PRIORITIZATION OF TECHNOLOGICAL DEVELOPMENT GOALS FOR POVERTY ALLEVIATION THROUGH SUSTAINABLE AND DIVERSIFIED AGRICULTURE

Tomohide Sugino[*]

Though positive impacts on rural development can be observed in diversified agriculture, statistical indicators have shown that agricultural diversification in Asian countries has stagnated over recent decades. Technological development is a dominant factor in determining the extent of diversification. A questionnaire survey was conducted with 259 respondents in eight Asian countries to establish the respondents priority of technological development goals that will potentially enhance agricultural diversification. The expected impacts of realizing these developments are also analyzed. The results showed that the development of pest tolerant crop varieties as well as economical measurements to improve soil fertility are given the highest priority among the 15 Research and Development (R&D) topics surveyed. Significant differences are observed among the responses received from researchers, extension staff and farmers, which indicate that awareness gaps regarding technological development exist among these stakeholders. Further efforts are necessary to formulate R&D activities to meet the demands of the farmers; the users of the technologies.

I. INTRODUCTION

The purpose of this article is to examine the priority of research and development topics as classified by respondents to a survey in order to achieve poverty alleviation through diversified agriculture in selected Asian countries.

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* Senior Researcher, Development Research Division, Japan International Research center for Agricultural Sciences (JIRCAS), Japan.

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'Agricultural diversification' means: transforming agriculture from major cereal (rice/ wheat) dominated cropping systems to more diversified systems, especially by promoting secondary crop production; or to integrate agricultural production with marketing or processing. Agricultural diversification has various positive impacts on development, including poverty alleviation, risk mitigation and enhanced sustainability. Among the avenues that lead to diversified agriculture, technological development represents one of the most important measurements. However, most of the Governments in the developing Asian region face financial difficulties and investment in R&D activities is very limited. While 22 high-income countries accounted for 44 per cent of global public agricultural R&D spending in 2000, 117 developing countries accounted for the remaining 56 per cent (ISNAR, 2005). This highlights the difficulty developing countries have in meeting all their technological development needs with their limited financial and human resources. Therefore, prioritization of R&D activities is important to foster technological development effectively. The study was conducted as part of a research project: "Identification of Pulling Factors for Enhancing the Sustainable Development of Diverse Agriculture in Selected Asian Countries (AGRIDIV)", coordinated by ESCAP and CAPSA (Centre for Alleviation of Poverty through Secondary Crops' Development in Asia and the Pacific). Eight countries (Bangladesh, India, Indonesia, Lao People's Democratic Republic, Myanmar, Sri Lanka, Thailand and Viet Nam) participated in the project.

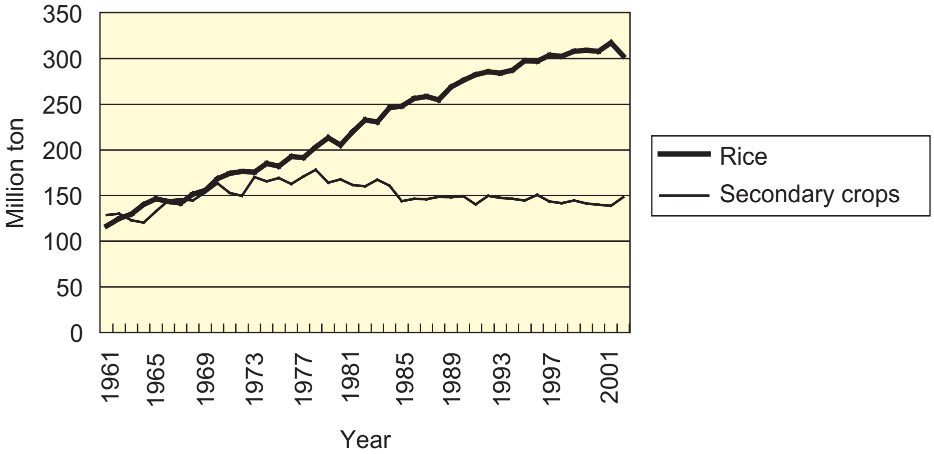
II. AGRICULTURAL DIVERSIFICATION AND ITS IMPLICATIONS ON POVERTY ALLEVIATION

Whereas the diet of the populations of developing Asian countries formerly consisted of a diversified mix of coarse grains, pulses, and root and tuber crops, there has been a shift away from these foodstuffs. Major cereals, especially rice, have become the staple food in the consumption basket of Asia (figure 1). This trend was partially induced by two factors, namely technological development and policy intervention.

Technological development is a combination of improved plant varieties, high yielding varieties, and modern cultivation techniques, such as the extensive use of chemical fertilizers, pesticides, irrigation and machinery, known as the "green revolution": it has achieved significant yield increases for rice and wheat. Furthermore, most countries have instituted supporting policies to expand major cereal production and stabilize prices to maintain food prices at lower levels to protect consumers.[1]

[1] However, according to economic development, some Asian economies such as Indonesia, the Republic of Korea, Thailand and Taiwan Province of China revised their rice price policy of maintaining lower rice prices to decrease the income gap between the agricultural and industrial sectors (NRIAE, 1993).

Figure 1. Food crop consumption in Asia



Source: Calculated from FAOSTAT (www.fao.org).

Note: *Secondary crops include maize,* millet, soybean, sweet potato and cassava.

There is no doubt that these "favoured-crop-biased policies" contributed to the improvement of access to food in the region. However, as financial sources became scarce, supporting policies centered on major cereals became a burden to the governments. Moreover, since the intensive efforts to improve rice yields have almost exploited the full potential yield, it is not surprising that producers have recently experienced a slowdown in the improvement of productivity (table 1).

Given these trends, initiatives at the decision and policymaking level must be taken and implemented to seek and provide ways and means to enhance agricultural diversification that enables sustainable development in developing Asian countries. Agricultural diversification is recognized as horizontal diversification or vertical diversification in relation to the direction in which the farm economy proceeds. Horizontal agricultural diversification involves diverse activities undertaken

Table 1. Annual yield increase of rice production in the developing Asian region

(per cent per year)

1961-1969	*1970-1979*	*1980-1989*	*1990-1999*	*2000-2005*
2.90	2.12	3.29	0.99	0.88

Source: Calculated from FAOSTAT (http://www.fao.org/).

within the farm production unit, whereas vertical diversification involves income-earning activities undertaken off-farm (Taylor, 1994).

Various positive impacts can be observed in diversified agriculture. Three major effects should be noted: poverty alleviation, stabilization and sustainability. The process of diversifying a rural economy can be a significant source of income growth for rural inhabitants. A well-diversified and flexible agricultural economy provides more stable incomes when commodity prices are unstable. Additionally a diversified cropping pattern may prove more sustainable in the long run than the intensive cultivation of a single crop (Timmer, 1992).

The term 'secondary crops' is usually used to indicate crops which are cultivated after rice harvested in the same fields (Sukartono and others, 2004). In this article, we define the term secondary crops as upland crops with a central focus on coarse grains, pulses and root and tuber crops. In the context of agricultural diversification, high-value commodities such as vegetables, fruits, animal husbandry and aquaculture usually receive more attention because farmers can expect higher returns. However, for small-scale farmers, especially in disadvantaged areas, they often cannot afford the initial investment to set up high-value commodity production. Though the value of coarse grains, pulses as well as root and tuber crops is not very high, the production costs of these crops are less and most of them can be grown even under unfavourable conditions such as in exclusively rain-fed areas. In addition, these crops have good potential to be used as raw materials for industrial uses, from traditional agro-processing like snacks to new materials such as biodegradable plastics. If these opportunities can be developed properly, farmers can expect higher incomes and also to improve their welfare.

III. CONSTRAINTS ON AGRICULTURAL DIVERSIFICATION IN ASIAN COUNTRIES

Trends of agricultural diversification

As mentioned in the previous chapter, agricultural diversification can have positive impacts on the welfare of rural poor people. However, well diversified agriculture has not yet been realized in many Asian countries. To overview the recent trend of agricultural diversification, the Simpson Index (SID) of East and South-East Asia, South Asia and eight Asian countries is shown in table 2. SID is one indicator that can quantify the degree of horizontal diversification. It is often used to quantify the biodiversity of a habitat in ecology but can also be used to illuminate the degree of diversity in cropping patterns. SID is defined as follows:

$$SID = 1 - \sum_{i=1}^{n} Wi^2, \quad Wi = Xi/(\sum_{i=1}^{n} Xi)$$

Where Xi is the value or area of the i^{th} commodity and Wi is the proportionate value or area of the i^{th} commodity in the total value or area. The minimum value of SID is 0 (the least diversified) whereas the maximum value is 1 (the most diversified).

SID in this article is calculated from the harvested area of ten crop groups; 1) rice; 2) wheat; 3) coarse grains; 4) roots and tubers; 5) pulses; 6) oil crops; 7) vegetables; 8) fruits and nuts; 9) spices and amenities of life (coffee, tea, tobacco, etc.); and 10) rubber and textiles.

Table 2. Recent trends of SID in selected years

Group		*Year*				
		1980	*1985*	*1990*	*1995*	*2000*
High	India	0.83	0.84	0.84	0.84	0.84
SID	Indonesia	0.77	0.77	0.78	0.79	0.78
	Sri Lanka	0.77	0.77	0.78	0.76	0.75
Middle	Myanmar	0.63	0.66	0.65	0.66	0.70
SID	Thailand	0.65	0.67	0.69	0.68	0.64
	Viet Nam	0.52	0.56	0.57	0.58	0.60
Low	Bangladesh	0.44	0.46	0.44	0.45	0.44
SID	Lao People's Democratic Republic	0.26	0.30	0.39	0.41	0.46
East and South-East Asia		0.74	0.75	0.76	0.76	0.75
South Asia		0.83	0.83	0.84	0.84	0.84

Source: Calculated from FAOSTAT (www.fao.org/).

Note: Three year average of harvested area was used for SID calculations to avoid the affect of annual harvest change caused by crop failure.

Table 2 demonstrates that the eight countries can be classified into three groups according to their respective value of SID.

Group 1 (High SID countries): India, Indonesia, Sri Lanka

Group 2 (Middle SID countries): Myanmar, Thailand, Viet Nam

Group 3 (Low SID countries): Bangladesh, Lao People's Democratic Republic

During the period 1980-2000, the SID of Group 1 remained above 0.75, whereas the SID of Group 3 remained below 0.5. The most remarkable increase of a SID was observed in the Lao People's Democratic Republic. Meanwhile, the SID of Bangladesh remained low with small fluctuations. Among the high SID countries, Indonesia and Sri Lanka reduced their SID meanwhile the SID of India has been stable for the latest 15 years. As a region, SID in East and South-East Asia have dropped over the last 10 years, meanwhile, no change has been observed in South Asia.

Constraints and driving factors to agricultural diversification

Though a remarkable SID increase was observed in the Lao People's Democratic Republic, SID has stagnated in the other countries and the region as a whole. Taylor (1994) indicated eight critical areas requiring attention for agricultural diversification, which include technological development, input supply and delivery systems, physical infrastructure, dissemination of information, organizational structures, development of markets, human resource development and public policies. In this chapter, we would like to focus on several factors and consider how they constrain or enhance agricultural diversification.

(1) Technological development

In the AGRIDIV project, we tried to identify the major constraints to agricultural diversification in the participating countries based on statistical data analysis and a rural survey. Out of the 80 factors suggested by the individual country studies, more than half relate to technological problems (table 3). Of course, the numbers assigned to the factors do not indicate their degree of seriousness. Moreover, previous experience has shown that technological development itself cannot necessary solve the problem of poverty, unless the developed technologies are properly accepted by farmers and implemented concurrently with other supporting measurements. Even so, technological development should be the first priority, taking into consideration the amount of prior investment in R&D for secondary crops.

Technological development of secondary crops has been very low primarily due to the limited financial resources of each Government. It is difficult to estimate the extent of financial resources that have been allocated to R&D activities for secondary crops. However, some factors indicate how little attention is paid by Governments to secondary crop development. For example, in Myanmar, less than 1 per cent of the total expenditure of the Myanmar Agricultural Service (MAS), which is the main technical body of the Ministry of Agriculture and Irrigation, is allocated to the Central Agricultural Research Institute (CARI), which is chiefly

Table 3. Constraints to agricultural diversification

(number of factors)

Field	
Technological development	43
Marketing	9
Access to credit	7
Processing	5
Price and trade policy	3
Infrastructure	2
Input	1
Organizational structure	1
Land policy	1
Others	8
Total	**80**

Source: Compiled by author based on Alam, J. (2005a), Anh, D.T. (2005), Douangsavanh, L. and others (2006), Kyi, A. 2005, Mahrouf, A.R.M., 2005, Roonnaphai, N., 2006, Singh, R.P. and others 2005a, Siregar, M. 2006.

responsible for research on secondary crops (Kyi, 2005). However, thanks to the limited interest shown in secondary crops, they still have room to be developed, while the yield of rice has faced stagnation over the past several years, in spite of continuous research efforts.

If governments allocate more resources to agricultural diversification, higher returns can be expected. This is because secondary crops have good profitability and comparative advantage, especially in rainfed upland areas. For example, analysis of the Domestic Resource Cost Ratio (DRCR), which is the indicator to show comparative advantage of crop production (Pearson, S.R. and others, 1976) showed that in Indonesia most secondary crops, except soybean, have a comparative advantage in the international market (Siregar, 2006).

(2) Inputs

Lack of effective marketing systems and the very limited access of farmers to credit with which to purchase inputs are the major impediments for securing adequate input supplies. Poor farmers in Bangladesh, for example, do not use the required material inputs for crops due to financial constraints (Alam, 2005a). In the Lao People's Democratic Republic, shortages of improved seeds and planting materials to foster crop diversification exist due to the absence of private input suppliers and the high price of imported materials (Douangsavanh and others, 2006).

As countermeasures to these problems, subsidy schemes have been implemented in various countries. The average quantity of fertilizer applied in developing countries is still far below developed countries (table 4). Moreover, most fertilizer application in developing countries is concentrated on major cereals and limited number of commercial crops. Therefore, the level of input use for secondary crop production is estimated to be quite low. The marginal productivity growth of the secondary crops is greater than that at the major cereal crops per unit of fertilizer input. In addition to institutional improvements, technological improvements such as site-specific fertilizing to maximize efficiency and the promotion of organic material use through the establishment of farmers group (to conduct collective activities that produce green manure) are also effective and more economical ways of addressing the constraints.

Table 4. Fertilizer consumption in selected Asian countries (2002)

(ton/ha)

Country	
Developed Asia	0.24
Viet Nam	0.21
Bangladesh	0.16
Sri Lanka	0.12
Thailand	0.09
India	0.09
Indonesia	0.07
Myanmar	0.01
Lao People’s Democratic Republic	0.004

Source: Calculated from FAOSTAT (www.fao.org/).

(3) Marketing

One common problem of secondary crop marketing in developing countries is the high costs attributable to inefficiency in the commodity chains. This is primarily because the marketing systems for secondary crops are yet to be well developed while major crops enjoy sufficient support from the government to improve the marketing systems, such as infrastructure and the dissemination of market information.

Contract farming between producers and consumers is one effective solution to improve market efficiency. Contract farming can provide mutual benefits to both producers and consumers, if effectively implemented. In Sri Lanka, maize farmers who began contract farming for feed millers earn higher prices than other farmers, while the feed millers can secure the raw material for feed processing (Mahrouf, 2006). However, partnerships between farmers and consumers are not easy to develop. For example, cassava farmers in Indonesia are sometimes suspicious about the way in which starch processors determine the quality of crops due to moisture and starch content, while the latter may insist on price cuts on the grounds of low crop quality, which is sometimes difficult to justify (Siregar and others, 2006). Though contract farming is a pure private commercial activity, coordination by a third party is required until the system matures. To foster mutual trust between the parties, intervention from the public sector will be necessary to make clear and fair rules for contract farming and to provide a monitoring system for the contract in its formative stage.

(4) Infrastructure and information

Irrigation systems in developing Asian countries have been constructed mainly for major cereal production and the irrigation coverage for secondary crops is lower than other (cash) crops. In India, while 65 per cent of the cropped area of major cereals is covered by irrigation, only 12 per cent of coarse cereals and 13 per cent of pulses are covered (Singh and others, 2005b). It is difficult to expect significant growth in irrigated areas in the future because: (i) the existing favourable land frontier in Asia has almost been exhausted; (ii) the exploitation of remaining irrigation potential is very costly, therefore, unbearable; (iii) large-scale irrigation projects have raised environmental concerns; and (iv) the maintenance of existing schemes has diverted public funds. Considering these constraints, we should focus on small-scale irrigation schemes using tube wells and small tanks, which can be developed and managed by resource poor farmers with proper financial and technological support from the government. Storage facilities are another focus of secondary crop marketing. Since most secondary crop farmers are poor and lack access to storage facilities, they are forced to sell their products immediately after harvest. This deprives the farmers of their liberty to decide when to sell their product, resulting in lower incomes. Dissemination of information regarding secondary crops is another concern. The urgent requirement is for price and market information be available in order to help farmers decide when to harvest their crops to maximize profit. Standards should also be established to help level the transactional playing field between farmers and consumers.

(5) Processing

The share of secondary crops consumed in the daily diet in Asia, has decreased continuously in recent decades (figure 1). Though the role of secondary crops is still important for people in disadvantaged areas who face difficulties in securing rice, the importance of secondary crops as staple foods has diminished due to the expansion of rice production and economic development in the region has made it easier for people to access major cereals.

In spite of this trend, the production of secondary crops is expanding due to the wide variety of uses as raw materials for industry. It is well-known that these crops are widely used for processed food, local snacks, starch and edible oil. 'Traditional processing' creates employment opportunities for rural people, particularly for women who are more vulnerable to poverty in rural areas. Though the scale of traditional processing units is small, their profitability is sometimes superior to that of more modern processing units. The income per production unit of traditional snack processors in Bangladesh is far better than the gross national income (GNI) per capita (table 5). Most secondary crops excel in nutrient value, compared to major cereals. Millet contains twice as much energy, four times as much protein, and nine times as much fat as rice. Mungbean contains three times more iron than spinach.[2]

In addition to "traditional" processing, "modern" processing using recently developed technologies enables a new dimension to secondary crop consumption. Biodegradable plastics and biofuels are typical product examples of modern processing. Biodegradable plastics can be used in the same way as conventional plastics but decompose in water and carbon dioxide with the action of naturally occurring microorganisms such as bacteria and fungi. One of the major biodegradable plastics is polylactic acid, which originates from crop starch. Biodegradable plastics have the potential to substitute 30 per cent of total world plastic production, which is approximately 100 million metric tons. (ARI, 1996).

Biofuels are liquid fuels for transportation, which are made from various kinds of biomass. The most common types of biofuels are ethanol made from carbohydrates and biodiesel made from vegetable oil. Food crops which are rich in carbohydrates or oil are used as raw materials for biofuel. The share of alcohol fuel in gasoline consumption in the United States of America was about 2.1 per cent in 2003 (EIA, 2003). If 2 per cent of gasoline consumption is substituted with

[2] Calculated by the author based on information from the Japan Science and Technology Agency, 2005.

Table 5. Cost and profit of small-scale processing in Bangladesh

	Sweet potato	Cake	Fuchka/ Chatpoti[a]	Chana-chur mix[b]	Jilapi[c]	French fries	Puffed corn	Fried maize	Potato flakes	GNI (2003)
Total production cost (TK) (1)	14 100	5 750	206 592	59 790	342 712	96 310	142 000	34 950	22 000	
Total return (TK) (2)	22 000	10 000	360 000	96 000	480 000	160 000	166 000	50 000	80 000	
Net profit (TK) (3)=(2)-(1)	7 900	4 250	153 408	36 210	137 288	63 690	24 000	15 050	58 000	
Labour input (manday) (4)	40	45	576	300	536	360	55	40	50	
Labour cost (TK) (5)	2 000	2 250	57 600	20 000	53 600	36 000	5 500	2 000	2 500	
Total income (6)=(3)+(5)	9 900	6 500	211 008	56 210	190 888	99 690	29 500	17 050	60 500	
Income per capita per day (TK) (7)=(6)/(4)	248	144	366	187	356	277	536	426	1 210	
Income per capita per day (US$)[d]	4	2	6	3	6	5	9	7	21	1

Source: Compiled by author based on data in Alam, 2005b. GNI data is from World Bank, 2005.

[a] A small puffed, oval shaped crispy ball made from flour

[b] Fried pulses mixed with rice flake and nuts

[c] A juicy coil-like sweet made from wheat and pulse flour

[d] US$ 1= 58 takas

alcohol, Asia and the Pacific need to increase maize production by 8.7 million tons or 4.8 per cent of current maize production (author's calculation).

IV. ANALYSIS OF R&D PRIORITIES

To support policy planners in deciding how to allocate resources for R&D activities in an appropriate manner, a questionnaire survey was conducted in the eight Asian countries (Bangladesh, India, Indonesia, Lao People's Democratic Republic, Myanmar, Sri Lanka, Thailand and Viet Nam) that participated in the AGRIDIV project.

Methodology

The questionnaire survey consists of two parts: step 1 and step 2. Step 1 includes questions about the profile of respondents. Step 2 is designed to reveal the importance, expected effects and expected support necessary for 15 R&D topics concerning agricultural diversification (table 6). The questionnaire was designed by referring to the survey sheet used for the Technology Forecast Survey, conducted by the Ministry of Education, Culture, Sports, Science and Technology of the Government of Japan (NISTEP, 2001).

The 15 R&D topics were collected from the study results of the AGRIDIV country studies. As mentioned in the previous chapter, 43 technological constraints to agricultural diversification were identified in the project. From the total list, the 15 most frequent constraints were selected for this survey, which seemed to represent common problems in the region and could significantly contribute to poverty alleviation in rural areas (table 7).

The questionnaires were distributed to collaborators of the study in their respective countries in February 2005. The collaborators were requested to select respondents for the survey who worked in the field of agricultural technological development. All the answer sheets were collected by the collaborators after completion by the respondents and returned to CAPSA by July 2005.

Results and discussions

(1) Profiles of respondents

The total number of respondents was 259 from eight countries. 41 per cent of the respondents are researchers followed by extension staff 14 per cent. 44 per cent of the respondents belong to research institutes followed by universities 15 per cent (tables 8, 9).

Table 6. Items included in the questionnaire

Step 1

1. Name of respondent
2. Sex
3. Year of birth
4. Profession (Choose from Research, Research management, Policy planning, Extension, Farming, Education and Others
5. Organization (Choose from Research institute, Administrative agency, Extension organization, Farm, Farmers' organization, University, Private company and Others

Step 2

A) the degree of the respondent's expertise in the respective research topics (Choose from the options below)

High:	You have considerable knowledge as a specialist about the topic through current research or work related to the topic.
Medium:	You were once engaged in research or work related to the topic; or have some specialist knowledge about the topic through research or work in a similar field.
Low:	You have read technical books or literature about the topic or have listened to experts connected with the topic.
None:	You have no expertise in the topic.

B) Degree of importance to your country (Choose from the options below)

High:	Extremely Important
Medium:	Important
Low:	Somewhat important
Unnecessary:	Not important
Unknown:	You have no expertise in the topic

C) Expected effect (Choose from the options below)

Poverty alleviation:	Contribution to poverty alleviation especially in rural areas. Increase or stabilize income and create job opportunities, contribution to rural welfare, etc.
Socio-economic development:	Contribution to creation of new industry and urban employment, development of social and economic infrastructure, etc.
Environmental issues:	Resolution of regional or global environmental problems, protection of the natural environment and ecology, prevention of environmental destruction and pollution, optimal use of natural resources, etc.
Intellectual resources:	Expansion of human intellectual resources through discovery of new rules and principles, establishment of original theories, development of art and culture, etc.

Table 6. *(continued)*

D) Effective measurement should be taken to implement the research topic and realize expected effect (Choose from the options below)	
Human resources development:	Foster human resources through education, training and securing an appropriate number of researchers, technical personnel and research supporters.
Infrastructure:	Develop research and development infrastructure such as equipment, establishment of databases, provision of reference materials and gene resources.
Funding:	More research funds injected by the government, international funding organizations, developed countries and private investment.
Integration with extension:	Reinforce integration of research and extension through capacity development of extension systems and closer collaboration between research and extension staff to promote technology transfer to farmers and other users.
Domestic research collaboration:	Research collaboration among organizations in your country.
International research collaboration:	Research collaboration with other countries in the region, developed countries or international research institutes.
Collaboration among sectors:	Promotion of collaboration among the academic sector (research institutes, universities etc.), and the government and private sectors (private companies, NGOs, farmers groups, etc.)

Source: Questionnaire survey, 2005.

Table 7. R&D topics surveyed

	Research topics	*Short title*
1.	Development of technology to improve soil fertility in an economical way (e.g. growing green manure crops, application of compost)	Economical soil improvement
2.	Development of effective use of inputs to minimize the cost and maximize the output (e.g. micro-doses of fertilizers: application of small quantities of fertilizers directly into the planting hole to minimize input costs)	Effective input use
3.	Development of technologies to prevent soil erosion in upland areas	Soil conservation
4.	Development of improved crop varieties with stable yield under abiotic stress like water deficiency or high temperatures (e.g. early maturing varieties to escape post-flowering moisture stress periods)	Stress tolerant variety
5.	Development of improved intercropping technology which minimizes labour inputs and maximizes overall products in the farmland (e.g. appropriate seeding rate choices for a two-crop intercropping)	Intercropping technology
6.	Development of cheaper agricultural machinery available to farmers	Cheaper machinery
7.	Development of labour saving technologies for crop cultivation	Labour saving technology
8.	Development of improved crop varieties with high disease and pest tolerance or high competitiveness with weeds	Pest tolerant variety
9.	Development of pest and weed control technology in economical ways (e.g. crop rotation with pest non-susceptible varieties, increased density of crops to close the canopy more rapidly, damage control from wild animals)	Economical pest control technology
10.	Development of appropriate water management technologies, which enable upland crop cultivation in lowland areas or paddy fields	Water management technology
11.	Development of improved processing technology to increase the demand of crops as processed food or feed	Food/feed processing technology
12.	Development of technology for non-food/feed processing and establishment of new uses (e.g. biodegradable plastics and biofuel from maize, cassava, etc.)	Non-food/feed processing technology
13.	Development of technology to decrease contamination of poisonous materials in crops to meet sanitary standards for export (e.g. cadmium, arsenic and sulfur dioxide content in cassava products)	Decreasing contamination
14.	Implementation of consumers' preferences surveys to be aware of changing demand for food	Consumer preference survey
15.	Clarification of profitability, production costs, marketing, environmental limitations, acceptance of new technologies and other socio-economic conditions of farmers	Socio-economic survey

Source: Questionnaire survey, 2005.

Table 8. Profession of respondents

Profession	*Persons*	*Percentage*
Research	107	41
Extension	36	14
Education	29	11
Policy planning	27	10
Farming	27	10
Research management	18	7
Others	15	6
Total	**259**	**100**

Source: Questionnaire survey, 2005.

Table 9. Place of work of the respondents

Organization	*Persons*	*Percentage*
Research institute	115	44
University	38	15
Extension services	36	14
Administration	24	9
Farm	24	9
Private company	5	2
Farmers' organization	2	1
Others	15	6
Total	**259**	**100**

Source: Questionnaire survey, 2005.

(2) Priority of R&D topics

The respondents were requested to evaluate the priority of the R&D topics by selecting their answer from four options: "high" (extremely important), "medium" (important), "low" (somewhat important) and "unnecessary" (not important). The answers from respondents who indicated they have no expertise of the topic were excluded from further analysis. The degree of importance of the topics was estimated by calculating the 'Importance Index (I-Index)'. Each option was assigned a weight, ranging from 1 to 0, according to the importance of the topics.

If all the respondents answered "high" for a specific R&D topic, the I-Index would be 100, while if all the respondents answered "unnecessary", the I-Index would be zero.

Table 10 shows the I-Index of all the surveyed R&D topics calculated using the answers of all the respondents from the eight countries. “Pest tolerant variety” received the highest I-Index as well as “economical soil improvement”. The I-Index of the other four R&D topics, namely, “effective input use”, “soil conservation”, “stress tolerant variety” and “food/feed processing technology” received almost the same level, which were equal to or more than 80. In this paper, we would like to select these six R&D topics as priority R&D topics for further analysis. Conversely, “consumer preference survey” followed by “intercropping technology” and “labour-saving technologies” received the lowest I-Index.

Comparing the I-Index among the respective eight countries, “labour saving technologies” has the largest standard deviation (SD=11.5), followed by “water management technologies” (SD=11.3). For the former, Sri Lanka received the highest I-Index, while the I-Index of the other seven countries was less than 70. As for the latter, the I-Index of Sri Lanka is also the highest and is the only country whose I-Index is greater than 90.

One salient feature of agriculture in developing Asian countries is the low productivity of labour and excess of labour in rural areas due to a lack of labour absorption in the industrial sector (Yamada, 1992). The results of evaluating the priority of R&D topics, as determined by respondents, show that these characteristics are clearly recognized. Cost-saving technologies, such as technologies to improve soil fertility using local resources (green manure crops, compost, etc.) and the development of varieties with high pest tolerances, which can reduce chemical fertilizer and pesticide usage are recognized as the most important of the 15 R&D topics. Meanwhile, “labour-saving technology” received a low priority evaluation, which will contribute to cost reduction, (because no money need be spent developing the technology), but may result negatively on employment unless alternative job opportunities are created.

If we compare the results of respective countries, we find that some countries have different tendencies for R&D prioritization. Unlike the other seven countries, Sri Lanka generated high priority responses to “labour-saving technology”. This seems attributable to the fact that labour saving is a key issue in Sri Lanka. The per capita gross national income of Sri Lanka is the second highest of the surveyed countries (World Bank, 2005). As a consequence, the agricultural wage rate is supposed to be higher than other countries in the survey group. In addition, the reconstruction project related to the tsunami disaster in 2004 accelerated

Table 10. Importance Index (I-Index) of 15 R&D topics

R&D topic	*Bangladesh*	*India*	*Indonesia*	*Lao People's Democratic Republic*	*Myanmar*	*Sri Lanka*	*Thailand*	*Viet Nam*	*Total*	*SD*
1. Economical soil improvement	95	71	96	83	87	95	79	86	88	8.7
2. Effective input use	86	75	85	62	93	93	81	77	80	10.3
3. Soil conservation	66	79	82	70	86	95	80	89	80	9.6
4. Stress tolerant variety	85	81	81	69	87	90	68	88	81	8.7
5. Intercropping technology	70	68	72	65	88	76	64	62	69	8.3
6. Cheaper machinery	86	84	82	62	83	92	72	71	78	10.0
7. Labour-saving technology	52	67	61	67	61	89	68	53	63	11.5
8. Pest tolerant variety	89	80	92	74	85	100	84	95	88	8.4
9. Economical pest control technology	79	79	73	63	82	98	78	80	78	9.7
10. Water management technology	73	84	70	60	63	93	83	74	74	11.3
11. Food/feed processing technology	83	90	87	69	88	88	81	76	82	7.2
12. Non-food/feed processing technology	73	75	61	57	58	82	83	66	70	10.1
13. Decreasing contamination	79	71	68	61	65	85	80	85	75	9.3
14. Consumer preference survey	74	75	73	58	50	68	71	55	67	9.8
15. Socio-economic survey	79	83	81	67	77	92	76	76	78	7.2

Source: Questionnaire survey, 2005.

the demand for labour in the country.[3] Against this backdrop, labour-saving technologies are of exceptionally higher priority in Sri Lanka.

Water is becoming a precious resource in the world due to global climate change and the burgeoning world population. Especially in Sri Lanka, water shortages have been a serious problem in the dry zone and the farmers have on established traditional tank-irrigation system. The highest I-Index for "water management technology" reflects the long experience of water management in Sri Lanka though the difference is not as significant as "labour-saving technology".

(3) Expected outcomes of implantation of the R&D topics

The results of the survey on the expected outcomes of R&D topics are shown in table 11. Among all the respondents in the eight countries, 80 per cent or more agreed that "poverty alleviation" would be achieved through the technological development of "intercropping technology" and "pest tolerant variety" (indicated as "A" in table 11). As for the outcome of "socio-economic development", 80 per cent or more of respondents answered "cheaper machinery", "labour-saving technology", "pest tolerant variety", "food/feed processing technology", "consumer preference survey" and "socio-economic survey" would have positive impacts (indicated as "A" in table 11). "Economical soil improvement", "soil conservation", "pest tolerant variety", "economical pest control" and "decreasing contamination" are the topics which 80 per cent or more respondents thought would contribute to "environmental issues" (indicated as "A" in table 11). There were no R&D topics surveyed for which more than 50 per cent of respondents thought implanting action would increase "intellectual resources".

Figure 2 displays compiled results from respondents and shows the number of countries for which 80 per cent or more of respondents answered that the specific technologies would contribute to poverty alleviation. In six countries, 80 per cent or more answered "intercropping technology" would contribute to poverty alleviation. Conversly, no country achieved 80 per cent affirmation by respondents for "soil conservation", "labour-saving technology", "decreasing contamination" or "consumers' preferences survey".

(4) Relationships between priority and expected effects

By analyzing the results of the survey on the three expected outcomes, namely, "poverty alleviation", "socio-economic development" and "environmental

[3] Speculation based on a personal communication to the collaborator in Sri Lanka.

Table 11. Expected effects and actions to realize these outcomes

	1. Economical soil improvement	2. Effective input use	3. Soil conservation	4. Stress tolerant variety	5. Intercropping technology	6. Cheaper machinery	7. Labour-saving technology	8. Pest tolerant variety
Importance Index	**88**	**80**	**80**	**81**	69	78	63	**88**
Expected effect								
Poverty alleviation	B	B	C	B	**A**	B	C	**A**
Socio-economic development	C	B	C	B	B	**A**	**A**	**A**
Environmental issues	**A**	C	**A**	D	D	D	D	**A**
Intellectual resources	D	D	D	D	D	D	D	D
Measurement								
Human resources development	B	B	B	B	C	B	B	B
Infrastructure	D	D	D	D	D	D	D	D
Funding	B	C	B	B	C	B	C	**A**
Integration with extension	B	B	B	C	B	C	C	B
Domestic research collaboration	B	C	C	C	C	C	C	**A**
International research collaboration	C	D	D	B	D	D	D	**A**
Collaboration among sectors	C	D	C	D	D	D	D	B

Table 11. *(continued)*

	9. Economical pest control technology	10. Water management technology	11. Food/feed processing technology	12. Non-food/ feed processing technology	13. Decreasing contamination	14. Consumer preference survey	15. Socio-economic survey
Importance Index	78	74	**82**	70	75	67	78
Expected effect							
Poverty alleviation	C	C	B	C	D	D	B
Socio-economic development	B	B	**A**	B	B	**A**	**A**
Environmental issues	**A**	B	D	B	**A**	D	D
Intellectual resources	D	D	D	D	D	D	D
Measurement							
Human resources development	B	B	B	B	B	B	B
Infrastructure	D	D	D	D	D	D	D
Funding	B	B	B	B	B	C	B
Integration with extension	**A**	C	C	C	C	C	B
Domestic research collaboration	**A**	B	C	B	C	C	C
International research collaboration	**A**	D	C	C	B	D	D
Collaboration among sectors	C	C	C	C	D	D	C

Source: Questionnaire survey, 2005.

Note: As for expected effects and measurements, each grade represents the following:

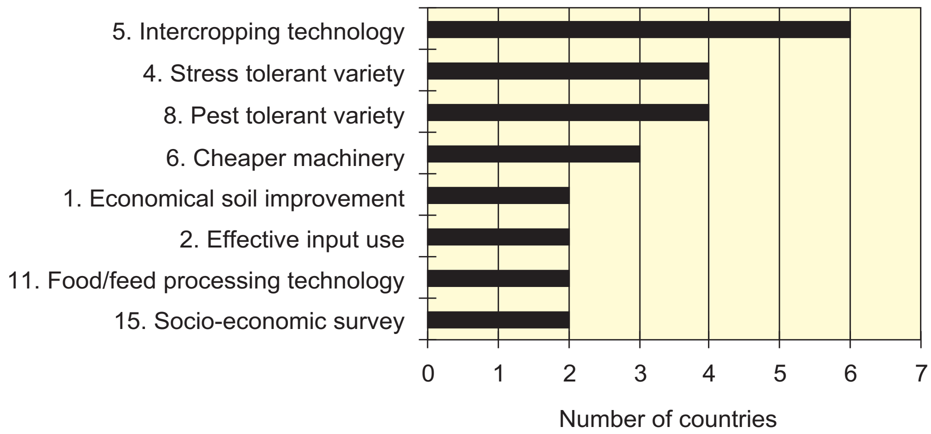
A: Quite effective (100-80% of respondents chose the option).

B: Effective (65-79%).

C: Somehow effective (50-64%).

D: Less effective (0-49%).

Figure 2. Number of countries where 80 per cent or more of the respondents expected poverty to be alleviated by implementating the R&D topics



Source: Questionnaire survey, 2005.

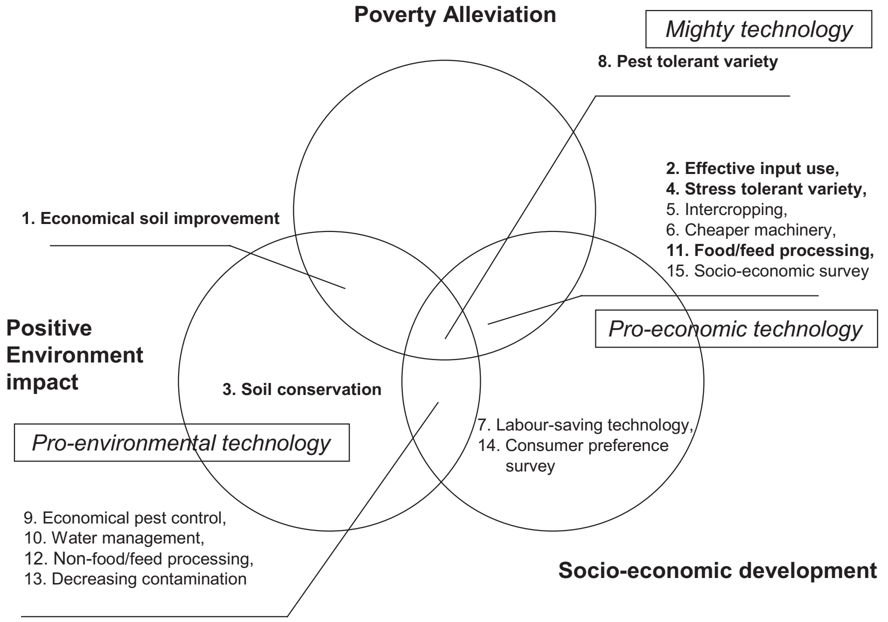
issues", we can examine why six R&D topics were classified with higher priority (I-Index=80 or more) in the surveyed region.

Among the options of expected outcomes, "poverty alleviation" can be used as a proxy for direct or short-term positive impact on the welfare of rural poor people. "Socio-economic development" can be used as a proxy for long-term positive impact on welfare. "Environmental issues" can be used as a proxy for external economic impacts (downstream impacts). In this discussion, we would like to determine if a specific R&D topic is effective for achieving a specific effect; if the R&D topic was supported by 80 per cent or more of respondents it is quite effective (indicated as "A" in table 11), effective if supported by 65 to 79 per cent (indicated as "B" in table 11), and somehow effective if supported by 50 to 64 per cent (indicated as "C" in table 11).

All the R&D topics can be classified based on the expected outcome (figure 3). Among the six priority topics, "pest tolerant variety" was the only topic recognized as quite effective for all three outcomes. We can conclude that this kind of technology is a "Mighty technology" which can realize multiple beneficial impacts on a range of outcomes.

The second group R&D topics, by priority ranking, consists of "economical soil improvement" and "soil conservation". They were recognized as quite effective

Figure 3. Classification of the surveyed R&D topics



Source: By author.

Note: Six Priority R&D topics are shown in bold. The classification was conducted by seeing whether each R&D topic received grade A or B (supported by 65-100% of respondents).

for "environmental issues", while "poverty alleviation" and "socio-economic development" scored relatively lower. This indicates that respondents recognized these technologies have more economic externalities than short/long term economic impacts. Supposing the budget of a Government is limited, whilst it is urgent to tackle poverty alleviation, these R&D topics would be considered less urgent. Therefore, external support is required for this second group of technologies, namely "pro-environmental technologies", to mitigate the negative impacts of agricultural development.

The third group of priority R&D topics consists of "pro-economic technologies" which are recognized as effective for improving rural welfare both on a short and long-term basis with less expected economic externalities. The group includes "effective input use", "stress tolerant variety" and "food/feed processing technology". They are thought to be quite effective or effective for short/long term welfare improvement but relatively less effective for dealing with economic externalities.

It is interesting to note that "effective input use" is included in this group, which means that respondents expected the reduction of fertilizer use would have less than positive effects on environmental problems. A possible interpretation is that the respondents are afraid of the negative impacts of reduced input use, especially concerned that reducing fertilizer inputs would result in a deterioration of soil fertility. "Stress tolerant variety" is an effective measure for expanding crop production in disadvantaged areas. However, the results of the survey show the respondents are afraid of the negative impacts of the technology: since the environment in disadvantaged areas is very fragile and the expansion of crop production in these areas could cause negative impacts unless properly managed. "Food/feed processing" or value adding activities are known to be effective measures to augment rural income and generate employment. The survey results indicate that in spite of the positive impact of adding value to produce and products, it can occasionally cause serious negative impacts to the environment such as water pollution and/or odors, which are serious problems in developing regions where environmental regulations are not well implemented.

The I-Index of "labour-saving technology" was low in most countries while it was thought to be quite an effective component of "socio-economic development" based on the survey results (table 11). This indicates that respondents clearly recognized its long-term impact. Most Asian developing countries have an excess capacity of labour in rural areas. However, if non-agricultural industry is developed in the near future, the surplus availability of rural labour drops relatively. The survey results reflect the respondents' perspectives of rural development in the future. A similar tendency can also be found for "non-food/feed processing technology", "decreasing contamination" and "consumer preference survey", for which it can be interpreted that these R&D topics are expected to be important only after preliminary economic development has been achieved.

(5) Effective steps to implement the research topics

The survey's results of effective steps that should be taken to implement the research topics and realize the expected effect are shown in table 11. While almost all the other options received relatively higher support from the respondents, less than 50 per cent replied that infrastructure development would be a useful measure to achieve the expected effects of technological development.

(6) Differences of attitude among researchers, extension staff and farmers

To reveal differences between the attitudes towards technological development, the survey results were compiled according to the occupation of the respondent (table 12). Researchers place much more priority than extension staff on “stress tolerant variety”, “intercropping technology” and “decreasing contamination”. The researchers also place significantly higher priority than farmers on “effective input use”, “stress tolerant variety”, “economical pest control technology” and “socio-economic survey”. Significant priority differences between extension staff and farmers were observed only for “effective input use”.

The differences found regarding “stress tolerant variety” between researchers and extension staff/farmers can be attributed to the respondents’ expectations of how the technology could contribute to environmental issues. While 60 per cent of researchers expect the development of stress tolerant varieties could have positive impacts on environmental problems, only 39 per cent of extension staff and 15 per cent of farmers felt the same. This result reflects the current status of technological development for plant varieties with abiotic stress. While the breeding of new plant varieties with resistance to pest and diseases is relatively easy because of the limited number of genes that can effectively enhance these characteristics, varieties resistant to abiotic stress, such as high temperature, drought and salinity are more difficult to produce because tolerance to abiotic stress is achieved by more complicated genetic systems and the introduction of a single specific gene is usually insufficient to acquire stress tolerance. As climate change on a global scale casts serious shadows over agriculture, researchers are more interested in technologies to mitigate the negative impacts of climate change. On the other hand, farmers and extension staff are still suspicious of whether the development of stress tolerant plant varieties can be put to practical use.

The difference between researchers and farmers regarding “effective input use” can also be attributed to the respondents’ expectations of how technology could contribute to environmental issues and boost intellectual resources. While researchers thought that efficient agro-input use could reduce negative impacts on the environment through reducing the runoff of nutrient from farmland, farmers worry that any decrease in agro-inputs would deteriorate soil fertility. The level of agro-input use in developing Asia is still lower than that of industrialized countries (table 4). However, in some specific areas, commercial crop production has been intensively implemented and the overuse of agricultural chemicals has become a serious environmental concern. Researchers pay attention to the overuse of inputs, while farmers without access to adequate input supplies gave less priority to this.

The reasons for the differences in priority between researchers and farmers on “socio-economic survey” seem to be contradictory. While researchers gave more priority than farmers to the subject, farmers expect more positive impacts on

Table 12. Importance index and expected outcomes of R&D goals by respondents' occupation

R&D topic	*1. Economical soil improvement*	*2. Effective input use*	*3. Soil conservation*	*4. Stress tolerant variety*	*5. Inter-cropping technology*	*6. Cheaper machinery*	*7. Labour-saving technology*	*8. Pest tolerant variety*
Importance index								
No. of R&D topic	1	2bc	3	4ac	5a	6	7	8
Researchers	87	83	81	85	68	79	61	89
Extension staffs	91	80	70	76	56	68	62	90
Farmers	82	64	79	62	58	71	67	77
Effects of poverty alleviation (percentage of respondents who expect positive impacts)								
No. of R&D topic	1	2	3	4	5	6	7	8
Researchers	72	75	57	77	83	68	60	78
Extension staffs	72	81	55	81	81	57	64	68
Farmers	76	85	57	62	73	82	67	91
Effects of socio-economic impact (percentage of respondents who expect positive impacts)								
No. of R&D topic	1	2	3c	4	5	6ac	7	8a
Researchers	61	66	69	76	72	90	87	64
Extension staffs	69	69	65	77	71	71	75	82
Farmers	59	65	29	77	47	59	67	73
Effects of environment improvement (percentage of respondents who expect positive impacts)								
No. of R&D topic	1	2ac	3	4ac	5	6	7	8
Researchers	86	71	89	60	46	22	21	79
Extension staffs	81	41	97	39	32	14	11	75
Farmers	71	20	86	15	27	12	11	55
Effects of intellectual resource (percentage of respondents who expect positive impacts)								
No. of R&D topic	1	2bc	3	4	5	6	7	8
Researchers	27	26	24	37	25	38	30	43
Extension staffs	25	28	39	42	19	29	21	46
Farmers	12	5	0	38	13	35	22	55

Table 12. *(continued)*

R&D topic	*9. Economical pest control technology*	*10. Water management technology*	*11. Food/feed processing technology*	*12. Non-food/feed processing technology*	*13. Decreasing contamination*	*14. Consumer preference survey*	*15. Socio-economic survey*
Importance index							
No. of R&D topic	9c	10	11	12	13a	14	15c
Researchers	78	75	81	69	79	66	81
Extension staffs	73	66	75	65	58	64	73
Farmers	60	68	64	79	64	50	63
Effects of poverty alleviation (percentage of respondents who expect positive impacts)							
No. of R&D topic	9	10	11	12	13c	14	15c
Researchers	60	58	69	54	19	26	63
Extension staffs	64	52	68	64	25	33	79
Farmers	60	55	73	71	57	17	88
Effects of socio-economic impact (percentage of respondents who expect positive impacts)							
No. of R&D topic	9	10	11c	12c	13b	14ac	15
Researchers	70	69	92	75	68	91	91
Extension staffs	64	64	88	59	55	92	71
Farmers	40	73	64	29	100	83	71
Effects of environment improvement (percentage of respondents who expect positive impacts)							
No. of R&D topic	9	10ac	11	12	13	14	15
Researchers	89	78	30	72	84	14	35
Extension staffs	82	56	20	73	80	25	32
Farmers	70	45	9	43	86	17	12
Effects of intellectual resource (percentage of respondents who expect positive impacts)							
No. of R&D topic	9	10	11	12	13	14	15c
Researchers	33	36	39	43	35	18	32
Extension staffs	39	16	40	36	25	8	25
Farmers	0	27	18	14	29	0	6

Source: Questionnaire survey, 2005.

a: $p < 0.05$ (Chi-square test) between researchers and extension staffs

b: $p < 0.05$ (Chi-square test) between extension staffs and farmers

c: $p < 0.05$ (Chi-square test) between farmers and researchers poverty alleviation from the socio-economic survey than researchers. There is no doubt that accurate information about the economic situation of farm households can be used positively to formulate policy measures to alleviate poverty. However, the results of the current survey have shown that researchers are less confident that the conclusions of a socio-economic study can contribute to poverty alleviation, although they admit the importance of the socio-economic study in general. More attention should be paid to promoting a socio-economic study, which could result in actual beneficial impacts on the welfare of the rural poor, as well as, producing scientific findings.

V. CONCLUDING REMARKS

This article highlights the level of priority placed by survey respondents on selected R&D topics in order to realize economic development through agricultural diversification using secondary crops. It also shows the trends of agricultural diversification by calculating SID. The article draws the following conclusions:

- The recent SID trends shows agricultural diversification in Asian countries has stagnated. The extent of diversification is determined by various factors. Above all, technological development has a crucial role because most developing countries focus their R&D activities on major cereals and less attention had been paid to secondary crops. Secondary crop production in developing Asian countries has a comparative advantage in international markets and offers better profitability in disadvantaged areas, especially upland areas that lack irrigation facilities. Therefore, appropriate support to R&D activities focusing on secondary crops will produce positive impacts on poverty alleviation in rural areas.

- Among the R&D activities concerned with agricultural diversification, cost-saving technologies, such as improving soil fertility with local resources (green manure crops, compost, etc.) and the development of varieties with high pest tolerance, which can reduce chemical fertilizer and pesticide inputs, should be enhanced. Labour-saving technology received a low priority ranking, which could contribute to cost reduction but may produce negative impacts for employment unless alternative job opportunities are created. However, if the non-agricultural sector is developed in the near future, the surplus availability of rural labour will decrease. R&D on labour-saving technology should be encouraged based on a long-term perspective.

- Researchers as producers of technologies, extension staff as mediators and farmers as end users of developed technologies have differing priorities and concerns surrounding technological development. Farmers themselves diversify their technological needs based on their economic situation, current cropping patterns and location of their fields. Farmer's technology preferences are poorly defined in cases where there is high diversity in environmental conditions, which is generally the case with small, poorer households (Menter and others, 2004). Moreover, the survey has shown that researchers may accord higher priority to research topics for which they are not confident of the actual impacts on poverty alleviation. To reduce these knowledge gaps among stakeholders of technological development, dialog among researchers, extension staff and farmers should be nurtured.

- The survey has provided an example of a prioritization process and interpretation of survey results. It should be noted that the results of the survey indicate only the rough direction of technology development. In addition, nearly half of the respondents are researchers and research managers. It is vital to keep it in mind that the survey results may be biased to the preferences of people who work in research institutes. Therefore, it is necessary to conduct further analysis using a participatory approach to identify specific research topics that can meet the practical needs of the end users of the developed technologies. We hope that the results of the survey will provide a good opportunity for all the stakeholders to consider an R&D strategy that can contribute to the overall goal of technological development, such as poverty alleviation and environmental conservation.

REFERENCES

Alam, J. (2005a). "Enhancing sustainable development of diverse agriculture in Bangladesh", CAPSA Working Paper No. 80, Bogor, Indonesia: ESCAP-CAPSA.

Alam, J. (2005b). "Secondary crop based farming systems and their integration with processing and marketing in Bangladesh", CAPSA Working Paper No. 87, Bogor, Indonesia: ESCAP-CAPSA.

Anh, D.T. (2005). "Enhancing sustainable development of diverse agriculture in Viet Nam", CAPSA Working Paper No. 86, Bogor, Indonesia: ESCAP-CAPSA.

ARI (Applied Research Institute) (1996). "Seibunkaisei Plastics (Biodegradable Plastics)", available on line at www.ari.co.jp/sentan/seibunkai.html (in Japanese).

Douangsavanh, L. and others (2006). "Enhancing sustainable development of diverse agriculture in Lao People's Democratic Republic". CAPSA Working Paper No. 89, Bogor, Indonesia: ESCAP-CAPSA.

EIA (Energy Information Administration) (2003). "Annual energy review 2003", EIA, U.S. Department of Energy, available on line at http://www.eia.doe.gov/emeu/aer/contents.html.

ISNAR (2005). "Agricultural science and technology indicators", available on line at http://www.sciencecouncil.cgiar.org/publications/pdf/SfAD%20Section%205.pdf.

JST (Japan Science and Technology Agency) (2005). "Food composition database", available on line at http://food.tokyo.jst.go.jp/.

Kyi, A. (2005). "Enhancing the sustainable development of diverse agriculture through CGPRT crops in Myanmar: Current status of CGPRT crop agriculture and identification of its development constraints", CAPSA Working Paper No. 85, Bogor, Indonesia: ESCAP-CAPSA.

Mahrouf, A.R.M. (2005). "Enhancing sustainable development of diverse agriculture in Sri Lanka", CAPSA Working Paper No. 83, Bogor, Indonesia: ESCAP-CAPSA.

Mahrouf, A.R.M. (2006). "Secondary crop based farming systems and its integration with processing and marketing in Sri Lanka", CAPSA Working Paper, Bogor, Indonesia: ESCAP-CAPSA (in press).

Menter H. and others (2004). "Scaling up", Scaling up and out: Achieving widespread impact through agricultural research Cali, Columbia, International Centre for Tropical Agriculture (CIAT). pp. 9-24.

NISTEP (National Institute of Science and Technology Policy) (2001). "The seventh technology foresight: Future technology in Japan toward the year 2030", NISTEP report No. 71, NISTEP, Ministry of Education, Culture, Sports, Science and Technology Japan, available on line at http://www.nistep.go.jp/achiev/ftx/eng/rep071e/idx071e.html.

NRIAE (National research institute for agricultural economics) (1993). "Azia shokoku no bukka seisaku (Price policy in Asian countries)", available on line at http://www.affrc.go.jp/seika/data_nriae/h05/aa30.html (in Japanese).

Pearson, S.R., N. Akrasanee and G.C. Nelson (1976). "Comparative advantage in rice production: a methodological introduction", *Food Research Institute Studies* vol. XV No. 2:127-137, Standford University, Standford California.

Roonnaphai, N. (2006). "Enhancing sustainable development of diverse agriculture in Thailand". CAPSA Working Paper No. 90, Bogor, Indonesia: ESCAP-CAPSA.

Singh, R.P. and others (2005a). "Enhancing sustainable development of diverse Agriculture in India", CAPSA Working Paper No. 82, Bogor, Indonesia: ESCAP-CAPSA.

Singh, R.P. and others (2005b). "Identification of pulling factors for enhancing the sustainable development of agriculture with special reference to maize in India", CAPSA Working Paper No. 88, Bogor, Indonesia: ESCAP-CAPSA.

Siregar, M. (2006). "Enhancing sustainable development of diverse agriculture in Indonesia", CAPSA Working Paper, Bogor, Indonesia: ESCAP-CAPSA (in press).

Siregar, M. and others (2006). "Secondary crops based farming systems and their integration with processing in Lampung, Indonesia", CAPSA Working Paper, Bogor, Indonesia: ESCAP-CAPSA (in press).

Sukartono and others (2004). "Raised beds improve secondary crop production in the rainfed rice-based cropping systems of Southern Lombok Eastern Indonesia". *In new directions for a diverse planet: Proceedings of the 4th international crop science congress. Brisbane, Australia,* 26 Sep – 1 Oct 2004, available on line at http://www.cropscience.org.au/icsc2004/poster/1/4/1216_sukartonov.htm.

Taylor D. (1994). "Agricultural diversification in Southeast Asia", In *Agricultural diversification in monsoon areas* (Tokyo, Asian productivity organization), pp. 7-51.

Timmer, C.P. (1992). "Agricultural diversification in Asia: Lessons from the 1980s and issues for the 1990s", *Indonesian Food Journal* 3(5): 68-82.

World Bank. (2005). "The world development indicators 2005", available on line at http://www.worldbank.org/data/wdi2005.

Yamada, S. (1992). "*Asia nogyo hatten no hikaku kenkyu", (A comparative study on Agricultural development in Asia)* (Tokyo, University of Tokyo Press) (in Japanese).