Diversity in Agricultural Research Resources in the Asia-Pacific Region

Agricultural Science and Technology Indicators Initiative

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May 2008

International Food Policy Research Institute
and
Asia-Pacific Association of Agricultural Research Institutions

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Printed in May 2008

Foreword

The Asia-Pacific region, comprising 39 countries, is characterized by huge diversity in size, population, agricultural and economic development. Despite having wide range of natural endowments in terms of agro-ecology/agro-climate, the richness of bio-resources, coupled with diversification of agriculture, the region today faces major challenges of food insecurity, high rate of poverty alleviation and malnutrition. Since most countries of the region are dependent on agriculture, growth and development of the sector are necessary for food security and improved livelihood for the rural people. Agricultural research and development have important role to play in this transformation.

The national agricultural research systems (NARS) in the region are quite heterogeneous. Commensurate with the needs of each country, research and development in agricultural sector has, over time, gained prominence. Various models from simple to highly complex (NARS-NARES) systems, now operate. While some of them are quite successful, many others are still struggling. Following the Asia-Pacific Association of Agricultural Research Institutions (APAARI) expert consultation in 1998 on "Research Management Mechanisms of NARS", tremendous progress has been made in the region for the functioning and management of agricultural research.

The present status report issued jointly by the Agricultural Science and Technology Indicators (ASTI) initiative of the International Food Policy Research Institute (IFPRI) and APAARI is based on a survey of 11 countries (South Asia: Bangladesh, India, Nepal, Pakistan, Sri Lanka; Southeast Asia: Indonesia, Laos, Malaysia, the Philippines, Vietnam; Pacific: Papua New Guinea) which was conducted in collaboration with national partners. The report utilizes information derived from published country briefs and reports, and the datasets obtained from the country surveys and also makes use of some non-ASTI information. Thus, the report is a comprehensive account of agricultural R&D in the Asia-Pacific region.

The report reviews and presents comparative analysis of trends in major investments and institutional developments for agricultural research in Asia-Pacific countries. It points out that the distribution of R&D spending among countries had been quite uneven, with China, Japan and India accounting for combined total of over 70 percent of regional spending. Investment for the region as a whole grew by 3.4 percent annually during 1981-2002. Most of this growth took place in the last decade when China and India, in particular, expanded their agricultural research spending. This development was also seen in relatively smaller countries like Malaysia and Vietnam, but not so in Pakistan, Indonesia and Laos. A similar diversity between countries was observed with regard to human resource capacity in agricultural R&D. China employed the largest number of agricultural researchers (over 50,000); India had the most qualified research staff; with lowest capacity for Laos and Vietnam; but overall, improvement was noticed in all the countries. For gender diversity, the Philippines had more women scientists than the others, and Pakistan had the lowest proportion of women scientists.

It was observed that bulk of the R&D in agricultural sector is still financed by the government, although there has been some diversification in recent years. Competitive funding mechanisms, internally generated funds, production or export levies, among other factors have all gained prominence as means for financing agricultural R&D in the Asia-Pacific region. Much variation was also evident in donor dependence; being higher in Laos and Nepal. Also, more recently, large projects have been funded by the World Bank such at NATP and NAIP in India. With regard to private sector partnership for agricultural research including funding, trends have indicated a substantial increase, especially for the emerging field of biotechnology, particularly in the Philippines and India.

It is our hope that this consolidated report will be useful to policy makers, senior managerial scientists and others, in respective countries/governments, for projecting the gaps *vis-à-vis* priorities for R&D funding with focus on improving efficiency and enhance productivity growth in the agricultural sector. It will be equally useful to other countries, national programs, and even to donors in assessing emerging R&D concerns of the Asia-Pacific region.

The ISNAR Division of IFPRI and APAARI appreciate the contributions made by Nienke Beintema, Gert-Jan Stads and various national collaborators in compiling the country reports that provided the basis for this synthesis report. It is our expectation that this joint publication will receive wider dissemination among national partners and all stakeholders in the region and elsewhere.

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Preface

This report reviews the major investment trends, human resource trends, and institutional developments in public agricultural research and development (R&D) in 11 countries of the Asia-Pacific region, drawing from comprehensive datasets derived from primary surveys. These data are linked with investment and human resources data from the Chinese government and other secondary sources to provide a wider regional and global context for the sample's agricultural R&D investment trends.

The Asia-Pacific region is a highly diverse region in terms of geography, population distribution, economic development, and cultural, political, and historic backgrounds. Employing more than 50,000 full-time equivalent (fte) agricultural researchers in 2002, China has the largest agricultural R&D system in the world in terms of number of research staff. But the region also encompasses small Pacific islands with less than 100 fte agricultural researchers each. Average degree levels of agricultural research staff also diverged widely from one country to the other. Nonetheless, all countries in our survey sample experienced improvements in qualification levels of agricultural scientists over the past decade, despite the challenges that certain countries face in rejuvenating their researcher pool.

Distribution of spending among countries in the Asia-Pacific region was also very uneven, with China, Japan, and India accounting for the lion's share of the region's agricultural research expenditures. Many countries in the region realized impressive growth in agricultural R&D spending in recent years, whereas growth in other countries was more sluggish (and in some cases negative). Funding for agricultural research is still predominantly through government allocations, although a number of countries now have a dual funding system where a portion of the government allocations are disbursed through a competitive funding system. A number of countries have sought to fund agricultural R&D by a tax on agricultural production or exports while other countries have been successful in commercializing their research results.

About the ASTI Initiative

The Agricultural Science and Technology Indicators (ASTI) initiative compiles, processes, and disseminates data on institutional developments and investments in worldwide agricultural R&D, and analyzes and reports on these trends. Tracking these developments in ways that facilitate meaningful comparisons among different countries, types of agencies, and points in time is critical for keeping policymakers abreast of science policy issues pertaining to agriculture. The main objective of the ASTI initiative is to assist policymakers and donors in making better informed decisions about the funding and operation of public and private agricultural science and technology agencies by making available internationally comparable information on agricultural research investments and institutional changes. Better-informed decisions will improve the efficiency and impact of agricultural R&D systems and ultimately enhance productivity growth of the agriculture sector. The ASTI initiative comprises a network of national, regional, and international agricultural R&D agencies and is managed by the International Food Policy Research Institute (IFPRI). ASTI data and associated reports are made freely available for research policy formulation and priority-setting purposes (http://www.asti.cgiar.org).

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Nienke Beintema heads the ASTI initiative, which is based within IFPRI's International Service for National Agricultural Research (ISNAR) Division; Gert-Jan Stads is a full-time consultant with the ASTI initiative.

Acknowledgments

The underlying dataset and individual country briefs on which this report is based were developed through a comprehensive survey conducted in 11 countries with numerous Asian collaborators during 2003–07. Funding for these surveys was provided by the World Bank via the Consultative Group on International Agricultural Research (CGIAR), and IFPRI. The authors thank Jifar Tarakegn for his capable research assistance and Kwadwo Asenso-Okyere, Shenggen Fan, Keith Fuglie, and Carl Pray for comments on the review draft of this report. The authors would also like to express their gratitude to the Asia-Pacific Association of Agricultural Research Institutions (APAARI) for facilitating the ASTI survey in the Asia-Pacific region.

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Acronyms

AARI	Ayub Agricultural Research Institute (Pakistan)
ACIAR	Australian Centre for International Agricultural Research
ADB	Asian Development Bank
AE	agriculrural expenditures
AFN	Asia Forest Network
AgGDP	agricultural gross domestic product
AICRP	All India Coordinated Research Projects
ANSWER	Asian Network for Sweetpotato Genetic Resources
APAARI	Asia-Pacific Association of Agricultural Research Institutions
ARBN	Asian Rice Biotechnology Network
ARI	agricultural research intensity
ASB	Alternatives to Slash-and-Burn Programme
ASPNET	Asia and Pacific Regional Network of the International Network for Improvement of Bananas and Plantains
ASTI	Agricultural Science and Technology Indicators
BARC	Bangladesh Agricultural Research Council
BAU	Bangladesh Agricultural University
CAAS	Chinese Academy of Agricultural Sciences
CARP	Council for Agricultural Research Policy (Sri Lanka)
CCRI	Cocoa and Coconut Research Institute (Papua New Guinea)
CGIAR	Consultative Group on International Agricultural Research
CIFOR	Center for International Forestry Research
CLAN	Cereals and Legumes Asia Network
COGENT	International Coconut Genetic Resources Network
CORRA	Council for Partnership on Rice Research in Asia
CRI	Coffee Research Institute (Papua New Guinea)

DENR	Department of Environmental and Natural Resources (The Philippines)
EA-PGR	Regional Network for Conservation and Utilization of Plant Genetic Resources in East Asia
ERDS	Ecosystems Research and Development Services (The Philippines)
FORDA	Forestry Research and Development Agency (Indonesia)
FRI	Fisheries Research Institute (Malaysia)
FRIM	Forest Research Institute Malaysia
fte	full-time equivalent
GDP	gross domestic product
IAARD	Indonesian Agency for Agricultural Research and Development
IARC	Integrated Agricultural Research Center (The Philippines)
ICAR	Indian Council of Agricultural Research
ICRISAT	International Crops Research Institute for the Semi-Arid Tropics
INGER	International Network for Genetic Evaluation of Rice
IPR	intellectual property rights
IRIEC	Indonesian Research Institute for Estate Crops
IRRI	International Rice Research Institute
JIRCAS	Japanese International Research Center for Agricultural Sciences
LIBIRD	Local Initiatives for Biodiversity Research and Development (Nepal)
MARD	Ministry of Agriculture and Development (Vietnam)
MARDI	Malaysian Agricultural Research and Development Institute
MBOP	Malaysian Palm Oil Board
NACA	Network of Aquaculture Centers in Asia & the Pacific
NAFRI	National Agriculture and Forestry Research Institute (Laos)
NARC	Nepal Agricultural Research Council
NARC	National Agricultural Research Center (Pakistan)
NARI	National Agricultural Research Institute (Papua New Guinea)
NGO	Non-Governmental Organization
OPRA	Oil Palm Research Association (Papua New Guinea)

OECD	Organization for Economic Co-operation and Development
PARC	Pakistan Agricultural Research Council
PCARRD	Philippine Council for Agriculture, Forestry and Natural Resources Research and Development
PhilRice	Philippine Rice Research Institute
PNGFRI	Papua New Guinea Forestry Research Institute
PPP	purchasing power parity
R&D	research and development
RWC	Rice-Wheat Consortium
SANPGR	South Asia Network on Plant Genetic Resources
SAU	state agricultural university
SAVERNET-II	South Asia Vegetable Research Network
SEANAFE	Southeast Asian Network for Agroforestry Education
SEASAKNet	Southeast Asian Sustainable Agriculture Knowledge Network
S&T	science and technology
TAMNET	Tropical Asian Maize Network
UNESCO	United Nations Educational, Scientific, and Cultural Organization
UPLB	University of the Philippines, Los Baños
UPM	University Putra Malaysia
USAID	United States Agency for International Development
UTFANET	Underutilized Tropical Fruits of Asia Network

Introduction

Overview

Over the past three decades, millions of people across the Asia-Pacific region[1] have benefited from an improved standard of living due to extraordinary economic growth, higher per capita incomes, and increased food security. Agricultural development was a major contributor to these successes combined with growth-promoting science and technology (S&T) that fueled the phenomenon known as the Green Revolution. As a result, the share of Asia's poor was cut drastically, from 50 percent in 1970 to 18 percent in 2004. The majority of these gains, however, occurred in China and Southeast Asia. The region as a whole still houses over two-thirds of the world's poor people, representing 600 million people living on US$1 per day or less, and South Asia remains home to 38 percent of the global population of undernourished people (von Braun 2007). Further, economic improvements have not been equitable, since the poorest people have benefited the least (Rosegrant and Hazell 2000; IFPRI/ADB 2007; World Bank 2007).

Whether directly or indirectly, the vast majority of Asia's rural population (some two billion people and growing) remains highly dependent on agriculture, forestry, and fisheries, but increasing population pressure, agricultural intensification, and inappropriate farming practices seriously threaten the rural environment, especially in South Asia (Rosegrant and Hazell 2000). New technologies are becoming increasingly complex, knowledge-intensive, and location-specific compared with those developed during the Green Revolution, necessitating more decentralized research and extension systems (Rosegrant and Hazell 2000) and increased and well-targeted investments in public and private agricultural R&D. Such investments are key, for example, to developing technologies to facilitate much-needed expansion in staple cereal production[2]. Further, population growth and economic development are significantly increasing the demand for fruits, vegetables, meat, and dairy products, and this shift will also create increased demand for biotechnologies (IFPRI/ADB 2007). Finally, specific technologies such as those applicable to rainfed

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[1] In this report, the Asia-Pacific region excludes the Middle East, which is traditionally aggregated under the Middle East and North Africa (MENA) region; Central Asia and the Caucasus are also excluded from this report due to lack of data.

[2] The consumption of cereals such as rice, wheat, maize, and sorghum – still the most important staple foods – has increased production in recent years causing stocks to decline and world prices to rise; during 2000-06, the global demand for cereals increased by 8 percent, whereas cereal prices more than doubled (von Braun 2007).

and irrigated rice production are needed to assist poor smallholder farmers who have yet to benefit from economic growth (IFPRI/ADB 2007). All this means that sustainable support for agricultural R&D, both financially and politically, is crucial if important challenges are to be addressed.

Quantitative data are an important input when it comes to assessing the contribution of agricultural S&T to agricultural growth. Such information is important for measuring, monitoring, and benchmarking agricultural S&T systems in terms of their performance, inputs, and outcomes. This report reviews the major investment trends, human resource trends, and institutional developments in public agricultural research and development (R&D) in 11 countries of the Asia-Pacific region from 1991 until 2002/03, drawing from a set of country briefs and reports prepared by Agricultural Science and Technology Indicators (ASTI) initiative using comprehensive ASTI datasets derived from primary surveys[3]. These data are linked with investment and human resources data from the Chinese Ministry of Science and Technology and other secondary sources to provide a wider regional and global context for the sample's agricultural R&D investment trends.

Macroeconomic Context

Unsurprisingly, the countries of the Asia-Pacific region are highly diverse. On the one hand, the region is home to the world's only two countries with populations higher than one billion (India and China); on the other hand, the region comprises numerous small Pacific-island nations each with a population of less than 100,000. Economic development is equally diverse, from the four high-income countries of the Organisation for Economic Co-operation and Development (OECD) (Australia, Japan, New Zealand and South Korea); to transition economies like Singapore, Hong Kong, and Taiwan; to low-income countries like Cambodia, Laos, and Nepal. Many of the region's economies have achieved much faster and sustained economic growth compared with other developing (and even developed) regions. Malaysia and Thailand, for instance, achieved upper middle-income status within the very short time span of about 25 years.

Table 1 provides a number of indicators of diversity among the 25 Asian countries included in this report. In 2006, China's total gross domestic product (GDP) was more than twice that of India and close to 1,500 times the average of the

[3] The 11 countries are Bangladesh, India, Indonesia, Laos, Malaysia, Nepal, Pakistan, Papua New Guinea, the Philippines, Sri Lanka, and Vietnam. In 2002, these countries represented 63 percent of agricultural R&D spending in the Asia-Pacific region excluding China and the four high-income countries (Australia, Japan, New Zealand, and South Korea). The original ASTI country briefs and reports (see Reference section) are available at http://www.asti.cgiar.org/pubs-ap.aspx.

sample's six Pacific countries. Predictably, average GDP per capita in the four high-income countries was more than seven times the average for the sample total and more than nine times the average for South Asia and Pacific subregions. In addition, the extent to which the economies of countries in the Asia-Pacific region depend on agriculture also varies widely from one country to the next. The agricultural sector accounted for just 2 percent of total GDP of the four high-income countries of the OECD. The corresponding share for the Pacific subregion was above one-third, which is not surprising given the prominence of industry and services in high-income countries. Myanmar is especially dependent on agriculture, which in 2006 represented a 58 percent share of GDP. Although this share is extremely high by

Table 1. Diversity indicators for the Asia-Pacific region, 2006

Category	Population	GDP	AgGDP	GDP per capita	Annual GDP growth (1991-2006)	AgGDP/ GDP
	(*million*)	(*million 2005 international dollars*)		(*2005 international dollars*)	(*percentage*)	
By income class						
India	1,110	2,654,983	422,468	2,392	6.3	15.9
Other low-income countries (9)	493	869,286	202,051	1,765	5.2	23.2
China	1,310	5,888,291	702,612	4,495	9.7	11.9
Other middle-income countries (10)	419	1,854,910	206,701	4,432	3.8	11.1
Japan	128	3,942,505	66,202	30,801	1.1	1.7
Other high-income countries (3)	47	1,887,736	65,620	39,969	4.5	3.5
By subregion						
China	1,310	5,888,291	702,612	4,495	9.7	11.9
India	1,110	2,654,983	422,468	2,392	6.3	15.9
South Asia, excluding India (5)	351	639,248	123,218	1,820	4.4	19.3
Southeast Asia (8)	553	2,066,119	277,752	3,734	4.3	13.4
The Pacific (6)	7	24,126	8,505	3,235	2.3	35.3
OECD countries (4)	175	5,830,240	131,823	33,272	2.0	2.3
Total (25)	3,507	17,103,008	1,666,377	4,877	4.9	9.7

Sources: World Bank (2007 and 2008); ADB (2007).

Notes: The number of countries in each subgrouping is indicated in parentheses. "Other low-income countries" include Bangladesh, Bhutan, Nepal, Pakistan, Cambodia, Laos, Myanmar, Papua New Guinea, and Vietnam; "other middle-income countries" include Sri Lanka, Indonesia, Malaysia, the Philippines, Thailand, Fiji, Kiribati, Samoa, Tonga, and Vanuatu; "other high-income countries" include Australia, New Zealand, and South Korea. GDP is gross domestic product; AgGDP is agricultural gross domestic product; OECD indicates Organisation for Economic Co-operation and Development.

Asian standards, it is still much lower than the corresponding shares of many Sub-Saharan African countries (Beintema and Stads 2006).

Public Agricultural Research

Institutional Developments

Formal agricultural research in Asia was initiated by the European (mainly British and Dutch) colonizing powers building on initial transfer and screening activities at the botanical gardens during the 19th century. These initial agricultural research efforts primarily focused on commodity-based research and were often funded through commodity levies on specific crops. These structures remained in place until well after countries attained independence in the 1940s and 1950s, leading to considerable fragmentation of national research efforts. During the 1960s, many Asian countries began to centralize and consolidate their agricultural research operations. In Bangladesh, India, Pakistan, and the Philippines (and more recently in Nepal, Sri Lanka, and Taiwan), this involved the establishment of an agricultural research council, which became responsible for the management and financing of agricultural research. Some councils also manage the operations of the agricultural research entities. In other countries, such as Indonesia, Malaysia, Papua New Guinea, and South Korea, all government agricultural research operations were merged to create a single national agricultural research institute, often with considerable operational autonomy (Pardey, Roseboom, and Anderson 1991; Pardey, Roseboom, and Fan 1998).

In countries like China and Japan that were never colonized, agricultural research systems developed quite differently. Although agricultural research in China started relatively early with the establishment of an agricultural experiment station in 1902, only a handful of isolated agricultural research entities were in operation when the People's Republic was proclaimed in 1949. The country's agricultural research infrastructure developed considerably during the 1950s and early 1960s but faltered during the Cultural Revolution from 1966 to 1976. After 1979, the Chinese government recognized the importance of an effective research system for agricultural productivity growth. Many of the former research agencies were revived and relocated back to the cities (Pardey, Roseboom, and Anderson 1991).

Over the past two decades, the institutional structure of most agricultural research systems in the Asia-Pacific region remained relatively unchanged. While there have been ongoing internal reorganizations, few countries have undertaken fundamental restructuring of their research systems as was common practice throughout the 1960s and 1970s. Important exceptions to this generalization are the former Soviet States in Central Asia and the Caucasus (Pardey, Roseboom, and Fan 1998)[4].

In line with the diversity discussed in the previous section, the current structure of agricultural research institutions in the region varies widely by country (Table 2). In most of the smaller countries, agricultural research is undertaken by a few government agencies and faculties of universities; in the large countries like China, India, and the Philippines the systems are extremely complex[5].

Table 2. The institutional structure of agricultural research in 11 sample countries, 2002/03

Country	Main government agencies[a]	Main universities[b]	Important nonprofit institutions[b]
Bangladesh	10 institutes under the Bangladesh Agricultural Research Council (BARC) (74%); 2 institutes and 2 laboratories under the Ministry of Science, Information, and Communication Technology (9%)	Bangladesh Agricultural University (BAU) (17%)	—
India	93 institutes under the Indian Council for Agricultural Research (ICAR) (37%)	38 State Agricultural Universities (SAUs) (54%)	—
Nepal	Nepal Agricultural Research Council (NARC) (77%)	2 agencies under Tribhuvan University (14%)	Local Initiatives for Biodiversity Research and Development (LIBIRD) (4%)
Pakistan[c]	Federal level: National Agricultural Research Center (NARC) (14%); 15 institutes and units under the Pakistan Agricultural Research Council (PARC) (7%) Punjab province: Ayub Agricultural Research Institute (AARI) (22%); 5 institutes and units under Livestock and Dairy Development Department (7%)	University of Agriculture, Faisalabad (3%)	—
Sri Lanka	8 institutes under the Ministry of Agriculture, Livestock, Land, and Irrigation (38%); 4 institutes under the Ministry of Plantation Industries (40%)	Faculty of Agriculture under the University of Peradeniya (5%)	—
Indonesia	9 institutes and centers under the Indonesian Agency for Agricultural Research and Development (IAARD) (49%); Indonesian Forest Research and Development Agency (FORDA) (11%); Indonesian Research Institute for Estate Crop (IRIEC) (5%)	Bogor Agricultural University (10%); 5 faculties under Udayana University (4%)	—

(*Contd...*)

[4] No data are available on the current structure and capacity of the agricultural research systems in Central Asia and the Caucasus.

[5] For more detailed information on national institutional developments, see the specific ASTI country briefs and reports listed in the reference section.

Table 2. (*Contd...*)

Country	Main government agencies[a]	Main universities[b]	Important nonprofit institutions[b]
Laos	National Agriculture and Forestry Research Institute (NAFRI) (85%)	2 faculties under the National University of Laos (15%)	—
Malaysia	Malaysian Agricultural Research and Development Institute (MARDI) (37%); Malaysian Palm Oil Board (MPOB) (17%); Forest Research Institute Malaysia (FRIM) (12%); Fisheries Research Institute (FRI) (5%)	4 faculties under University Putra Malaysia (UPM) (7%)	—
The Philippines	14 Integrated Agricultural Research Centers (IARC) of the Department of Agriculture (15%); Philippine Rice Research Institute (PhilRice) (11%); 14 Ecosystems Research and Development Services (ERDS) of the Department of Environmental and Natural Resources (DENR) (5%)	26 units under the University of the Philippines, Los Baños (UPLB) (8%)	—
Vietnam	28 institutes and centers under Ministry of Agriculture and Rural Development (MARD) (71%); 4 institutes under the Ministry of Fisheries (7%)	Hanoi Agricultural University (4%); Water Resources University (4%); Agro-Forest University in Ho Chi Minh City (3%)	—
Papua New Guinea	National Agricultural Research Institute (NARI) (34%); Papua New Guinea Forestry Research Institute (PNGFRI) (26%)	2 departments under the PNG University of Technology (4%)	PNG Cocoa and Coconut Research Institute (CCRI) (17%), Oil Palm Research Association (OPRA) (12%), Coffee Research Institute (CRI) (7%)

Sources: Compiled by authors from ASTI country briefs and reports (ASTI 2005-08).

Notes: Agency shares of total public agricultural research staff (in full-time equivalents) for 2002/03 are shown in parentheses.

[a] Data include government agencies with at least a 5-percent share of total public agricultural R&D staff.

[b] Data include universities and nonprofit institutions with at least a 3-percent share of total public agricultural R&D staff.

[c] Of the four Pakistani provinces and two territories, only the Punjab comprised research agencies employing more than a 5-percent share of the country's total agricultural R&D staff.

The Chinese agricultural research system involves a number of ministries and is highly decentralized. Agricultural research at the national level is primarily conducted by the Ministry of Agriculture's Chinese Academy of Agricultural Sciences (CAAS), Chinese Academy of Fishery Science and Chinese Academy of Forestry, along with their associated institutes. Some additional agricultural research is also conducted by a variety of institutes within other ministries. At the provincial level, agricultural research is carried out at academies and related government-sponsored agricultural research institutes. Their focus is mostly on local issues and conditions. The agricultural research institutes at the prefecture level, which are important due the size of prefectures, conduct applied and adaptive R&D[6]. It is worth noting that agricultural research, extension, and education in China are undertaken by separate institutions, which has hampered the generation and transfer of technologies and related activities (Fan, Qian, and Zhang 2006).

In contrast, India has a system of integrated research, extension, and education, following the so-called land-grant system of the United States. Public agricultural research in India comprises the Indian Council for Agricultural Research (ICAR) and its 93 institutes, 35 state agricultural universities (SAUs), and a number of other government and higher education agencies. ICAR's institutional network consists of national institutes for basic and strategic research, national bureaus for conservation and exchange of germplasm and soil survey work, central research institutes for commodity-specific research, and national research centers for applied, commodity-specific strategic research. ICAR established a large network of district-level agricultural research centers that are responsible for technology transfer and farmers' training (Pal and Byerlee 2006). In addition, ICAR manages a large number of "All India Coordinated Research Projects" (AICRPs), most of which are based within SAUs. AICRPs are a mechanism for building a nationwide cooperative network for interdisciplinary research.

Although the agricultural research system in the Philippines is much smaller than those of China, India, and certain other Asian countries (Indonesia and Pakistan, for example), its organization is highly complex, partly due to the large number of agencies and partly due to their regional distribution. The Philippine Council for Agriculture, Forestry and Natural Resources Research and Development (PCARRD) is the central coordinating body of agricultural R&D activities in the Philippines. It was created to establish, support, and manage the operations of a national network of government and higher education agencies involved in crop, livestock, forestry, fishery, soil and water, mineral resources, and socioeconomic research. PCARRD provides support to 132 implementing agencies, as well as 14 regional consortia scattered across the archipelago.

Institutional Distribution

The government sector still dominates public agricultural research in most of the 11 countries included in the ASTI survey round. On an average, the government sector employed 62 percent of the sample's public agricultural R&D staff in 2002/03 (Table 3), while the higher education sector accounted for 38 percent, and the

[6]In China, provinces are divided into prefectures, which are comparable with counties in countries like the United States. China has 33 provinces and 333 prefecture-level regions, including prefectures, prefecture-level cities, autonomous prefectures, and leagues (Wikipedia 2007a).

nonprofit sector for just 0.2 percent. At the country level, these relative shares shifted only slightly between 1991 and 2002/03.

Table 3. The institutional orientation of agricultural research, 1991 and 2002-03

Region/ country	Share of fte researchers					
	1991			2002/03		
	Government	Higher education	Nonprofit	Government	Higher education	Nonprofit
South Asia	(*percentage*)					
Bangladesh	90.5	9.5	0	89.1	10.9	0
India	42.4	57.6	0	43.6	56.4	0
Nepal	na	na	na	80.6	13.6	5.8
Pakistan	92.0	8.0	0	91.7	8.3	0
Sri Lanka	91.0	9.0	0	88.0	12.0	0
Southeast Asia						
Indonesia	na	na	na	68.5	31.5	0
Laos	na	na	na	85.1	14.9	0
Malaysia	90.9	9.1	0	86.3	13.7	0
The Philippines	64.9	35.1	0	64.1	35.4	0.5
Vietnam	76.9	23.1	0	80.3	19.7	0
The Pacific						
Papua New Guinea	61.6	2.5	35.9	60.5	3.9	35.5
Sample total (11)	na	na	na	61.7	38.0	0.2

Sources: Compiled by authors from datasets underlying the ASTI country briefs and reports (ASTI 2005-08).
Note: "na" indicates not available.

The higher education sector has gained prominence in a few countries, but the individual capacity of many higher education agencies remains very small. In 2002, for example, 148 higher education units were involved in agricultural research in the Philippines, 112 of which employed 10 fte researchers or fewer. India employed more agricultural researchers working in the higher education sector than in the government sector due to the aforementioned land-grant system, which closely links education and research.

While nonprofit institutions, by definition, are not controlled by national governments, they are often linked to producer organizations and hence receive most of their funding through taxes levied on production or exports. Nonprofit organizations in Papua New Guinea operate this way, as do many nonprofit agencies that conduct research on export crops in Latin America and Africa.

Agencies funded through taxes in Asia, however, do not always have nonprofit status. The R&D institutes conducting research on the principal export crops of Malaysia and Sri Lanka, for example, are financed through export levies, but they still fall under the direct supervision of government ministries. Nevertheless, these types of agencies often have more bureaucratic freedom than their parent organizations, which gives them more flexibility when it comes to generating funding and employing (and incentivizing) staff. Nepal was one of the few countries in the survey sample with a number of small non-governmental organizations (NGOs) active in agricultural research[7]. These NGOs are entirely funded by foreign donors, and they mainly focus on issues related to rural development. Overall, however, nonprofit institutions play only a limited role in agricultural research in the Asia-Pacific region.

Human Resources

Overall Trends

Since the 1970s, most countries in the Asia-Pacific region have made considerable progress in building their research staff capacity, both in terms of total researcher numbers and qualification levels (in terms of postgraduate degrees). The participation of female scientists has also increased in some countries (see Box 1). Time-series data on total research staff were available for the 11 sample countries and China. In 2002, China employed more than 50,000 full-time equivalent (fte) researchers in the public agricultural sector, while India employed close to 17,000 (Table 4)[8]. Three other sample countries employed 3,000 or more fte's: Indonesia, Pakistan, and the Philippines. In contrast, the small agricultural research systems of Laos and Papua New Guinea employed just over 100 fte researchers each.

Combined total number of agricultural research staff in the 12 sample countries declined by an average of 0.9 percent per year during 1991-2002, but if China is excluded, numbers actually grew by 1.2 percent per year (Table 4 and Figure 1). Despite a steady rise in agricultural R&D expenditures in China, researcher numbers declined by more than 10 percent - from about 60,000 in 1991 to 50,198 in 2002, due to a 26 percent cut in managerial and support staff during 1994-98 and an increase in the number of retirees (Fan, Qian, and Zhang 2006). More recent data, however, show that the total number of research staff has rebounded such that the 2005 total was close to the recorded 1991 level. Since 1991, the total number of agricultural

[7] Some NGOs in other Asia-Pacific countries were also involved in agricultural research, but their activities were small and often ad-hoc.

[8] fte researcher numbers for India include technicians holding university degrees at the ICAR institutes and within SAUs.

Box 1: Female researchers in agricultural R&D

Over the past few decades, the number of female scientists and managers working in agricultural research has increased significantly in both industrialized and developing countries, although empirical studies have repeatedly shown a disproportionately low number of women working in senior scientific positions. In addition, the attrition rate of female researchers in S&T agencies is higher than that of their male colleagues (Sheridan 1998; IAC 2006). In the 11-country sample for 2002/03, one in every five agricultural researchers was female, but this average masks large variations across countries (Figure A). With the exception of Sri Lanka, South Asian countries had far lower female researcher ratios compared with Southeast Asian countries. In Pakistan, for example, only 6 percent of all agricultural researchers were female, and most were employed in federal government or higher education agencies. Only 83 of the nearly 3,200 fte agricultural researchers at Pakistan's provincial government agencies were female (4 percent), and just 1 percent of all agricultural researchers with PhD degrees at the provincial government agencies were female - a strikingly low figure. In contrast, female participation in agricultural research in the Philippines, at 40 percent, was exceptionally high both by Asia-Pacific regional standards and by developing-country standards, in general. This is not surprising, given that Philippine society has always had much greater gender equality compared with certain other parts of the region. Interestingly, education and literacy levels in the Philippines were higher for women than for men in the late 1990s. Low average shares of female scientists are common in other developing world regions, the average being 20 percent (Beintema 2006). Unfortunately no information is available on female participation in developed countries.

Female scientists are also consistently less well-qualified than their male counterparts (Figure B). In 2002/03, for example, fewer women than men held PhD degrees on average (29 compared with 41 percent). Across the Asia-Pacific region, however, the share of female students enrolled in agriculture and related sciences has been increasing, and in a number of countries (such as Indonesia, Malaysia, and the Philippines) female students now outnumber male students. Rising numbers of women employed in the field of agricultural research are therefore anticipated in the years to come (Beintema 2006).

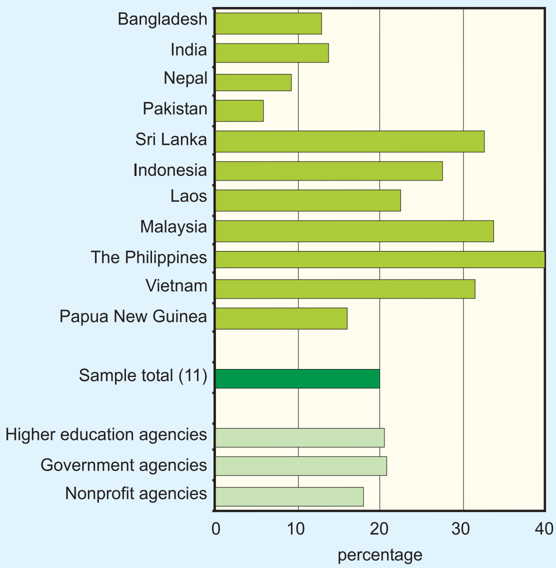

Figure A. Share of female research staff by country, 2002/03.

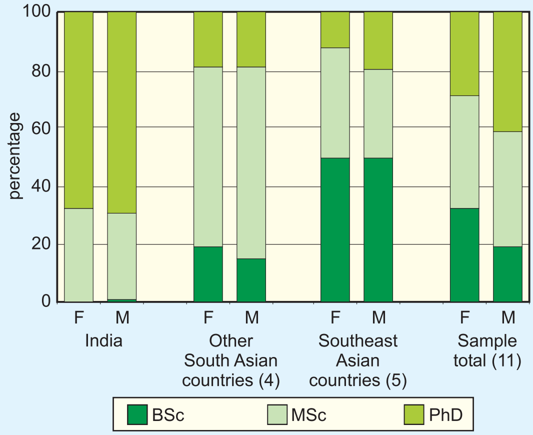

Figure B. Degree levels of female and male researchers, 2002/03.

researchers in India has remained fairly constant (in fte's), although the number declined by about 500 fte researchers during 2000-03 as a result of unfilled vacancies due to staff retirements combined with a national recruitment freeze. More recently, the Government of India has addressed this negative trend by approving the creation of 1,000 new researcher positions at the ICAR institutes. Indonesia's staff of agricultural researchers grew considerably during the early 1990s to more than 5,100 fte's in 1995, but totals have fallen since as a combined result of major reorganizations in government-led agricultural R&D and the East Asian financial crisis[9].

Table 4. Public agricultural research staff, 1991-2002

Region/ country	Total researchers			Growth rates[a]		
	1991	1996	2002	1991-1996	1996-2002	1991-2002
	(*full-time equivalents*)			(*percentage*)		
China	60,114	53,083	50,198	–1.4	–1.0	–2.2
South Asia						
Bangladesh	1,635	1,772	1,807	1.6	0.2	0.9
India[b]	14,968	16,675	16,737	2.2	0.1	1.1
Nepal[c]	na	346	428	na	3.4	3.6[c]
Pakistan	3,223	3,428	3,508	1.2	0.4	0.6
Sri Lanka	539	572	583	1.3	0.3	0.8
Southeast Asia						
Indonesia	4,548	4,760	4,751	1.2	0.2	0.04
Laos[c]	na	na	109	na	na	3.4[c]
Malaysia	937	1,041	1,118	2.1	1.3	1.6
The Philippines	2,424	3,053	3,213	4.9	0.6	2.3
Vietnam	1,862	1,991	2,732	1.4	5.4	4.0
The Pacific						
Papua New Guinea	86	108	107	4.6	0.4	2.3
Sample total (11)	30,596	33,842	35,093	2.1	0.6	1.2
Sample plus China (12)	90,710	86,925	85,291	–0.1	–0.4	–0.9

Sources: Compiled by authors from datasets underlying the ASTI country briefs and reports (ASTI 2005-08). China data are from MOST (various years); 1991 research staff for India and Indonesia were estimated using ASTI data and information from Pal and Byerlee (2006), and Fuglie and Piggott (2006), respectively.

Note: The number of countries in each category is shown in parentheses; na indicates not available.

[a] Annual growth rates are calculated using the least-squares regression method, which takes into account all observations in a period; they, therefore, are not based solely on the first and last years of a particular period.

[b] fte researcher numbers include technicians holding university degrees at the ICAR institutes and SAUs.

[c] 1991-2002 growth rates for Nepal and Laos are based on estimated time-series data for 1991-95 and 1991-97, respectively.

[9] The crisis, which began in the summer of 1997, gripped much of Asia; the countries most affected were Indonesia, South Korea, and Thailand, but the economies of Hong Kong, Laos, Malaysia, and the Philippines were also damaged (Wikipedia 2007b).

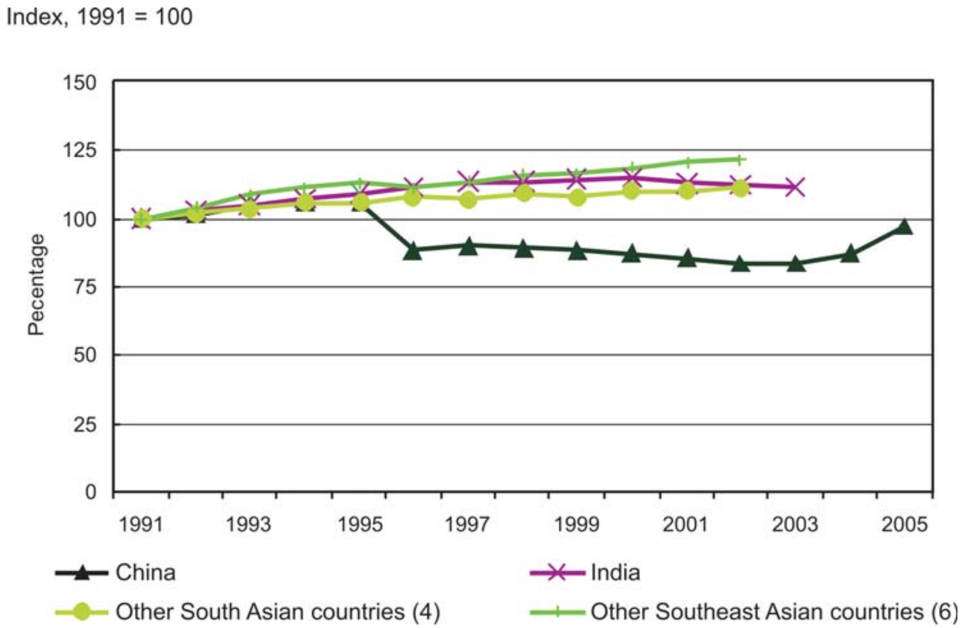

Figure 1. Trends in public agricultural research staff, 1991-2005.

Sources: See Table 3. Data for China for 2003-05 are from MOST (various years).

Notes: See Table 3. "Other Southeast Asian countries" include Papua New Guinea.

The remaining nine sample countries fall into three different patterns of research staff growth for the period 1991-2002: agricultural research staff numbers in Laos, Nepal, and Vietnam grew relatively rapidly, at rates of 3.4 to 4.0 percent per year; numbers in Malaysia, Papua New Guinea, and the Philippines grew more moderately at 1.6 to 2.3 percent per year; and numbers in Bangladesh, Indonesia, Pakistan, and Sri Lanka grew by less than 1 percent per year. Most countries in this last category experienced slow or declining growth in their numbers of agricultural research staff as a result of national recruitment freezes at different points in time.

Degree Levels

In 2002-03, close to three-quarters of the total fte researchers in the sample of 11 countries (excluding China) had postgraduate-level training, with 35 percent holding PhD degrees and 39 percent holding MSc degrees (Figure 2). Average degree levels of agricultural research staff in Asia's higher education agencies were higher than those in the government and nonprofit sectors - a pattern that was prevalent among most of the region's countries and that is consistent with other regions of the world such as Africa and Latin America. In 2002/03, half of Asia's agricultural researchers in the higher education sector were trained to the PhD level.

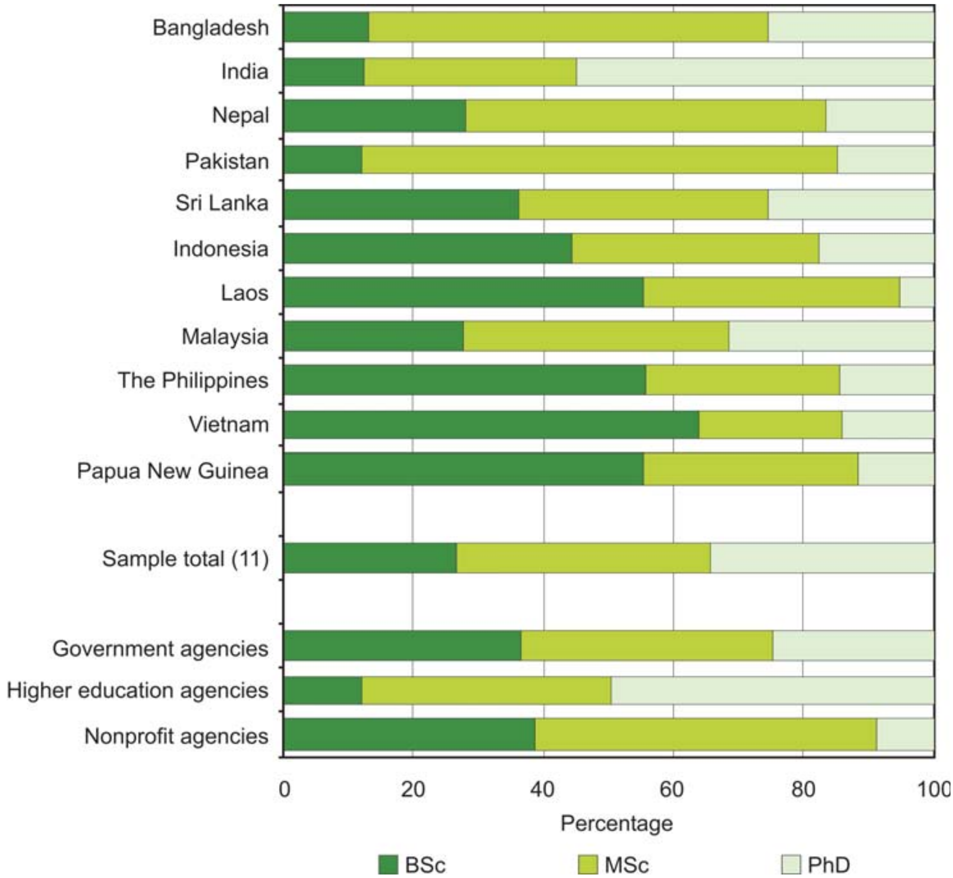

Figure 2. Degree status of public agricultural researchers, 2002/03.

Sources: Compiled by authors from datasets underlying the ASTI country briefs and reports (ASTI 2005-08).

Notes: fte researcher numbers for India include technicians holding university degrees.

While there were large variations across countries, generally speaking the shares of researchers with postgraduate (that is, MSc and PhD) degrees was higher in the five South Asian countries than in the six Southeast Asian countries. Levels of staff with postgraduate degrees were particularly low in Laos and Vietnam, countries with a history of political and economic isolation, but the Philippines and Papua New Guinea also had relatively few researchers trained to the MSc or PhD level. Although Pakistan had one of the highest shares of agricultural staff holding postgraduate degrees, the country's share of PhD-trained agricultural researchers, at just 15 percent, was among the lowest of the 11-country sample. Research staff at the provincial agricultural research agencies had particularly low levels of training: on an average, only 8 percent held PhD degrees in 2003 (up from 3 percent in 1991). India, on the other hand, probably has the most highly qualified pool of agricultural research staff in the developing world as a result of continued investments in researcher training by the Indian government. In 2003, 55 percent of all agricultural research staff in India (including technical staff with university degrees) was trained to the PhD level.

Although time-series data on degree levels were available for most sample countries, the benchmark years varied, making it difficult to compare developments in researcher qualifications over time. All 11 countries, however, reported improvements in the qualifications of their research staff over the past decade. In Bangladesh, for example, the share of PhD-qualified researchers doubled between 1981 and 2002, while in India the corresponding share increased by 12 percentage points from 1991 to 2003.

Different countries have different strategies for building the capacity of their research staff, but donor-financed projects have played, and continue to play, an important role in facilitating postgraduate training in many countries of the Asia-Pacific region. Several countries received considerable financial support for higher education, often as part of large World Bank loans or through contributions from donor countries and agencies, such as the Australian government and the United States Agency for International Development (USAID). The World Bank financed training projects in Bangladesh, Indonesia, Nepal, and Pakistan, and USAID was involved in projects in Bangladesh, Nepal, Pakistan, and the Philippines. Australia was the dominant donor for training of agricultural R&D staff in Vietnam and Cambodia, although it also funded smaller scale training in other countries.

Many national governments also actively support training of research staff, either abroad or at home. The Malaysian Agricultural Research and Development Institute (MARDI), for example, allocated significant funding to in-service training in new areas where the institute's capacity is lacking, in addition to financing long- and short-term postgraduate training for research staff. This strategy was intended to redress the institute's recent trend of declining shares of PhD-qualified research staff, which fell from 22 percent in 2002 to 16 percent in 2004. In South Asia, Sri Lanka's Council for Agricultural Research Policy (CARP), India's ICAR, the Nepal Agricultural Research Council (NARC), and the Pakistan Agricultural Research Council (PARC) have entered into agreements to run long- and short-term training programs at the regional level. Training within the region is considered advantageous given the focus on local conditions; it is also more cost-effective than training in developed countries. Furthermore, regional training increases the likelihood that trainees will return home after they attain their qualifications.

The Challenge of Retaining Capacity

Most of the 11 sample countries (excluding China) have difficulties attracting and retaining qualified research staff, especially in the government sector. In Bangladesh, Laos, Nepal, Pakistan, and Sri Lanka remuneration at the government agencies is low, opportunities for advancement are limited, and other incentives are also lacking. As a result, many (often senior and well-qualified) researchers have left the government sector in search of opportunities at universities, private sector, in non-research agencies, or abroad. In Pakistan and Sri Lanka, for example, promotions are based on seniority rather than performance. It is common in Pakistan for researchers to retire without moving beyond their original salary scale and for senior staff to be promoted to management positions outside their area of expertise[10].

An alarming trend in Malaysia, Pakistan, Vietnam, and more recently India is that many of the most experienced and highly qualified researchers are approaching retirement age. In Malaysia, for example, a large staffing gap exists between senior researchers who are approaching retirement and their younger colleagues in their late 20s and early 30s. MARDI's total fte researcher numbers, for example, dropped from 463 in 1996 to 410 in 2002. Attempts to redress this problem have led to accelerated recruitment in recent years, particularly in areas such as biotechnology and strategic research. Similar recruitment efforts are taking place in India and other countries both to build agricultural research staff numbers and to reduce the disparity in staff qualifications. In Vietnam, for example, the government's training efforts have had a noticeable effect in recent years. From 1996 to 2003, the number of fte researchers with PhD degrees in the 26 government agencies rose from 145 to 228, and the number of MSc-qualified researcher grew from 66 to 350.

But the aforementioned history of political isolation of Cambodia, Laos and Vietnam has imposed an additional barrier to capacity development in these countries. A lack of knowledge of English has seriously hindered postgraduate training opportunities abroad, but it has also limited access to international publications. Until recently, the libraries of Vietnam's Ministry of Agriculture and Development (MARD) were well equipped with publications from the former Soviet Union (in Russian), but more up-to-date publications were lacking, for example, from Western countries, international conferences, or countries with agroclimatic characteristics similar to Vietnam.

[10] In some provinces in Pakistan, key positions such as breeders for the country's four principal crops (wheat, cotton, rice, and sugarcane), were in September 2005 vacant due to staff retirement, long periods of recruitment freezes, and a lack of suitable candidates.

Research Focus

The allocation of resources among various lines of research is a significant policy decision, so the ASTI surveys collected detailed information on the allocation of fte researchers across specific commodity areas. In 2002, more than half of the nearly 36,000 fte researchers in the 11-country sample conducted crop research, while 13 percent undertook livestock research (Table 5). Forestry and natural resources research accounted for 8 and 7 percent of total fte's, respectively, while the remaining 18 percent of the researchers focused on fisheries, postharvest or other research areas. Large differences were observed in focus of agricultural research across countries. In Nepal, Pakistan, Papua New Guinea and Sri Lanka, for example, crop research constituted almost two-thirds of all agricultural research conducted, whereas in Laos this share was just 28 percent. Forestry research accounted for a quarter of all agricultural research carried out in Papua New Guinea, compared with only 1 to 3 percent in Bangladesh, Pakistan and Sri Lanka.

Table 5. Researcher focus by major commodity area, 2002/03

Subregion/ country	Crops	Livestock	Forestry	Fisheries	Post-harvest	Natural resources	Other
South Asia				(percentage)			
Bangladesh	49.3	4.9	2.6	6.1	10.9	16.5	9.7
India	58.4	14.8	6.7	5.3	3.9	6.1	5.0
Nepal	63.0	16.1	6.9	5.0	1.1	2.8	5.2
Pakistan	60.9	15.7	1.1	3.4	0.6	10.0	8.4
Sri Lanka	63.9	8.3	2.4	6.2	3.5	3.3	12.3
Southeast Asia							
Indonesia	39.0	8.8	12.5	3.7	3.9	9.6	22.5
Laos	28.3	12.6	17.3	11.4	2.4	19.7	8.4
Malaysia	55.3	11.0	14.6	6.9	6.0	3.1	3.1
The Philippines	54.6	10.7	10.5	6.9	1.8	3.5	12.0
Vietnam	41.0	13.5	13.1	8.2	2.4	9.0	12.8
The Pacific							
Papua New Guinea	63.2	7.2	25.0	0.0	0.0	2.2	2.4
Sample total (11)	53.5	12.8	8.0	5.4	3.6	7.3	9.4

Sources: Compiled by authors from datasets underlying the ASTI country briefs and reports (ASTI 2005-08).

The major crops being researched in a 10-country sample (excluding China and Sri Lanka) were rice, fruit, and vegetables, which in 2002 accounted for 17, 15, and 9 percent of all fte crop researchers, respectively (Table 6). Other important crops include maize and wheat. Close to half the crop researchers, however, focused on a wide variety of other crops, each representing less than 5 percent of the total number of fte researchers working on crops (which is not surprising given the wide variety of agroclimatic conditions in the region). Rice is an important crop under research in all 10 countries, although at different levels of intensity. Wheat research is important in all four South Asian countries, ranging from 7 percent of all crop researchers in Bangladesh and India to 19-20 percent in Nepal and Pakistan. Only limited research on wheat was conducted in Indonesia and Vietnam (less than 1 percent). Maize and sugarcane are important crops in half of the sample countries. In Malaysia, Papua New Guinea, and Indonesia, 39, 18 and 6 percent of the crop research staff, respectively, concentrated on oil palm research, reflecting the importance of this crop for the agricultural sector and the economy as a whole in these countries. Coconut palm is also an important crop under research in Papua New Guinea and Indonesia (10 and 7 percent, respectively).

Table 6. Crop researcher focus by major crop item, 2002/03

Country	Major crop items
Bangladesh[a]	Rice (23%), fruit (15%), vegetables (10%), wheat (7%), maize (7%), sugarcane (6%)
India	Rice (16%), vegetables (10%), fruit (8%), wheat (7%), sugarcane (5%), cotton (5%)
Nepal	Rice (26%), maize (26%), wheat (20%), vegetables (8%), fruit (5%)
Pakistan[a]	Wheat (19%), fruit (15%), sugarcane (10%), vegetables (8%), rice (8%), cotton (8%)
Indonesia[a]	Rice (14%), fruit (10%), vegetables (8%), soybeans (7%), maize (7%), coconut palm (7%), oil palm (6%)
Laos	Rice (44%), fruit (14%), vegetables (13%), maize (12%)
Malaysia[a]	Oil palm (39%), fruit (18%), rice (10%), rubber (9%), vegetables (8%), ornamentals (6%)
Philippines[a]	Fruit (45%), rice (23%), maize (8%), vegetables (7%)
Vietnam	Rice (27%), fruit (13%), maize (10%), vegetables (9%)
Papua New Guinea[a]	Oil palm (18%), cocoa (15%), coconut palm (10%), coffee (10%), rice (9%), fruit (8%), sugarcane (7%)
Sample total (10)[a]	Rice (17%), fruit (15%), vegetables (9%), wheat (6%), maize (5%), sugarcane (5%)

Sources: Compiled by authors from datasets underlying the ASTI country briefs and reports (ASTI 2005-08).

Notes: Major crop items are defined as those that form the focus of at least 5 percent of the total crop research staff in a particular country. Percentages indicate the share of full-time equivalent crop researchers allocated to the specific crop item. Data for Sri Lanka were unavailable.

[a] Includes data from the private sector.

Support Staff

The average number of support staff per scientist was 3.2 in 2002, comprising 0.9 fte technicians, 0.8 fte administrative personnel, and 1.6 other support staff such as laborers, guards, and drivers (Figure 3). Higher education agencies employed only 1.1 fte support staff per researcher, but this relatively lower ratio compared with other institutional categories is consistent with findings in other parts of the world. Also consistent is the high support-staff-to-researcher ratio found in the nonprofit sector (7.2), explained in part by the high number of other support staff employed in the production of coffee, coconut, and oil palm at nonprofit agencies in Papua New Guinea.

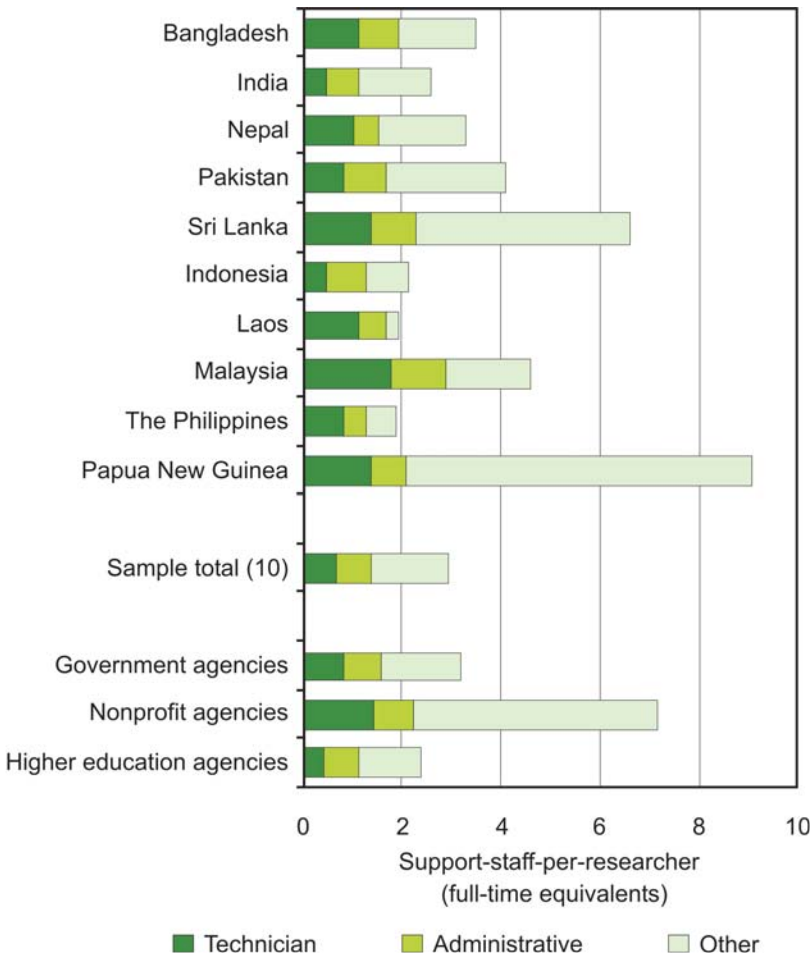

Figure 3. Support-staff-to-researcher ratios by support staff category, 2002/03.

Sources: Compiled by authors from datasets underlying the ASTI country briefs and reports (ASTI 2005-08).

Note: Data for Vietnam were unavailable.

Large differences were identified at the country level, ranging from a support-staff-to-researcher ratio of more than 9.0 in Papua New Guinea to ratios below the 2.0 mark in the Philippines and Laos. All the sample countries, with the exception of Papua New Guinea, showed a considerable drop in the number of support staff per researcher during the late 1990s and early 2000s. Reasons for these declines in the Philippines and Laos, for example, were recruitment freezes and an upgrade of technicians to the BSc level, respectively.

Agricultural R&D Spending

In 2002, spending on public agricultural R&D totaled close to $5.1 billion (in 2005 international dollars) for the 12 countries included in the sample (Table 7). Of this amount, half was spent in China and more than a quarter in India. Malaysia reported the third largest expenditure, followed by Indonesia, Pakistan, the Philippines and Bangladesh. The remaining five countries spent less than $100 million on public agricultural research in 2002. Financial data in the remainder of this report are provided in real values using GDP deflators and purchasing power parity (PPP) indexes taken from the World Bank (2007, 2008)[11]. The financial data in this report differ from those published in the underlying country briefs and reports as well as other previous ASTI reports that presented global agricultural R&D investment trends (Pardey and Beintema 2001; Pardey et al. 2006). This was due to a major revision in the PPP indexes for China, India, and many other developing countries, which were released by the World Bank in early 2008 (Beintema and Stads 2008).

Total public agricultural research spending for the 12-country sample increased from $2.9 billion in 1991 to $5.1 billion in 2002 (in 2005 international prices), representing an average growth rate of 4.6 percent per year. China was responsible for most of this growth, given that agricultural research expenditures more than doubled from $1.2 billion in 1991 to $2.6 billion in 2002 as a result of increased government support (Table 7 and Figure 4). Although steady growth in agricultural R&D spending was observed for the sample countries combined, more detailed data reveal a substantial degree of cross-country variation around the regional averages described above. Total public agricultural research spending in Pakistan, for example, fell by about one-third between 1991 and 1999, partly because of the completion of

[11] PPPs are synthetic exchange rates used to reflect the purchasing power of currencies, typically comparing prices among a broader range of goods and services than conventional exchange rates. Using PPPs as conversion factors to denominate value aggregates in international dollars results in more realistic and directly comparable estimates of agricultural research spending across countries than would result from the use of market exchange (see the appendix for further explanation).

various projects funded by USAID and other donors at PARC, and partly due to declining public funding overall. The Asian financial crisis of the late-1990s also had a severe impact on agricultural R&D spending in countries like Indonesia and the Philippines. In Indonesia, for example, real agricultural R&D spending fell by one-third during 1997/98 alone, and spending levels remained below pre-crisis levels in 2003. Laos has suffered mass inflation in recent years. The country's agricultural R&D expenditures more than halved in real terms during 1999-2003 as a result.

Table 7. Public agricultural research spending, 1991-2002

Region/ country	Total spending			Growth rates[a]		
	1991	1996	2002	1991-1996	1996-2002	1991-2002
	(*million 2005 international dollars*)			*percentage*)		
China	1,174	1,531	2,574	4.7	9.0	5.4
South Asia						
Bangladesh	81	82	109	1.2	5.7	3.4
India	746	861	1,355	2.8	8.4	6.5
Nepal[b]	na	15	26	na	12.1	7.0[b]
Pakistan	223	188	171	-2.6	-1.1	-2.6
Sri Lanka	39	42	51	1.1	5.0	3.5
Southeast Asia						
Indonesia	220	255	177	3.6	-7.9	-4.4
Laos[b]	na	na	13	na	-5.1	0.4[b]
Malaysia	227	267	424	2.6	6.9	4.4
The Philippines	80	121	141	9.2	0.7	4.4
Vietnam	8	22	56	18.8	19.6	19.1
The Pacific						
Papua New Guinea	28	35	28	4.6	-4.8	0.1
Sample total (11)	1,680	1,907	2,551	2.6	5.0	3.9
Sample total plus China (12)	2,854	3,438	5,125	3.5	6.8	4.6

Sources: Compiled by authors from datasets underlying the ASTI country briefs and reports (ASTI 2005-08); revised PPP indexes and GDP deflators from World Bank (2007, 2008); data for China are from MOST (various years); 1991 research staff for India and Indonesia were estimated using ASTI data and information from Pal and Byerlee (2006) and Fuglie and Piggott (2006), respectively.

Notes: The number of countries in each category is shown in parentheses; na indicates not available.

[a] Annual growth rates are calculated using the least-squares regression method, which takes into account all observations in a period; the resulting growth rates therefore reflect general trends that are not disproportionately influenced by exceptional values, especially at the end point of a period.

[b] 1991-2002 growth rates for Nepal and Laos are based on estimated time-series data for 1991-95 and 1991-97, respectively.

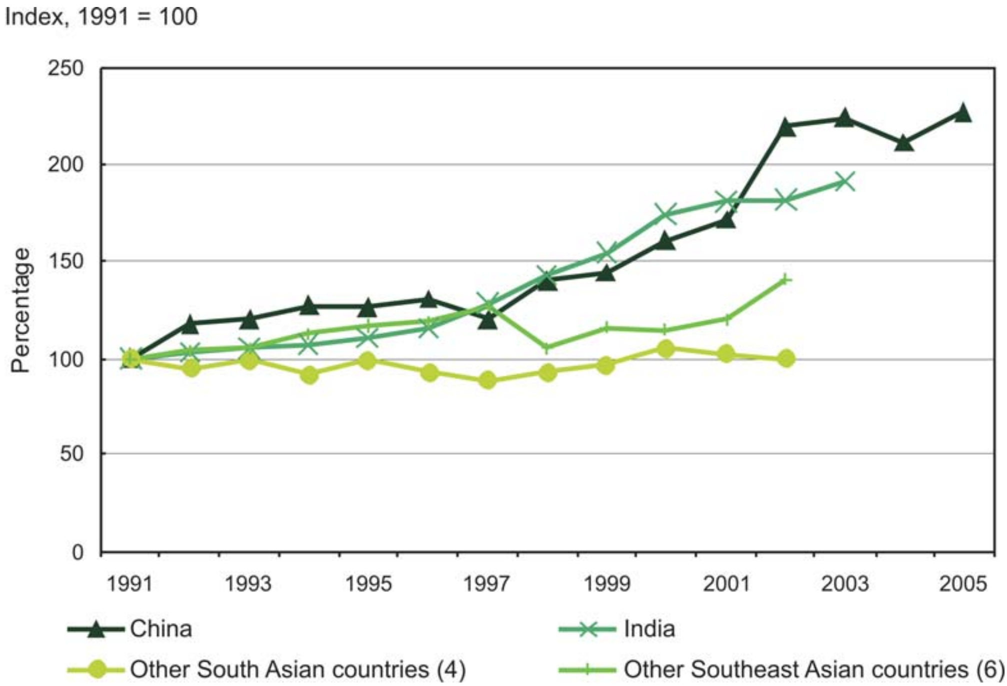

Figure 4. Trends in public agricultural R&D spending, 1991-2005.

Sources: See Table 6. Data for 2003-05 for China are from MOST (various years).

Notes: See Table 6. “Other Southeast countries” include Papua New Guinea.

High annual growth rates over the period 1996 to 2002 are notable for Vietnam (20 percent) and Nepal (12 percent). In Vietnam, this strong increase resulted from the prioritization of agricultural and rural development by the national government, while in Nepal it was the result of a large World Bank loan that ran from 1998 to 2002. India’s agricultural R&D expenditures grew at 8.4 percent per year during 1996-2002, which represents a considerable increase over the rate of 2.8 percent per year during the early 1990s. This reflects the Indian government’s commitment to all fields of research, including the agricultural sector (Pal and Byerlee 2006).

Intensity Ratios

Another way to evaluate a country’s agricultural R&D commitment, and to place it within an international context, is through a comparison with the size of the country’s agricultural sector. The most common indicator of this research intensity is total public agricultural R&D spending as a percentage of agricultural GDP (AgGDP). In 2002, the 12 sample countries invested a combined total of $0.43 for every $100 of agricultural output, which is considerably higher than the comparable 1991 share of 0.34 percent (Figure 5). In other words, on an average, growth in agricultural research spending in these countries outpaced growth in agricultural production. It should be noted, however, that the region's investment intensity level is still low compared with other world regions; the 2000 average for Sub-Saharan Africa, for example, was 0.65 (Beintema and Stads 2008).

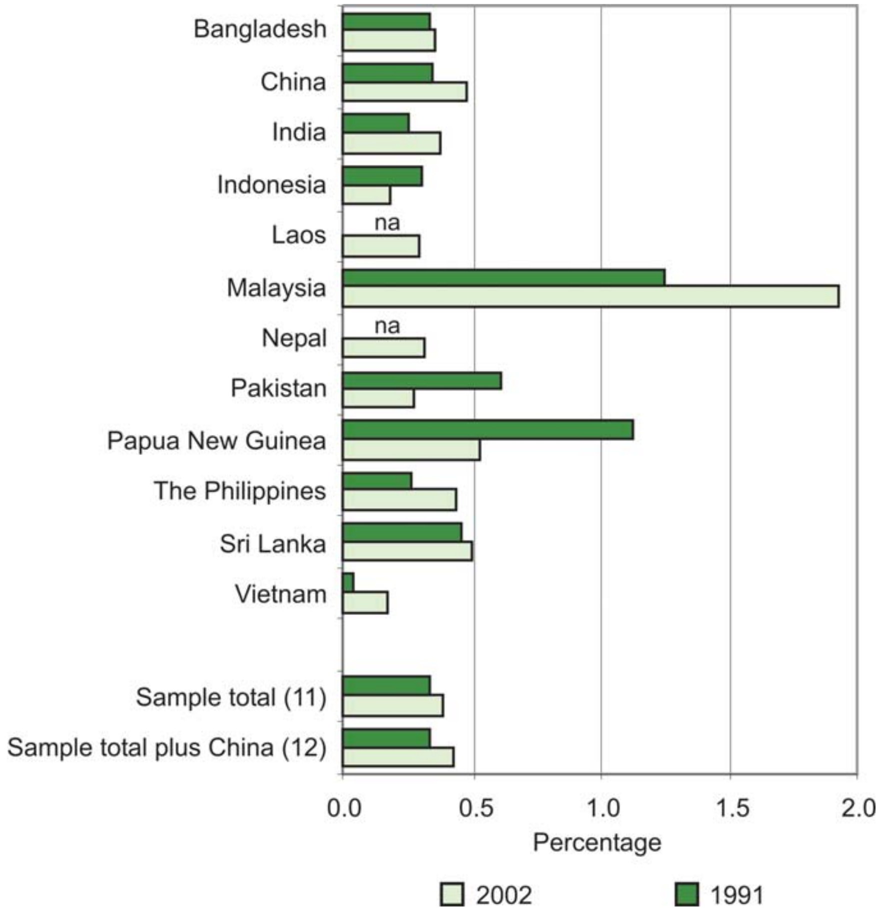

Figure 5. Intensity ratios, 1991 and 2002.

Sources: **See Table 6. Agricultural GDP data, revised PPP indexes and GDP deflators from World Bank (2007, 2008).**

Notes: **The number of countries in each category is shown in parentheses. Intensity ratios are the ratio of total pubic agricultural R&D spending to total Agricultural GDP.**

These averages mask significant differences among countries. In 2002/03, agricultural research intensity ratios for almost all the sample countries were below 0.50 percent. Malaysia, an upper middle-income country, is the exception; in 2002 Malaysia invested $1.92 in agricultural research for every $100 of agricultural output, representing an increase of roughly 50 percent over the country's corresponding 1991 ratio. This substantial increase was the result of very high growth in public agricultural research expenditures mostly by the country's three government-owned commodity boards, combined with a small decline in Malaysia's AgGDP over this period. In contrast, other countries, such as Pakistan and Laos, experienced severe drops in their research intensity ratios, mostly because of the abovementioned strong declines in agricultural R&D spending.

There is no official recommendation as to the preferred level of agricultural research intensity. During the early 1980s, the World Bank recommended a target of 2 percent, which was based on developed-country spending levels. This target did not account for the more limited opportunities for innovation in developing countries (Roseboom 2004). In addition, the expectation that agricultural R&D investments would continue to grow at the high rates of the 1980s was not met. A more realistic research intensity target of 1 percent has been recommended in more recent literature (for example, Pardey and Alston 1995; Roseboom 2004; and Casas, Solh, and Hafez 1999). Nevertheless, using intensity ratios as a rule of thumb is not always appropriate because they do not take into account the policy and institutional environment within which agricultural research takes place or the broader size and structure of a country's agricultural sector and economy (see Box 2). For example, small countries need more investments in research because they cannot benefit from economies of scale in the same way that larger countries can. Countries with greater agricultural diversity or more complex agroecological conditions also have more complex research needs and hence require higher funding levels (Pardey and Alston 1995; Casas, Solh, and Hafez 1999). In addition, technological breakthroughs spill across countries with similar agroclimatic conditions. A low intensity ratio in a country that imports many of its agricultural technologies is therefore not necessarily a cause for concern.

With the exception of Malaysia (1.92 percent) and Papua New Guinea (0.89 percent), agricultural research intensity ratios for a 12-country sample were below 0.50 percent. A serious boost in investments with a view to meeting the recommended 1 percent target would certainly have a positive impact on the overall efficiency and effectiveness of agricultural research in these countries, but the need is less acute is some than in others. Pakistan and Laos, for example, are indeed grossly underinvesting in agricultural R&D. Despite having a 2002 intensity ratio of just 0.37 percent, however, India has significantly increased its agricultural R&D investments such that the overall agricultural research system is well equipped in terms of infrastructure and human resources; there are certain areas, however, like biotechnology that require further investment.

Box 2: Decomposing agricultural intensity ratios

Comparing agricultural intensity ratios across countries does not have much meaning without assessing the underlying conditions in each country. One way of doing this is to decompose the intensity ratio by looking at the following components (Elliott 1995):

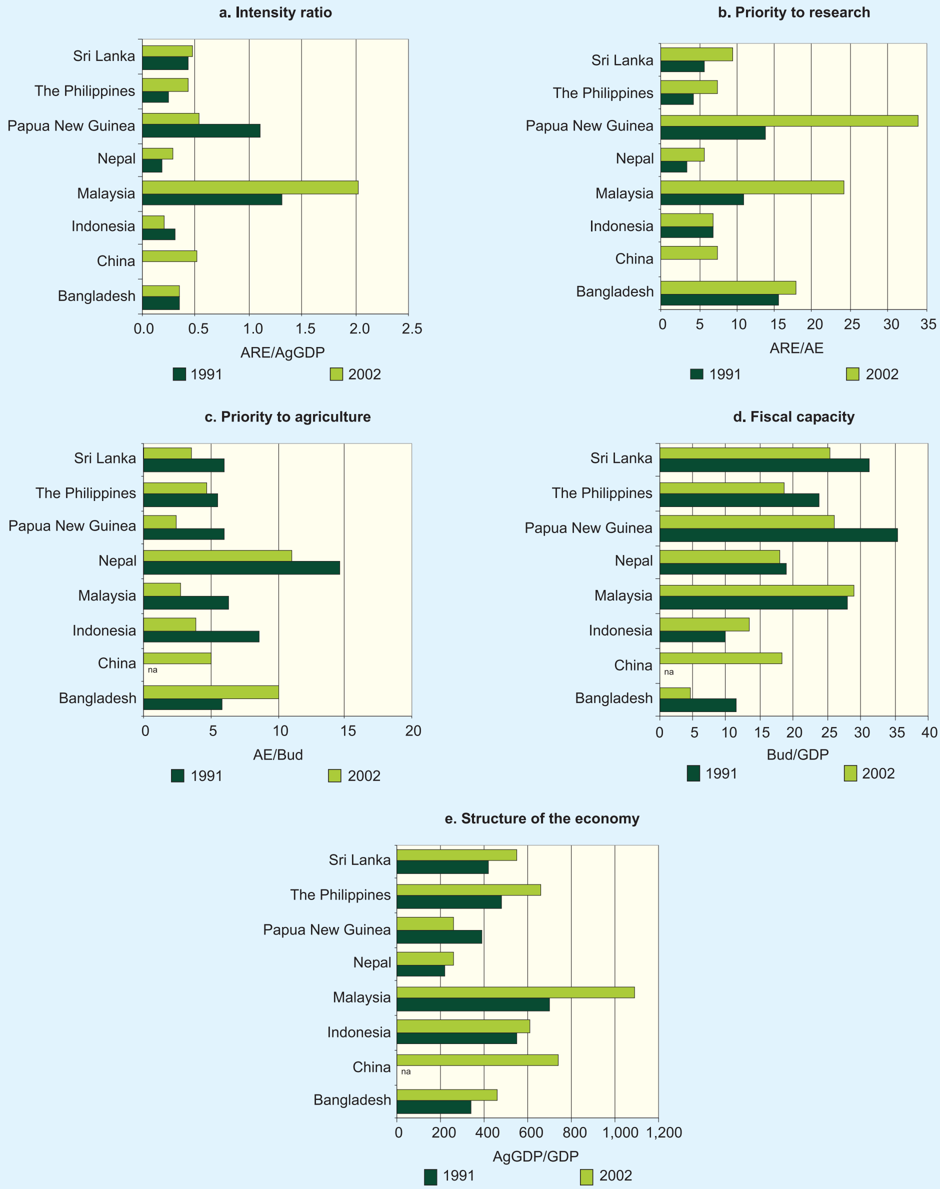

Figure A. Decomposing agricultural intensity ratios for eight countries, 1991 and 2002.

Sources: For agricultural R&D spending, see Table 2; government budget data are from IMF (2000, 2004); GDP and AgGDP data are from World Bank (2007); revised PPP indexes from World Bank (2008).

Note: na indicates not available

Box 2: (*Contd...*)

- The priority to agricultural research within a country's agricultural strategy, which can be measured as the share of the government's agricultural expenditures (AE) allocated to agricultural research (ARE).
- The priority of agriculture within the government's overall strategy, which can be measured as the share of the government budget (Bud) allocated to agriculture (AE).
- The will or weight of the government to control the economy (that is, the fiscal effort or burden), which can be measured as the share of government budget (Bud) in the total Gross Domestic Product (GDP).
- The percentage contribution of agriculture to GDP (AgGDP).

These components lead to the following formula:

$$ARE/AgGDP = ARE/AE * AE/Bud * Bud/GDP * GDP/AgGDP.$$

Information on total government budget allocations was obtainable for 8 of the 11 sample countries (Figure B.1). The intensity ratios for these countries ranged from 0.22 percent for Indonesia to 2.04 for Malaysia (panel a). Decomposing these intensity ratios provided some interesting insights:

- The priority to agricultural research was highest in Papua New Guinea, Malaysia, and Bangladesh (panel b). It should be noted, however, that large shares of agricultural R&D are often contributed by nongovernment sources. In Nepal and Indonesia, for example, only 23 and 43 percent of total agricultural funding was derived from government sources, respectively. For the other countries, the share of government sources ranged from two-thirds to over 90 percent.
- Most countries raised the priority of agricultural research (panel b), but at the same time most lowered the priority of agriculture (panel c) during 1991-2002.
- Papua New Guinea and Malaysia - a low and an upper middle-income country - were among the countries with a fiscal effort of 25 percent or higher (Panel d).
- The contribution of agriculture to GDP declined in all countries (panel e), with the exception of Papua New Guinea, where it increased from 26 to 38 percent during 1991-2002.

Agricultural R&D Spending within a Broader Regional and Global Context

Agricultural R&D investment trends were calculated for the Asia-Pacific region as a whole for the period 1981-2002 based on the information collected through the ASTI survey rounds and additional secondary sources (Table 8)[12]. In 2002, the region spent a total of $9.6 billion on public agricultural R&D (in 2005 international prices). Not surprisingly, the size of agricultural R&D investments differs considerably across countries. China and Japan each spent more than one-quarter of the region's public agricultural R&D expenditures; 14 percent were spent in India. The 11 low-income countries (excluding India) accounted for only 5 percent of the region's public agricultural R&D expenditures. Other countries with significant spending on agricultural research were Malaysia, South Korea, Thailand, and Australia, with total expenditures ranging from $400 to $640 million each.

[12] The data in this section exclude city states, such as Singapore, and a few small Pacific islands for which data were unavailable.

Table 8. Regional and global trends in public agricultural R&D spending, 1981-2002

Region/ country	Total spending				Regional shares			
	1981	1991	1996	2002	1981	1991	1996	2002
	(million 2005 international dollars)				*(percentage)*			
Asia-Pacific region by income class								
India	396	746	861	1,355	8.0	11.1	11.0	14.1
Other low-income countries (11)	244	390	394	440	4.9	5.8	5.0	4.6
China	711	1,174	1,531	2,574	14.4	17.5	19.5	26.8
Other middle-income countries (13)	610	966	1,199	1,308	12.4	14.4	15.3	13.6
Japan	2,128	2,534	2,480	2,683	43.2	37.7	31.6	27.9
Other high-income countries (4)	841	909	1,391	1,264	17.1	13.5	17.7	13.1
Asia-Pacific by subregion								
China	711	1,174	1,531	2,574	14.4	17.5	19.5	26.8
India	396	746	861	1,355	8.0	11.1	11.0	14.1
South Asia excluding India (5)	234	357	329	359	4.8	5.3	4.2	3.7
Southeast Asia (9)	598	967	1,225	1,355	12.1	14.4	15.6	14.1
The Pacific (11)	22	32	39	34	0.4	0.5	0.5	0.4
OECD countries (4)	2,969	3,443	3,870	3,945	60.2	51.2	49.3	41.0
Asia-Pacific total(31)	4,930	6,719	7,856	9,623	100	100	100	100
Global total (141)	15,513	20,266	21,395	22,924 (2000)	—	—	—	—

Sources: Compiled by authors from datasets underlying the ASTI country briefs and reports (ASTI 2005-08); revised PPP indexes and GDP deflators from World Bank (2007, 2008) ; data for Australia, Japan, and New Zealand are from OECD (various years), Mullen (2007), and ABS (various years); data for China are from MOST (various years) and Fan, Qian, and Zhang (2006); data for South Korea are from Choi, Sumner, and Lee (2006); global data are from Beintema and Stads (2008); 1991 spending data for India were estimated using data from the ASTI database, and Pal and Byerlee (2006).

Notes: The number of countries in each category is shown in parentheses. “Other low-income countries” include Bangladesh, Bhutan, Cambodia, Laos, Myanmar, Mongolia, Nepal, Pakistan, Papua New Guinea, the Solomon Islands, and Vietnam; “other middle-income countries” include Fiji, Indonesia, Kiribati, Malaysia, the Marshall Islands, Micronesia, Palau, the Philippines, Sri Lanka, Samoa, Thailand, Tonga, and Vanuatu; “other high-income countries” include Australia, French Polynesia, New Zealand, and South Korea. The income-class totals were scaled up from national spending estimates for 17 countries that represented 95 percent of the reported regional total (89 percent if China and India were excluded). OECD indicates Organisation for Economic Co-operation and Development. The data in this section exclude city states such as Singapore and a few small Pacific islands for which data were unavailable.

In 2000, the $8.7 billion of total agricultural R&D spending in the Asia-Pacific region (including five high-income countries) accounted for 38 percent of the global total of $22.9 billion (Beintema and Stads 2008). This is a considerable increase from the corresponding ratio of 32 percent in 1981. The regional share of the global total in 2000 excluding the high-income countries was 21 percent[13].

[13] These totals differ from the regional totals presented in Pardey et al. (2006) because they include Australia, Japan, and New Zealand, which Pardey et al. treat as a separate developed-country category. Furthermore, the overall global totals from Beintema and Stads (2008) are lower due to the aforementioned PPP index revisions by the World Bank (2008).

During the 1981-2002 period, public agricultural R&D spending in Asia-Pacific region as a whole grew, in inflation-adjusted terms, by an average of 3.0 percent per year. Most of this growth took place in China and India, where total public spending more than tripled over this period. Growth in agricultural R&D spending in Japan and the remaining 28 countries combined was much lower than in China and India.

In 2002, the 31 Asia-Pacific countries invested a combined $0.70 for every $100 of agricultural output, which was slightly higher than the 1981 share of 0.68 percent (Figure 6). Globally, it has been observed that developed countries have much higher intensity ratios than developing countries, with a few higher middle-income

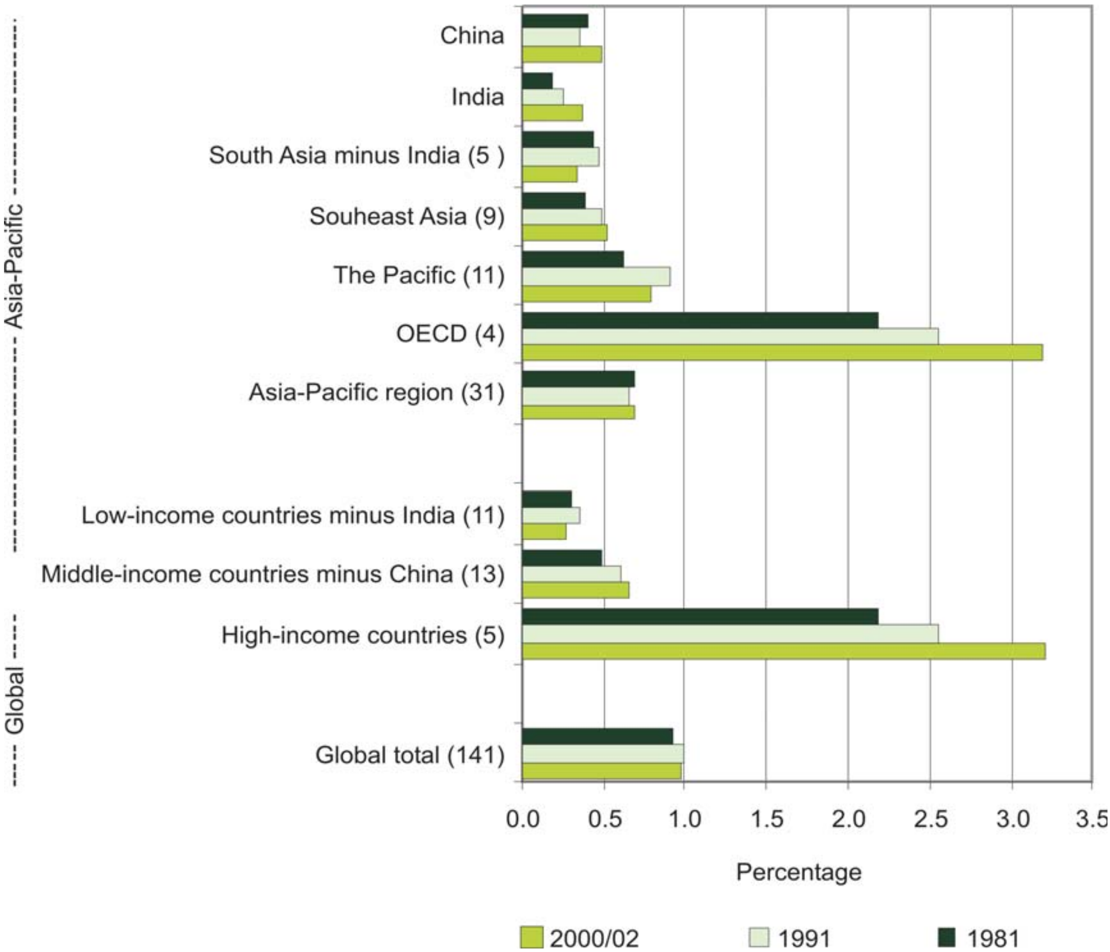

Figure 6. Regional and global intensity ratios, 1981-2002.

Sources: See Table 8. Agricultural GDP data are from World Bank (2007, 2008).

Notes: The number of countries in each category is shown in parentheses. Global, low- and middle-income country, and high-income country intensity ratios are for 2000; other ratios are for 2002.

country exceptions. High intensity ratios were recorded in all higher income countries in the Asia-Pacific region in 2002, ranging from 1.70 percent in New Zealand to 4.16 percent in Japan. Since 1981, Japan's agricultural output growth has been much slower than the country's agricultural research spending, and after the mid-1990s, agricultural output actually declined. As a result, Japan's intensity ratio increased with more than 60 percent over the past two decades. In 2002, agricultural research intensity ratios for nearly all low- and middle-income countries in the Asia-Pacific region were under 0.50 percent, except for Malaysia and Papua New Guinea, as described above.

Diversity of Financing

Although government allocations represent the principal source of funding for public agricultural research in most countries of the Asia-Pacific region, funding sources differ tremendously across countries. In 6 of the 10 sample countries for which detailed funding data were available, government contributions accounted between two-thirds (Malaysia and Sri Lanka) and over 90 percent (India) of total agricultural research funding in 2002/03 (Figure 7).

Public agricultural research in Laos and Nepal has traditionally been very donor-dependent. The principal agricultural research agencies in these two countries received more than three-quarters of their funding from donor contributions in 2002/03. Since its establishment in 1999, Laos' National Agriculture and Forestry Research Institute (NAFRI) has relied almost exclusively on donor support, notably from Sweden, the International Rice Research Institute (IRRI), and Denmark. Nepal's NARC, on the other hand, received sizeable sums as part of the World Bank-financed Agricultural Research and Extension Project, which ran from 1998 to 2002. In contrast, donor funding was insignificant (less than 3 percent) in financing public agricultural research in Malaysia and Sri Lanka.

The World Bank was an important contributor to agricultural research activities in certain Asian countries through loan-supported projects in the 1990s and early 2000s. Projects variously focused on agricultural research and on agriculture more generally, with an agricultural R&D component. Some projects aimed to reshape a country's entire national agricultural research system, whereas others focused on specific crops, agencies, or general research management and coordination. Bangladesh, India, Indonesia, Nepal, and Pakistan, in particular, received sizeable World Bank loans during the 1990s and early 2000s. Other important donors and multilateral development banks investing in the region's agricultural R&D include the Asian Development Bank (ADB), USAID, and the Australian government.

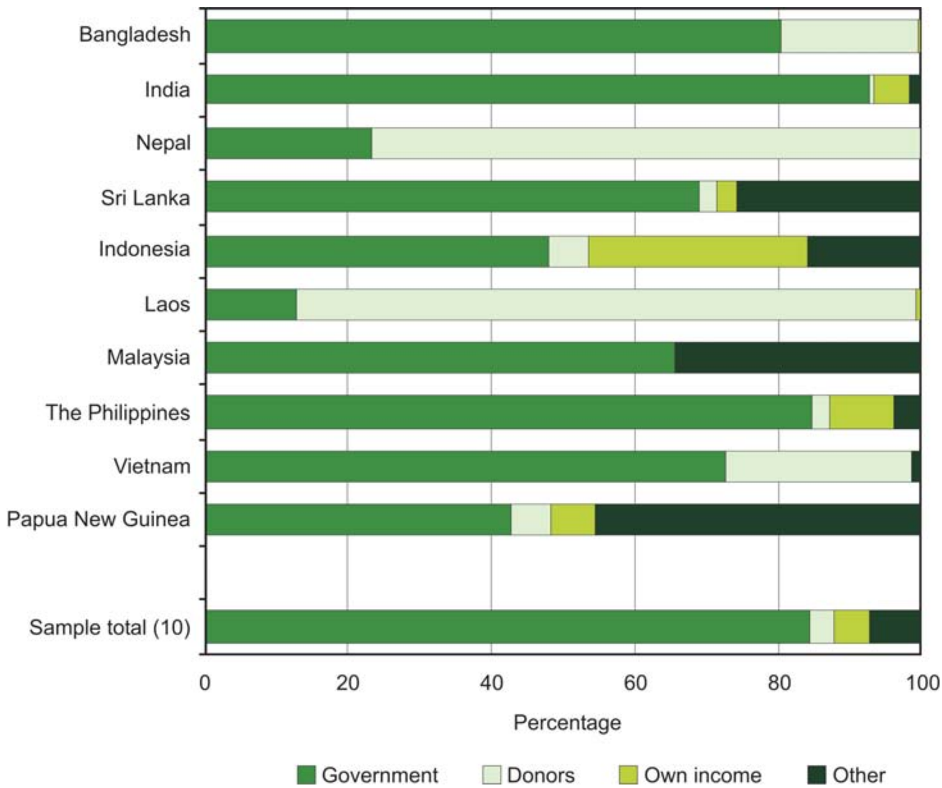

Figure 7. Funding sources, 2002/03.

Sources: Compiled by authors from datasets underlying the ASTI country briefs and reports (ASTI 2005-08).

Notes: The number of countries in each category is shown in parentheses. Data for Bangladesh, Nepal, Laos, and Vietnam are for the main agricultural research agency only; data for Sri Lanka, Indonesia, Malaysia, and the Philippines include a broader coverage of government agencies; data for Papua New Guinea include the main agricultural research agency and two of the three nonprofit organizations; data for India include all the institutes of the Indian Council for Agricultural Research (ICAR) and the State Agricultural Universities (SAUs).

In recent years, funding sources and mechanisms have become more diversified in a number of Asian countries (Table 9). New mechanisms of financing public agricultural R&D are gradually gaining ground. Internally generated resources, for example, have become an increasingly important component of funding agricultural R&D in China and Indonesia. Since the mid-1980s the Chinese government has encouraged research institutes to generate income through the provision of research services and commercial activities, a proportion of which can be retained by the generating agencies (Fan, Qian, and Zhang 2006)[14]. Conducting contract research for public/private enterprises and the sale of plantation crops and technology inputs (such as seed stock) constituted the most important income sources during 1994-

[14] In recent years, financial support from Chinese government sources has increased sharply due to the improvement of the government's financial revenues.

Table 9. Diversity in funding sources and mechanisms for public agricultural R&D

Country	Funding trends
Bangladesh	The affiliated institutes under the Bangladesh Agricultural Research Council (BARC) are mainly funded through direct government appropriations. Additional funding sources include other government sources, World Bank loans, and donor contributions. A very small share is derived from public enterprises and other sources.
India	Funding for public agricultural research and education is provided by the government in the form of block grants with allocations determined through five-year plans. The Indian Council for Agricultural Research (ICAR) receives most of its funding from the central government, although in the 1990s and the early 2000s some additional funding was derived from a World Bank project and other donor sources. Internally generated income and other sources of funding are negligible. The State Agricultural Universities (SAUs) receive about two-thirds of their funding from allocations from the state government and a considerable amount from central government allocations through ICAR. SAUs are relatively more successful in generating internal resources.
Nepal	Agricultural R&D in Nepal is supported by the national government, foreign donors, and loans from the World Bank and the ADB. The Nepal Agricultural Research Council (NARC) has had a long history of donor support from USAID and the World Bank. Other sources of funding are negligible.
Pakistan	Funding for public agricultural research is mainly provided through direct allocations from the national government, along with limited funding from foreign donors and internal sources.
Sri Lanka	Agricultural research is primarily financed by the government through a dual funding system. The majority of funds are directly provided to the agencies, while funds for strategic research are channeled via the Council for Agricultural Research Policy (CARP) through a competitive grant program. A few research agencies under the Ministry of Agriculture, Livestock, Lands, and Irrigation receive sizable shares of their budgets from public or private enterprises. The four research agencies under the Ministry of Plantation Industries focusing on export crops (tea, coconut, rubber, sugarcane) are mainly financed through a sales levy (cess), although coconut research is supplemented by considerable additional government support.
China	Since the mid-1980s the Chinese government has encouraged research institutes to generate income through the provision of research services and commercial activities. Part of these earnings can be retained by the agencies that have generated them, so the share of such income increased considerably in the late 1990s. In recent years, the government has substantially increased its contribution to agricultural research, following a boost in the country's overall budget and greater prioritization of science-based growth strategies. As a result, the share of government funding in total research funding has once again increased.
Indonesia	Most of the funding for the eight agencies under the Indonesian Agency for Agricultural Research and Development (IAARD) is provided by the national government. Only a small share is derived through foreign donors, loans, or other sources. Fisheries and agricultural research at the universities are also largely financed by the national government. Under existing policy there is little incentive for institutes to generate internal income because any such revenues would have to be transferred to the treasury. In contrast, the most important sources of income for the Indonesian Research Institute for Estate Crops (IRIEC) are the sale of plantation crops and technology inputs (e.g. seed stock) followed by contract research for public/private enterprises. Unlike IAARD agencies, IRIEC has semi-autonomous status and can

Contd...

Table 9. (*Contd...*)

Country	Funding trends
	keep any revenues it generates from product sales. The Forestry Research and Development Agency (FORDA) is also less dependent on financial support from the national government; about half of its budget is derived from "the reforestation fund," which levies a per hectare assessment on logging.
Laos	The share of government funding for agricultural research has declined continuously since 2001, mainly due to limited funds in the national budget. The donor community has contributed very generously to agricultural R&D and to the programs and projects of the National Agriculture and Forestry Research Institute (NAFRI). Since its establishment in 1999, NAFRI has depended almost exclusively on donor support (mainly from Sweden, IRRI, and Denmark), with the result that its donor-driven research agenda does not always contribute to Laos' overall agricultural R&D needs.
Malaysia	The Malaysian Agricultural Research and Development Institute (MARDI) is unique in that nearly 100 percent of its funding is provided by the Malaysian government, either through direct allocations or through a competitive grant system. Other government agencies and universities are also eligible for funding through this competitive grant system. Oil palm and rubber research are largely financed through cess revenues of exports. One reason for the success of these commodity taxes is that the private sector is directly involved in the research programs of the commodity boards. A similar mechanism has not been pursued for cocoa because sluggish world market prices have dampened production levels in Malaysia.
The Philippines	Public agricultural R&D agencies in the Philippines are primarily financed by the national government through a dual funding system. The central government provides direct support (that is, core funding) for each public agricultural R&D agency and channels project funding for strategic research via specialized government agencies. Compared with some of the other countries in the region, the Philippines is far less dependent on foreign donors when it comes to agricultural R&D. Increasing numbers of regional agricultural R&D agencies are generating their research funds internally given that most government agencies are mandated to do so. Nevertheless, internally generated income is generally channeled back into the national treasury and can only be approved for use by the agencies through a formal request, with justification for the intended use. This practice discourages many agencies from increasing their share of internally generated revenue.
Vietnam	Core funding for public agricultural research agencies is provided by the national government. Funding from public/private enterprises and internally generated resources, however, plays a small but significant role in financing research activities at specific agencies. Donor funding (mainly bilateral support from Japan, Australia, and Europe) also represents an important share of total funding for the agencies under the Ministry of Agriculture and Development (MARD). In the 1980s, the countries of Central and Eastern Europe (the former Soviet Union and Eastern Bloc) were principal donors to Vietnamese agricultural R&D.
Papua New Guinea	The National Agricultural Research Institute (NARI) receives most of its funding through government allocations while the remainder is contributed by donors. The three commodity-specific research agencies (for cocoa and coconut, coffee, and oil palm) are largely financed through a sales levy (cess) on production or exports.

Sources: Compiled by authors from the ASTI country briefs and reports (ASTI 2005-08); data for China are from Fan, Qian, and Zhang (2006); additional information for India is from Pal and Byerlee (2006).

2003 for the Indonesian Research Institute for Estate Crops (IRIEC)—Indonesia's largest government agency in terms of R&D expenditures. In the Philippines, many of the regional agricultural research agencies are also generating their own resources. Officially, such income must be transferred to the treasury, but Philippine agencies can request a formal exemption to this rule if their allocation is considered justified.

Malaysia, Papua New Guinea, and Sri Lanka have introduced commodity levies for export crops. Producers pay a tax on the production or export value of the commodity, and a share of the resulting revenues is earmarked for research. The mechanisms for collecting revenues and the shares allocated to research vary across commodities and countries. Research in Malaysia (for oil palm and rubber), Papua New Guinea (for cocoa, coffee, and oil palm), and Sri Lanka (for tea, coconut, and rubber) is largely financed through export levies, explaining the high shares of "other funding sources" in these countries. A levy system was in place in Indonesia for export crops until the 1980s, but widespread fraud at the provincial level led to its abolition. Talks began in 2005 regarding reinstating a similar system. The deforestation fund works on the same principal, whereby the Forestry Research and Development Agency (FORDA) receives a share of revenues raised through a per hectare levy on logged forest land.

In order to promote enhanced financial diversity and efficiency, various Asian countries such as India, Indonesia, Malaysia, and Sri Lanka have created competitive funding mechanisms as an alternative means of disbursing government funds to agricultural research. Competitive funds have several advantages and disadvantages compared with the conventional direct government allocations. They are seen as an effective means of redirecting research priorities; increasing the involvement of universities and private companies in research; establishing stronger links among government, academic, and private research agencies; and increasing flexibility. However, competitive mechanisms often involve higher transaction costs; promote short-term and applied research activities over more fundamental, longer term ones; and often fund operational costs only. For these reasons, many argue that competitive grant systems are best used as a complement to conventional block grants (Beintema and Pardey 2001; Echeverría 2006).

Private Agricultural Research

The amount of agricultural research conducted by the private sector has grown in recent years, especially in the developed world. Nevertheless, the role of the private sector in the developing world is still small and is likely to remain so given the weak funding incentives for private research. In addition, many of the private-sector activities in developing countries focus solely on the provision of input technologies or technological services for agricultural production, but most of those technologies are produced in the developed world (Beintema and Stads 2006; Pardey et al. 2006)[15].

Nonetheless, involvement of the private sector in agricultural research is higher in Asia, at least in a number of countries, than in the rest of the developing world. In a few countries the share of agricultural research conducted by private firms has increased considerably (Pray and Fuglie 2001), and as discussed earlier in this report, private-sector funding of public agricultural research has also increased in a number of countries. In some countries, private companies outsource their research needs to government agencies, while in other countries farmers pay levies on their production or exports of cash crops.

In Bangladesh, Laos, Nepal, and Sri Lanka, the private sector accounted for less than 1 percent of total (public and private) spending in agricultural R&D (Table 10). In Laos, for example, the private sector is still underdeveloped - a legacy of the country's Marxist-Leninist past. Permits are difficult to obtain for private-sector start-up companies in agriculture, and standardized tax laws are largely absent. In Vietnam, where the private sector accounted for just 3 percent of total public and private spending in 2002, until recently virtually all companies were government-owned.

The private sector is responsible for the vast majority of scientific research conducted in Malaysia's manufacturing sector, but it undertakes only limited research in the agricultural sector (5 percent of total public and private spending in 2002). Most of these investments were in plantation crops (oil palm, coconut palm, sugarcane, and rubber), and nearly all the companies have government linkages. The current government has identified agriculture as one of three engines for growth; it has therefore instituted a number of agricultural development policies and programs, including mechanisms to promote private-sector involvement in agricultural research such as an investment tax allowance, tax exemptions, and financial and professional assistance for privately performed R&D. Pakistan's political and economic climate, coupled with unresolved intellectual property rights (IPR) issues, is still regarded as unfavorable by many private investors. The Pakistani government, however, has taken various steps to increase private-sector involvement in agricultural R&D with the result that the share of private research appears to have risen in recent years.

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[15] For reasons of confidentiality, many private companies are reluctant to provide information on their resources and investments in agricultural research. In addition, private research activities in a number of Asian countries are often small-scale and ad-hoc, making accurate information difficult to capture. Where data for all the private agencies in Asia included, the private-sector share in overall agricultural research investments would be slightly, but seemingly not substantially, higher.

Table 10. Estimated public and private agricultural R&D investments, 2002/03

Region/ country	Expenditures			Shares	
	Public	Private	Total	Public	Private
	(*million 2005 international dollars*)			(*percentage*)	
South Asia					
Bangladesh	109.4	0.6	110.0	99.4	0.6
India	1,355.0	na	na	na	na
Nepal	25.5	0.0	25.5	100.0	—
Pakistan	170.9	10.4	181.3	94.2	5.8
Sri Lanka	51.3	0.3	51.5	99.5	0.5
Southeast Asia					
Indonesia[a]	177.0	41.3	218.3	81.1	18.9
Laos	12.6	0.1	12.6	99.2	0.8
Malaysia	424.3	22.4	446.7	95.0	5.0
The Philippines[b]	141.1	30.7	171.8	82.1	17.9
Vietnam	55.9	1.6	57.5	97.2	2.8
The Pacific					
Papua New Guinea	28.2	2.7	30.9	91.4	8.6
Sample total, excluding India (10)	*1,167.7*	*107.5*	*1,275.2*	91.6	8.4

Sources: Compiled by authors from datasets underlying the ASTI country briefs and reports (ASTI 2005-08).
Notes: The number of countries in each category is shown in parentheses; Na indicates data were not available.

[a] Private sector investments for Indonesia were scaled up to account for companies that did not share financial data. The share of these omitted companies was estimated to be 30 percent of plantation crop research, 60 percent of seed research, 20 percent of forestry research, and 70 percent of agricultural research carried out by agrochemical companies.

[b] Private sector investments for the Philippines were scaled up to account for companies that did not share financial data. The share of these omitted companies was estimated to be about 15 percent of the private-sector agricultural R&D spending.

Accounting for close to one-fifth of public and private agricultural R&D spending, the private sector plays a more important role in Indonesia and the Philippines than it does in other countries in the region. Indonesia in particular experienced a rapid increase in private-sector involvement in agricultural R&D. The share of private-sector investments has risen substantially over time, from 3 to 7 percent between 1985 and 1995 (Fuglie and Piggott 2006), and to 19 percent in 2003. Private agricultural research is carried out by a large variety of firms, including plantation, seed, forestry, food-processing, and fisheries companies[16]. Private investments in

[16] Although the number of seed companies investing in hybrid rice alone has increased considerably since 1995 (based on Fuglie and Piggott 2006), these companies reported limited or no research activities when interviewed as part of the ASTI survey in 2005. Similar responses were obtained from the main agrochemical multinational companies with facilities in Indonesia.

Indonesia have seemingly not been as strongly affected by the Asian financial crisis as public investments. The vast majority of private agencies in the Philippines focus their research efforts on plantation crops, notably bananas, as well as pineapples. In recent years, however, research activities in most plantation companies have decreased because the Philippines are slowly losing ground to Latin American countries (especially Ecuador). Multinational fruit growers are increasingly relocating their research to Latin America and, according to some, the Philippines government is taking insufficient measures to redress this. The Philippines private sector also focuses on crops likely (hybrid) rice, maize, and vegetables. Specific government policies designed to stimulate private-sector research appear to have had limited impact.

Due to the very high number of private companies with agricultural R&D programs in India, it was very difficult to obtain details on the country's private agricultural R&D. As a result, spending by India's private sector was excluded from ASTI data analysis. Pray and Bassant (2001), however, found that private research spending at minimum doubled from 1985 to 1996. This increase occurred due, first, to growth of India's already sizable agricultural input market and, second, to the liberalization of restrictions on investment in the food and input industries by both Indian and foreign firms. Breakthroughs in biotechnology and plant research were also important, particularly for the seed and biotech sectors (Pray and Bassant 2001).

Private-sector involvement in Chinese agricultural research has also risen. Since the rural reforms of 1978, the number of agribusinesses in China has increased substantially. Zhang, Fan, and Qian (2006) estimated that about one-fifth of these agribusinesses are involved in agricultural research, resulting in a private-sector share of total agricultural R&D spending of 9 percent in 2003. Most of these firms, however, were still at least partially state-owned. The overall low share of private (that is, nonstate owned) companies in agricultural R&D is the result of various government policies. These included government monopolies (or near monopolies) in most agricultural input production and distribution activities, weak intellectual property rights and ownership rules that have hampered the investment of foreign firms in China, and import restrictions on agricultural inputs (Pray 2001). In recent years, a number of policies have been introduced by the Chinese government to promote private-sector involvement in agricultural research. These include value-added tax exemptions or reductions, loan reductions for export-oriented products, and financial subsidies. The government has given up its monopolies on agricultural input distribution, although input markets are still regulated by the government through a legal framework (Zhang, Fan, and Qian 2006). However, Fan, Qian, and Zhang (2006) argue that although the legal IPR framework is in place, stricter and more transparent enforcement is needed; restrictions on foreign investments need to be removed because they have hindered investment and technology transfer of the newest internationally developed seed varieties to Chinese farmers; and the procedures for obtaining tax exemptions, reductions, or loans for private companies are unduly complex.

Regional and International Collaboration

Awareness of the need for regional and international partnerships in agricultural research has grown in recent decades, which is reflected in the large number of regional and global networks that have been established. Networks have proved to be a successful method of collaboration and information sharing, and they allow specialization of particular national agricultural research systems in certain fields (Beintema and Stads 2006). They also help countries to remain up-to-date with global scientific developments and concerns (Paroda and Mruthyunjaya 1999). Cross-country collaboration is cost-effective because countries can more readily capture technology spillovers across geographical and national boundaries. Some Asian countries already have well-developed national agricultural research programs and produce technologies and methods that are applicable to other countries in the Asia-Pacific region and other parts of the world. Multilateral organizations, such as the Consultative Group on International Agricultural Research (CGIAR), also address the issue of technology spillovers and provide global public goods to all countries (FAO 1998).

The Asia-Pacific region has a wide number of networks related to agricultural research. Prime among these is the Asia-Pacific Association of Agricultural Research Institutions (APAARI), which was established in 1991 with the aim of promoting "the development of national agricultural research systems in the Asia-Pacific region through facilitation of intraregional, interinstitutional, and international cooperation." APAARI works with over 20 member countries, as well as a number of CGIAR centers, regional organizations, and other organizations. The association promotes the exchange of scientific and technological knowledge; the improvement of research capacity; and strong linkages across national, regional, and international partners (Paroda 2006). A large number of smaller regional networks, most of which appear to be managed by one or more CGIAR centers, focus on specialized research themes of relevance to the region (Table 11).

The majority of the region's international research is carried out by the CGIAR. In 2006, 29 percent of the CGIAR's total expenditure of US$426 (that is, US$124 million) was spent on activities specifically related to the Asia-Pacific region (CGIAR

Table 11. Important regional agricultural R&D networks

Network name
Alternatives to Slash-and-Burn Programme (ASB)
Asia and Pacific Regional Network of the International Network for Improvement of Bananas and Plantains (ASPNET)
Asia Forest Network (AFN)
Asia Pacific Grouper Network
Asian Network on Sweetpotato Genetic Resources (ANSWER)
Asian Rice Biotechnology Network (ARBN)
Cereals and Legumes Asia Network (CLAN)
Council for Partnership on Rice Research in Asia (CORRA)
Development and Use of Hybrid Rice in Asia
International Coconut Genetic Resources Network (COGENT)
International Network for Genetic Evaluation of Rice (INGER)
Network of Aquaculture Centers in Asia & the Pacific (NACA)
Regional Co-operation in Southeast Asia on Plant Genetic Resources
Regional Network for Conservation and Utilization of Plant Genetic Resources in East Asia (EA-PGR)
Rice-Wheat Consortium (RWC)
South Asia Network on Plant Genetic Resources (SANPGR)
South Asia Vegetable Research Network (SAVERNET-II)
Southeast Asian Network for Agroforestry Education (SEANAFE)
Southeast Asian Sustainable Agriculture Knowledge Network (SEASAKNet)
Tropical Asian Maize Network (TAMNET)
Underutilized Tropical Fruits of Asia Network (UTFANET)

Source: Compiled by authors from various presentations given at APAARI's annual meeting in September 2007.

Secretariat 2007). Although this represents a slight increase in absolute terms over 2002 levels, the share declined from 33 percent. This amount also represents a 2 percent share of the $5.7 billion of total agricultural R&D spending by developing countries in the Asia-Pacific region in 2002 (calculated in 2005 international dollars). Of the current 15 CGIAR centers, 5 are headquartered in the region—IRRI located in the Philippines, the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) located in India, the World Fish Center located in Malaysia, the Center for International Forestry Research (CIFOR) located in Indonesia, and the International Water Management Institute (IWMI) located in Sri Lanka—and the remaining 10 centers have offices and research programs in the region. All 15 CGIAR centers have formal links with China, for example, and 5 of them operate country-based offices. In addition to ICRISAT (with offices in Andhra Pradesh and New Delhi), 7 other CGIAR centers have offices in New Delhi (CGIAR 2005).

The CGIAR played an important contribution to the Green Revolution in Asia during the 1960s and 1970s, developing new varieties of rice, maize, and wheat that ultimately transformed agricultural production and substantially increased food production and income generation (CGIAR 2005). But the needs of Asia-Pacific countries for agricultural technologies (like other regions and countries) have changed. As a result, the focus of the CGIAR has shifted away from cereals toward other crop commodities, farming systems, livestock, (agro)forestry, aquaculture, and irrigation (Alston, Dehmer, and Pardey 2006). Paroda and Mruthyunjaya (1999) argue that the CGIAR's germplasm and varietal-testing programs continue to be important to Asia-Pacific countries and should therefore continue. They also argue that CGIAR centers should be more active in advising countries on IPR issues related to agricultural research, increase their focus on biotechnology and germplasm enhancement research, and play a more active role in regional forums (Paroda and Mruthyunjaya 1999).

Several other international and regional organizations have a presence and conduct or fund agricultural research in the Asia-Pacific region. The Australian Centre for International Agricultural Research (ACIAR), for example, does not conduct research in the region's developing countries itself but it does develop international agricultural research partnerships that focus on reducing poverty, improving food security, and sustaining natural resource management. ACIAR supports over 300 bilateral projects in developing countries, primarily in the Asia-Pacific region and to a lesser extent in southern Africa. The aim is to promote capacity building and knowledge and technology exchange through close collaborations with partnering institutions. In 2007, ACIAR's budget totaled 60 million Australian dollars (about US$50 million), 75 percent of which was disbursed as grants to partnering research agencies, including the CGIAR centers (ACIAR 2007). The Japanese International Research Center for Agricultural Sciences (JIRCAS) conducts experimental research for the technological advancement of agriculture, forestry, fisheries, and related industries. Although JIRCAS's mandate includes all developing countries, most of its research is conducted in Asia. In 2007, JIRCAS employed 107 scientists, and its budget was 3.5 billion yen or close to US$30 million (JIRCAS 2008).

Conclusion

The Asia-Pacific region is highly diverse in terms of geography; population distribution; economic development; and cultural, political, and historic backgrounds. With over 30 distinct countries, the region comprises about 60 percent of the world's population, including more than half of the world's poor (IFPRI/ADB 2007). As evidenced above, this high level of diversity is also reflected in the region's agricultural R&D efforts. In 2002, the Asia-Pacific region as a whole, including high-income countries, spent $9.6 billion on agricultural R&D (in 2005 international prices). Unsurprisingly, distribution of spending among countries was very uneven, with China, Japan, and India accounting for a combined total of about 70 percent of the region's spending. Regional investments as a whole grew by 3.0 percent per year during 1981-2002. Most of this growth took place in the last decade, when China and India in particular accelerated their agricultural research spending. Some of the smaller countries such as Malaysia and Vietnam also realized impressive growth in agricultural R&D spending in recent years, whereas growth in countries like Pakistan, Indonesia, and Laos was more sluggish (and in some cases negative), for a variety of reasons including the Asian financial crisis, the completion of large donor-financed projects, and mass inflation.

A similar diversity exists across countries in the region's human resource capacity in agricultural R&D. With over 50,000 agricultural fte researchers, China has by far the highest capacity. In contrast, agricultural research systems of countries like Laos and Papua New Guinea employed just over 100 fte's. Average degree levels of agricultural research staff also differ widely, with India having the region's (if not the developing world's) most highly qualified research staff. More than half of the country's agricultural researchers were trained to the PhD level in 2003. Average degree levels in countries with a history of political isolation, such as Vietnam and Laos, are much lower. Nonetheless, all countries in the survey sample improved the capacity of their agricultural scientists in terms of higher education over the past decade, despite widespread challenges facing certain countries in terms of attracting and keeping well-qualified staff. Large gender discrepancies are prevalent in staff composition as well. While the Philippines reported an uncommonly high ratio of female research staff (4 of every 10 agricultural scientists) Pakistan recorded an extremely low share (only 6 in 100 agricultural researchers are female).

Although the bulk of Asian agricultural R&D is still financed by national governments, many countries raised agricultural research revenues through other means. Competitive funding mechanisms, internally generated resources, and production or export levies, among others, have all gained prominence across the region. Donor dependency for the Asia-Pacific region as a whole is much lower than in Sub-Saharan Africa, although it remains extremely high in countries like Laos and Nepal. The private sector has also become more involved in financing public agricultural research in certain countries. In addition to financing public research, the private sector in some Asia-Pacific countries has also become more active in conducting agricultural research. In countries like Indonesia and the Philippines, close to 20 percent of all agricultural R&D investments were made by the private sector in 2002/03. In many other countries, however, the investment climate for private investors is poor, making private investments in agricultural R&D negligible and often non-existent.

Overall, some of the region's countries have well-managed and well-funded systems producing world-class research, while others (some of which are highly agriculture-dependent) have experienced significant declines in their R&D spending and research intensity levels. Sustainable financial and political support for agricultural R&D is crucial, as is the creation of attractive investment climates for private investors, if the challenges of sustainable economic and social development facing the region are to be met.

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Appendix

ASTI Methodology and Data Collection

The ASTI initiative involves a large amount of original and ongoing survey work focused on developing countries, but it also maintains access to relevant S&T data for developed countries collected by other agencies. The initiative maintains collaborative alliances with a number of national and regional R&D agencies, as well as international institutions and over the years has produced numerous national, regional, and global overviews and policy analyses of agricultural R&D investment and institutional trends. For each country in which ASTI is active, the research team typically works with the national agricultural research institute, which coordinates the in-country survey round and coauthors and co-publishes the resulting country briefs with IFPRI. These surveys focus on research agencies, not research programs.

The dataset for the 11-country sample underpinning this report includes information on more than 800 agencies and was processed using internationally accepted statistical procedures and definitions developed by the Organisation for Economic Co-operation and Development (OECD) and the United Nations Educational, Science, and Cultural Organization (UNESCO) for compiling R&D statistics (OECD 1994; UNESCO 1984). Agricultural R&D investments are measured on a performer basis. Estimates were grouped into four major institutional categories: government agencies, higher education agencies, nonprofit institutions, and business enterprises. Public agricultural research is defined to include government agencies, higher education agencies, and nonprofit institutions, thereby excluding private enterprises. Government agencies are directly administered by the national government and are typically departments or institutes within a certain ministry. Nonprofit institutions, on the other hand, are not directly controlled by the national government and have no explicit profit-making objective. These agencies are often linked to producer organizations or commodity boards. Higher education agencies are academic agencies that combine university-level education with research. They include agricultural faculties as well as specialized R&D institutes placed under universities. Private-sector agencies are agencies whose primary activity is the production of goods and services for profit. Some of these companies have an R&D unit dedicated to agricultural research, but R&D is generally not their main activity. Agricultural research activities undertaken by international organizations are explicitly excluded from the dataset and are reported separately.

Agricultural research, as defined here, includes research on crops, livestock, forestry, fisheries, natural resources, the use of agricultural inputs, and the socioeconomic aspects of primary agricultural production. Also included is research concerning the onfarm storage and processing of agricultural products, commonly referred to as postharvest or food-processing research. Not included in the current data compilation are research activities in support of agrochemical, agricultural machinery, or food processing industries (which are better reported under those industries), as well as the more basic and discipline-oriented research activities undertaken by departments such as microbiology and zoology. Strict delineations, however, have not always been possible.

In each of the 11 countries included in this study, a complete list of agencies involved in agricultural R&D was identified at the onset of the survey and each agency was approached to participate in the survey. To this end, three different survey forms were developed: one for government agencies and nonprofit institutions, one for faculties and schools, and one for the private sector. All forms had different sets of questions with the one for government agencies and nonprofit institutions requesting the most detail. In general, the forms consisted of four sections:

- Institutional details such as address, affiliation, organizational structure (including number of research stations), institutional history, and so on;
- Human resource information, such as number of researchers by degree level, head count and full-time equivalents (that is, staffing adjusted for time spent on research), share of female researchers, and support staff by various categories;
- Financial resources, such as expenditures by cost category and funding source; and
- Research focus by commodity (about 35-40 items) and by theme (about 20 items).

Time-series data were collected for the main indicators (research investments, research funding sources, and research staff totals); the remaining indicators were mostly for a particular benchmark year. Additional qualitative information was collected through country visits involving in-depth meetings with various agencies, given that quantitative information often doesn't provide the full picture of developments in agricultural R&D resources.

The reported research personnel data are expressed as full-time equivalent (fte) researchers. Researchers should hold at least a BSc degree or equivalent. fte corrections were made only when more than 20 percent of the reported research staff time was spent on activities other than R&D, such as extension, teaching, or technical services. The contribution of PhD students in research taking place at higher education agencies is usually not included.

Internationally Comparable Measures of R&D, Using PPPs

Comparing economic data across countries is highly complex due to important price differences. Putting the agricultural R&D expenditures of two countries side by side is particularly difficult, because roughly two-thirds of research expenditures is typically spent on local research and support staff, rather than on capital or other goods and services, which are usually traded internationally.

The quantity of research resources used in economies with relatively low price levels tends to be understated when R&D spending is converted from different countries to a single currency using official exchange rates. Similarly, the quantity of resources used in countries with high price levels tends to be overstated. Purchasing power parities (PPP) are conversion rates that equalize the purchasing power of different currencies by eliminating the differences in price levels between countries. Therefore, a PPP rate can be thought of as the exchange rate of dollars for goods in the local economy, while the U.S. dollar exchange rate measures the relative cost of domestic currency in dollars. A country's international price level is the ratio of its PPP rate to its official exchange rate for U.S. dollars. Thus the international price level is an index measuring the cost of a broad range of goods and services in one country relative to the same bundle of goods and services in a reference country, in this case the United States. For example, Japan's international price level (that is, the ratio of PPP to exchange rate) of 1.57 in the year 2000 implies that the price of goods and services in Japan was 57 percent higher than the price of comparable goods and services in the United States during that year. In contrast, the corresponding 2000 ratio for Kenya of 0.20 indicates that a bundle of goods and services that cost $20 in Kenya would have cost $100 in the United States (Pardey and Beintema 2001).

No fully satisfactory method has so far been devised to compare consumption or expenditures among countries, either at different points in time or the same point in time. The measures obtained, as well as their interpretation, can be highly sensitive to the deflator and currency converter used. Most financial data in this report have been expressed in "international dollars" for the benchmark year 2005. At the country level, all expenditure and funding data have been collected in local currency units. These amounts were subsequently converted to 2005 international dollars by deflating the local currency amounts with each country's GDP deflator of base year 2005 and converting to U.S. dollars with a 2005 PPP index. The GDP deflators were taken from the World Bank's World Development Indicators (World Bank 2007). In early 2008, the World Bank released a revised set of PPP indexes with a base year of 2005 (World Bank 2008). These indexes differ considerably for important developing countries such as China and India. The revised PPP index for China, for example, is two-thirds higher than the corresponding rate in the World Development Indicators (World Bank 2007). Due to these revised PPP indexes, the allocation of public agricultural research investments across countries and regions deviate significantly than the global investment trends published in Pardey and Beintema (2001), and Pardey et al. (2006) (Beintema and Stads 2008).