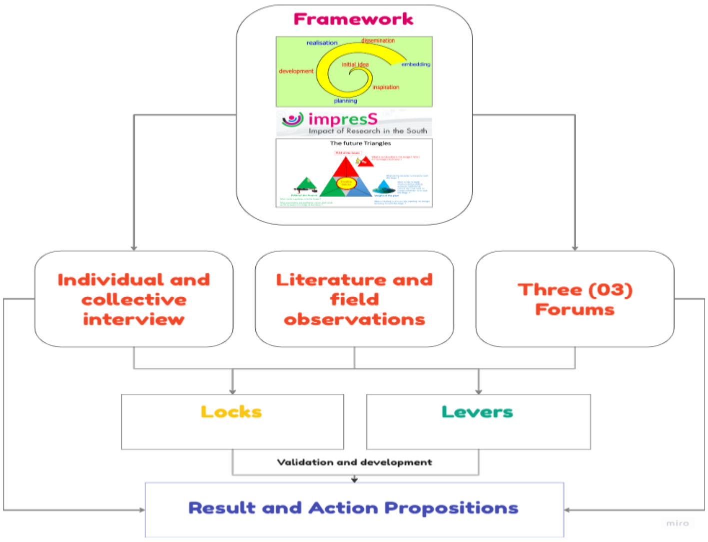

Figure 1: Conceptual frameworks employed in the study.

First of all, we conducted a comprehensive review of the literatures regarding the production and application of bio-inputs and microbial knowledge in Cambodia, with a focus on rice production. We review both national and international literature on scientific and technical knowledge based on existing innovations. This collection of articles and reports then was shared and used a basis of discussion with identified stakeholders as the preliminary findings of bio-input innovation process in Cambodia. The aim is to reduce the knowledge asymmetry within the community of practice concerning the application of microorganism knowledge for innovation for agricultural sector.

We then mobilized an approach to characterize the key stakeholder system (Stakeholder analysis) involved in the different phases of the innovation process of bio-input. The approach involved identifying, describing, and analyzing the roles, interests, and interactions of various stakeholders (Table 1) at each stage of the bio-input innovation process. In addition, inspired by “Spiral of Innovation” approach (Figure 1), we also investigated the trajectory of emergence and development of bio-input from the inception to various stages of innovation process.

As part of the stakeholder analysis framework, we collected data in 2 provinces (Takeo and Kampong Chhnang): this included field observations, online and face-to-face survey to collect qualitative and quantitative data with main actors of agricultural bio-input innovation process (Table 2). Specifically, we explored main locks and levers at different contexts including the production of agricultural bio-inputs, adoption and application, interactions among actors in the system, and evaluation of agricultural bio-inputs among those actors. Actors interviewed included 10 farmers, 9 people from NGOs, 4 people from farmer organizations, 7 people from enterprises, 6 international researchers, 7 national researchers and 4 people from public institution (Table 2) and the questionnaire is presented in Annex 4.

This study also adopted some parts of ImpresS ex ante framework (Blundo Canto and De Romemont, 2020; http://impress-impact-recherche.cirad.fr)[1]. Within this approach framework, we prepared two (02) case studies on agricultural bio-input production for self-consumption and commercialized orientation of Bokashi where we also used value chain analysis to understand the levers and locks of the innovation process. With a better understanding the status of emergence trajectory of bio-input development from both literature review and stakeholder analysis approach (Figure 1), we also used "Future Thinking for Transforming" [2], developed by the futurist Sohail Inayatullah in the last forum, for facilitating a strategic planning and intervention to support the growth and impact of innovations. We conducted dialogue with key actors about the innovation process and its hypothetical impacts in two separated forums; and lastly the research team also organized a participatory-analysis and validation workshop with the same key actors invited in the previous forum (Table 3). With this, collective analysis of the status and knowledge to generate collective actions/pathways potentially being for scaling up of agricultural bio-input development toward Agroecological transition in the medium term of 5 years were developed. All the forums conducted at graduate school of Royal University of Agriculture (RUA).

Table 1: Key actors and their roles

	Major Actors	**Influential Actors**	**Impacted Actors**
Actors	Farmers Enterprises ACs	Public institution NGOs - Project Implementers Researcher (national and international)	Farmers Enterprises ACs
Roles	Production Application Commercialization Training participants Feedback	Implementing the scientific research Initiating the innovations	Production Application Training participants Feedback

Table 2: Actor categories interviewed.

Type of Actors	**Description of Institutions**
Farmers	Takeo; Kampong Chhnang
Cooperatives	TrUAC; Cheab Santepheap Neary Klahan AC; Krang Lavea AC; Preah Vihear Meanchey Union Agricultural Cooperative
Enterprises	Cambodian Organic Agriculture Association (COrAA); HUSK Ventures JUNLEN; Bayon Heritage; EM enterprise; Smart Agro
Researchers	ECOLAND; CESAIN; Faculty of Engineering and Bio resources, RUA; Faculty of Agriculture and Food Processing, University of Battambang; Division of Research and Extension (DRE), RUA; Cambodian Agricultural Research and Development Institute (CARDI); Faculty of Agronomy, RUA
Public institutes	MAFF/GDA; DALRM/GDA
NGOs	GRET; CIRAD; Farmer and Nature Net (FNN); Agronomes et Veterinaries Sans Frontieres (AVSF); Uni4Coop; HEKS; GIZ; SSLA; DCA

Table 3: Series of forums conducted during the study.

No	Forum Description	Date	# of Actors	Main approach
1st & 2nd	Validated narrative of the innovation, findings for broaden knowledge and dissemination	8th Sep 2023 15 Sep 2023	17 people 16 people	Presentation of Microorganism-based Innovations in Cambodia. Exercise: Hope-Fear-Surprise (Agri. Bio-Input)
3rd	Build a practical connection in the area of bio-input innovation process and collaborative action.	17th Nov 2023	19 people	Presentation of bio-input initiatives process in Cambodia Exercise: Tringles of the Future (Agri. Bio-Input)

Main Results

1. Characterization of Agricultural Bio-Inputs in Cambodia

1.1 Types of the bio-input production and application in the studied areas

According to Cambodia's law on the management of pesticides and fertilizers [9], biological fertilizer refers to fertilizer that contains active biological substances as microorganisms that could fix and stimulate any existing nutrients in the atmosphere or soil; or stimulate the decomposition of organic materials and plant or animal residues, to produce the nutrients for plant or crop growth. Agricultural bio-inputs combines organic materials and organic micro-organisms; the most common organic materials used are animal manure (especially from cow, pig and chicken), crops or crop residue (such as Azula, water hyacinth, neem leaf, chili, vine, etc.) while effective micro-organism (EM) are used as the sources of the microorganism. The bio-inputs have been used in Cambodian agriculture with a long time based on existing knowledge and practices, low costs of production, and market requirement.

Based on the field observation, case studies, and interviews, different types of agricultural bio-inputs have been currently produced and used in the studied areas (

Table 4). The diversity of bio-inputs depended on the farming systems, whether rice-based, crop-based, or livestock-based. horticulture mobilized the widest range of bio-inputs. Most of them were natural and/or microorganism-based fertilizers and pesticides for vegetable and rice paddy crops, which are the main production of most small-scale farmers. Farmers typically reported that natural and chemical fertilizers were used in tandem for paddy rice production. Nonetheless, chemical inputs continued to play a significant role in crop production. Natural fertilizers, such as dry compost and animal manure, were primarily applied during land preparation, while chemical fertilizers were utilized during the growth stages of the rice.

Table 4: Different types of bio-agricultural inputs in the studied areas

Types of Bio-Inputs	Descriptions	Photo from Fields
Dry Compost	Common practice using the animal manure and other waste (such as animal manure, kitchen waste, rice husk, water, crop residue, and others) mixing to decompose either anaerobic or aerobic conditions before ready for soil fertility improvement. The materials are placed as layers, watering and storing for at least 3 months.	
Dry animal manure	Livestock manure collected and dried at home commonly from cows, chicken and pig. Some chicken farms also pack and sell to producers.	
Liquid Compost	The liquid form of compost is produced from mixture of organic wastes from green leaves and animal manure. Water composition is high which decomposing for at least 3 weeks with frequent stirring. Dilution is usually required before use.	
Bio-Slurry	This fertilizer is collected from bio-gas system after energy/gas production. It is commonly used in liquid form and directly applied to fields or crops.	
Bokashi	Bokashi fertilizer is a mixture of different organic materials and microorganisms. Unlike dry compost, bokashi fertilizer uses good and nutrient rich materials like rice husk, rice bran, rice husk charcoal, grounded green leaves, dried animal manure, termite mount, crude sugar, and etc.	
Liquid Fertilizer	Liquide form of compost and/or bio-pesticide produced by mainly specific ingredients and crops with strong smell and/or tastes such as neem leave, chili, herb and etc. Dilution is usually required before use.	

Types of Bio-Inputs	Descriptions	Photo from Fields
Natural Pesticide	Mixing of specific neem leaves, chili, herb and etc. Dilution with cleaning detergent is usually required before use.	
EM	Effective Microorganism is a good microorganism used in soil health improvement. EM was produced by mixing cooked rice, crude sugar (palm or sugarcane) and then storing under cold ground.	
SBN	A type of liquid fertilizer with a specific formula including high composition of ripened fruits, sugar and protein-rich materials like egg, fish, and other crops.	
Trichoderma	Trichoderma is a green fungus naturally living in the soil. It is one type of Biological Control Agent (BCA) which is a natural organism that is used to fight pests.	(Not Available)
Vermicompos t	Vermicomposting is an innovative technique that uses earthworms to transform various organic materials (such animal and crop wastes) into refined compost.[1]	

1.2 Actors and functions in bio-input production and application

Of the different actors engaged includes:

1. Farmers: Engage in the utilization of agricultural bio-inputs but face limitations in their production capacity.
2. Agricultural Cooperatives (ACs): Play a crucial role as facilitators in the production, distribution, and application of agricultural bio-inputs.
3. NGOs or Enterprises: Collaborate closely with ACs in promoting the production and application of agricultural bio-inputs.
4. Companies: Supply semi-finished bio-inputs, finished products, and non-biological complementary inputs to meet the needs of farmers.
5. Researchers: Likely to focus on specific types of agricultural bio-inputs which are potentially scalable.

Data received from field observations and farmer interviews suggested that there was a limited variety and quantity of bio-inputs being utilized in the studied areas. Based on the production system, the agricultural bio-input were mainly needed in either self-consumption, safe-production producer groups, and contract-farming context. Accordingly, farmers mentioned they were able to save on the costs of fertilizers by using compost made mainly from cow and chicken manure and other organic matters. However, small number of farmers still raising the cow or chicken in their system, while the rest of the farmers were more likely had only chemical fertilizer option to maintain or increase the crop yields. However, even farmers could produce some composts based on different context mentioned here, they still applied chemical fertilizers and pesticide at different stages of the rice cycle.

Farmers and companies shared similar interests in biological inputs. Overall, farmers' production of bio-inputs was insufficient to meet their demand, forcing them to rely on companies for semi-finished bio-inputs (like EM and Trichoderma), finished products (such as vermicompost and bokashi), and non-biological complementary inputs.

ACs were key facilitators in production and application of these sustainable inputs through collaborating closely with NGOs or enterprises. For instance, through different activities for establishing the producer groups – such as the organic production groups facilitated by FNN and UNI4COOP, Tramkak Union of Agricultural Cooperatives (TrUAC) mobilized farmers to save, produce and utilize natural fertilizers and other alternative ecological practices to improve their soil health and fighting against different pests in rice paddy and horticulture productions.

NGOs were actively involved in promoting agroecological practices among farmers, with a specific focus on production and use of bio-inputs. Danchurch Aid in Cambodia (DCA), for instance, provided training on bio-input related topics to 136 farmers in Battambang and other provinces leading to practices adoption. DCA also supported local NGOs such as SSLA, FNN, Banteay Srey and others to promote agroecology to approximately 1,500 farmers. While they themselves did not produce any products, they advocated for the adoption of these practices as a way to limit chemical input use, notably using rice husk charcoal and. They reported that farmers were generally hesitant initially due to the additional cost of liquid bio-inputs, but over the last three years, there had observed a growing understanding and willingness to invest in these alternatives. While vegetables were the main destination of bio-inputs, they mentioned that some farmers were experimenting with bio-inputs (biofertilizers) with fruit and chili production. Application of agricultural bio-inputs for rice crops was reportedly limited.

While self-consumption is the main driving force for the dissemination of organic practices, market demand remained low. Consequently, some NGOs and private companies are working to improve this organic and safe production value chain through promoting the sustainable practices in farming and connecting farmer's products to the market such as direct marketing of SSLA's target area, organic paddy rice contractual arrangement facilitated by FNN for instance. These organization also have been working to increase production capacity and improve technical aspects of the bio-inputs and its application such as spray application, with the use of drones proving convenient in some areas like Preah Vihear. In Preah Vihear, according to Preah Vihear Mean Chey union of agricultural cooperatives (PMUAC) coordinating the contractual arrangement of organic rice, activities have included the production of compost, green manure, and cover crops, aimed at soil quality preservation, with positive results observed through demonstration and extension services to farmers. Collaboration with organizations like ECOCERT has also been instrumental in evaluating and certifying bio-inputs and organic standards of paddy rice for export.

Based on key informant interview with main actors, farmers mostly relied on traditional knowledge and nature-based bio-inputs such as compost and bio-pesticide. The researchers, on the other hand, tended to focus on new technologies that were not necessarily widely adopted by the farmers or private sector, such as solid/liquid compost and natural pesticides made from biogas, plant waste and Trichoderma. Research appears to be focused on dry/liquid compost, natural pesticides, biogas plant waste, and Trichoderma, with less emphasis on Bokashi or EM.

2. Development and Policy Frameworks of Bio-Input Production and Application

2.1 Historical chronogram of bio-input innovation

For agricultural development of Cambodia, it is necessary to look at the changes operated since the fall of Khmer Rouge regime, (7th Jan 1979). Since that time (Figure 2), agriculture has played an important role in food security and economic development of Cambodia as defined it in the SEDP II[4] and later national strategic development plan (NSDP) Agriculture has thus contributed to 3.5% growth per annum.

During Khmer Rouge[5] regime, only local and natural inputs were used for the fertilization as no chemical inputs were available. It remains the same for some years afterward. While consumption by hectare was comparable with all neighboring countries in 1979, the consumption has remained significantly lower than Thailand and Vietnam. According to World Bank data, in 2008 it was estimated that fertilizer consumption was d around 9.9 kilograms per hectare of arable land in 2008[3]. It was thus lower than that of the neighboring countries from 1979-2021 except Lao PDR as Thailand and Vietnamese agriculture were intensified during the 80's and 90's.

There had never been any regulation on the use of fertilizer and pesticide in Cambodia, even before the Khmer Rouge regime, until 1998, when the first regulation on the standards and management of agricultural inputs was issued (Figure 3). Yet, this legislation more specifically focused on enhancing agriculture's contribution to national growth, regulate agricultural inputs to ensure efficacy and safety in line with national and international standards, raise public awareness about agricultural input usage, prevent pesticide-related risks, and ensure food security and safety for public health and the environment. No effective enforcement mechanism was included in this regulation.

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[4] The Socio-Economic Development Plan II (SEDP II) in Cambodia was a government-led initiative implemented between 2001 and 2005. It was designed to build on the successes of the first SEDP (1996–2000) and aimed to improve Cambodia's overall economic and social conditions in a post-conflict era.

[5] Officially known as Democratic Kampuchea (1975-1979)

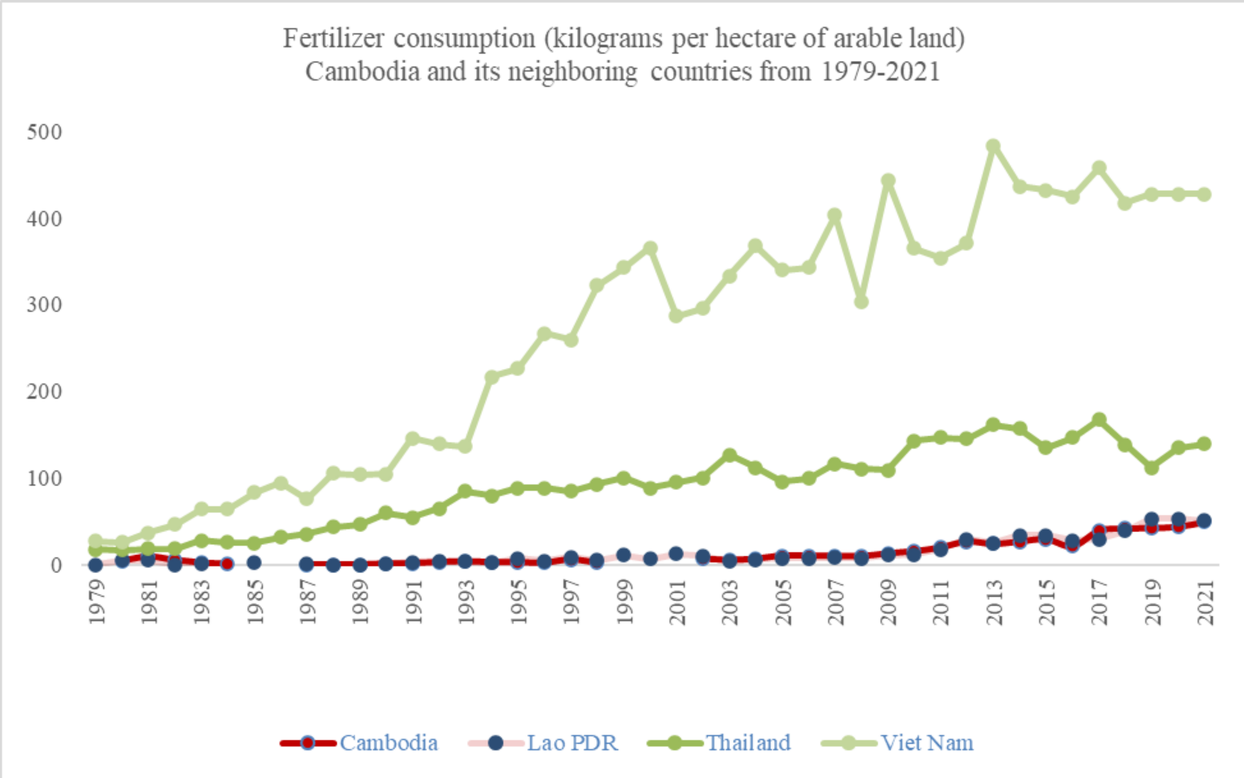

Figure 2: Fertilizer consumption (kilogram per hectare of arable land) in Cambodia.

In recent decades, Cambodia has adopted various legal and practical measures to support agroecology and reduce harmful chemicals, such as: national strategic development plan (2003), law on pesticide and fertilizer (2012), national policy on green growth (2013). By realizing the importance contribution of agricultural development after implementation of Socioeconomic Development Plan (SEDP-I and SEDP-II) with a primary focus on stabilizing Cambodian society, National Strategic Development Plans (NSDP) were developed and passed by emphasizing on the agricultural intensification and exports. For example, the paddy production and rice export policy were introduced in 2010, followed by the laws on contract farming in 2011, pesticide and fertilizer regulations in 2012, and agricultural cooperatives in 2013, all of these have been implementing at the moment to boost agricultural development. As these strategies focused on improving the agricultural productivity their implementation was associated with an increase of chemical input use and improved seeds for various productions including paddy rice (Figure 3).

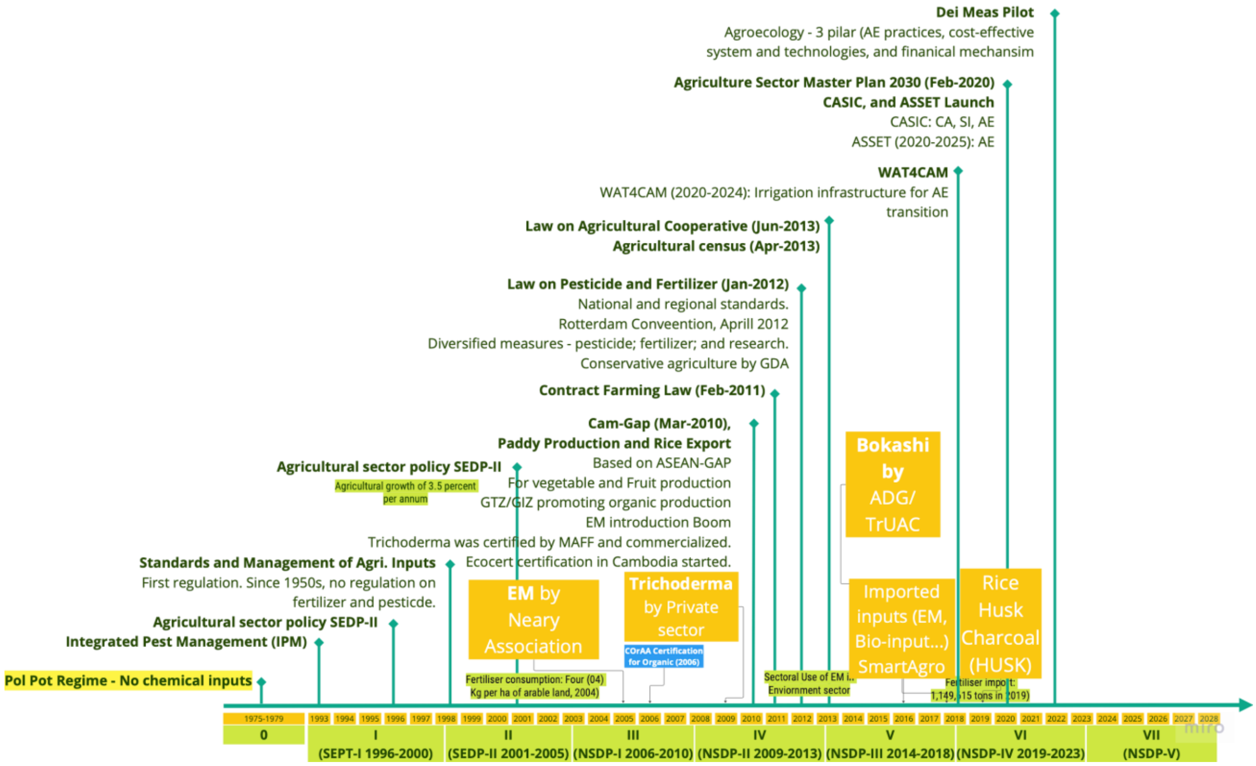

Figure 3: Historical chronogram of bio-input innovations in Cambodia.

In parallel with this intensification strategy aiming at achieving food security for domestic consumption, some concern over the sustainability of agricultural and food systems emerged as early as in the early 2000. Different concepts and initiatives on conservative agriculture (CA) and agroecology have thus been developed in the last 20 years: in 2004, for example, the General Directorate of Agriculture (GDA) of MAFF, introduced conservative conservation agriculture, focusing on innovative cropping systems and practices based on the principles of Conservation Agriculture (CA). a practice that minimizes soil disturbance and maintains soil cover. The approaches have been tested and disseminated through the years and has been scaled up nationwide in 2020 through Cambodia Conservation Agriculture and Sustainable Intensification Consortium (CASIC).

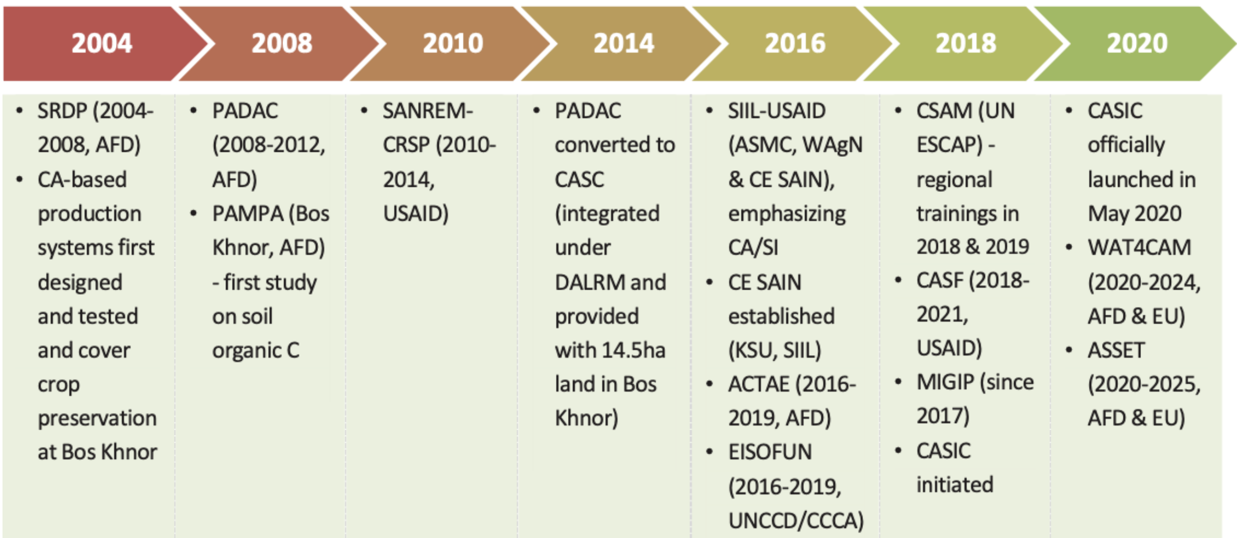

Figure 4: Timeline of CA development in Cambodia.

In 2006, The Cambodian Organic Agriculture Association (COrAA) was found to provide certification service to the domestic market demand for organic agricultural products to individual and/or group producers in Cambodia. COrAA is a nationwide alliance for the promotion of organic agriculture. COrAA aims to help farmers shift to organic farming, promote awareness of organic benefits, certify organic products, support their marketing, encourage research, and foster dialogue with stakeholders.

Trichoderma was first experimented with by researchers in 2009. It has been promoted by researchers, NGOs, and farmers for various crops including in rice paddy production, horticulture and fruit trees [6], [7], [8]. It was certified by MAFF for commercialization in 2011.

In 2010, a new framework, based on the ASEAN-GAP framework, Cambodian Good Agricultural Practices (Cam-GAP) was developed by MAFF. The Cam-GAP aimed to improve the quality and safety of vegetable and fruit production, as well as to enhance market access and competitiveness for farmers. Around the same time, GTZ/GIZ promoted EM technology for organic production in Cambodia focusing on the.

In 2012, the law on pesticide and fertilizer was enacted, providing the first legal framework for the regulation of pesticide and fertilizer in Cambodia. The law stipulated the national and regional standards for pesticide and fertilizer, as well as the procedures for registration, importation, distribution, storage, use and disposal. The law also aligned with the Rotterdam Convention, which Cambodia ratified in April 2012. The convention aims to promote shared responsibility and cooperation in the trade of hazardous chemicals. In addition to the legal measures, various initiatives were implemented to promote agroecology in Cambodia. During this time, Ecocert, an international organic certification body, started its operation in Cambodia.

In 2013, the first agricultural census reported that around 70 percent of households applied chemical fertilizers while around 50 percent of households used or prefer to use organic fertilizers. In 2010, the country launched a rice export policy which targeted the export of one million tons of rice in 2015. This strategy emphasized the importance of intensification of paddy production and thus use of chemical inputs for improving productivity.

In 2020, several projects were initiated to support agroecology and conservation agriculture (CA) in Cambodia. The Agroecology and Safe food System Transitions (ASSET) was a research project aiming to transform food and agricultural systems in Southeast Asia including Cambodia, Lao PDR and Vietnam into more sustainable, safer and inclusive systems, through harnessing the potential of Agroecology [9]. A part of the ASSET, Agroecology Learning Alliance in South-East Asia (ALiSEA) is a regional network aiming to facilitate knowledge sharing and collaboration among agroecology stakeholders in the region. The specific objective of ALiSEA is to strengthen knowledge and experience sharing among agroecological initiatives and actors; to increase visibility and credibility of agroecological movement towards policy makers and consumers; and to scale up the development and adoption of agroecological practice among farmers [10]. Cambodia Conservation Agriculture and Sustainable Intensification Consortium (CASIC) was a development project that aimed to strengthen coordination and support stakeholders in order to promote conservation agriculture and sustainable intensification in Cambodia towards agricultural modernization and agroecological transition [11].

2.2 Some selected projects engaging agricultural bio-input initiatives.

Among all the key actors, they had different interests in the production and promotion of bio-inputs. Based on the products of bio-input, different initiatives were introduced by NGOs, farmer organizations and public institutions. Enterprises were important for scaling up the production and application in the business model to improve the accessibility of the bio-input products.

Figure 5 illustrates different actors engaging in the different stages of the spiral of innovation of agricultural bio-inputs. GIZ, ADG/Uni4Coop, NKA and ACs promoting the various approach toward the sustainable development in agriculture and system through sustainable practices/inputs including organic production, EM and Bokashi. Later the efforts diffused well in the case of NKA for instance with a lot of training and trainees. At the same period, the governmental institutions also regulated and implemented some projects for the productivity intensification and sustainable agriculture such as standard and management of inputs, CamGAP, recognition of Trichoderma and rice export policy. Later, various local NGOs and AC seized the market opportunities for the safe or organic markets to improve farmer's standard of living with the services provided by the certification bodies like COrAA and Ecocert. With this inspiration, there were more interests from the other ACs and Farmers of different provinces to improve livelihood through intensification of productions or niche market of safe, chemical free, or organic markets. In this stage, the service and input suppliers, either NGOs or private sectors actively growth. Currently, different projects are aiming to scale-up smart agriculture and sustainable agriculture development, which planning, and research and development of the bio-inputs were observed among academia and private sectors.

Figure 5: Mapping of actor system currently involved agricultural bio-input initiatives.

3. Case Study of Bio-Input Value Chains

3.1 Homemade of bio-pesticide in Kampong Chhnang province

Cheab Santipheap Satrey Klahan agricultural cooperative located in Kampong Chhnang produced and suppled organic paddy rice and vegetables with the support of a local NGO, known as Farmer and Nature (FNN). The cooperative members have been using bio-inputs in production and application since the beginning of their career as farmers. Bio-inputs were used for organic vegetables and rice both for self-consumption and organic market in Kampong Chhnang and Phnom. One of the main products of the farmers was organic paddy rice production under contract farming practice with Amru Co., Ltd, a well-known private company of rice export in Cambodia. Besides, to response with the market of safe and organic production, with the governmental policy and net-houses were used for incorporation with different integrated pest management among the professional farmers.

Around thirty percent of organic paddy-rice producers in the agricultural cooperative purchased and used the organic fertilizer known as Coop organic fertilizer (Figure 6). As mentioned by the cooperative director, the rest of organic paddy-rice producers in the area only used animal manure and no chemical inputs in organic paddy-rice production. According to responsible FNN staff, one ha of paddy rice was fertilized with 8-10 bags of 25 kg of organic fertilizer at an average of 8.5$/bag. As indicated in the leaflet in Figure 5, this Coop organic fertilizer is certified by ECOCERT[6], thus being allowed in organic contractual arrangement.

Figure 6: Organic fertilizer products.

A vegetable farmer also produced on a small scale of bio-pesticide known as "Cholincy" for individual demand. According to the farmers, this bio-pesticide is based on microorganism for the

[6] Ecocert is an organic certification organization, founded in France in 1991. It is accredited by the French Accreditation Committee (COFRAC) and provides certification for over 150 standards in the food, farming, forestry, textiles, cosmetics and eco-products sectors worldwide.

fermentation processes which she learned this through the video in YouTube and self-practices. She used this pesticide for short-cycle vegetables (3 months). She reported the raw materials including water, fish sauces, seasoning and eggs. To produce it, she used a 50L-150L covered container to produce the product under anaerobic conditions. The main difficulties were the time and workforce required for collecting the necessary materials for the production. In this case, she usually collected once every 3 months and the bio-pesticide could be used after 2-week fermentation by diluting with fresh water before applying to the vegetables. Farmers had to be more active in identifying the material sources generally grown naturally in the villages.

Figure 7: Local plant "chromolaena odorata" commonly used for bio-inputs.

Farmers reported different challenges in producing and applying bio-pesticides (Figure 8). However, they concerned about the effort and time required to identify and collect the raw materials for the production. Basically, for the bio-input production, farmers reported different formulas with different raw materials depending on the it availabilities. These raw materials include plants with strong smell and tastes such as neem leaves or bark, herbs, banana truck, chilly, lemon grass, ginger and others which then mixing the helpful materials such as water, soap, seasoning and crude palm sugar. These raw materials are basically grown naturally in the wild or around the village and found locally.

Members mentioned that farmers in the past commonly used 2 local plants Azola and chromolaena odorata, in compost or as green manure both to improve soil health and plant growth and pest protection. It was also used to treat rice blast/bacterial leaf blight during the rice growth period. They also mentioned various plants and materials available locally and seasonally for production of bio-pesticide such as neem leaf, chili, palm sugar, etc.

Many were also skeptical about its effectiveness compared to chemical pesticides. Besides, they complained about the time needed to have visible effects and the need to combine it with mechanical pest control to optimize the effectiveness. This was a discouraging factor compared to chemical pesticides. While vegetable farmers thought it was effective in repelling harmful insects due to its smell and taste (Figure 9), it was not effective to fight worms such as nematode, an important issue.

Due to the perception of low effectiveness, local demand, in practice, was limited which affecting the scale of production remained low and the product was not commercialized. It must be said that self-production of natural or bio-inputs was also a requirement of organic certification as proof of safe/organic producers. The products were rarely shared among the farmers, even if most vegetables knew about it.

Figure 8: Organic vegetable producer showed microorganism culture in plastic containers used for the bio-pesticides with net house.

Figure 9: Bio-pesticides fermentation in plastic containers (left) and application (middle and right) in organic vegetable production

3.2 Commercialization of bokashi by Tram Kak Union of Agricultural Cooperatives in Takeo province

Tram Kak Union of Agricultural Cooperative (TrUAC), located in Takeo province is a union of agricultural cooperatives founded on 24th November 2021. It has four main businesses in producing and supplying (i) organic fertilizer (bokashi), (ii) animal feeds, (iii) rice seed (Phka Romduol variety), and (iv) chicken.

In 2016, the ADG (later on transforming to Uni4Coop), an international NGO/project introduced bokashi feedback from the farmers in application by improving plant and soil health, one of the cooperative Udom Sorya AC organized collective production and supplying it as an agricultural-input service to its members and non-members in 2017. It was later scaled up to commercialization in the same year. This also included improving the quality of the bokashi. Indeed, a bokashi sample produced by TrUAC was analyzed in 2017, which reported the following composition– N:1.1-P:7.35 - K:0.68. Thus, the produce was low in nutrients compared to chemical fertilizer[7]. Consequently, this required TrUAC to improve its product's quality. Different groups of researchers from academic institutions including RUA, Santapol (local private school offering bachelor's degree) and intern students from foreign countries were mobilized and developed to

[7] The most common DAP (Buffalo Head) in the study area reports its nutrients on its package (N:20 - P:15 - K:5).

assess[8] its effectiveness of the fertilizers. This allowed to provide an adjusted formula as shown in Table 5 by using the SBN[9] instead of EM.

Table 5: Original and adjusted formula of the TrUAC's bokashi.

No	Ingredients	Unit	Original	Adjusted	Remarks
1	Chicken manure	Kg	33.04	33.04	
2	Cow/pig manure	Kg	44.05	44.05	
3	Palm sugar	Kg	1.32	1.32	
4	Rice husk	Kg	1.32	1.32	
5	Rice bran charcoal	Kg	6.61	6.61	
6	Rice straw	Kg	1.32	0	Rice straw was mainly used for the cow feeds and presumably could be complemented.
7	Animal borne	Kg	1.32	1.32	
8	Termite nest	Kg	6.61	6.61	
9	Cow urine	L	3.96	3.96	
10	EM	L	0.44	0.44	SBN was used instead of EM.

TrUAC then asked the support from UNI4COOP to further improve the quality further in 2022. According to UNI4COOP, a project mobilizing the Faculty of Agronomy of Royal University of Agriculture (RUA) to improve its nutrient contents. However, the result of this effort was not yet available by the time of this study.

There also was a demand for pellets by the farmers as this would be easier for the application (throwing across the paddy fields). Udom Sorya AC thus invested in machinery to transform the Bokashi product into pellet as shown in Figure 10. The pellet production is follows the different stages: mixture of different materials in the shade (Table 1), which is then covered with plastic sheet for one month to facilitate the composting process for about one month. The product is then transformed into a pellet and packed in bags of 25kg based on the demand of rice producer (due to applicable reason to be easy to through across the paddy field).

Figure 10: Production of Bokashi at Udom Sorya AC.

[8] The reports were not available at the moment; The research team would reach out to Uni4coop to get the reports later on. They might be invited for the forums in September 2023.

[9] SBN is the liquid supplement based on microorganism from fishes, egg, and various ripened fruits and vegetables

In the current market context, the added value of bokashi was good. In its ongoing price of 35,000 Riel/package (25kg), TrUAC made a moderate margin, corresponding to 28.5% of its production cost (Figure 11).

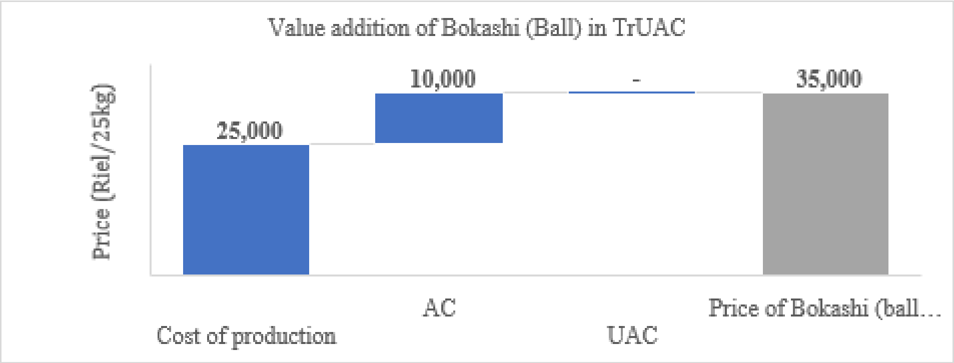

Figure 11: Gross margin of bokashi in Udom Sorya AC.

Bokashi price is competitive compared to other organic and chemical fertilizers (Table 6) even if high compared to local price of chicken manure, which is widely believed as good in terms of quality and nutrients than bokashi. With different local materials, different types of bio-input or natural fertilizer produced and commercialized for the local demand even the demand remained low. Its unit price remained low compared to that of chemical (imported products).

Table 6: Unit price of bio-inputs and its supplement products on the local market

Types of fertilizer vs its local price	Unit (kg/bag)	Local Price * (USD/unit)	Local Price (USD/kg)
TrUAC bokashi fertilizer (pellets, operated by AC)	25	$8.75	$0.35
TrUAC bokashi fertilizer (powder, operated by AC)	25	$8.25	$0.33
Chicken manure (pack in back mixing with rice straw)	25	$0.88	$0.04
Coops organic fertilizer (Local product, Enterprise, certified by ECOCERT)	25	$9.00	$0.36
Carbon Based Fertilizer (Enterprise)	20	$8.00	$0.40
Chemical fertilizer (Imported product)	50	$40.00	$0.80

* Local prices were collected during Dec 2023.

The bokashi business of TrUAC still faces significant challenges in both supply and demand. The current maximum production capacity is estimated to be around 30tons/month. But so far, only 50 tons have been produced and commercialized in total, with 50 % of the demand coming from non-cooperative members. Yet, TrUAC was proud to have managed to be sustaining this business and develop proper packaging for promotion. Despite this economic potential TrUAC was still struggling to survive due to:

- Lack of raw materials such as animal manure and forest soil, especially during the rainy season.
- a challenging drying process during rainy season due to limited drying space.
- Limited storage and operation space: TrUAC warehouse has 4m x 10m size for the different stages of bokashi production, including drying. Consequently, storage space stock and operations are limited.
- The machinery for transforming to pellet-bokashi has been upgraded to achieve higher productivity in year 2021 but farmers were unsatisfied by the new size of the pellet (too big) as they felt it could be wasted when applied in rice field.
- Low market demand: only 40% of the demand comes from the external market. The existing data of sales suggested that bokashi was more suitable for crops (horticultures or trees) rather than rice.

There is a need to identify new market segments as Bokashi is assessed as more suitable for horticultural and fruit crops than rice.

The limited demand is also related to the perception of limited or delayed efficiency of the product compared to conventional fertilization.

-
- The Union relies on motorbike and Tuk-Tuk for transportation which are not adapted for large or distant orders.
- Knowledge at farmers level could be improved for example through social media (AC Facebook page for example) as it appeared that farmers could not describe and explain it differences between bokashi and animal manure.

The study identified locks in in the value chain depending as presented in …. Figure 11 Differentiated the different flows between the main actors along the value chain around 3 main dimensions (product, knowledge & information and financial).

Input supplies were easily accessible at Oudom Soriya agricultural cooperative for production while TrUAC provided the product to other AC members of TrUAC and outsiders. While the Bokashi formular was well known and shared, its quality depended on quality control and management process. to make sure of high quality. economics of scale strategies, the TrUAC's bokashi products could access to a broad market internally and externally with mobilizing economics of scale. They were however still potential to improve the overall process and integration between these different dimensions, by thinking the process with a circular economy framework: increased collection of inputs materials by members, diversification of product-portfolio (powder, pellet, or others), and leveraging packaging activities, and other marketing activities.

Thus, several key activities would be required to ensure the growth of bokashi business, such as promotional strategies (demonstrations, official registration and mass media advertising), reliable sourcing of raw materials especially during the rainy season and effective marketing and business planning.

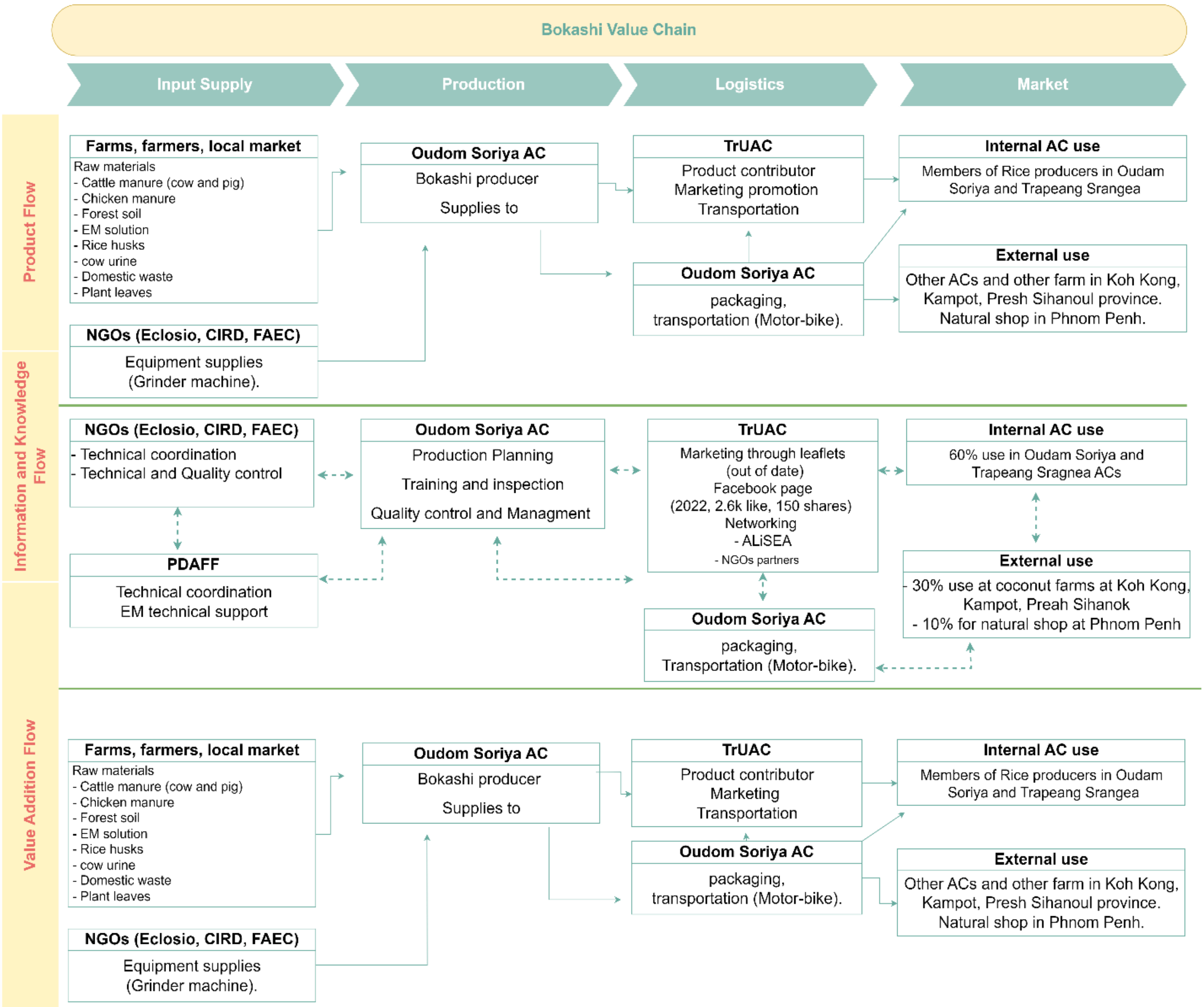

Figure 11: Diagram of bokashi value chain produced and commercialized by Udom Sorya AC.

According to TrUAC BoD, limited local demand was due to the farmer's skepticism on the bokashi's effectiveness. Other reasons might be related to limited capacity in accessing to the raw materials, facilities (machine, warehouse and transportation), and promotion. In addition, it was reported that it required to use twice of the amount of chemical fertilizers to get a similar result (they also claim that the effect of bokashi would last longer (in term of strong crops, good grain of paddy rice, good smell and taste of rice, and good soil for the next cropping cycles.

In conclusion, the journey of bokashi fertilizer from its inception in 2016 by ADG and Eclosio to its current commercial status has been characterized by an effort to improve its quality and marketing. While farmers have provided positive feedback on its efficacy in enhancing plant and soil health, challenges persist in refining its formula and increasing nitrogen content. Collaboration with organizations like UNI4COOP and RUA is pivotal in addressing these challenges. Despite achieving moderate gross margins and maintaining competitive pricing, the business faces constraints in accessing raw materials, production facilities, and promotional activities, hindering its growth and market penetration.

With the existing national platform to coordinate and support stakeholders in order to promote conservation agriculture and sustainable intensification in Cambodia towards agricultural modernization and agroecological transition, it indicated the crucial roles and functions of national platform to facilitate key actors for further improvement or research and development of the bio-input innovation. According to ALiSEA, there was a need for policymakers to be engaged in formulating relevant policies. However, this collaborative development of this shared vision and its pathways would require stronger foundations of understanding the potential risks of microorganisms and its multidimensional benefits for smallholder farmers and agricultural development.

4. Strengthening of Bio-Input Network

The following part synthesis the main outcomes of the interviews (qualitatively with 10 farmers, 9 people from NGOs, 4 people from farmer organizations, 7 people from enterprises, 6 international researchers, 7 national researchers and 4 people from public institutions) carried out to analyze the perception of bio inputs in Cambodia.

4.1 Contribution of bio-input application

Farmers, enterprises, NGOs, and researchers highlighted the potential of bio-inputs to reduce production costs, improve soil quality, and potentially increase farmer income. However, they stressed notes that increased income was not guaranteed, and some challenges remained such fluctuating income and yield decreases. Despite these challenges, there were positive impacts on health, welfare, and the environment. Collaboration among stakeholders and raising awareness were deemed essential for the successful dissemination of these kinds of products.

For Farmers and Cooperative, biogas used was particularly valuable for reducing production costs and expenses. But it does not necessarily lead to increased income. Natural farming practices were assessed to have positive impacts on the surrounding environment. There thought they were differences in production cycles and yields between farmers within and outside AC: AC members used an average of 1 bag of chemical fertilizer per hectare for rice production, while those outside the AC might use up to 3.5 tons per hectare. They estimated that Approximately 50% of AC members used chemical inputs such as herbicides and fertilizers.

For **enterprises**, the main benefits of bio-inputs use were on improving soil quality, health, and fertility while increasing efficiency and income for farmers. They also though Bio-inputs led to better quality of products and allowed to cut inputs expenses. They thought that farmers acknowledged the health benefits and were willing to adopt bio-inputs despite some challenges, such as fluctuating income compared to conventional methods.

According **to NGOs,** the increasing use of bio-inputs in vegetable production was influenced by market dynamics such as organic product prices. They highlighted the following benefits: improved soil quality, reduced input costs, but acknowledged that bio-pesticides might have lower efficiency compared to chemical inputs. They also acknowledged that organic production The income might not be increased due to lower yield and prices. However, they had positive return from concerning health and welfare, as well as long-term cost savings compared to chemicals use. They though adoption of bio-inputs might take time but had real benefits in soil improvement and cost reduction over time. They believed collaboration between suppliers and raising awareness was essential for a better dissemination of the products.

Researchers for their part highlighted how the use of bio-slurry could significantly decrease chemical inputs by half and improve vegetable prices. They reported that many farmers utilized bio-slurry for products they consumed themselves, potentially enhancing farmer welfare, reducing input costs. They thought that higher organic product prices could increase income. They believed that organic farmers were satisfied with the reduced input costs and easier product sales, and that the use led to improved soil and plant quality. They thought that bio-inputs could boost farmer income provided their market could be established and that it would benefit both users and environment. Additionally, they stressed that long-term use enhanced soil quality and production yields. However, they underlined that while the evidence was not entirely clear, compost in organic production could reduce production costs in the long term, even if farmers might need large compost supplies. They mentioned that chemical pesticides had a serious negative impact on farmer welfare. For them, reducing production costs and promoting self-consumption could also directly benefit consumer's health and farmer's welfare.

4.2 Risks and opportunities of bio-inputs

Respondents knew that microorganisms were already utilized across various sectors including health, clean water supply, and odor reduction in animal manure. Researchers also knew that applications extended to food and pharmacology, but the effectiveness varied depending on the type of microorganism and the research level on each microorganism. Generally, they believed that the broad spectrum of sectors involved meant a careful consideration of the emergence of certain risks, such as the presence of viruses from manure. The researchers highlighted those standard protocols typically mandated a waiting period of 90-120 days prior to harvesting to mitigate these risks. They mentioned that Compost management, should be closely monitored to prevent adverse environmental impacts, due to possible issue concerning E. coli and odor control.

Farmers and cooperatives suggested that there was less or no risk from bio-input during production and application. Their perception was thus slightly different from researcher, enterprise and NGO respondents which mentioned that there would be a difference in risk between locally produced microorganisms and those introduced from outside the country. They suggested that locally produced microorganisms would be acceptable, while foreign ones might transform and have negative effects. In general, all respondents also claimed that using microorganisms was less risk than using chemicals.

researcher and some NGO respondents mentioned the potential risks associated with certain bio-inputs in agriculture. They referred to possible imbalance by introducing these inputs in the ecosystem which could also affect human health if not sterilized properly. They gave Examples of diseases outbreak of in other countries such as bacterial contamination in bio-slurry, and the presence of harmful microorganisms like E. coli in the stream and food chain. Yet, the respondents believed that such risks remained low and that the use of isolated microorganisms should not significantly impact the environment or human health. Nonetheless, they emphasized the importance of research in controlled environments to understand the potential effects of different microbial strains.

4.3 Relationship between respondents and with researchers

Respondents mentioned there was a need for fostering innovation partnerships among public and private sectors, as well as civil society organizations, with the objective to support bio-input research and development, production, marketing, and adoption. One of the main challenges for bio-input development and adoption in Cambodia was lack of a clear regulatory framework and quality standards. Currently, there was no specific law or regulation governing bio-inputs in Cambodia, resulting in confusion and uncertainty among producers and users. Moreover, no national laboratory or certification body could test and verified the quality and efficacy of bio-inputs. Indeed, Cambodia as developing country had limited infrastructure and engagement in the high-tech research associated biotechnology because of the costs laboratories, equipment, materials and human resources. As a result, some bio-input products might be substandard, ineffective, or even harmful to crops and the environment.

However, some initiatives have been launched by various stakeholders, such as MAFF, RUA, CARDI, and some private companies. For instance, SmartAgro mentioned having collaborated with CIRAD and RUA to test the effectiveness of the various Biological Control Agent products.

HUSK had been testing the effects of rice husk charcoal and bio pesticide production in collaboration with HEKS, an NGO working on organic cashew nut productions. These initiatives aimed to improve the quality and availability of bio-inputs, capacity building, extension services, and market linkages. According to researchers from RUA, the students either from bachelor's or master's degree were also engaged in various studies to connect the scientific knowledge and practical knowledge through different experiments and field testing. However, it was found that there was little collaboration among the enterprise and researchers in the field of bio-input research. When a couple enterprises mentioned some collaborations with researchers, this was an informal form of collaboration.

According to the interview of farmers, they were engaged in these research and trial initiatives in a passive manner while researchers were favored in farm experiments of new products. Thus, this is important for the researcher either from the research center or universities such as RUA, Institute of Technology of Cambodia (ITC), University of Battambang (UBB) to work with NGOs and farmers to access to some funds and technologies along the process. For example, the introduction of bokashi in TrUAC was permitted by the engagement from ADG/UNI4COOP which facilitated the participatory assessment and later extension and commercialization of bokashi. TrUAC, PMUAC and cooperative in Kampong Chhnang were not really actively involve with the research and development activities with other stakeholders. Furthermore, international research from either Cirad (found in the ASSET project) and IRD collaborating with Institute of Technology of Cambodia (ITC) work with scientific approach by using laboratories either in the country (known as Pasteur, ITC and RUA) or abroad before the field testing with the local farmers.

5. Perception of Constraint and Opportunities of Bio-Input Development in Cambodia

With the results from data collection process, the same key actors involved in the data collection was then mobilized to 3 forums to further participatory analyzed and validate those results. Among the respondents of the interview basically participated in 2 separated forums (1^{st} and 2^{nd}) with the same contents. The specific objectives are to validate narrative of the innovation and findings enhances knowledge and supports dissemination, and to build a practical connection in the bio-input innovation process through collaborative action.

5.1 Constraints of bio-input development

The collective analysis during the forums focusing on discussion and sharing the lock in locks in terms production, technical effectiveness, marketing, and policy frameworks. Although across different type of actors, it was found a consistent and similar views on the locks of bio-input production and application lying along its supply chain from production to application.

During the workshop gathering The ACs and Union of ACs three themes of the locks –limitation was mentioned: local resource for production, efficacy or marketing. Enterprises insisted also on limited policy support, NGO staff provided a similar view to ACs and enterprises but added the constraint related to research and development in biotechnology and microorganism. Lack of investment in this area also resulted from the demand of the market which requires the holistic approach to understand the importance of the bio-inputs if different dimensions among all key actors especially farmers, consumers, and policy makers.

Overall, the challenges revolved around the adoption and efficacy of bio-inputs in agricultural practices. It considered economic, technical, and environmental factors. In our fast-changing agricultural development and modernization area, dependency on chemical inputs has become a common trend. Small scale investment and production of bio-inputs would be challenging to ensure competitiveness in this context.

enterprises highlighted the following, the barriers to production and commercialization of bio-input products:

1. **Government Registration:** Lack of specific guidelines and pricing for products like Biological Crop Agents complicates certification processes. Government certification costs can vary significantly, affecting business models and profit margins.
2. **Challenges from Small-Scale Producers**: Small-scale producers, often using social media for sales, may neglect quality control and formal trading procedures. Enforcement of regulations on these producers is lacking, impacting market fairness.
3. **Limited Market for Agroecological Food**: The absence of a sizable market for Agroecology products, combined with minimal premium prices, discourages farmers from adopting agroecological practices. Without market incentives or government subsidies, farmers are reluctant to change their agricultural methods.
4. **External Market Requirements**: International market standards, such as EU regulations on crop production practices, influence production methods. Compliance with these standards is necessary for export markets, requiring adjustments in agricultural practices.
5. **Local Market Size**: Currently, the local market for agroecological food is small and unstable, hindering consistent sales and growth.
6. **Infrastructure and Knowledge Sharing**: Access to machinery, technical knowledge, and support services is essential for farmers transitioning to agroecological practices. Establishing effective extension services and distribution networks requires significant investment and collaboration.
7. **Holistic Policy Approach**: Addressing these barriers necessitates coordinated efforts across government ministries, private enterprises, farmers, and other stakeholders. Political commitment to policy formation and implementation is crucial for overcoming these challenges.

For farmers, the main barriers are the following. (1) **limitation of technical knowledge** among producers, coupled with insufficient experimentation and demonstrations of effectiveness, (2) **scarcity of local resources** limits volume of production was also derived from the. This includes a shortage of cow manure, organic matter, and microorganisms (3) **technical complexities** involved in bio-input production further exacerbate the issue (Figure 11).

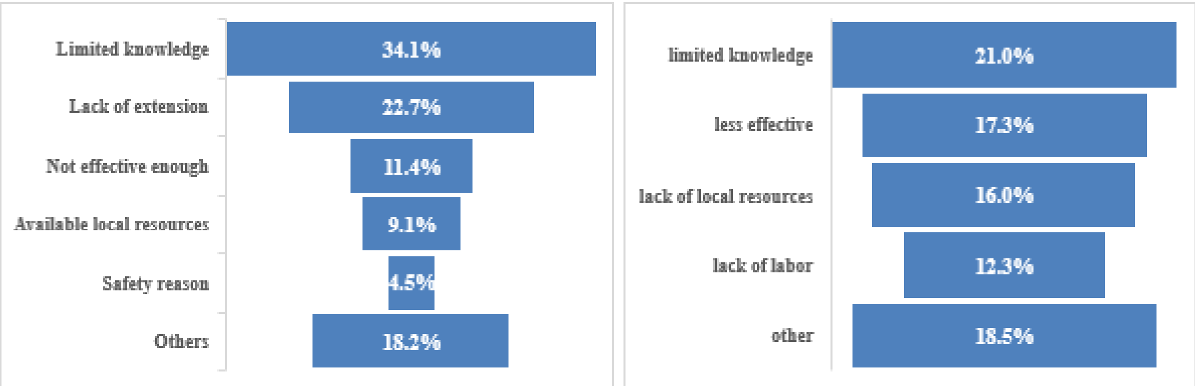

Figure 12: (Left)- Main locks that block the increase of use each bio-input at level of farm (left); (Right)- Main locks that hinder the use of knowledge on microorganisms (right)

Other limitations discussed concerned the **marketing challenges**: bio-inputs struggle to compete with conventional chemical products. Inadequate promotion and marketing strategies result in low demand for bio-inputs, creating a vicious cycle of limited investment and market penetration. High competition with chemical alternatives, which are perceived to be more readily available, faster acting, and more efficient, further dampens the prospects for bio-input adoption. This disparity in demand and perceived efficacy not only undermines the viability of bio-input businesses but also perpetuates the higher prices associated with bio-inputs compared to chemical alternatives.

Policy deficiencies also play a crucial role in impeding the growth of the bio-input sector. **The absence of supportive policies, subsidies, and safety nets** deprives bio-input businesses of the necessary incentives and resources for sustainable development. Complicated and costly certification processes add another layer of bureaucratic barriers, discouraging producers from engaging in bio-input manufacturing. Without a conducive policy environment and political will to promote bio-inputs, the sector struggles to overcome these systemic challenges and realize its full potential.

Finally, technical and knowledge gaps hinder the effective application of bio-inputs in agricultural practices. Limited technical support, insufficient laboratory facilities, and unclear principles of use undermine the confidence of both producers and end-users in the efficacy of bio-inputs. The slow evaluation of effectiveness and quality, coupled with the preference for short-term solutions among farmers, further impedes adoption. Extension services lack the necessary expertise and promotion skills to effectively communicate the benefits of bio-inputs, perpetuating misconceptions and mistrust among farming communities.

Bio-input adoption encountered various obstacles that obstructed its progress and expansion. On one side, the supply of labor and resources was restricted by factors such as migration flows, livestock rearing, and other competing activities. On the other side, the market demand for bio-inputs was influenced by the availability of alternative products, especially chemical ones, which offered lower costs or higher yields. It was reported that production of agricultural bio-inputs is a complex and challenging activity that depends on various factors, such as the availability and quality of the inputs, the market demand and prices, and the labor requirements and risks.

In short, our empirical data from interviews and forums showed that the combination of unclear policies, limited production factors, high costs, constrained biotechnology research, small markets with high prices, and perceived low effectiveness of agricultural bio-inputs forms a vicious cycle perpetuating agricultural challenges and hindering bio-input development.

5.2 Levers of bio-input development

In order to break the vicious cycle identified above, various actions have been proposed by interviews and forums which are summarized in Figure 14. Addressing the locks of agricultural bio-input production and application requires a holistic approach encompassing policy reform, technical capacity building, and targeted marketing strategies. By addressing these key challenges, stakeholders can unlock the full potential of bio-inputs to enhance agricultural sustainability and resilience in the face of evolving environmental and economic pressures.

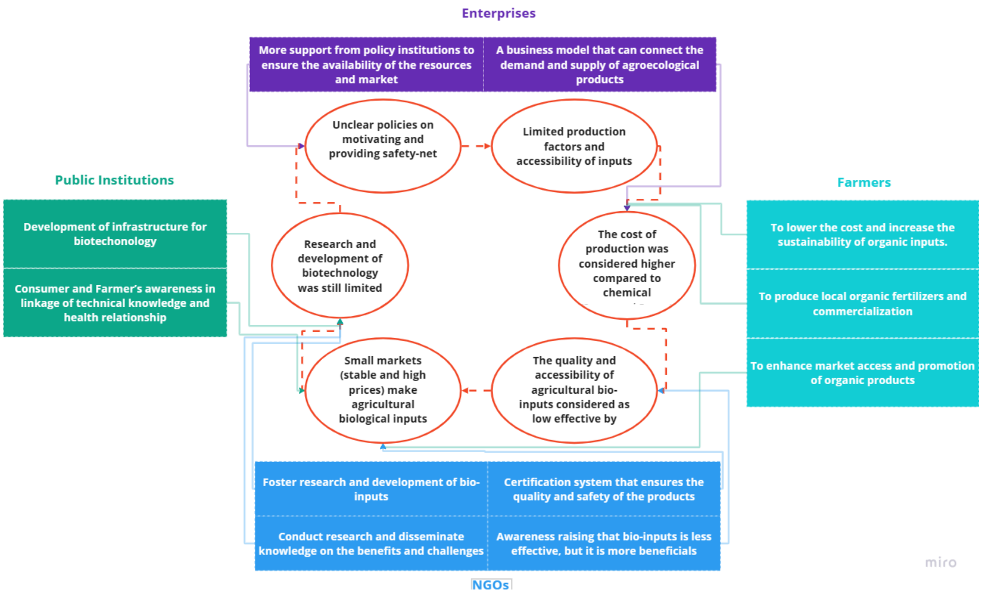

Figure 13: Bottlenecks on demand and supply side, creating a vicious cycle of under innovation.

First, building infrastructure for biotechnology could contribute to improve bio inputs quality and effectiveness. Second, a policy framework supporting the consumer and farmer's awareness, the linkage of technical knowledge and beneficial relationships would be necessary. Third, implementation of reasonable price premium in AE products could incentivize the food system actors to engage in AE production and open the market for bio inputs. Fourth, business model facilitated the connection of demand and supply of bio input product in such an AE food system market could be experimented. Five, it would be important to acknowledge the role of agricultural cooperatives and unions of agricultural cooperatives to better coordinate the bio-demand and supply of bio inputs. Finally, on farm testing of different materials could help to reduce costs and improve the efficiency of the system. Finally, a connected network of NGOs and researchers could develop research and development of the bio-inputs and extension to identify the best practices to smallholder farmers.

In addition, all actor suggested that there was a need to develop awareness and knowledge of both farmers and consumers about the benefits of biological inputs in order to stabilize or boost the market demand in regard notably of safe vegetable markets and organic exports. Some value chain may have a strategic role in this regard to expand the market such high value crops and modern market chains such as pepper, cashew or vegetables that concerns aa broad range of farming context

Thus, a number of examples have been identified to drive research toward high quality biological inputs (including imports) and to promote the trade of agricultural biological inputs with the participation of local producers and communities, researchers and private companies. Promoting commercial production and use of agricultural biological inputs requires the participation of local producers, agricultural communities, researchers and private companies. The roles of the public institutions would be crucial to promote fair and prioritized actions in production, distribution and commercialization.

5.3 Hopes/Fears/Suprises concerning the possible future agricultural bio-inputs

The hope/surprise expressed by the forum of participants underlined that most participants were still a little skeptical about the potential of bio inputs to disseminate in a large manner. This underlined the need to strengthen the collaboration and consolidate a strong network of actors of the value chain in order to address the risks expressed at this stage. This included: a risk of a sector characterized by high costs, limited accessibility, and dominated by large industries, ‘2) the risk of not reduced policy support and lack of awareness (3) the risk of increased importation of synthetized inputs limiting the market of bio inputs (4) the risk of uncontrolled impact on soil and biodiversity or new disease and environmental harm.

Table 7: Future triangle of agricultural bio-input thematic areas

<table>
<tr>
<td rowspan="2">HOPES:
Bio-inputs used will be increased in the high quality and quantity in Cambodia and contributing to sustainability in Agriculture in term of good living environment for humans in the future.
It involves the restoration of soil functions, the enhancement of agro-ecological value chain, the use of bio-inputs, and the dynamic of bio-input value chain.
Policy supports the productions and applications of bio-inputs in agriculture throughout the dynamic value chains. Policy supporting sustainability in agriculture should consider the technical efficiency, the economic viability, and the social acceptability of the practices.
Technical efficiency in biotechnology to produce input product with quality standard, efficiency and safety.
Knowledge dissemination and sharing are also important to foster innovation and collaboration among stakeholders. Bio-input extension or promotion service is an importance point that could be reduce the use of chemical inputs and increase the use of bio-inputs.</td>
<td>SUPRISES:
Cooperation between scientists and farmers in biotechnology could improve and transform bio-input accessibility through local production and commercialization to make a positive change in reducing and minimizing chemical input application.
Policy support and incentive framework could be critical for achieving the innovation and commercialization of bio-inputs achieving the reduction of chemical inputs.
There is one of an important surprise for us, where we don't really believe that we will have the right use of bio-input in the future.</td>
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<tr>
<td>ACTS:
NGOs aim to promote the use of bio-inputs instead of synthetic inputs in agricultural production. Awareness raising that bio-inputs is less effective comparably with chemical inputs, but it is more beneficials (not limiting only economic aspects). We provide a certification system that ensures the quality and safety of the products for the consumers, as well as rewards the farmers for their efforts. We also engage in policy dialogue on bio-inputs, collaborating with universities and other stakeholders to conduct research and disseminate knowledge on the benefits and challenges of this approach.
The farmer organization aims to improve organic agriculture by advocating for policy changes that lower the cost and increase the sustainability of organic inputs. It also seeks to collaborate with relevant actors in the public and private sectors to enhance market access and promotion of organic products. It recognized the growing demand for bio-inputs in the production system and for safe foods among consumers and strives to meet these standards. It encourages ACs to produce local organic fertilizers and reduce reliance on imports from other countries. It also ensures the quality and trustworthiness of bio-inputs</td>
</tr>
</table>

FEARS: • Higher use of chemical inputs could be because of the high cost of bio-input and the availability and accessibility of chemical inputs which is distributed by the private sector or company where could impact on the soil (soil pollution or reduce soil quality) and cause health risks. • Big industry is taking over farmers and SME rights to produce bio-inputs. • Limited bio-inputs production and application due to higher cost and wrong way of application. • The lack of adequate policy interventions for agroecology and the food system leads to insufficient awareness and understanding of agroecology. • Dependency of farmer on the import synthesis inputs while allowing only small share of the bio-input market due insufficient bio-inputs. • Excessive use of synthesis inputs would negatively impact soil and biodiversity. • Inefficiency of bio-inputs or microorganisms may pose the risk of emerging of new diseases, human health risk, and environment due to microorganism side effects.	and supports more research on their development and use efficiently. • Private sectors are looking for more support from policy institutions to ensure the availability of the resources and market for their production. They also need a business model that can connect the demand and supply of agroecological products. • Policy makers are concerned about the risks of the bio-inputs as the biotechnology remaining limited in the nation. Development of infrastructure for innovations is one of the focus with CASIC platform.

Yet they acknowledged that an increased use had the potential to restore soil functions, improve agro-ecological value chains. Emphasis is placed on considering technical efficiency, economic viability, and social acceptability. Additionally, it suggests the significance of knowledge dissemination, collaboration, and extension services to promote the adoption of bio-inputs and reduce reliance on chemical inputs.

6. Proposition of Pathways to Bio-Input Development

The last part of the forum (3rd forum) was to design a pathway for the development of bio inputs. It was chosen to focus on four (04) main products. That is compost/bokashi, Trichoderma, EM and bio-pesticide by using a future triangle methodology. The content of each group is presented in the annexes. The pathways for the 4 groups are presented in Table 8 to Table 11. This provides the basis for the design of an action research project focusing on the development of bio inputs project.

6.1 Compost/Bokashi

Networking is key in a marketing context. Active and strong networking of engagement in selling the bokashi products. There were different activities within the network around the production and sale of the products throughout the value chain and marketing. The branding and marketing of the bokashi products including at the farmer levels. This will trigger the supplier and result in an increase in production. Networking will be beneficial in this context. Social communication via social media to improve promotion and demand of bokashi. We should have been engaged in participatory research to improve the technical knowledge and understanding of challenges that are required for the solutions. Different kinds of training including the technical and communication of the benefits of using the compost or bokashi.

According to Table 8, the 5-year pathway for the compost and bokashi were cleared mapped out. In 2024, the focus is on identifying barriers in the production and application of bio-products among stakeholders. Communication and training initiatives are prioritized. In 2025, experiments aim to improve product quality and identify suitable production techniques. Promotion efforts include meetings, field testing, and engagement with community leaders. In 2026, the emphasis shifts to disseminating the benefits of bio-products through workshops, training sessions, and certification processes. Marketing strategies, including social media, are explored. By 2027, the focus is on actively selling and promoting bio-products in the market. Efforts include dissemination of documents, increasing production and promotion, and enhancing networking among stakeholders.

Table 8: Five-year scenarios of compost/Bokashi

<table>
<tr><th>Past</th><th>Present</th><th>Future</th></tr>
<tr>
<td>▸ Labor intensive
▸ Raw materials to produce are difficult to find.
▸ Not confident on the use of compost and bokashi.
▸ Materials (green, straw) and available but not in sure farm and connection is.
▸ Limited research lab
▸ Procedure or certification and registration is complex.
▸ Unclear policy supports.
▸ Farmers do not value compost
▸ Limited nitrogen and less efficient than chemical inputs.</td>
<td>▸ Improving the formular of bokashi to improve nutrient
▸ Improve their health but it is not popular.
▸ Bokashi is easy to transport (already in bag)
▸ NGOs encourage farmers to produce and use compost and bokashi.
▸ Farmer, ACs, and other actors work on promotion compost and bokashi.
▸ Existing networking initiative
▸ There is technology and labs able to make some quality assessment.
▸ Opportunity for innovation for new product
▸ Good compost of material can compare to bokashi.</td>
<td>▸ Living labs are engaged in quality.
▸ Promote and disseminate to farmers.
▸ Higher application and production
▸ Collaborative works for R&D
▸ Government encourages farmers to produce and use through subsidies and policies</td>
</tr>
<tr><td colspan="3">5-Year Scenarios:
2024: Identifying the barriers in the production and application among the stakeholders
▸ Communication to all actors about bio-products
▸ Training in ac about bio-products
2025: Experiment on quality to have good quality of n ratio for the input
▸ Finding the appropriate technique in production (short production cycle and high quality)
▸ To promote production in ac meeting and in fields testing
▸ Experiment with certificate.
▸ Engage with communal chief / village chief for training on product.
2026: Disseminating of its benefits through different approaches
▸ Workshop on big value chain (marketing community and quality improvement)
▸ Training on how to promote on social media and broad communications.
▸ Certification process
2027: Bokashi, compost is ready and available - active in selling in market and promoting of the products widely.
▸ Dissemination documents
▸ Increasing production and promotion
▸ Improving the networking among stakeholders</td></tr>
</table>

6.2 Trichoderma

Participatory research is key. Engaging different actors on what are the benefits and opportunities for the production and application of bio-inputs. Participatory planning is important to get the activities which respond to different needs and interests. Eventually, we want to see the knowledge focusing on the living lab and pgs. Participatory living lab for the research for the bio-inputs so that we can collect small community with different stakeholders engaging in different tasks of research. For instance, farmers could test and do data collection for scientific study with researchers. One of the ways is using existing networks like ALiSEA to conduct participatory research and sharing the results through this network relating to bio-input study. With the small-grant of ALiSEA, the thematic bio-input innovation would be practical and encouraged. Students could be part of the research with different contexts. They could go scientifically focused.

Based on Table 8, the pathway of Trichoderma is more scientific and commercial orientation. The Living Labs initiative focuses on fostering participatory planning involving various stakeholders such as NGOs, researchers, SMEs, and farmers. It aims to identify and address the diverse needs of farmers and the private sector. Additionally, it involves engaging students in the testing of bio-input, with around 300 students per year conducting diversified research on bio-products, comparing planting methods with plot control. Decision making within this framework involves participatory research on Trichoderma, field testing, improving effectiveness, and identifying alternative high-quality resources for production, with subsequent recommendations. Lastly, the process involves laboratory analysis for licensing purposes.

Table 9: Five-year scenarios of Trichoderma

<table>
<tr><th>Past</th><th>Present</th><th>Future</th></tr>
<tr><td>

Knowledge limitation concerning emerging impacts of large use of Trichoderma.
Inconvenient packaging
Unaffordable price for farmers.
Lack of technical support for farmers.
Knowledge limitation concerning the effective use of Trichoderma.
Slow effectiveness
Limited research lab involved in Trichoderma.
Lack of understanding the effectiveness and benefit of Trichoderma.

</td><td>

NGOs and researchers are willing to cooperate to promote the development of Trichoderma.
NGOs encourage farmers to use Trichoderma.
Existing network initiatives.

</td><td>

Application technical improvement to retailers and farmers.
AC can extract Trichoderma by themselves.
Promote and disseminate the information about this product to farmers.

</td></tr>
<tr><td colspan="3">
5-Year Scenarios:
Living labs

We need to have a participatory planning.
Engaging different actors - NGOs, researchers, SME, farmers
Different types of needs of farmers and private sectors to be identified and resolved.
Engaging students in testing of bio-input
300 student/year with diversified research of bio-products (planting vs plot control)

</td></tr>
</table>

Decision making ▸ Trichoderma participatory research ▸ Testing in the fields ▸ Effectiveness improvement ▸ Identifying alternative resources for production with high quality and make the recommendation. Licensing ▸ Laboratory analysis

6.3 Effective Microorganisms (EM)

Certification of PGS is practical for EM products. We can start collecting and bringing together among the EM producers and defining a clear roadmap for the standard practically enough for implementation. The ingredients to be used will be defined for the effective standard. We need to work with research and access to the laboratory analysis. In addition, we could work with competent government staff (i.e. PDAFF) in capacity building and certification processes based on the existing experience from other countries. Then, EM producers ensure the internal control system with internal lab testing to maintain the quality standard. With certification, it is possible to have a strong brand name and receive a fair value added in the market.

Similar to Trichoderma's pathway, quality control measures include establishing demo farms, conducting production inspections, and utilizing research and lab resources for improvement and certification. Collaboration with government entities is highlighted for registering EM processes and providing training to officials in other countries. Certification procedures involve both external lab analysis and internal testing, ultimately adding value to EM products in the market (Table 9).

Table 10: Five-year scenarios of EM

Past	**Present**	**Future**
▸ Lack of scientific research on the composition in the EM product. ▸ Lack of technical supports for farmers to produce EM ▸ Lack of EM suppliers ▸ Difficult to find raw materials. ▸ EM requires many types of raw materials. ▸ EM products were packed for the local market only but not yet achieving standard labelling. ▸ Lack of awareness among consumers to support EM product.	▸ Promotion of EM produce in the community level. ▸ Support community to do planning of the EM business and promotion. ▸ Train farmers to better understand the value chain of EM.	▸ Living labs are engaged in quality of EM. ▸ Continue working with relevant stakeholders and universities to produce and promote EM. ▸ Support communities to produce EM by using local row materials. ▸ Higher use and production of EM. ▸ Promote and disseminate the information about EM to farmers.
5-Year Scenarios: Knowledge sharing /training to producers ▸ Agreement between EM producers collectively ▸ Bring together EM producers.		

- Define the ingredients and marking process (defining the standards for the productions)

Quality control system

- Demo farm
- Production inspection

Research and lab resources for quality improvement and certification.

- Working with government to have process for registering EM
- Training for government officers in other countries

Certification of the products

- Lab analysis (externally)
- Lab testing (internally)
- Value added in the market

6.4 Bio-Pesticide

Policy is a focus to have recognition of bio-input products. Representative farmers could contribute inputs in policy dialogue with bottom-up approach. SME and research to produce evidence for the policy. These actors could actively engage in this dialogue for the bio-inputs. In addition, AC role is important for production and application at community level. The summary is about the need for policy support from MAFF for bio-inputs, the role of extension in transferring information and knowledge on bio-pesticide production and application among ACs and farmers.

Table 11: Five-year scenarios of bio-pesticides

Past	**Present**	**Future**
• Short lifespan of biopesticides • Low efficiency of biopesticides	• Lab testing of biopesticides is limited. • Improve efficiency of biopesticides • Advertisement of biopesticides producing and using through social media. • Encourage farmers to produce more biopesticides.	• Living labs are engaged in quality of bio-pesticides. • Continue working with relevant stakeholders and universities to produce and promote biopesticides. • Try to apply biopesticides on rice production. • Higher use and production of biopesticides. • Promote and disseminate information about biopesticides to farmers.
Five-Year Scenarios: • MAFF should produce a policy supporting bio-input. • PDAFF is a mechanism to transfer information on bio-input produce/use from ACs/farmers to ministries or MAFF.		

- Comparing/advocating on bio-input production and application.

The workshop concludes with a sense of direction and purpose, acknowledging the limitations on time for detailed resource discussions. Despite this, there's confidence in identifying the next steps for the near future. We have a basis and pathways where we should go. Even though we don't have time to go deeper in the discussion regarding the resources required to make these activities more practical, it is believed that we have the next step for the near future. The workshop has yielded valuable outcomes, and various organizations, such as CIRAD, ECOLAND, and others are poised to continue making significant contributions in this thematic area.

Conclusion

In Cambodia, the bio-input innovation process is currently at the planning stage, characterized by strategic initiatives. Stakeholders are actively shaping the trajectory of innovation, with dynamic networks like ALiSEA and CASIC facilitating collaboration. Actors demonstrate a strong willingness to engage in participatory efforts, fostering a culture of collaboration and innovation.

Human resources, including researchers, public institutions, private enterprises, NGOs, and farmers, exhibit notable commitment to advancing the innovation agenda. Their active involvement underscores the importance of collective effort in driving progress. Initiatives such as the Health Plant project and the Pre-tag project have further catalyzed collaboration and contributions from diverse stakeholders.

The collaborative spirit among stakeholders is evident in their dedication to advancing bio-input innovation in Cambodia. This collective commitment lays a solid foundation for future progress and ensures that innovative solutions continue to be developed and implemented effectively. Moving forward, sustained collaboration and engagement will be essential for realizing the full potential of bio-input innovation in the country.

Acknowledgment is extended to all stakeholders, including the Health Plant project, the Pre-tag project, and participating actors, for their invaluable contributions to advancing the bio-input innovation agenda in Cambodia. Their collective efforts are instrumental in driving positive change and fostering innovation in the agricultural sector.

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Annex

Annex 1 List of participants in the interview.

No	Respondent Name	Institution Name	Type of Actor
1	Mr. Sok Sothearath	EAST-WEST SEEDS	Enterprise
2	Mr. Semea Vin	HUSK VENTURE	Enterprise
3	Mrs. Sovanly Ing	NKA	Enterprise
4	Mr. Yem Samnang	EAST-WEST SEEDS	Enterprise
5	Mr. Sok Sarang	ECOCERT	Enterprise
6	Mr. Kann Kunthy	AMRU Rice Group	Enterprise
7	Mr. Marc Eberle	SmartAgro	Enterprise
8	Soa/Bayon Heritage	SOA/BAYON HERITAGE	Enterprise
9	Mr. Meang Rithea	Cambodian Organic Agriculture Association	Enterprise
10	Ms. Chan Sophal	Agricultural Cooperative	Farmer Organization
11	Ms. Chum Thea	Agricultural Cooperative	Farmer Organization
12	Mr. Oeur Sam Ath	Preah Vihear Mean Chey Union of Agricultural Cooperatives	Farmer Organization
13	Mr. Chhong Sophal	Farmer and Nature Net (FNN)	Farmer Organization
14	Mr. Kong Moeurn	Tramkak Union of Agricultural Cooperative	Farmer Organization
15	Mr. Sarom	Agricultural Cooperative	Farmer Organization
16	Ms. Nget Moe	Agricultural Cooperative	Farmer Organization
17	Dr. Mathilde Sester	CIRAD	International Scientific Research
18	Dr. Lionel Moulin	IRD	International Scientific Research
19	Ms. Kakada Oeum	IRD	International Scientific Research
20	Dr. Adeline Barnaud	IRD	International Scientific Research
21	Dr. Raphaelle Ducrot	CIRAD	International Scientific Research
22	Mr. Chea Leangsrun	CESAIN	National Scientific Research
23	Dr. Bontong Borarin	DRE/RUA	National Scientific Research
24	Ms. Linna Ngang	ECOLAND	National Scientific Research
25	Mr. Seyha Duk	FST/RUA	National Scientific Research
26	Dr. Srean Pao	Faculty of Agriculture and Food Processing, University of Battambang	National Scientific Research
27	Dr. Sophoanrith Ro	Faculty of Agronomy, RUA	National Scientific Research
28	Dr. Samnang Nguon	Dean of Graduate School, RUA	National Scientific Research
29	Dr. Lyhour Hin	Faculty of Engineering and Bio Resources, RUA	National Scientific Research
30	Mr. Savoeurn Meang	Agronome Et Vétérinaires Sans Frontières (AVSF)	NGOs
31	Mr. Sophoan Min	Agronome Et Vétérinaires Sans Frontières (AVSF)	NGOs
32	Mr. Sethya	HEKS	NGOs
33	Mr. Mey Veata	UNI4COOP	NGOs

No	Respondent Name	Institution Name	Type of Actor
34	Mr. Guillaume Jumel	Sustainable Soil for Life Association (SSLA)	NGOs
35	Ms. Celia Del Campo	DCA	NGOs
36	Mr. Phalla	GIZ	NGOs
37	Mr. Phalit Phat	GIZ	NGOs
38	Mr. Pat Sovann	GRET	NGOs
39	Ms. Im Sothy	GDA, MAFF	Public Institution
40	Dr. Kean Sophea	DEPARTMENT OF HORTICULTURAL CROPS, GDA, MAFF	Public Institution
41	Dr. Rada Kong	MAFF- DEPARTMENT OF AGRICULTURAL LAND RESOURCE MANAGEMENT / GDA	Public Institution
42	Dr. Makara Ouk	MAFF (former. CARDI DIRECTOR)	Public Institution

Annex 2 List of participants in the forums.

No	Forum 1 - 8/9/2023	Forum 2 - 15/9/2023	Forum 3 - 17/11/2023	Name of Participant	Institution	Type of Institution
1	1			Mr. SAVOEURN MEANG	Agronome et Vétérinaires Sans Frontières (AVSF)	NGOs
2	1			Mr. SOPHOAN MIN	Agronome et Vétérinaires Sans Frontières (AVSF)	NGOs
3	1		1	Mr. PAT SOVANN	GRET	NGOs
4	1		1	Mr. CHEA LEANGSRUN	CESAIN	National scientific research
5	1	1	1	Mr. SORITH HOU	RUA	National scientific research
6	1	1	1	Ms. LINNA NGANG	ECOLAND	National scientific research
7	1		1	Dr. MATHILDE SESTER	Cirad	International Scientific research
8	1		1	Dr. LIONEL MOULIN	IRD	International Scientific research
9	1		1	Ms. KAKADA OEUM	IRD	International Scientific research
10	1	1	1	Dr. RAPHAELLE DUCROT	Cirad	International Scientific research
11	1		1	Ms. CHAN SOPHAL	Agricultural Cooperative	Farmer organization
12	1			Ms. CHUM THEA	Agricultural Cooperative	Farmer organization
13	1			Mr. OEUR SAM ATH	PMUAC	Farmer organization
14	1		1	Mr. KONG MOEURN	Tram Kak Union of Agricultural Coooperatives (TrUAC)	Farmer Organization
15	1		1	Mr. SOEURNG VANNA	Tram Kak Union of Agricultural Coooperatives (TrUAC)	Farmer Organization
16	1		1	Mr. SEMEA VIN	Husk Venture (biochar et produits dérivés)	Enterprise
17	1			Mrs. SOVANLY ING	EM (Pionnier au Cambodge)	Enterprise

18		1		Dr. KEAN SOPHEA	Department of Horticultural Crops, GDA, MAFF	Public institution
19		1		MS. IM SOTHY	MAFF- Department of Agricultural Land Resource Management / GDA	Public institution
20		1		MR. MORN MAKARA	Farmer and Nature Net (FNN)	NGOs
21		1		Mr. MEY VEATA	UNI4COOP	NGOs
22		1	1	Mr. GUILLAUME JUMEL	Sustainable Soil for Life Association (SSLA)	NGOs
23		1	1	Ms. CELIA DEL CAMPO	DCA	NGOs
24		1		Mr. PHALIT PHAT	GIZ	NGOs
25		1	1	Mr. SEYHA DUK	FST/RUA	National scientific research
26		1	1	Ms. NGET MERL	Tram Kak Union of Agricultural Coooperatives (TrUAC)	Farmer Organization
27		1	1	Mr. SEM SAROM	Tram Kak Union of Agricultural Coooperatives (TrUAC)	Farmer Organization
28		1	1	Ms. YE SARIM	Cheab Neary Santhepheap Agricultural Cooperative	Farmer Organization
29			1	Mr. ANTHONY JOHN	Husk Venture (biochar et produits dérivés)	Enterprise
30		1		Mr. YEM SAMNANG	East-West Seeds	Enterprise
31		1		Ms. BORATANA UNG	Green Cluster Co. ltd.	Enterprise
Total	17	16	19			

Annex 2 Photos of data collection activities

Photo 1 Interview and field observation of bio-input production and application by horticulture farmer, Kampong Chhnang province, Cambodia

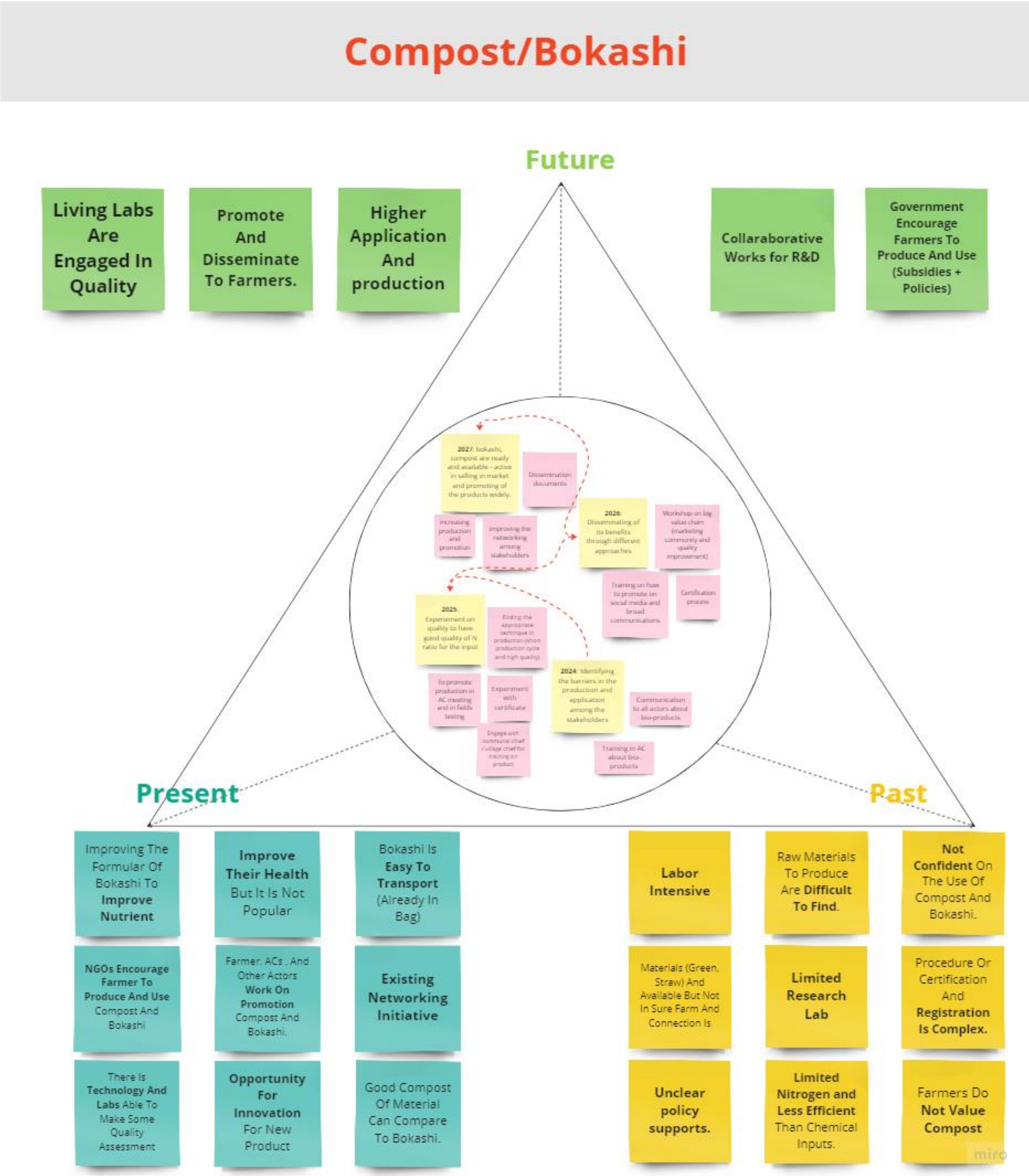
Photo 2 Interview and field observation of Bokashi production and application by Udom Sorya AC, Takeo province, Cambodia

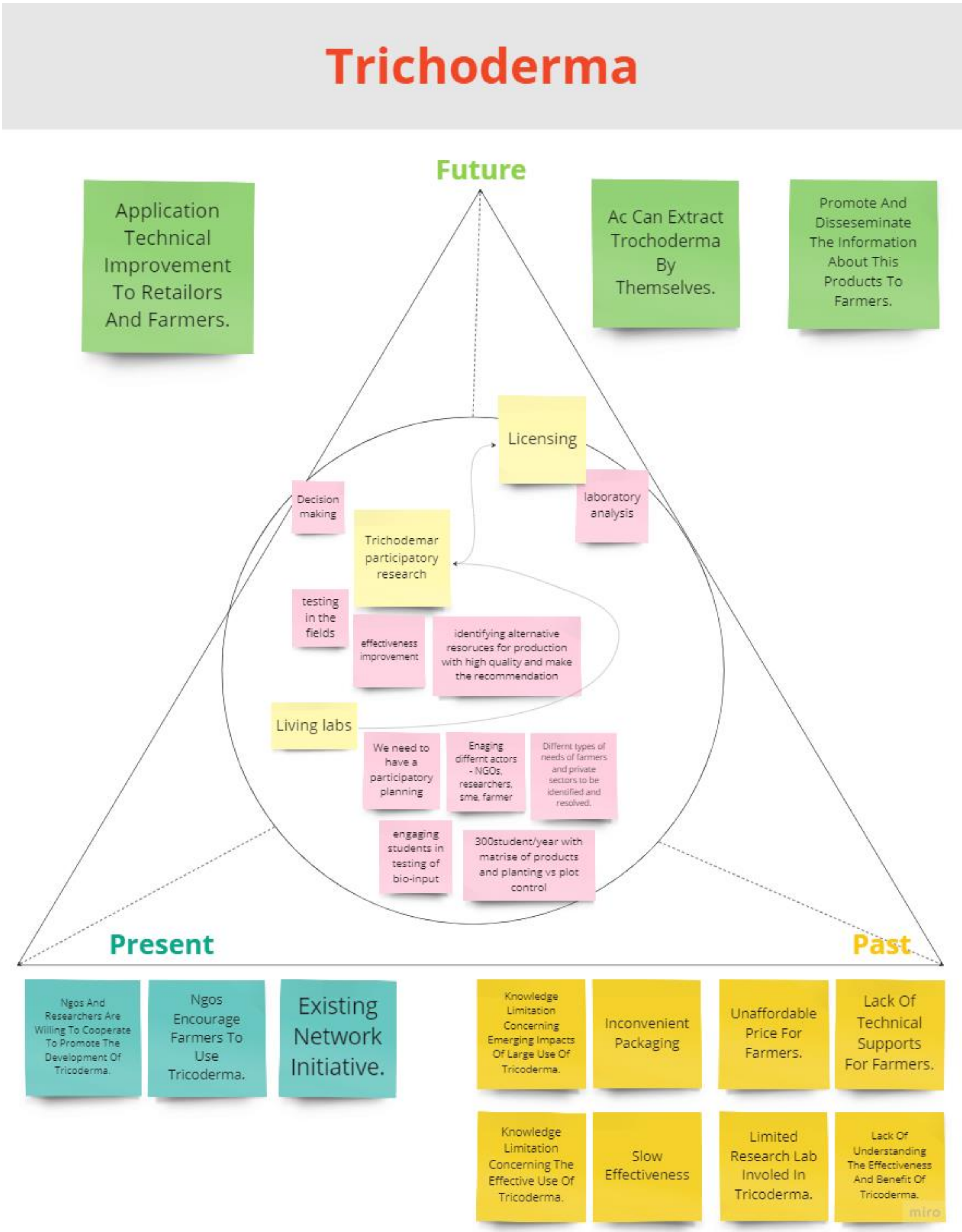
Photo 3 Group discussion of future triangle of EM during Forum #1 at Royal University of Agriculture, Cambodia

Photo 4 Group discussion of future triangle of EM during Forum #2 at Royal University of Agriculture, Cambodia

Photo 5 Group discussions of five-year scenario of different bio-inputs during Forum #3 at Royal University of Agriculture, Cambodia

Annex 3 Results of group discussion about the pathways of bio-inputs




Trichoderma
Future
Application Technical Improvement To Retailors And Farmers.
Ac Can Extract Trochoderma By Themselves.
Promote And Disseseminate The Information About This Products To Farmers.
Licensing
laboratory analysis
Decision making
Trichodemar participatory research
testing in the fields
effectiveness improvement
identifying alternative resoruces for production with high quality and make the recommendation
Living labs
We need to have a participatory planning
Enaging differnt actors - NGOs, researchers, sme, farmer
Differnt types of needs of farmers and private sectors to be identified and resolved.
engaging students in testing of bio-input
300student/year with matrise of products and planting vs plot control
Present
Past
Ngos And Researchers Are Willing To Cooperate To Promote The Development Of Tricoderma.
Ngos Encourage Farmers To Use Tricoderma.
Existing Network Initiative.
Knowledge Limitation Concerning Emerging Impacts Of Large Use Of Tricoderma.
Inconvenient Packaging
Unaffordable Price For Farmers.
Lack Of Technical Supports For Farmers.
Knowledge Limitation Concerning The Effective Use Of Tricoderma.
Slow Effectiveness
Limited Research Lab Involed In Tricoderma.
Lack Of Understanding The Effectiveness And Benefit Of Tricoderma.
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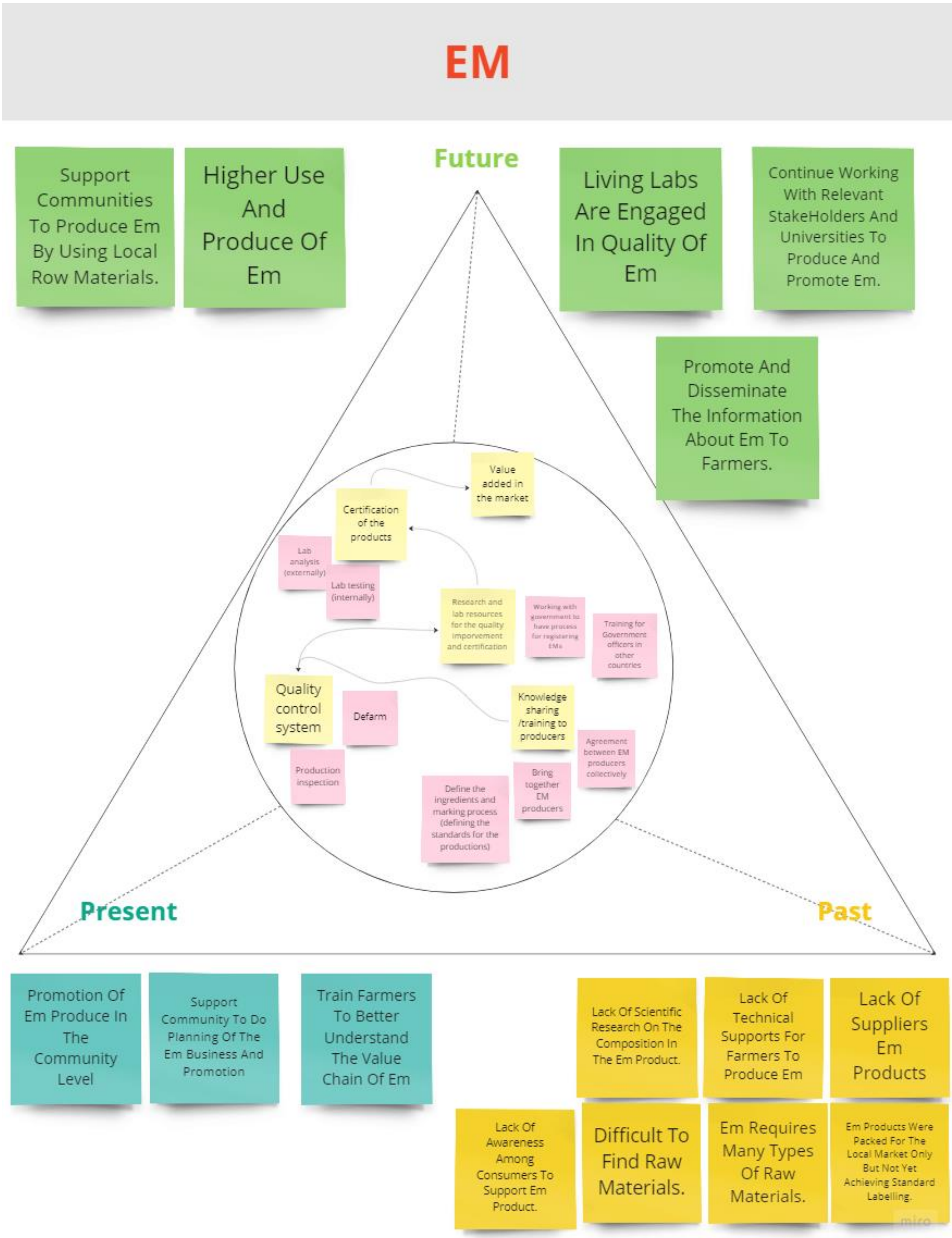
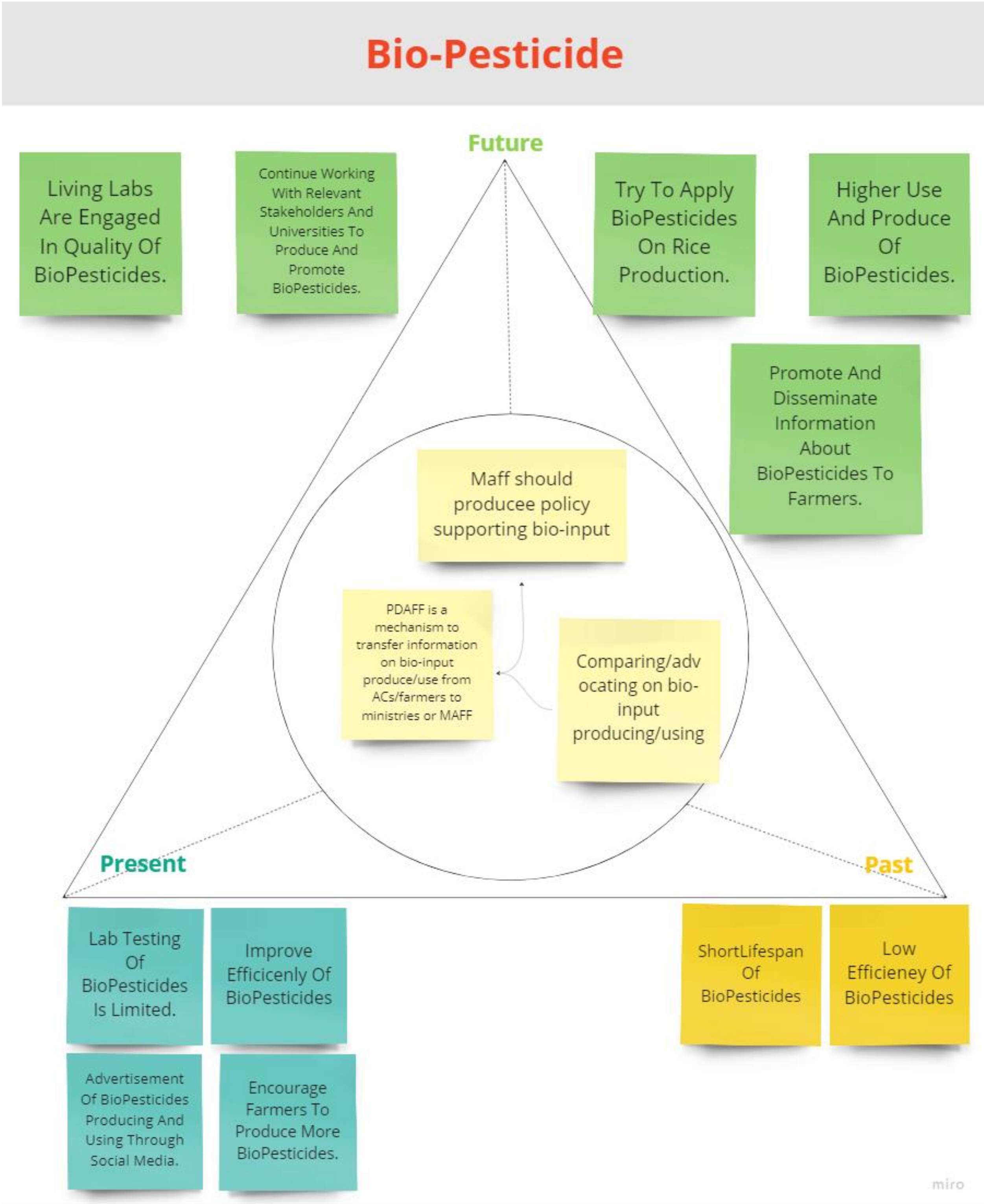


EM
Future
Support Communities To Produce Em By Using Local Row Materials.
Higher Use And Produce Of Em
Living Labs Are Engaged In Quality Of Em
Continue Working With Relevant StakeHolders And Universities To Produce And Promote Em.
Promote And Disseminate The Information About Em To Farmers.
Value added in the market
Certification of the products
Lab analysis (externally)
Lab testing (internally)
Research and lab resources for the quality imporvement and certification
Working with government to have process for registering EMs
Training for Government officers in other countries
Quality control system
Defarm
Knowledge sharing /training to producers
Agreement between EM producers collectively
Production inspection
Bring together EM producers
Define the ingredients and marking process (defining the standards for the productions)
Present
Past
Promotion Of Em Produce In The Community Level
Support Community To Do Planning Of The Em Business And Promotion
Train Farmers To Better Understand The Value Chain Of Em
Lack Of Scientific Research On The Composition In The Em Product.
Lack Of Technical Supports For Farmers To Produce Em
Lack Of Suppliers Em Products
Lack Of Awareness Among Consumers To Support Em Product.
Difficult To Find Raw Materials.
Em Requires Many Types Of Raw Materials.
Em Products Were Packed For The Local Market Only But Not Yet Achieving Standard Labelling.


Bio-Pesticide
Future
Living Labs Are Engaged In Quality Of BioPesticides.
Continue Working With Relevant Stakeholders And Universities To Produce And Promote BioPesticides.
Try To Apply BioPesticides On Rice Production.
Higher Use And Produce Of BioPesticides.
Promote And Disseminate Information About BioPesticides To Farmers.
Maff should producee policy supporting bio-input
PDAFF is a mechanism to transfer information on bio-input produce/use from ACs/farmers to ministries or MAFF
Comparing/advocating on bio-input producing/using
Present
Past
Lab Testing Of BioPesticides Is Limited.
Improve Efficicenly Of BioPesticides
Advertisement Of BioPesticides Producing And Using Through Social Media.
Encourage Farmers To Produce More BioPesticides.
ShortLifespan Of BioPesticides
Low Efficieney Of BioPesticides
miro

Annex 4 Guided questions for interview

INNOVATION PROCESSES BASED ON MICROORGANISMS: BIO-INPUTS IN CAMBODIA

Institution:
Date of survey:
Method of survey:
Surname first name of the respondents:
Position:
Mail:
Phone:
Consent:
Introduction of institutions/cooperatives:

I. Production of bio-input

Do you produce (has product) bio-inputs: biopesticides or biofertilizers specify which ones?

- Bokashi?
- EM?
- Compost?
- Liquid compost?
- Biopesticide with “neem”?
- Other? (precise?)
- Other? (precise?)

For each product give the technical composition.

For each bio-product (Bokashi, EM, compost, Bio-pesticide neem, other) give:

- The project origin of the initiative?
- Who gives the technical guide of formular? (can you give me one?)
- The investment you are realized.
- For The volumes produced on each year (of each product)?
- What were your motivations for producing each bio-input?
- Where do you produce these bio-input?
- Do you know other producers of the bio-input in Cambodia?
- What is the mechanism for distribution or give at producers?

Can you summarize the 3 main locks (limiting factors) that block the increase of your activity of production, sale or use of bio-inputs?

- (Rank locks in order of importance (put a, b, c (from +important or - important)
- Can you estimate the cost of each bio-input?
- The cooperative buys organic fertilizer? ___ If yes, how many per year?
- Other fertilizer chemical? _____-Pesticides? ____________

II. Adoption and use of production bio-input in the farm

How many producers do you know in your cooperative using bio-input?

- Bokashi?
- EM?
- Compost?
- Liquid compost?
- Biopesticide with “neem”?
- Other? (precise?)

- Other? (precise?)

What types of producers (give me 3 or 4 types) in relation with the production or application of bio-inputs?
Any other characteristics?

III. If the cooperative or ONG give "training" to the producer.

How many trainings on bio-input you/your organization have provided in the last 5 years?

- Date / Thematic (in relation to bio-input) / Number of farmers.
- Date / Thematic (in relation to bio-input) / Number of farmers.
- Date / Thematic (in relation to bio-input) / Number of farmers.
- ….. …..

Can you summarize the 3 main locks (limiting factors) that block the increase of use each bio-input
(bokashi, compost, EM, bio-neem, other) a level of farm?

- (Rank locks in order of importance (put a, b, c (from +important or - important)
- In which main crops that the farmers use each the bio-input?
- For rice production, have any bio-input have been used so far?

What were the results observed after application of bio-inputs? by each type of bio input.

IV. System Actors and interactions

Do you have a relationship with research in bio-inputs?

If so, which researchers? What are these relationships?

Do you have any relations with support services, public or private in relation to bio-input?

Specify which? What are these relationships?

Do you have relationships with other companies importing and producing bio-inputs, if so, of what nature?

What other enterprises or cooperative producing bio-input in Cambodia?

Do you certify bio-inputs? How is the certification process, who certifies?

What can be the cost of certification / ton produced (including informal cost)?

V. Other Innovations based on microorganisms.

In what agronomic practices do you think these microorganisms can be used outside the manufacture of bio-inputs (say yes or no)?

When you said "yes" above, specify the precise nature of the uses in practice?

If there are several "yes" which and the most important practice in terms of adoption?

What are the 3 locks (constraints) that hinder the use of knowledge on microorganisms in farmers' practices from the most important to the least important?

VI. Evaluation of bio-inputs

What is the nature of the risks that must be taken into account as a priority on bio-inputs?

In your experience, has the use of bio-inputs resulted in users you know by:

a. More consumption of chemical pesticides? ____ If so, explain which ones and why?
b. less chemical consumption? ____If so, explain which ones and why?

In your experience, how has the use of bio-inputs improved (or not) the situation (income, welfare) of farmers?

What questions do you want to ask us?

Do you have reports of articles you know on the subject, or have you published that you could share with us?

When will you be able to join our workshop in September?