A Review of Agricultural Research System in Thailand: The Development, Policies, Institutions, Investment Patterns, and Impact Assessment

Review of Integrative Business & Economics Research

Waleerat Suphannachart
Faculty of Economics, Kasetsart University
Bangkok, Thailand

ABSTRACT

This article aims at reviewing the agricultural research system in Thailand. By reviewing literature and analyzing the data using descriptive statistics the article provides an overview of the agricultural research system with respect to its historical development, policy guidance, public funding and relevant institutions, investment trends and patterns, and returns on research investment. This could serve as a basis for analyzing issues regarding agricultural research investment in Thailand. The review shows the percentage shares of agricultural R&D in agricultural GDP had experienced downward trends. Among major research performers, agricultural research activities have primarily been conducted by the government, followed by universities and private enterprises. The government share in total agricultural R&D spending has declined while that of universities increased. The role of private sector is relatively small. Economic returns on the public agricultural R&D investment are high; however, there is no evidence for universities and private-firm R&D. Research policy should provide a continued support for agricultural R&D and stimulate more collaboration from the private sector. Emphasis should also be placed on developing consistent and comprehensive record of agricultural R&D data.

JEL Classification: O38, R58
Keywords: Thailand, agricultural research, R&D investment, returns to agricultural R&D

1. INTRODUCTION

Agricultural research plays an important role in sustaining agricultural growth in many developing countries. Investing in agricultural research is essential in generating new technologies, improving machineries, crop varieties, animal breeds, and farming techniques that help boosting agricultural production using fewer

ISSN: 2304-1013 (Online); 2304-1269 (CDROM)

resources. Thailand, one of the world's major agricultural producers and exporters, has long been investing in agricultural research. Previous studies show the longstanding investment in agricultural research had contributed to the Thai agricultural productivity growth which has important implications on living standards, poverty alleviation, food security, and overall economic growth. The returns on public research investment have also shown to be high implying an underinvestment in agricultural research (Suphannachart and Warr, 2011, 2012). However, stimulating research spending alone is not enough for solving the underfunded issue. Improving quality, priority setting, and evaluating system of agricultural research conducts are also important. This requires a clear understanding of overall agricultural research system as well as credible database that could support effective research plans, conducts and evaluations both at aggregate and disaggregate levels.

Although there has long been an investment in agricultural research there has not been a systematic record of agricultural research and development (R&D) data in Thailand. A lack of consistent and comprehensive data could prevent further research, particularly in economics, from analyzing issues that could improve the effectiveness of agricultural research system. Not only agricultural R&D data are unavailable systematically but also information on agricultural research system is quite scatter as there are several agencies involving in research conduct. This paper aims at providing an overview of the Thai agricultural research system. It gathers information and statistics from various sources to draw an overall trends and characteristics of agricultural research activities. By reviewing literature and analyzing the data using descriptive statistics the paper could provide a clearer picture of the agricultural research system, starting from the development of agricultural research system, the direction of agricultural research policy, the research funding process, the current stage of agricultural research investment, and the returns on the research investment. This could serve as a basis for analyzing issues regarding the agricultural research investment in Thailand.

The paper consists of five sections beginning with an historical summary of the agricultural research system. Agricultural research policies and strategies are reviewed to draw a common direction of research focuses. Agricultural research funding is then described, followed by an overview of agricultural R&D investment. The characteristics and trends of the major types of agricultural research investment – public, university, private and foreign are also described. Finally, an economic impact

ISSN: 2304-1013 (Online); 2304-1269 (CDROM)

assessment of overall agricultural research system is reviewed and discussed.

2. HISTORICAL DEVELOPMENT OF THE AGRICULTURAL RESEARCH SYSTEM

Agricultural research in Thailand began in 1903 when a Thai prince who graduated in agriculture abroad returned home and set up education programs in farming as well as an agricultural breeding program (Isarangkura, 1986). However, the agricultural research activities only became active after World War II due to the pre-war lack of personnel and the government's low priority for research investment (Pochanukul, 1992). The worldwide expansion of agricultural research and extension programs in the post World War II era, especially in the 1950s, 1960s, and 1970s, was heavily funded by grants and loans from international agencies (Evenson, 2001, p.615).

The historical development of agricultural research system is closely linked with the evolution of technology application in Thai agriculture, which was summarized in a review study by the Asian Development Bank (Office of Agricultural Economics, 1998). Prior to 1955, agricultural production relied on traditional technology. From 1955 to 1965, there was moderate application of two-wheel hand tractors and other imported technology, e.g., fertilizer, irrigation and new seeds. A more systematic introduction of production techniques took place during 1966 to 1975. In 1975-1976, the green revolution was launched with the introduction of high yielding varieties for rice, corn and soybean. Since 1977, the agricultural research focus has been extended to cover other areas particularly in developing pest resistant varieties, and natural and organic farming (Office of Agricultural Economics, 1998). More recently, research has focused on increasing agricultural productivity while preserving natural resources and protecting the environment.

Thailand's agricultural research system become more structured after 1956-59 when the National Research Council of Thailand (NRCT) was set up to look after all research activities. Its direction was set in line with the national development plan prepared by the National Economic and Social Development Board (NESDB) that was also established in the same period (Isvilanonda and Praneetvatakul, 2003). National research policy and guidance became more organized when the first research policy was set in 1977. However, there has never been a national agricultural research plan. There is only a technology and science development plan which broadly guides agricultural research activities in various institutions (Isarangkura, 1986, p.24).

ISSN: 2304-1013 (Online); 2304-1269 (CDROM)

The importance of agricultural research has been realized since the first national development plan in 1961. Improvement in agricultural research was emphasized as a fundamental basis for future development in the first and second plans. Since the late 1970s, the government has reinforced the role of science and technology in raising productivity. A clear linkage between productivity and research was spelled out, emphasizing the enhancement of productivity and higher value added products through several areas including support of R&D and transfer of technology in agriculture. In the ninth development plan, the emphasis of R&D promotion was on science and technology which includes biotechnology research.

The agricultural research system in Thailand mainly consists of research in crops, livestock and fisheries, conducted by various institutions, primarily government agencies. Agricultural research institutes were initially centralized in the Bangkok area and later decentralized in regional research centers. However, research is still top-down in the sense that the involvement of farmers and other stakeholders in determining research priorities is rare. The prioritization and adaptation process are dominated by the executive boards in the Ministry of Agriculture and Cooperatives (MOAC).

3. AGRICULTURAL RESEARCH POLICY AND STRATEGY

Agricultural research policy in Thailand is embedded in the National Research Policy and Strategy prepared by the Office of the National Research Council of Thailand. The approval of annual government budget uses this research policy as a guideline for allocating research budget. The current policy is under the Eighth National Research Policy and Strategy (2012-2016) which was set in line with the Eleventh National Economic and Social Development Plan (2012-2016). In order to overcome the middle income trap the national development plan aims at stimulating economic growth and competitiveness through investing in R&D and strengthening agricultural competitiveness.

Under the current research plan there are 13 target research groupings consisting of 1) Application of sufficiency economy, 2) National stability and promotion of good governance, 3) Educational reform and learning creation, 4) Water resources, 5) Global warming and alternative energy, 6) Sustainable Agriculture, 7) Promotion of health, disease prevention, treatment and health rehabilitation, 8) Environmental

ISSN: 2304-1013 (Online); 2304-1269 (CDROM)

management and development of natural resources diversity, 9) Innovative and major industrial technology, 10) Tourism management, 11) The elderly society, 12) Logistic systems, and 13) Reform of the national research system (NRCT, 2012). These R&D focuses have also been translated into issue-based and commodity-based strategies including R&D strategies for major agricultural products such as rice, rubber, sugarcane, cassava and oil palm. In overall, emphasis of agricultural R&D have been given to adding value to agricultural commodity in order to enhance its competitiveness and to managing natural resources in a sustainable manner.

With regards to agricultural research investment and personnel there is no specific detail on agriculture but the Eighth National Research Policy and Strategy aims at increasing the national research expenditure of not less than 1 percent of the gross national product and increases the country research personnel to 10 researchers per 10,000 populations. The ratio of private to government research investment has also been targeted to be increased to 1:1. This is also in line with the targets set by the Eleventh National Economic and Development Plan and the First Science, Technology and Innovation (STI) Plan (2012-2021) prepared by the Ministry of Science and Technology. Despite minor differences in target settings all the government agencies aim at boosting R&D investment and personnel in all sectors with an emphasis on stimulating more involvement of the private sector.

There are several agencies announcing policies and strategies relating to agricultural R&D in Thailand. They are summarized in Table 1. Most of them follow the guideline set by the NRCT. In particular, the Department of Agriculture (DOA), responsible for conducting crop research, has stated clearly that its first R&D strategy focuses on agricultural value adding in order to increase exports while relying less on imports. Agricultural Research Development Agency (Public Organization) or ARDA provides funding for agricultural research that can be applied for commercial, public, and policy usages. ARDA research strategy has been set in line with the NRCT policy and has divided its strategy into three stages; research for urgent solution, research for mid-term and long-term solution on agriculture, and research for innovation. National Innovation Agency (NIA), on the other hand, focuses on organic agriculture and food processing research. Moreover, the Thailand Board of Investment (BOI) has promoted R&D investment projects by granting maximum tax privileges. Since there are very detailed information on each policy and strategies their websites are shown for the search of more and complete information.

ISSN: 2304-1013 (Online); 2304-1269 (CDROM)

Table 1 Summary of policies and strategies relating to agricultural R&D in Thailand

Institutions/ Strategies	Policy focuses relating to agricultural research and development	Sources
NESDB/ Eleventh National Development Plan (2012-2016)	Strategy for strengthening the agricultural sector, food, and energy security in which R&D plays crucial role in: - generating value-added in the agricultural production, and - ensuring food security and developing bio-energy	www.nesdb.go.th
NRCT/ Eighth National Research Policy and Strategy (2012-2016)	• Sustainable agriculture - Increasing agricultural competitiveness while ensuring food security through - productivity-enhancing R&D - value-adding R&D - market-driven R&D • Environmental management and development of natural resources diversity • Bio-energy and alternative energy • Issue/commodity-based R&D strategies (2013-2016) include: - Climate change - Water resource management - Environmental management - Sufficiency economy - Food and security - Rice - Rubber - Oil palm - Sugarcane - Cassava industry - Horticulture - Thai herbs	www.nrct.go.th
MOAC/ Agricultural Development Plan (2012-2016)	• Encourage crop varieties improvement (including energy crops), animal and fishery breeding in response to climate change and competitiveness issues. • Minimize agricultural losses through agricultural machinery and post-harvesting R&D. • Encourage research collaboration among government, private firms, universities, entrepreneurs and research institutes.	www.oae.go.th
DOA/ DOA R&D Strategy (2011-2015)	Agricultural value adding and sustainable uses of resources.	www.doa.go.th
ARDA/ Third ARDA Implementation Strategy (2012-2016)	• Proactive agricultural R&D: commercial, public and policy: - Funding research to solve urgent problems e.g. longan, rice, rubber, shrimps. - Funding research for mid-term and long-term	www.arda.or.th

ISSN: 2304-1013 (Online); 2304-1269 (CDROM)

	solution e.g. GDP-enhancing R&D, climate change-responded R&D. - Funding research for innovation • Capacity building of researchers	
BIOTEC	R&D of food, plant and animal biotechnology, with a special emphasis on using biotechnology to improve yield and quality.	www.biotec.or.th
NIA/ Strategic based innovation strategy	• 'Thai Delicious' encourages R&D on food processing emphasizing on value-creation and ready-to-eat food products that helps serving Thailand as Kitchen to the World. • 'Organic agriculture business' encourages food safety through R&D on organic agriculture for the whole supply chain.	www.nia.or.th
BOI/ Policy and Criteria for Investment Promotion (Announcement No.222557)	• Encourage R&D, innovation, value creation in the agricultural sector to enhance national competitiveness. • Promote activities that are environment-friendly, save energy or use alternative energy to drive balanced and sustainable growth - Activities of special importance that will be granted maximum tax privileges (no corporate income tax exemption cap) include economic forest plantation (except Eucalyptus), R&D, and biotechnology.	www.boi.go.th

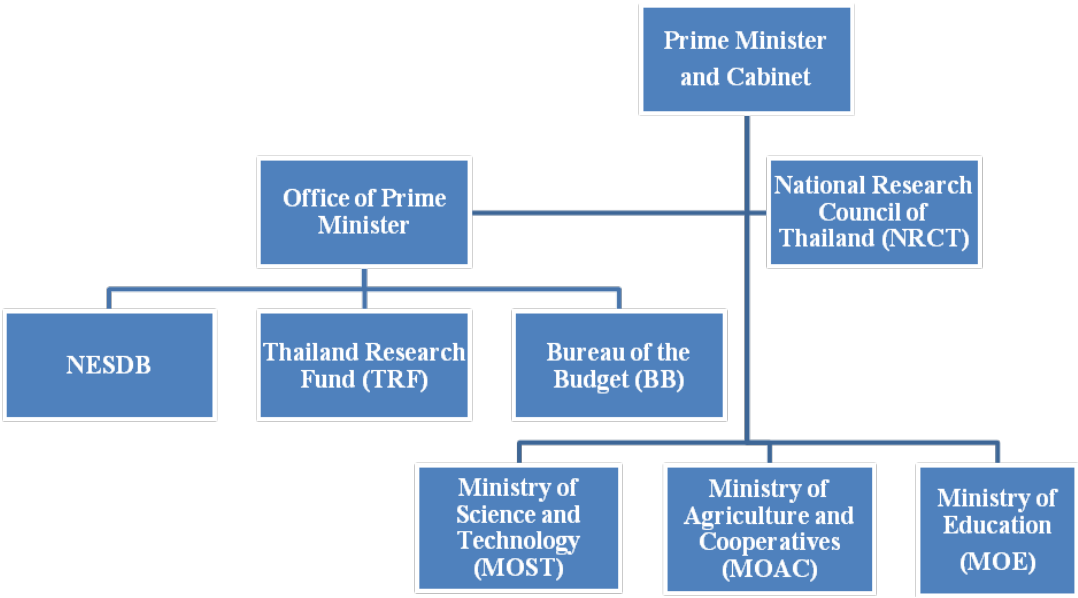
Moreover, Thailand Development Research Institute (TDRI), the renowned public policy research institute, has proposed forward-looking policies for quality growth under the three possible scenarios of Thailand in the next three decades (Tangkitvanich and Bisonyabut, 2014). One of the scenarios relating to agricultural research is called "modern farming and knowledge-based services" in which the majority of Thai people resides and works in these two sectors (agriculture and services). In order to overcome the middle income trap and aging society challenges, Thailand needs to modernize the agricultural sector with helps of R&D so that less labor required in this sector and then released to develop other sectors. Tangkitvanich and Bisonyabut (2014) suggest that modern farming should be able to ensure more on food safety and value-added products. This requires larger farm size with more intensive uses of agricultural machinery, precision farming, crop variety and animal breeding improvement, supply chain management, logistics and marketing, and more importantly, smart farmers. Agricultural research should also support organic agriculture that will be able to meet increasing demands for health-conscious food products.

ISSN: 2304-1013 (Online); 2304-1269 (CDROM)

4. AGRICULTURAL RESEARCH FUNDING AND INSTITUTIONS

This section reviews agricultural research funding and involved agencies, mainly in the public and public-enterprise sectors. The government budget is the major source of national agricultural research funding in Thailand. The budget allocation mechanism involves the NESDB in determining general guidelines for economic development direction, and the NRCT in examining whether the proposed research projects are feasible and justified by the national development plan and the corresponding research policy and strategies. The budget allocation then has to pass final approval from Cabinet. The structure of the main funding channels is shown in Figure 1.

Figure 1 Structure of Agricultural Research Funding



Source: Adapted from Fuglie (2001).

The approved budget is mainly provided by the Bureau of the Budget under the Office of the Prime Minister to the research performing ministries. In addition, each research performing agency may apply for competitive grants from the NRCT and the Thailand Research Fund (TRF). All research projects proposed by government institutions through both funding channels have to be approved by the NRCT, an autonomous agency under the Prime Minister (Isvilanonda and Praneetvatakul, 2003).

The MOAC, MOE and MOST, shown in Figure 1, are the three major ministries

ISSN: 2304-1013 (Online); 2304-1269 (CDROM)

receiving funding from the government budget. During 1992-1996, MOAC accounted for 52.4 percent of total government budget on research activities, followed by MOE (21.72 percent) and MOST (13.97 percent) (Areekul, 2000). The MOAC is the leading agricultural research performer and the largest share has been dominated by crops research with relatively small budgets for livestock, forestry and fisheries (Fan et al., 2004).

The MOAC consists of four major research performing departments: the Rice Department for rice research, the Department of Agriculture (DOA) for crops research (other than rice),[1] the Department of Livestock Development (DLD) for livestock research, and the Department of Fisheries (DOF) for fisheries research. Although there have been several changes in the MOAC organization structure these four departments remain the core research agencies. Each department consists of many research stations located in all regions. There are also public organizations attached to the MOAC including the Agricultural Research Development Agency (ARDA). The ARDA was established in 2003 providing competitive grants to accelerate commercial agricultural research.

Public universities also conduct significant agricultural research, receiving government funds through the Ministry of Education (MOE) and through grants from the TRF and the NRCT. They also receive funding from other private and international sources. The leading research institutes in agricultural science since the 1960s encompass Kasetsart University in the Central region, Khon Kaen University in the Northeast, Chiang Mai University in the North, and Prince of Songkla University in the South. Maejo University in the North is also important as it is the oldest agricultural education institution and used to serve as a research station for Kasetsart University. It was previously known as the Mae Joe Institute of Agricultural Technology and was reorganized and upgraded from an agricultural college to university level in 1975 (Isarangkura, 1986).

Agricultural biotechnology research is funded mainly through the National Science and Technology Development Agency (NSTDA) which is an autonomous agency under the Ministry of Science and Technology. The rest of public agricultural research funding was shared by the Ministry of Industry (for sugar and sugarcane) and the

[1] Prior to 1972, the Rice Department was separated from the DOA. It was incorporated into the DOA in 1972 and was separated out again in 2006.

ISSN: 2304-1013 (Online); 2304-1269 (CDROM)

Ministry of Finance (for tobacco).

In the past, the government R&D departments could seek external grant assistance for research projects through the Department of Technical and Economic Cooperation (DTEC) under the Prime Minister's Office. Since 2004, Thailand International Development Cooperation Agency (TICA) under the Ministry of Foreign Affairs has been the successor of DTEC. Most of the assistance from foreign sources, e.g., USAID, The World Bank, and the International Fund for Agricultural Development (IFAD) was directed to development projects rather than to pure agricultural projects (Isarangkura, 1986).

Other sources of funding are from private companies and bilateral and international organizations. In addition, the government supports private investment in agricultural research by providing tax incentives and subsidized loans (Fuglie, 2001). To a large extent, agricultural research is still considered a service provided by the public sector. Table 2 summarizes a list of major public institutions conducting agricultural research in Thailand with their main sources of funding.

Table 2 Major Public Institutions Conducting Agricultural Research and Sources of Funding

Institutions	Sources of funding	Remarks
1. Ministry of Agriculture and Cooperatives (MOAC) - Department of Agriculture - Rice Department - Department of Livestock Development -Department of Fisheries	- Government budget - National Research Council of Thailand (NRCT)	All research projects require an approval from NRCT
2. Public Organization under MOAC - Agricultural Research Development Agency (ARDA) - Highland Research and Development Institute (HRDI)	- Asian Development Bank (ADB) funds - Commercial service fees - Loans and grants from donor governments and public agencies	ARDA only provides financial support to commercial research.
3. Ministry of Industry - Sugarcane and Sugar Institute	- Government budget	
4. Ministry of Finance - Tobacco Monopoly	- Government budget	
5. Ministry of Science and Technology - National Centre for Genetic Engineering and Biotechnology (BIOTEC) under the NSTDA	- Government budget - Revenue from providing services and commercial projects - Competitive grants from both national and international sources.	

ISSN: 2304-1013 (Online); 2304-1269 (CDROM)

6. Ministry of Education - Kasetsart University - Chiang Mai University - Khon Kaen University - Prince of Songkla University - Maejo University	- Government budget - Competitive grants from both national and international sources - Private sector funding	

Source: Adapted from Isarangkura (1986)

5. OVERVIEW OF AGRICULTURAL RESEARCH INVESTMENT

This section provides an overview of agricultural research investment patterns in Thailand compared with other developing countries. An emphasis is given to domestic R&D and sources of data which raises the need for more systematic record of agricultural R&D data. Since there are several sectors involving in conducting agricultural research investment trends and characteristics of major research performers; public, private, universities, and foreign research institutes are also discussed.

5.1 Overall trends and patterns of agricultural research investment

For overall agricultural R&D a global source of information on agricultural R&D statistics is the Agricultural Science and Technology Indicator (ASTI), led by the International Food Policy Research Institute (IFPRI). The ASTI provides consistent and comparable country-level data sets of agricultural R&D focusing on developing countries; however, the data on Thailand is quite limited. Its recent report shows the global public agricultural R&D spending has been increasing which was accelerated by the investment from developing countries notably China and India (Flaherty et al., 2013). During 2000 to 2008, the global public spending in agricultural research had increased by 22 percent while the global spending by private firms had increased by a higher rate of 28 percent (ASTI, 2013). The majority of private-sector R&D had concentrated on food processing. Thailand is an exception as its percentage share of the public agricultural R&D investment had been declining markedly from 1996 to 2008, in which the 2008 intensity ratio (0.32) is lower than an average ratio of the middle-income countries and far less than those of the high-income country and Asia-Pacific averages, shown in Table 3.

Table 3 Public Agricultural R&D intensity ratios in middle-income group in Asia-Pacific, 1996-2008

Country	Public agricultural R&D spending as a share of agricultural GDP		
	1996	**2002**	**2008**
Malaysia	1.15	1.92	1.05

ISSN: 2304-1013 (Online); 2304-1269 (CDROM)

China	0.33	0.46	0.50
India	0.25	0.38	0.40
Papua New Guinea	0.77	0.54	0.39
Philippines	0.34	0.48	0.33
Sri Lanka	0.43	0.53	0.34
Thailand	0.69	0.51	0.32
Indonesia	0.37	0.28	0.31
Pakistan	0.36	0.24	0.25
Vietnam	0.09	0.17	0.17
Lao PDR	na	0.30	na
Middle-income country average	0.34	0.43	0.43
High-income country average	3.23	3.48	4.13
Asia-Pacific average	0.62	0.70	0.63

Source: Adapted from Flaherty et al. (2013), ASTI Regional Synthesis Report.
Note: The Agricultural Science and Technology Indicators (ASTI) initiative, led by the International Food Policy Research Institute (IFPRI), is a comprehensive and trusted source of information on agricultural R&D systems across the developing world.

For Thailand, the domestic sources of agricultural R&D data mainly used in economic studies are drawn from the Bureau of the Budget and the office of NRCT. Prior to 1996 when there was no official record of the research expenditure in Thailand, the budget data from the Bureau of the Budget were used in economic analysis. The Bureau of the Budget provides data on approved budget expenditure classified by government agencies. This data source can be traced back to 1960 which allows a long time series and so suitable for a statistical analysis.[2] However, only the approved public research budget can be drawn and no detailed information on actual spending is available systematically.

The NRCT data comprises the national survey data containing all R&D undertaken in Thailand and the government budget-based R&D data. The NRCT has reported the results of the national survey on R&D expenditure and personnel on a two-year basis since 1996. The survey contains data on R&D expenditure in all major sectors of performance including the government, universities and private firms which can be classified by fields of study; natural science, engineering & technology, medical sciences, agricultural sciences, social sciences, and humanity. This gives an overall trend in R&D but no details on each sector. In 2006, the NRCT has launched the National Research Project Management (NRPM) online system that provides more detailed data on the public R&D at a project- and commodity level basis. The data can be retrieved online starting from 2008. There is still no systematic record of the

[2] See examples of previous studies that employed the time-series budget data in economic analysis from Suphannachart and Warr (2011 and 2012).

ISSN: 2304-1013 (Online); 2304-1269 (CDROM)

private-sector R&D which has increasingly played an important role in the agricultural research system.

There exists data discrepancy among sources of R&D data. For example, the public agricultural R&D intensity ratios reported by the ASTI, shown in Table 3, are quite different from those reported locally by the NRCT, shown in the last two columns of Table 4, especially when comparing the ratios between the two sources in 1996. The public agricultural research budget data obtained from the Bureau of the Budget, mostly used in previous (time-series) studies, are also different from the NRCT survey (Suphannachart, 2009). This section does not aim to judge which source is more credible but to point out this cautious fact before describing R&D data from the local sources.

As the NRCT survey provides more details on R&D characteristics this study employs its data to show an overview of agricultural research investment in Thailand. Nonetheless, inconsistency exists among various issues of the NRCT survey reports. Earlier issues had provided more details on the characteristics of agricultural R&D than the recent issues making it difficult to keep a consistent record of the R&D series. The available data on total agricultural R&D spending, number of researchers, and types of R&D are briefly shown below but due to inconsistency in the reporting format some data are not available in recent years.

Table 4 Agricultural R&D Intensity Ratios in Thailand

	Total AgR&D (mill Baht)	AgGDP (mill Baht)	AgR&D/ AgGDP (%)	Public AgR&D (mill Baht)	PublicAgR&D/ AgGDP (%)
1996	1,571.74	420,493	0.37	1,140.79	0.27
1997	1,458.77	427,076	0.34	1,127.45	0.26
1999	1,565.82	426,092	0.37	979.15	0.23
2001	3,189.00	458,734	0.70	2,529.01	0.55
2003	3,135.77	596,642	0.53	1,912.44	0.32
2005	3,570.86	700,380	0.51	1,323.26	0.19
2007	2,918.32	848,688	0.34	893.29	0.11
2009	6,032.79	945,606	0.64	4,382.07	0.46
2011	5,457.00	1,310,995	0.42	2,548.00	0.19

Source: National survey on R&D expenditure and personnel of Thailand, various issues, National Research Council of Thailand (NRCT) and National Income of Thailand 2013, National Economics and Social Development Board (NESDB).

According to the NRCT survey reports, the total R&D spending in agricultural sciences has steadily increased from 1996 to 2009 but slightly dropped in 2011, as

ISSN: 2304-1013 (Online); 2304-1269 (CDROM)

shown in Table 4. However, when comparing the agricultural R&D spending with agricultural GDP (current prices) the percentage share do not depict an increasing trend. The agricultural R&D spending as share of agricultural GDP (intensity ratio) reached its peak in 2001 and later decreased. In 2011, both total and public agricultural R&D intensity ratios fell from the 2009 ratios to 0.42 and 0.19, respectively. The drop in the intensity ratios was partly due to the severe flooding occurred during the 2011 monsoon season. The flooding mainly affected the government R&D sector which is the largest agricultural research performer in Thailand (NRCT, 2013).

In terms of research categories, the NRCT has classified research activities into three main categories:

1. Basic research: knowledge from basic research is a theory, law or hypothesis for researchers to apply in future research.
2. Applied research: aims at producing new knowledge or technology for practical uses.
3. Experimental Development: existing knowledge or technology is developed or improved for better uses.

Agricultural research activities are mostly characterized under applied and experimental development research. In 2005, the majority of agricultural research is applied research (51.6 percent), followed by experimental development (33.9 percent) and basic research (14.5 percent) (NRCT, 2007). Unfortunately, the NRCT has stopped recording the agricultural science research data classified by research categories since 2007 and so the latest available data is in 2005. Note that the R&D spending of major crops classified by research categories can be accessed online via the NRPM system.

In terms of research personnel, over the period of 1996 to 2011 the majority of researchers in agricultural science were in the government sector, followed by universities, while those in other sectors were minor (Table 5). However, the number of researchers in the government sector has been declining while those in universities have been rising. The share of government researchers was the largest in 1996 but has declined over the period of 1996 to 2011 while the share of university researchers increased. Of these agricultural researchers, the majority were master-degree graduates, followed by bachelor-degree and PhD graduates, respectively. Most of the data on private-sector researchers are not available. In total, the number of researchers

ISSN: 2304-1013 (Online); 2304-1269 (CDROM)

has been declining steadily since 2007. Despite the government efforts to promote R&D through various policies and strategies a falling number of researchers in agricultural science can pose a serious problem and threatens the development of the agricultural research system.

Table 5 Researchers (headcount) in Agricultural Science Classified by Sector of Performance, 1996-2011

	Government	Universities	Public Enterprise	Private Enterprise	Private Non-Profit	Total
1996	**3,988**	**1,015**	**49**	**5**	**143**	**5,200**
% in total	76.69%	19.52%	0.94%	0.10%	2.75%	100.00
1997	**3,216**	**828**	**68**	**56**	**1**	**4,169**
% in total	77.14%	19.86%	1.63%	1.34%	0.02%	100.00
1999	**2,786**	**1,654**	**32**	**16**	**0**	**4,488**
% in total	62.08%	36.85%	0.71%	0.36%	0.00%	100.00
2001	**2,406**	**2,383**	**71**	**362**	**0**	**5,222**
% in total	46.07%	45.63%	1.36%	6.93%	0.00%	100.00
2003	**1,889**	**1,691**	**37**	**na**	**6**	**3,623**
% in total	52.14%	46.67%	1.02%		0.17%	100.00
2005	**1,980**	**1,881**	**86**	**984**	**65**	**4,996**
% in total	39.63%	37.65%	1.72%	19.70	1.30%	100.00
2007	**2,235**	**2,709**	**56**	**na**	**36**	**5,036**
% in total	44.38%	53.79%	1.11%		0.71%	100.00
2009	**2,173**	**2,574**	**56**	**na**	**53**	**4,856**
% in total	44.75%	53.01%	1.15%		1.09%	100.00
2011	**1,484**	**2,940**	**69**	**na**	**43**	**4,536**
% in total	32.72%	64.81%	1.52%		0.95%	100.00

Source: National survey on R&D expenditure and personnel of Thailand, various issues, National Research Council of Thailand (NRCT). Note: Agricultural science includes crops, livestock, fisheries and forestry research.

5.2 Major research performers

Agricultural research has been carried out by several research agencies and some research results utilized in Thailand was spilled from overseas. It is thus important to review characteristics and investment patterns of major research performers; public, private, university and foreign research. Typically for developing countries, agricultural research is largely conducted by the government. According to the NRCT survey shown in Table 6, the government has dominated R&D expenditure in agricultural science, followed by universities and private enterprises. The role of university research has become increasingly important in recent years; particularly in 2005 and 2007 when its R&D spending share slightly exceeded that of the government. The private sector also conducts research, well-known in seeds and livestock research. However, the surveyed private R&D spending may be

ISSN: 2304-1013 (Online); 2304-1269 (CDROM)

underestimated as their questionnaire responding rate is quite low compared with other sectors (NRCT, 2007).

Table 6 R&D Expenditure in Agricultural Science Classified By Sector of Performance, 1996-2011

	Government	Universities	Public Enterprise	Private Enterprise	Private Non-Profit	Total
1996	**1,140.79**	**369.55**	**1.22**	**50.07**	**10.10**	**1,571.74**
% in total	72.60%	23.50%	0.10%	3.20%	0.60%	100.00%
1997	**1,127.45**	**270.30**	**12.77**	**47.57**	**0.67**	**1,458.77**
% in total	77.30%	18.50%	0.90%	3.30%	0.00%	100.00%
1999	**979.15**	**574.17**	**8.30**	**4.20**	**0.00**	**1,565.82**
% in total	62.50%	36.70%	0.50%	0.30%	0.00%	100.00%
2001	**2,529.01**	**387.53**	**21.28**	**251.17**	**0.00**	**3,189.00**
% in total	79.30%	12.10%	0.70%	7.90%	0.00%	100.00%
2003	**1,912.44**	**705.17**	**43.20**	**473.07**	**1.95**	**3,135.77**
% in total	61.00%	22.50%	15.10%	0.10%	0.00%	100.00%
2005	**1,323.26**	**1,424.76**	**48.08**	**766.34**	**8.34**	**3,570.86**
% in total	37.10%	39.90%	1.30%	21.50%	0.20%	100.00%
2007	**893.29**	**1,124.89**	**22.47**	**869.81**	**7.86**	**2,918.32**
% in total	31.00%	38.50%	0.80%	29.80%	0.30%	100.00%
2009	**4,382.07**	**770.78**	**43.60**	**817.00**	**19.33**	**6,032.79**
% in total	72.63%	12.78%	0.73%	13.54%	0.32%	100.00%
2011	**2,548.00**	**1,808.00**	**96.00**	**977.00**	**28.00**	**5,457.00**
% in total	46.69%	33.13%	1.76%	17.90%	0.51%	100.00%

Source: National survey on R&D expenditure and personnel of Thailand, various issues, National Research Council of Thailand (NRCT). Note: Agricultural science includes crops, livestock, fisheries and forestry research.

Farmers also conduct some limited research. Their trial-and-error methods have been said to contribute to technological progress in the horticulture sector and the swine industry (Siamwalla et al., 1993, p.97). Nevertheless, their role in overall agricultural research system is regarded as minor. Major types of agricultural research investment – public, university, private and foreign are discussed in detail as follows.

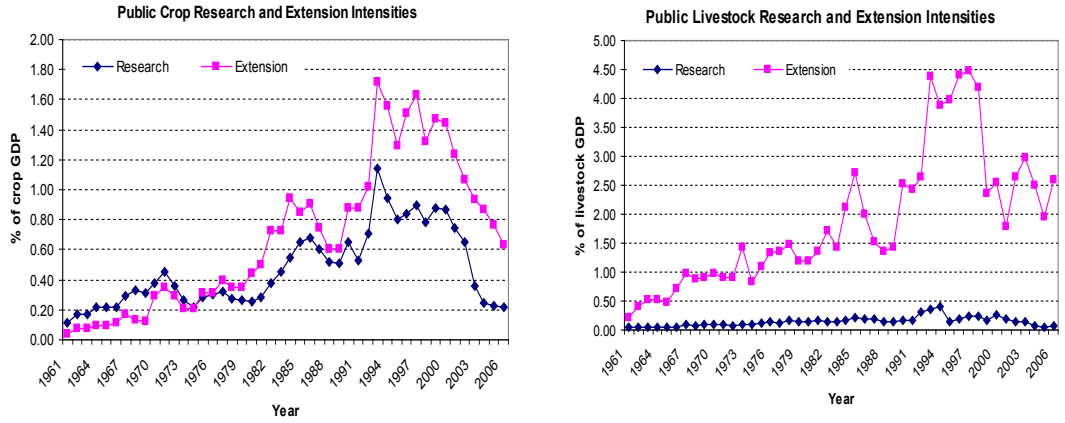
5.2.1. Public Investment in Agricultural Research

Agricultural research activities have primarily been conducted by the government and agriculture has dominated public R&D expenditure in Thailand. Nonetheless, the percentage share of public agricultural research investment in agricultural GDP is still minor, at less than 1 percent. Focusing on crops and livestock that dominate Thai agricultural outputs and exports, Figure 2 shows that during 1961 – 2006 crops research intensity, measured as the research budget share in the crops GDP, was on

ISSN: 2304-1013 (Online); 2304-1269 (CDROM)

average at 0.47 percent while the livestock research budget accounts for 0.14 percent of livestock GDP. Both sub-sectors recorded downward trends in agricultural research and agricultural extension investment.

Figure 2 Agricultural Research and Extension Budget Relative to Agricultural GDP



Source: Public agricultural research and extension budget from the Bureau of the Budget and agricultural GDP from the National Economic and Social Development Board.

Both crops and livestock research investment generally increased over three decades from 1961, but began to decline from the mid-1990s, and particularly after 2000. A slight pick-up in the agricultural research budget expenditure was observed in 2006. Crops research expenditure grew at an average annual rate of 9.6 percent in current prices during 1961 to 2006. The government budget allocated to livestock research is very modest. Livestock research expenditure grew by 8.5 percent annually in current prices over the 1961 – 2006 periods.

The government plays a dominant role not only in agricultural research but also in extension (the dissemination of research results). Public agricultural research and extension (R&E) are mainly conducted by the MOAC sharing around 95 percent of the total government budget for agricultural R&E (Poapongsakorn, 2006, p.54). More than 50 percent of the MOAC's R&E budget is dominated by crops. Before the 1960s, public R&E programs concentrated on rice, particularly irrigated rice. Since the 1960s, there has been some diversification of R&E from rice to other crops, particularly rubber and field crops, e.g., corn, sorghum and cotton (Poapongsakorn et al., 1995, p.95). The crops research budget tends to follow demand trends rather than the introduction of new crops. This means the budget was likely expanded in

ISSN: 2304-1013 (Online); 2304-1269 (CDROM)

profitable crops that can raise farmers' income (Siamwalla et al., 1993).

Crops research is largely commodity-specific, focusing on developing pest resistant and high yielding varieties. Farming system research to promote mixed cropping and integrated farming is minor. Other research is by discipline, e.g., plant protection, soil and fertilizer research. Adoption of new technologies by farmers depends on the effectiveness of efforts by the Department of Agriculture (DOA) and the Department of Agricultural Extension (DOAE) and how relevant they are for the farmer.

Livestock research initially focused on veterinary (e.g., control and cure of animal diseases). Later, more emphasis was shifted to husbandry (e.g., breeding, nutrition and artificial insemination) and farm management. Livestock research and extension programs conducted by the Department of Livestock Development (DLD) mainly focus on large-scale animals, especially beef cattle, dairy cows and buffalos while small-scale animals like swine and poultry are in the hand of private companies.

As shown in Figure 2, trends of crops R&E expenditure as percentage shares of their GDP are in the same direction. Government spending on crops extension activities has outpaced that of research since 1975 when The World Bank began providing loans to the Thai government in order to adapt and extend its efficient extension operation.[3] In contrast, the data clearly shows the unbalanced investment between livestock research and extension. The increased overall emphasis on livestock in the government budget allocation has been occupied by extension, which had a much higher rate of growth than research. The extension budget is higher than research as more staff is hired and is available at the district level. The majority of the R&E budget goes to salaries and wages. However, some studies criticize the inefficiency in the agricultural extension system (Poapongsakorn, 2006).

5.2.2. University Investment in Agricultural Research

Universities have also been actively involved in agricultural research programs. Typically, there is research collaboration between universities, government, private companies and international research institutes. For example, Kasetsart University is the most important public-sector partner of the Thai hybrid corn industry as well as providing elite germplasm for private breeding programs (Fuglie, 2001). Universities

[3] The World Bank also introduced the training and visit (T&V) system of extension in the DOAE, which required a number of extension staff to visit farms nationwide (Isarangkura, 1986).

ISSN: 2304-1013 (Online); 2304-1269 (CDROM)

are also important sources of skilled researchers and trained scientific staff providing training and technical services to both public and private sector research.

While the DOA focuses on major crops research, universities conduct research on minor crops such as cassava and mungbeans. The most notable success story of university research was in the disease resistant varieties of maize, known as Suwan 1 and Suwan 2, developed at Kasetsart University, and funded by the Rockefeller Foundation (Office of Agricultural Economics, 1998). Universities also collaborate with the DOA in conducting crops research as well as conducting research on behalf of the private company, Charoen Pokphand (CP) Group, under a contract system (Office of Agricultural Economics, 1998).

There is no systematic database of university involvement in agricultural research and their funding sources are various. The major source of funding is from the government budget and the major players are public universities, especially Kasetsart University, Chiang Mai University and Khon Kaen University. On average, about 10 percent of the government research budget has been allocated to universities (Office of Agricultural Economics, 1998). Universities also received funding from other sources, such as international research agencies and private companies. According to the NRCT survey, university research expenditure in agricultural science increased markedly and its share in total agricultural research spending was the highest in 2005 and 2007 but later slightly dropped and picked up again in 2011.

5.2.3. Private Investment in Agricultural Research

The role of the private sector has been important since 1970 when the Charoen Pokphand (CP) Group established a joint venture with a U.S. poultry breeding firm, Arbor Acres (Fuglie, 2001). The CP Group has played an important role in Thai livestock production, particularly in developing feed technology. Animal feed has always been its core business. Private animal research concentrates on poultry and swine, with a principal goal of improving feed efficiency.

The private sector has also played an active role in plant breeding since the late 1970s. Its research is concentrated in developing hybrid seeds for field crops, especially maize used as a main ingredient of animal feed (Fuglie, 2001). Besides developing animal feed and seeds (primarily hybrid corn, vegetables and fruit for export), there is also private research in the form of crop protection chemicals, livestock

ISSN: 2304-1013 (Online); 2304-1269 (CDROM)

pharmaceuticals, animal breeding and farm machinery. The private research focus has been adjusted over time to serve market demands and business needs.

Although the private sector has been actively involved in agricultural research in Thailand, there is no systematic record of private investment in research. Fuglie (2001) conducted a survey of private investment in agricultural research in 1996 and estimated that the private sector was responsible for about 13 percent of total agricultural research in Thailand. This is consistent with other developing countries, where the private sector accounts for about 10 to 15 percent of the total research budget (Byerlee and Alex, 1998). Within Asia, the amount of private research investment in Thailand was ranked second after India, followed by Malaysia and China (Pray and Fuglie, 2001). It was estimated that the private research in Thailand accounted for about 0.1 percent of agricultural GDP. However, these estimates are higher than that of the NRCT (Table 6).

In the review study by the ADB (Office of Agricultural Economics, 1998), the absence of a significant private sector was identified as a characteristic of the Thai agricultural research system. Recognizing the importance and limited role of the private-sector, the government encourages more of their involvement. For example, the Board of Investment (BOI) promotes investment in R&D activities through tax and non-tax incentives. The BOI package includes corporate income tax exemption, a waiver of import duty on machinery and raw materials and permission for foreign companies to own agricultural land for research purposes. This is seen by the private sector as encouraging measures especially for seed companies (Fuglie, 2001, p. 92). The government has also encouraged private investment in agricultural research by focusing public resources on activities to complement, rather than compete with the private sector (Fuglie, 2001).

5.2.4. Foreign Research and International Research Collaboration

Foreign research also plays an important role in transferring technology or knowledge to research agencies in Thailand. It initially came in the form of imported technology. Moderate applications of imported technology, such as fertilizer, new seeds and animal breeds, became a part of Thai agriculture in the mid-1950s and later on were extended to more advanced technology. In the early 1960s, collaborative research was initiated between Thailand and the International Rice Research Institute (IRRI) which was later included under the umbrella of the Consultative Group on International

ISSN: 2304-1013 (Online); 2304-1269 (CDROM)

Agricultural Research (CGIAR) (Isarangkura, 1986). The CGIAR, established in 1971, now sponsors 15 international research centers and works in collaboration with national agricultural research agencies in many countries. The flows of agricultural technology between developed and developing countries through international agricultural research, notably the CGIAR, increased markedly after 1960 but began to decline from the early 1990s (Pray and Fuglie, 2001, p.21).

The most obvious example of technology transfer to Thai agriculture has been in rice, primarily irrigated rice varieties developed by IRRI. The first IRRI scientist assigned to Thailand during 1966 to 1982 brought with him a large collection of IRRI rice genetic materials, contributing to rice improvement in Thailand. The IRRI materials were crossed with Thai varieties yielding the first nonglutinous, semi-dwarf, photoperiod-insensitive, high-yielding varieties that were then released to Thai farmers (IRRI, 1997). Later, a number of joint research and training programs, primarily between IRRI and the MOAC, followed.

Thai agricultural research agencies also work in collaboration with other CGIAR centres, namely the International Maize and Wheat Improvement Centre (CIMMYT) for maize and wheat research and the International Centre for Tropical Agriculture (CIAT) for cassava research. The CIMMYT introduced plant materials in 1963 which led to organized wheat research in Thailand. Likewise, hybrid seeds from the CIAT were introduced in 1975 for breeding purposes which formed the initial basis for cassava varietal improvement in Thailand (Isarangkura, 1986).

Furthermore, germplasm was brought in from many other countries, such as India, Japan, the United States and Australia, as well as through the Food and Agriculture Organization (FAO) (Isarangkura, 1986). However, the research results using materials from these other sources were not very fruitful as in the case of rice varieties developed by IRRI.

The spillovers of foreign technology for livestock can be traced back to the import of the American Brahman in 1954. Foreign research also came through assistance in providing parent stocks, primarily by USAID and the Danish government. Poultry and swine industries also rely on imported breeds and materials from overseas. In contrast to crops, there does not seem to have been significant research collaboration with the CGIAR centers in the case of livestock.

ISSN: 2304-1013 (Online); 2304-1269 (CDROM)

6. ECONOMIC RETURNS ON AGRICULTURAL RESEARCH INVESTMENT

The major agricultural research performers have long invested in the research system, therefore, it is worth evaluating their payoffs to the society as a whole. This section briefly reviews economic returns on agricultural research investment that are commonly used for assessing the overall agricultural research system. A need for consistent and comparable database on agricultural R&D is highlighted.

Measuring returns on research investment is of particular importance to developing countries where agriculture plays a crucial role and a limited budget has to be allocated to various competing alternatives. At a country-level, economic impact of agricultural research is often measured as an internal rate of return (IRR), in which the research benefits are estimated based on agricultural productivity growth that is deem as a result of R&D and the research costs are annual R&D expenditure (Evenson, 2001).[4] The calculated IRR is also known as the social rate of return in which the word 'social' refers to economywide benefits from higher productivity that benefit not only farmers but also food processing, agro-industry and consumers, who gain from increased availability and lower cost commodities (Fuglie and Heisey, 2007). ASTI (2013) and Flaherty et al. (2013) show that the accelerated growth of global agricultural R&D spending, mentioned in Section 5, has yielded very high payoffs. The rate of return on R&D investment for developing countries as a whole is 82 percent and for countries that achieved remarkable growth in R&D spending like China and Brazil the returns are 136 percent and 176 percent, respectively.[5]

In Thailand, there are few studies measuring returns on the public agricultural R&D but there are none for other types of research performers, mainly due to data constraint. Measuring the economywide benefits based on productivity growth requires consistent and long time-series data as it takes time for research to have a full impact on agricultural productivity. Existing studies that measured IRR on the public investment in agricultural research in Thailand are summarized in Table 7. The first two studies by Setboonsarng and Evenson (1991) and Pochanukul (1992) employed

[4] See Evenson (2001) for a summary of over 200 studies that measured rates of returns on agricultural research. All of these studies are based on aggregate data and the majority is time-series data.
[5] The rates of return are calculated based on the cumulative growth of total factor productivity (TFP) during 1970-2009.

ISSN: 2304-1013 (Online); 2304-1269 (CDROM)

similar methods using profit function and seemingly unrelated regression (SUR) and found IRR on the public crop research around 42 percent and 44.95 percent, respectively. Suphannachart and Warr (2011) also measured IRR on the public crop research using total factor productivity (TFP) function and error correction modeling (ECM) technique and found the IRR equal to 29.5 percent. Suphannachart (2009) estimated IRRs, using similar method but controls for different explanatory variables, for overall agricultural R&D and crops and livestock R&D separately. The IRRs for the overall agriculture is 40.44 percent, for crops is 34.74 percent and for livestock is 130.84 percent. Despite different methodologies and study period previous studies have confirmed that the returns on agricultural R&D are higher than the opportunity cost of public funds and high enough to justify continued public investment in agricultural research. The high rates of return also imply that the past investment has been too small.

Table 7 Summary of studies measuring rates of return on public agricultural R&D

Study	Period	Method	Scope	IRR
Setboonsarng&Evenson (1991)	1967-1980	Profit function/ SUR	Crops	42%
Pochanukul (1992)	1961-1987	Profit function/ SUR	Crops	44.95%
Suphannachart&Warr (2011)	1970-2006	TFP function/ ECM	Crops	29.50%
Suphannachart (2009)	1970-2006	TFP function/ ECM	All Agriculture	40.44%
			Crops	34.74%
			Livestock	130.84%

As reviewed in the previous section, the government is not the only sector conducting agricultural research and its role has been declining in terms of research investment values. Given the increasingly scarcity in resources and decreasing research personnel, it is thus important as well to measure the rates of return on agricultural R&D conducted by universities and private enterprises. Investigating which type of research contributed most to productivity growth requires long time-series data and so the data constraint hinders the estimation of agricultural research impact on productivity and the associated rates of return. Further research could explore on the attribution issues among the major research performers. Nonetheless, investigating the issue of which sector yields the highest payoff places a heavy burden on the data.

ISSN: 2304-1013 (Online); 2304-1269 (CDROM)

7. CONCLUSION

This paper briefly reviews the agricultural research system in Thailand with respect to its historical development, policy guidance, public funding and relevant agencies, investment trends and patterns, and returns on research investment. The agricultural research system has taken place since the post World War II era but became more structured when the National Research Council of Thailand was set up in the late 1950s and the first national research policy was drafted in 1977. Since then the agricultural research activities and the government budget funding process have been guided by the national research policies which have been set in line with the national development plans. Under the current research policy, direction of agricultural research activities was geared toward adding value to agricultural products and managing resources for sustainable agricultural growth. Emphasis has also been placed on stimulating R&D spending, increasing capable research personnel, and improving research collaboration especially with the private sector.

By compiling R&D data from different sources, the findings show the declining trend of agricultural research spending as share of agricultural GDP and Thailand was lagged behind many other developing and developed countries. Among the major research performers the government still dominates agricultural R&D activities though its role is declining. A number of government agencies are responsible for the conduct of agricultural research in which the Department of Agriculture is the main agency. Universities have gained more shares in the agricultural research conduct, both in terms of annual expenditure and number of researchers, but the role of private firms is still minor. Despite the policy focus on the private-sector R&D, a systematic record of the private enterprise R&D is still missing and so little is known about its involvement and research direction. In addition, the total number of researchers in agricultural science has been falling in which the government sector experienced the largest fall. The majority of researchers are in the universities which mostly are not full-time researchers and their research may not match with the need of business sector. If R&D were to be more market-friendly and client-oriented then there shall be more participation from the private sector. Moreover, the unbalanced investment between research and extension should be investigated and linkages among research, extension and farmers should be strengthened.

Although there has long been an investment in agricultural research and several agencies are involved in the system there is still no single agency responsible for

ISSN: 2304-1013 (Online); 2304-1269 (CDROM)

collecting and reporting agricultural research statistics in Thailand. The national surveys on research expenditure and personnel conducted by the NRCT are useful source of overall R&D data, though details on agricultural science are quite rough. If the NRCT still keep a consistent record of agricultural R&D a longer series would allow an aggregate-level impact assessment that measure the rate of return on research investment by individual research performers. Measuring the economic impact of research investment in the form of productivity growth has been a standard practice in evaluating an overall agricultural system in many countries (ASTI, 2013). The lack of systematic record of agricultural R&D investment can be an obstacle to develop effective policy tools that could help strengthening the agricultural research system. Policy should not be directed only to increasing research funds but also to improving database that will be used to support the effective allocation of research resources.

REFERENCES

[1] Agricultural Science and Technology Indicator (ASTI) (2013), *ASTI Global Assessment of Agricultural R&D Spending* (Online) http://www.asti.cgiar.org/globaloverview, April 16, 2013.

[2] Areekul, S. (2000), Assessment Project on National Research in Thailand, 1992-1996: A Full Report (in Thai). *Prepared for the Office of the National Research Council of Thailand.* Bangkok.

[3] Byerlee, D., Alex, G. E. (1998), *Strengthening National Agricultural Research Systems: Policy Issues and Good Practice,* Washington D.C., The World Bank.

[4] Evenson, R. E. (2001), Economic Impacts of Agricultural Research and Extension. In Gardner, B. L. & Rausser, G. C. (Eds.) *Handbook of Agricultural Economics, edition 1, volume 1, chapter 11, pages 573-628.* Elsevier.

[5] Fan, S., Jitsuchon, S. & Methakunnavut, N. (2004), The Importance of Public Investment for Reducing Rural Poverty in Middle-Income Countries: The Case of Thailand. *DSGD Discussion Paper No.7.* Washington, D.C., International Food Policy Research Institute.

[6] Flaherty, K., Stads, G-J., Srinivasacharyulu, A. (2013), *Benchmarking agricultural research indicators across Asia-Pacific*. ASTI Regional Synthesis Report, International Food Policy Research Institute and Asia-Pacific Association of Agricultural Research Institutions.

[7] Fuglie, K. O. (2001), Private Investment in Agricultural Research: Thailand. *Agricultural Economic Report No. (AER 805).* Washington, D.C., Economic

ISSN: 2304-1013 (Online); 2304-1269 (CDROM)

Research Service of the U.S. Department of Agriculture (ERS/USDA).

[8] Fuglie, K., O., Heisey, P. W. (2007), Economic Returns to Public Agricultural Research. *USDA Economic Brief No.10.* United States Department of Agriculture, Economic Research Service.

[9] International Rice Research Institute (IRRI) (1997), Fact about Cooperation: Thailand and IRRI. Available at http://www.irri.org/media/facts/pdfs/THAILAND.pdf.

[10] Isarangkura, R. (1981), Inventory of Agricultural Research Expenditures and Manpower in Thailand. In Douglas Daniels and Barry Nestel (Ed.) *Proceedings of a workshop.* Singapore, 8-10 June 1981.

[11] Isarangkura, R. (1986), Thailand and the CGIAR Centers: A Study of Their Collaboration in Agricultural Research. *CGIAR Study Paper No.16.* Washington, D.C., The World Bank.

[12] Isvilanonda, S., Praneetvatakul, S. (2003), Evaulation of National Research System in Thailand (in Thai). Bangkok, Applied Research Center, Faculty of Economics, Kasetsart University.

[13] Office of Agricultural Economics (1998), Thailand Agriculture Sector Needs Assessment Study. *A Draft Final Report of TA 3002-THA Prepared under Technical Assistance Provided by the Asian Development Bank.* Bangkok, Ministry of Agriculture and Cooperatives.

[14] Office of National Research Council of Thailand (NRCT) (2007), National Survey on R&D Expenditure and Personnel of Thailand. Bangkok, Office of Research Policy and Strategy.

[15] Office of National Research Council of Thailand (NRCT) (2012), The Eighth National Research Policy and Strategy (2012-2016). Bangkok, Office of the National Research Council of Thailand.

[16] Office of National Research Council of Thailand (NRCT) (2013), Thailand Research and Development Index 2013. Bangkok, Office of the National Research Council of Thailand.

[17] Pray, C. E., Fuglie, K. (2001), Private Investment in Agricultural Research and International Technology Transfer in Asia. *Agricultural Economic Report No. (AER 805).* Washington, D.C., Economic Research Service of the U.S. Department of Agriculture (ERS/USDA).

[18] Poapongsakorn, N. (2006), The Decline and Recovery of Thai Agriculture: Causes, Responses, Prospects and Challenges. *Rapid Growth of Selected Asian Economies: Lessons and Implications for Agriculture and Food Security.*

ISSN: 2304-1013 (Online); 2304-1269 (CDROM)

Bangkok, FAO Regional Office for Asia and the Pacific.

[19] Poapongsakorn, N., Siamwalla, A., Titapiwatanakun, B., Netayalak, P., Suzuki, P., Pookpakdi, A., Preedasak, P. (1995), *Agricultural Diversification / Restructuring of Agricultural Production Systems in Thailand,* A Paper prepared for The Food and Agricultural Organization of the United Nations. Bangkok, Thailand Development Research Institute.

[20] Pochanukul, P. (1992), An Economic Study of Public Research Contributions in Thai Crop Production: A Time and Spatial Analysis. Ph.D. dissertation. *Graduate School.* Kyoto University, Japan.

[21] Siamwalla, A., Setboonsarng, S., Patmasiriwat, D. (1993), Agriculture. In Warr, P. G. (Ed.) *The Thai Economy in Transition.* Cambridge, Cambridge University Press.

[22] Suphannachart, W., Warr, P**. (**2012), "Total Factor Productivity in Thai Agriculture: Measurement and Determinants." In Fuglie, Keith O., Sun Ling Wang and V. Eldon Ball, (eds.) Productivity Growth in Agriculture: An International Perspective. Oxfordshire, UK: CAB International.

[23] Suphannachart, W., Warr, P. (2011), "Research and Productivity in Thai Agriculture." Australian Journal of Agricultural and Resource Economics 55(1): 35-52.

[24] Suphannachart, W. (2009), Research and Productivity in Thai Agriculture. Unpublished PhD dissertation, The Australian National University, Canberra.

[25] Tangkitvanich, S., Bisonyabut, N. (2014), "Towards Quality Growth: Challenges and Opportunities of Thailand in the Next Three Decades" 2014 TDRI Year-End Conference on Positioning Thailand in the Next Three Decades: Four Challenges to Quality Growth. Bangkok, 24 November, 2014 (in Thai).

ISSN: 2304-1013 (Online); 2304-1269 (CDROM)