1 Introduction

Advances in Science and Technology (S&T) are the key to economic development, wealth creation and social well-being on a country. New scientific knowledge and appropriate technologies are essential to resolve economic, social and environmental issues specific to countries. The S&T sector contribute in combating hunger, malnutrition, diseases, environment degradation, as well as take the country forward by increasing agriculture productivity and industrialization. To reap the benefits of advances in S&T, scientific findings and technological interventions must be applied at the right time, in right scale, while carefully considering their impact on individuals, communities and the environment.

A major challenge in S&T sector is to establish proper institutional arrangements to make maximum use of it for national development. Capacity of a country's S&T sector to generate new knowledge through research and to provide globally competitive services will depend on several factors such as ; adequate investment in R&D on identified areas of national importance, a well-established R&D network, availability and development of human resources, and sound public-private partnership in research and commercialization etc. Therefore, the sector has an important role to play in policy decisions in the areas of food and agriculture, health, energy, environment and industrialization.

In order to make policy decisions, it is vital to review the status of S&T of a country on regular basis. The National Science and Technology Commission is mandated to submit a report annually to the Government of Sri Lanka, reviewing the status of S&T of the country. Therefore, the purpose of this report is to fulfill the above mandate of NASTEC and to provide the Government with necessary information on the performance of S&T sector in year 2013.

The report is based on information collected through a questionnaire survey in which 27 S&T institutions participated.

Information were collected on five broad areas: i) Human resources, ii) Physical resources, iii) Research inputs, iv) Research outputs, and v) services provided by S&T institutes.

The report provides information and analysis on above areas by allocating separate chapters for each area.

Table 1.1: Institutions participated in the survey

Sector	Institutions
Agriculture	Department of Agriculture (DOA) Farm Mechanization Research Centre (FMRC) Field Crop Research and Development Institute (FMRC) Fruit Crop Research and Development Institute (FRDI) Hector Kobbekaduwa Agrarian Research and Development Institute (HARTI) Horticulture Crop Research and Development Institute (HORDI) Institute of Post-Harvest technologies (IPHT) Plant Genetic Resources Centre (PGRC) Rice Research and Development Institute (RRDI) Sri Lanka Council for Agriculture Research Policy (SLCARP)
Engineering	Arthur C. Clarke Institute for Modern technologies (ACCIMT) National Engineering Research and Development Centre (NERDC)
Medicine/Health	Veterinary Research Institute (VRI)
Plantation	Coconut Research Institute (CRI) Rubber Research Institute of Sri Lanka (RRISL) Tea Research Institute (TRI) Sugarcane Research Institute (SRI)
Other	Atomic Energy Authority (AEA) Industrial Technology Institute (ITI) National Building Research Organization (NBRO) Gem and Jewelry Research and Training Institute (GJRTI) National Institute of Fundamental Studies (NIFS) National Aquatic Resources Research and Development Agency (NARA) National Science Foundation (NSF) Natural Resources Management Centre (NRMC) Sri Lanka Accreditation Board (SLAB) Sri Lanka Institute of Nanotechnology (SLINTEC)

2 Human Resources in Science and Technology

Human resources in Science and Technology (HRST) is defined as “Persons having graduated at the tertiary level of education or employed in a science and technology occupation for which a high qualification is normally required and the innovation potential is high” (Canberra Manual, Organization for Economic Co-operation and Development).

The stock of HRST can be used as an indicator of development in today’s knowledge-based economy. However, in most South-Asian countries, the systems/ institutions that transfer knowledge to economic advantage are severely under-developed. The existing knowledge is seldom integrated into development process.

Number of researchers per Million inhabitants is used as an indicator to show the status of S&T in countries. According to UNESCO Institute for Statistics (USI) this figure was 93 for Sri Lanka in year 2010. The average count of Researchers per Million inhabitants for Asia is 554 and the world average for this indicator is 1080. This figure is 3655 for ‘Developed countries’ and 580 for ‘Developing countries’. Other countries in the South-Asian region are heading well before us with India having 137 researchers per Million inhabitants, and Pakistan having 152 (UNESCO Science Report 2010). All these statistics show that Sri Lanka is far below the standard levels.

2.1. Human Resources Strength in S&T institutions

Table 2.1 shows the number of staff members attached to S&T institutions during year 2013. Scientific staff takes the highest place in human resources strength with 53% of the total human resources being scientific personnel.

Table 2.1: Number of staff members in S&T institutions

Staff Category		Count	Total Count	Percentage
Scientific	Research Staff	897	2216	53%
	Scientific Support Staff	1287		
	Librarians/IO	32		
Accounting	Accountants	33	215	5%
	Support Staff	182		
Administration	Executives	98	693	17%
	Support Staff	595		
Other	Office aides, drivers, etc.	1038	1038	25%
Total		4162	4162	100

From the total scientific staff, majority consist of scientific support staff, which comprise of Technicians, Research Assistants etc. Research staff consists of Senior Research Officers, Research Officers, Senior Scientists, Scientists, and Scientific Officers etc. and takes only 41% of scientific staff.

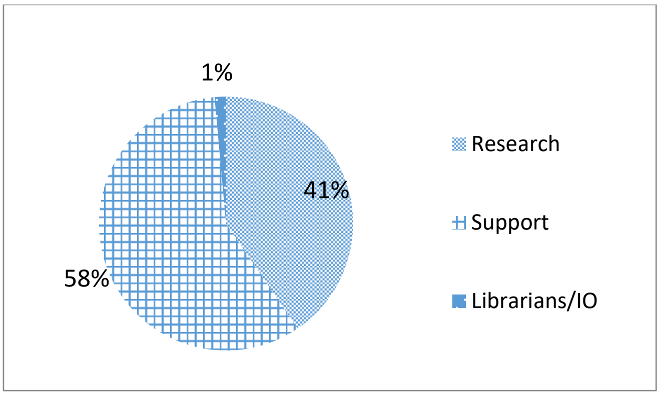

Figure 2.1: Composition of Scientific Staff

Although scientific Support staff exceed the Research staff, it has been revealed that the scientific staff themselves have to attend to many minor things, which could have been done by the supporting staff. Researchers/scientists point out this as a wastage of valuable time that could have been used for research work.

Lack of man power in Science and Technology is a common issue to all South Asian countries (UNESCO Science Report, 2010). Almost all S&T institutions in Sri Lanka are working with less than allocated number of staff and are facing the issue of inability to fill the cadre positions approved by the Government. This is a huge threat to survival of the S&T institutions, as they are unable to fulfill their mandates and carryout the services expected from them. These institutions are unable to hire skilled manpower due to low remunerations and minimal opportunities for trainings due to lack of funds.

Table 2.2: Availability of staff and required number of staff in S&T institutions

Staff Category		Approved Total Carder Positions	Carder Positions filled	Percentage filled	Percent filled (Broad Areas)
Scientific	Research Staff	1,185	897	76%	79%
	Support Staff	1,594	1,287	81%	
	Librarians/IO	36	32	89%	
Accounting	Accountants	34	33	97%	98%
	Support Staff	185	182	98%	
Administration	Executives	125	98	78%	85%
	Support Staff	689	595	86%	
Other	(Office aides, drivers, etc.)	1,337	1,038	78%	78%
Total		**5,185**	**4,162**	**80%**	

Table 2.2 shows that only 79% of scientific staff requirement had been filled by these institutions. From that also, only 76% of Research staff requirements had been filled. The institutions are unable to fill the vacancies due to various reasons. Mainly the remunerations offered are not in par with the educational qualifications and experience requested. Furthermore, location of the institution, lack of promotion and training opportunities, lack of fringe benefits such as accommodation, transportation, schooling for children etc. add to this situation.

Staff retention is a serious issue in Engineering related research institutes. The Arthur C. Clarke Institute for Modern Technologies has filled only 38% of their required cadre of Researchers. There are only 24 Research officers serving the institute and the highest qualification possessed is a Master's Degree. The National Engineering Research and Development Centre has only 45 ROs, which is 63% of their required cadre. Here also none of the ROs have a PhD Degree.

There are only 32 Information officers or librarians in these institutions, which is 89% of the total approved carder positions.

The status of man power in Accounting and Administration staff is in better condition when compared to scientific staff. Availability of accounting staff is quite adequate where 98% of the required number had been filled. The institutions have filled 89% of administrative positions and any difficulties in filling these positions were not much highlighted.

The status of human resources in S&T institutes reveals that recruitment and retention of scientists within these institutes is a major challenge. While considering adequate and fair remunerations and other fringe benefits for scientists, the Government should adopt some strategies to promote these careers, and create recognition for scientists as a profession. This should be done in parallel with popularizing science among the general public. Mass media can play a huge role in this process and it should be supported by the Government and Research organizations.

Like most of the South Asian countries, Sri Lanka is also facing the challenge of brain drain, i.e. the much needed talented man power, especially in the Science and Technology, leaving the country seeking greener pastures. This migration becomes an added cost to the economy since country's higher education receives huge subsidies and the benefits of these investments are reaped by the developed countries at our cost.

2.2. Composition of Research staff

According to the UNESCO Science Report, 2010, females contribute 41% to total number of researchers in Sri Lanka. This figure is 14.8% in India, and 23.4% in Pakistan.

From the total 897 research personnel in S&T institutions, 51% (460) are Females and 49% (437) are Males. Therefore, there is no any significant gender discrimination in S&T, as experienced by other South Asian countries.

When the areas of expertise are concerned, Research Officers (ROs) s specialized in Science and agriculture take major shares contributing 41% and 40% respectively to the total number of ROs. This is not a surprising fact as most of the institutions involved in this survey are agriculture-based research institutions.

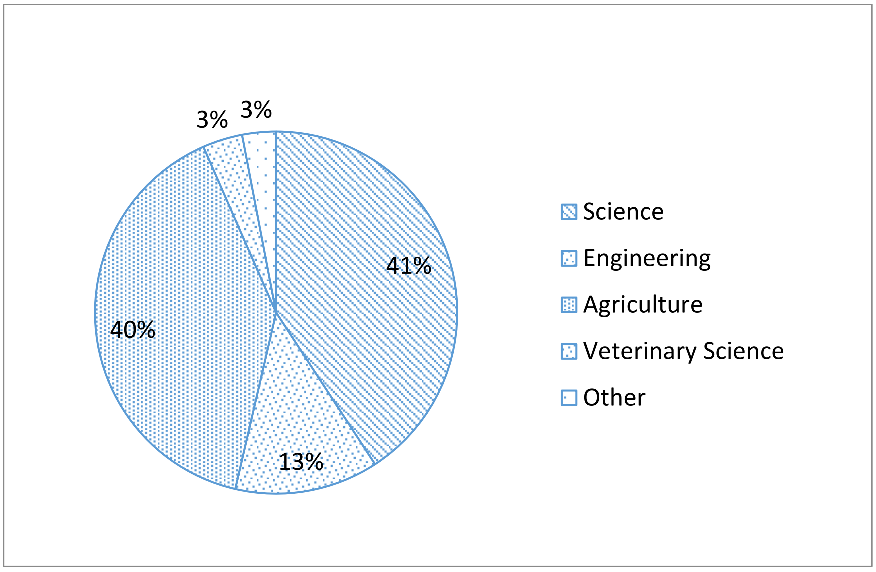

Figure 2.2: Composition of Research Staff based on 'area of expertise'

Figure 2.3 indicates that Female ROs dominate the areas of Science and Veterinary Science. Gender distribution in the area of Agriculture is almost equal, however in science a slight difference is present with 54% of ROs being Females. Male ROs dominate in the area of Engineering.

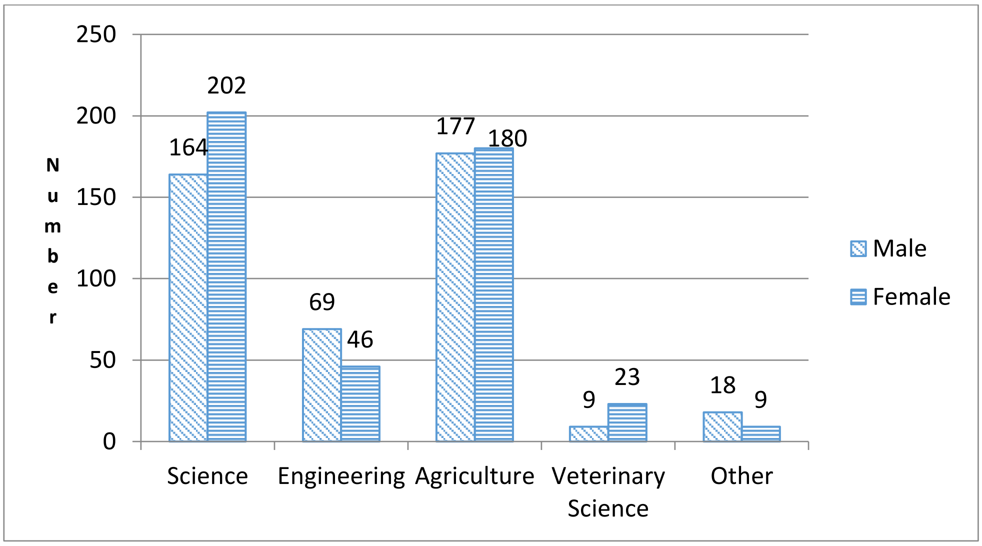

Figure 2.3: Composition of research staff based on Gender and 'area of expertise'

2.3. Educational Qualifications

Table 2.3 shows that only 67 out of 460 female ROs have PHD Degrees and only 33 have MPhil Degrees.

Table 2.3: Highest qualifications of ROs based on Gender

Qualifications	No. of Male ROs	No. of Female ROs	**Total**
PhD	89	67	156
MPhil	42	33	75
MSc/MA	123	147	270
Bachelors	156	198	354
Diploma	27	15	42
Total	**437**	**460**	**897**

The reason that females do not follow postgraduate research degrees may be due to inability to keep work-family life balance. This may hinder their career progress, and limit their involvement in advanced research.

The S&T institutions should adopt some mechanism to encourage female ROs following research degrees while at work, which will motivate them to perform better in their jobs. The mechanisms can be adopting flexi hours, providing transport facilities, accommodation etc.

2.4. Age distribution

As shown in Table 2.4, majority of the ROs (34%) attached to S&T institutions are in the middle age (age = 40 – 50 years), category, while 23% are above 50 years of age. This 23% is closer to their retirement age. It was also noted that senior officers are taking additional responsibilities related to administration when they become heads of departments, Deputy Director or Director. When competent senior researchers are burdened with administrative work, they do not have time for research and also to guide the junior researchers. The institutions should take proper measures to develop the research as well as administrative capabilities of the next level of ROs to shoulder the responsibilities of the seniors when they retire and leave the institutes.

Table 2.4: Age catogories of Research staff

Age Category (years)	Male	Female	Total	
	Count	Count	Count	%
>50	132	76	208	23
40-50	142	163	305	34
30-40	110	138	248	28
<30	53	83	136	15
Total	**437**	**460**	**897**	100

Special attention is also needed for the 28% ROs in the age group of 30-40 years as they are most likely to contribute to the productivity of the institutes in future. They should be offered with postgraduate scholarships and trainings to develop their capacities to serve the institution. This will indirectly help in retaining the competent human resources.

2.5. Human Resource Development

Table 2.5 shows the No. of staff members trained at S&T institutions during year 2013. Accordingly, only 27% of staff members attached to these institutions have received some kind of training during the year. Agriculture-related research institutes are functioning much better compared to other institutes as they have sent 45% of their staff members for trainings. Other institutions have not paid adequate attention to develop their human resources through formal training programmes. This is not a satisfactory situation at all.

Table 2.5: Staff members participated in training programmes in year 2015

Sector	Participation in trainings	No. of Employees	Representation of participation (%)
Plantation RRI, CRI, TRI, SRI	102	1,085	9
Agricultural FMRC, DOA, FCRDI, FRDI, HARTI, HORDI, IPHT, PGRC, RRDI, SLCARP	571	1,275	45
Medical and Health VRI, MRI	11	174	6
Engineering ACCIMT, NERDC	258	1,051	25
Other GJRTI, IFS, NARA, NSF, NRMC, SLAB, SLINTEC, ITI, AEA, NBRO	165	577	29
Total	**1,107**	**4,162**	**27**

A common situation to all these institutions is that they do not have annual training plans. Usually the trainings are offered to staff members in an ad-hoc manner, as and when the information received by the institutions. For long term sustainability and increased performance of these institutes it is necessary to have annual training programmes based on identified needs. The institutes may request funds to sponsor postgraduate programmes for their staff members when preparing annual budgets.

2.6. Human resource output from universities

The higher education sector in Sri Lanka faces the challenge of ensuring the quality of higher education and its relevance to our economy. The universities should be able to produce graduates based on market-driven curricular to cater to the needs of the industrial sector.

Figure 2.4 shows the output of graduates from universities and Higher Education Institutes in Sri Lanka in year 2012 and 2013.

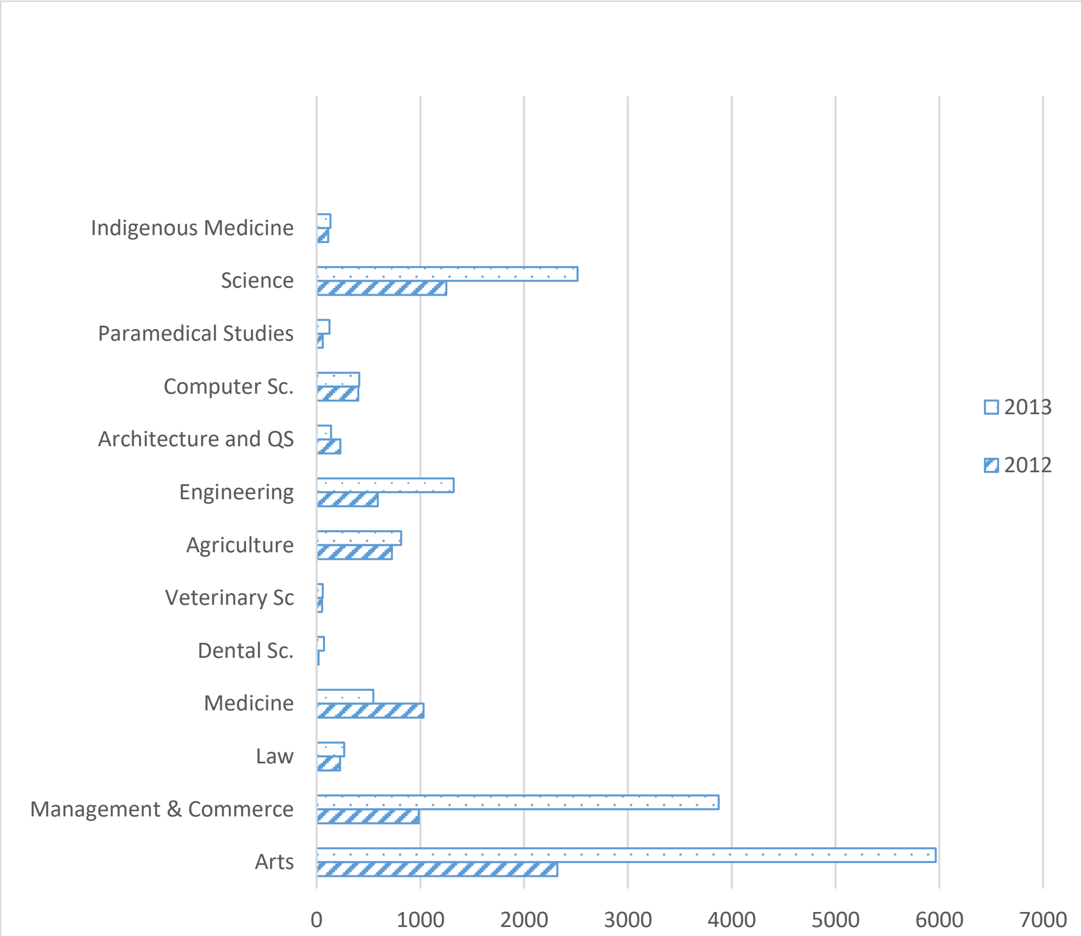

Figure 2.4: Graduates output by universities and higher education institutes in Sri Lanka

(Source: University Grants Commission)

The UGC statistics clearly shows that highest number of graduates are produced in the Arts stream. Generation of scientists from subject streams of Engineering, Agriculture and Science are very low (only 32% of the total output). However, there is a slight increase in number of graduates in those streams in year 2013, compared to 2012. This is a positive trend.

Sri Lanka is not producing adequate human resources in Science and Technology (HRST). This should be considered by the Government in allocating financial and other physical resources for higher education in future. HRST will contribute to development of S&T in the country that is expected to provide solutions for many pressing issues within the country: increase agriculture productivity, overcome malnutrition, natural disaster management and preservation of environment etc.

2.7. Towards a Knowledge Economy

It is a well-known fact that S&T capabilities are essential for meeting the challenges of development in the 21st century knowledge economy where knowledge and education (human capital) is treated as an asset in development. The key component of knowledge economy is greater reliance on intellectual capacities than on physical and natural resources.

Sri Lanka was placed 101 out of 146 countries with Knowledge Economy Index (KEI) of 3.63 in year 2012 (The World Bank). The KEI considers whether the environment of the country is conducive for knowledge generation and usage of that knowledge for economic development. It is the simple average of four factors namely: Economic incentives and institutional regime (EIR), Innovation and Technological adaptation, Education and Training, and Information and Communication Technologies (ICT) infrastructure.

The EIR comprises of the incentives that promote the efficient use of existing knowledge and creation of new knowledge. An efficient innovation system consisted with research centers, universities and other relevant institutions can tap the global knowledge and adopt it to local context. It is essential to have an educated and appropriately trained human resources for knowledge creation and use of knowledge for economic development. Availability of ICT infrastructure facilitate effective communication and dissemination of knowledge and information.

Table 2.6 : Knowledge Economy Index of some selected countries in year 2012

Country	Rank (out of 146 countries)	KEI
Sri Lanka	101	3.63
India	110	3.06
Pakistan	117	2.45
Bangladesh	137	1.49
Countries above Sri Lanka		
Sweden	1	9.43
Canada	7	8.92
USA	12	8.77
UK	14	8.76
Japan	22	8.28
Korea	29	7.97
Malaysia	48	6.1
Thailand	66	5.21

Source: www.worldbank.org

According to World Bank statistics on KEI, Sri Lanka is placed above other countries in South Asia. However, it has been indicated that Sri Lanka has come down in the list of KEI from 82nd place in year 2008 to 101 in year 2012.

If Sri Lanka to survive in the in knowledge economy there is an urgent need to take steps in development of human resources in S&T, invest in development of S&T institutions, promoting ICT infrastructure, increase expenditure on research and development activities and promote entrepreneurship through university-research institute-industry collaborations. It is true that private sector is the 'engine of growth'. But this engine has to travel on rails provided by the public sector in terms of development policies, regulations and services. Therefore, the Government should take initiatives in taking the country towards knowledge economy.

3 Performance of S&T Institutes

The performance of 28 public sector S&T institutions surveyed is evaluated in terms of their input and output related information. They comprised of financial expenditure, number of researchers, number of inventions created and commercialized, number of research publications produced and patents/awards granted.

3.1 Sector-wise expenditure in S&T

Table 3.1 presents the sector-wise expenditure in 2013, along with the number of institutions in each sector, and number of available researchers.

Table 3.1: Sector-wise research expenditure and number of researchers in 2013

Sector	Number of Institutions	Number of Researchers	Expenditure on Research (SLR Mn.)
Plantation	4	168	209.24
Agriculture	11	235	636.62
Medical and Health	1	32	113.77
Engineering	2	69	239.38
Other	10	393	600.14
Total	**28**	**897**	**1799.15**

As shown in the table the highest research expenditure reported in 2013 was for 'Agriculture sector', whereas the lowest was for 'Medical and Health sector'. A higher number of researchers and a higher number of institutions in the 'Agriculture sector' may be the reasons for the highest research expenditure compared to the other sectors.

The expenditure in S&T has resulted in many outputs such as inventions, research publications, and national/international patents.

3.2 Inventions and Innovations

The important outputs of S&T sector institutions are new products, processes, and technologies, which are considered as inventions in this study. A product is defined as a "good" developed by the institution based on its own research (e.g. 'Screw Type Virgin Coconut Oil Expeller'). A process is defined as a methodology developed to produce a product (e.g. 'New Rubber Vulcanizing Process'). A technology is considered as an application of knowledge in a particular area using technical procedures (e.g. 'GSM' or 'CDMA' technology for mobile communication).

Out of the 28 public sector S&T institutions, Council for Agricultural Research Policy (CARP), National Science Foundation (NSF), and Sri Lanka Accreditation Board (SLAB) do not engage in the development of products, processes, and technologies due to their nature of mandate.

During the year 2013, a total number of 101 new processes, products, and technologies have been developed by 19 S&T institutions out of the remaining 25 institutions. Their sector-wise distribution is given in Table 3.2.1. List of products, processes and technologies invented by S&T institutions are given in the Annexure 1.

Table 3.2: Number of inventions developed in 2013

Sector	Processes	Technologies	Products	Total
Plantation	9	6	8	23
Agriculture	9	20	14	43
Medical and Health		1	1	2
Engineering	2	2	4	8
Other	1	1	22	25
Total	21	31	49	**101**

Ten institutions, out of the 19 involved in developing inventions in 2013, have commercialized their inventions. Institutions involved in commercialization have faced difficulties such as lack of financial support by the government for technology transferring programs. The other barriers faced by S&T intuitions in technology transferring programmes include inadequate staffs, unavailability of equipment and machinery, inaccessibility of data for economic analysis of existing products, poor linkages between research and extension staff.

3.3 National/International Patents and Awards Received

Number of national patents obtained by the public sector S&T institutions surveyed in 2013 was two. None of the institutions has obtained international patents during 2013. However, national and international patents obtained by the same set of institutions in 2012 were 3 and 6 respectively. Therefore, obtaining patents in 2013 was low compared to 2012. Lack of awareness and attention of S&T staff in obtaining patents for inventions, lack of interest to get patents, and the long duration taken for granting patents in the past may be the reasons for this reduction in 2013.

National awards in 2013 consisted of best research awards, medals for research work, Presidential awards for publications, etc. Number of national and international awards obtained by the S&T institutions were reported as 29 and 2 respectively in 2013. The highest number of national awards has been received by Institute of Fundamental Studies (IFS) and it was 17. Number of national and international awards received in 2012 were 17 and 6 respectively. Hence, there is an improvement in 2013 compared to 2012 in receiving national awards by the public sector S&T institutions. Although, low in obtaining international awards, receipt of national awards is a good indication of the progress by public sector S&T intuitions.

3.4 Research publications

Number of research publications such as papers in SCI journals, abstracts, books, and monographs is another performance indicator of S&T status of a country.

Table 3.3: Number of different types of publications produced by S&T institutions in 2013

Type	2013
In SCI journals	42
In SCI extended journals	33
In refereed journals	101
Abstracts of papers presented at Conferences /Symposiums etc.	295
As monographs	1
As books	30
As chapters in books	16
Journals published by the institutes	6
Others (Bulletins, leaflets, etc.)	80

The total number of papers published in Science Citation Index (SCI) journals, SCI extended journals, and refereed journals for 2013 were 176. It was 146 in 2012. Thus, it amounts to a 20% increase in 2013 compared to 2012. This might be an important reflection of the government policy on promoting research publications, especially in SCI journals. National Research Council (NRC) has encouraged local scientists and researchers by rewarding them in the recent past. It is obvious that the highest number of publications produced by the public sector S&T institutions in the above table is 'Abstracts of papers presented at Conferences/Symposiums'. The comparative figure for the same in 2012 was 100. It is almost a 195% improvement in 2013 compared to 2012. Catalytic effect of encouraging environment setup by the NRC, enthusiasm of researchers and scientists in presenting papers at Conferences/Symposiums may be the reason for this improvement.

4

Effectiveness of Public Spending on Science and Technology

Information related to public spending on S&T and their effectiveness in terms of output related indicators are presented in this section. The input and output indicators covered in this section include Gross Expenditure on R&D as a percentage of GDP (GERD), researchers per million inhabitants, national/international patents obtained and national/international awards received.

4.1 Financial expenditure in S&T

Gross Expenditure on R&D as a percentage of GDP and the number of researchers per million people in few Asian countries including Sri Lanka (2008-2012) are presented in Table 4.1. Comparison of the indicator in Sri Lanka with other Asian countries could provide us with valuable insights on R&D in Sri Lanka.

Table 4.1: Gross Expenditure in Research and Developent in selected Asian countries

Country	GERD			
	2008	**2010**	**2011**	**2012**
China	1.47	1.76	1.84	1.98
Singapore	2.66	2.05	2.23	2.10
South Korea	3.36	3.74	4.04	-
Pakistan	-	-	0.33	-
India	0.84	0.80	0.81	-
Sri Lanka	0.11	0.16	-	-

Source: World Development Indicator Database, World Bank

It is clear that GERD in Sri Lanka has increased from 0.11% in 2008 to 0.16% in 2010, and this accounts for a 31% increase within a two year period. In fact, this indicates that some effort has been made for the development of R&D sector in the country, in the recent past. However, GERD in Sri Lanka was much lower compared to the other five Asian economies during this period. Therefore, more attention should be given to further increase the GERD in Sri Lanka to be on par with the other Asian economies

4.2 Researchers in S&T

Table 4.2: Number of researchers per million inhabitants in selected Asian countries

Country	Researchers per million inhabitant			
	2008	**2010**	**2011**	**2012**
China	1,199	890	963	1,020
Singapore	5,834	6,307	6,494	6,438
South Korea	4,947	5,451	5,928	-
Pakistan	-	-	149	-
India	-	160	-	-
Sri Lanka	96	103	-	-

Data show that the number of researchers per million inhabitants has an upward trend from 2008 to 2010 in Sri Lanka. However, it is far behind the other five Asian countries, and also the world average, which was 1,285 in 2010 (WDI, WB).

4.3 Patents

Patents protect inventions and ensure that inventors get the benefits resulting from the inventions, thereby providing incentives for creativity, encouraging further inventions and promoting investment. The number of patents obtained is an indicator to measure the level of S&T activity within the country, and also a good predictor of intensity of S&T. Table 4.2 presents the number of patents granted to selected Asian countries from 2010 to 2013.

Table 4.3: Patents granted to selected Asian countries in 2010-2013

Country	Number of patents granted			
	2010	**2011**	**2012**	**2013**
China	135,110	172,113	217,105	207,688
Singapore	4,442	5,949	5,633	5,575
South Korea	68,843	94,720	113,467	127,330
Pakistan	238	469	312	282
India	7,138	5,168	4,328	3,377
Sri Lanka	504	272	126	307

Source: World Intellectual Property Organization Database

As shown in Table 4.3, there has been a decline in the number of patents obtained by Sri Lanka from 2010 to 2012. It has risen to 307 in 2013, but, was still less than the number in 2010. As per the country comparison given in the above table, the number of patents obtained by Sri Lanka was far behind other Asian countries, except Pakistan.

Most of the S&T institutions in Sri Lanka have invented products, processes, and technologies as research outputs. Those inventions have to be patented and protected them from copying or imitating, but, it was found that the awareness about Intellectual Property Rights (IPR) among the scientific staff in most of the public sector S&T institutions is minimal. This may be one of the reasons for the low number of patents obtained in 2013. Creating interest and awareness among the S&T staff about obtaining patents should be addressed as an urgent need.

5 Infrastructure Management in S&T

Infrastructure, in the broad sense is a critical input for development of any country and refers to road networks, electricity supply, telecommunication facilities, water and sanitation services etc.

Infrastructure in science and technology can be categorized as Tangible assets and Intangible assets. Physical resources and facilities required for effective functioning of the S&T institutions can be considered as tangible assets. These include buildings, laboratories, computers and research equipment, as well as human resources and financial resources. Knowledge and skills of people, and Internet connectivity, software, institutional websites, databases etc. can be considered as intangible assets.

5.1. Physical infrastructure

Table 3.1 shows the availability of physical infrastructure such as laboratories, libraries, auditoriums etc. in S&T institutions. Institutions such as NSF and SLAB who are not involved in research activities do not have laboratories. Few institutions such as ITI, SRI and NERD Centre have engineering workshops.

All the institutions have auditoriums or conference halls that are used for conducting seminars, conferences, workshops, symposia etc. Almost all institutes have libraries. However, whether these libraries have latest literature should be looked into. Furthermore, it has been indicated by the librarians of several institutes that the available resources in libraries are under-utilized.

Certain institutions do not get adequate portion from their budgets to subscribe for relevant international scientific journals, as their subscription fee is very high. It would be better to have a central place for international journals, with access to individual scientists at a nominal cost, or give the usage facilities to institutions at a reasonable membership charge.

As these research institutions were built many years back, the physical space has not been increased with the expansion of staff. Many institutions complain lack of space in laboratories, where researchers are compelled to work in a congested environment.

Table 5.1: Availability of physical infrastructure in S&T institutors

Institute	Laboratories	Workshops	Auditorium	Libraries
Arthur C. Clarke Institute for Modern Technologies	5	-	1	1
Atomic Energy Authority	9	-	1	1
Coconut Research Institute	9	1	1	1
Department of Agriculture	5			1
Farm Mechanization Research Centre	1	1	1	
Fruit Crop Research & Development Institute	5	1	1	-
Field Crops Research & Development Institute	3	1	1	1
Gem & Jewelry Research & Training Institute	4	-	2	1
Hector Kobbekaduwa Agrarian Research & Training Institute	5	-	4	1
Horticultural Crop Research & Development Institute	8	-	1	1
Industrial Technology Institute	8	1	2	1
Institute of Fundamental Studies		2	2	1
Institute of Post-Harvest Technology	3	1	3	1
National Aquatic Resources Research & Development Agency	5	1	3	1
National Building Research Organization	5		1	1
National Engineering Research & Development Centre	5	4	1	1
National Science Foundation	-	-	1	1
Natural Resources Management Centre	2	-	-	-
Plant Genetic Resources Centre	6	-	2	1
Rice Research & Development Institute	5	-	3	1
Rubber Research Institute	8	1	3	2
Seed Certification Centre	5	-	2	-
Sri Lanka Accreditation Board	-	-	1	-
Sri Lanka Institute of Nano Technology	7	2	2	1
Sugar Cane Research Institute	2	1	-	1
Tea Research Institute	9	2	6	1
Veterinary Research Institute	2	-	1	-

5.2. Equipment for research work

Availability of research equipment vary across the agriculture research institutes. Some institutes are well-equipped, while some institutes such as Fruit Crop Research and Development Institute and Rubber Research institute do not possess adequate equipment necessary for their research. Other institutions such as ITI, IFS, NERD Centre are comparatively well-equipped for scientific research and possess even highly expensive equipment.

Table 5.2: Some major equipment available in S&T institutes and their uses

Equipment	Applications/ uses
Atomic absorption spectrophotometer	Analyze micro nutrients
UV visible spectrophotometer	Qualitative and quantitative analysis of organic compounds
Gel running apparatus	Separation and analysis of macromolecules (DNA, RNA and proteins) and their fragments, based on their size and charge.
Hybridization incubator	Membrane hybridization
CO_2 incubator	Culture cells with optimum temperature, moisture and pH
Mass spectrophotometer	Identify the amount and type of chemicals present in a sample by measuring the mass-to-charge ratio and abundance of gas-phase ions
Gas Chromatograph	Measure substances that vaporize below 300 °C
Bomb colorimeter	Determine the heat of combustion of a chemical reaction.
Ozone test chamber	Evaluate the ozone ageing resisting performance of rubber
ION chromatography system	Separation of ions and polar molecules based on their affinity to the ion exchanger

Table 5.2 shows some major equipment available in these institutes and their uses. Some of the equipment are available in only one institute. Field Crop Research Institute has specialized equipment such as Hybridization incubator and the IPHT has a Dietary Fiber Extractor used for dietary fiber determination. Industrial Technology Institute (ITI) has a Liquid chromatography-tandem mass spectrometry (LC-MS/MS) which can be used for detection and identification of chemicals of particular masses in complex mixtures such as natural-products extracts, Other institutes possess equipment

necessary for their specialized work. Arthur C. Clarke Institute for Modern Technologies has Mixed single oscilloscope and a 45 cm Cassegrain Telescope used for their specific space related work.

Sri Lanka Institute of Nanotechnology (SLINTECH), which is specialized in conducting nanotechnology research has modern equipment such as Atomic Force Microscope, Thermo-Gravimetric Analyzer (TGA), Differential scanning calorimeter (DSC), Dynamic Mechanical Analyzer (DMA) etc. SLINTEC was established as a public-private partnership entity to capture cutting-edge research. Therefore, it is essential for this institute to maintain standards in par with the modern technological developments taking place in the world.

Certain institutions complain lack of equipment, and some do not have even the basic equipment. Although these institutions manage to function with the available equipment, some are outdated and not operating properly. There are some equipment purchased way back in Year 1988. Therefore, there is a need to replace outdated and malfunctioning instruments because the accuracy of test results generated by these equipment is questionable.

None of the institution has an expert or no one has been given specialized training to maintain or service sophisticated, high-cost equipment. Therefore the suppliers of these equipment maintain a monopoly in servicing/repairing equipment where they charge a high price for that. In most of the time they do not attend to the requests in time. When the instruments are malfunctioning, it takes some time to get them repaired from external experts, which is time consuming as well as costly.

It is also noted that some equipment are under-utilized, compared to their cost of purchasing and maintaining. Some institutions have purchased high-end equipment, mainly for providing services, without any business plan or forward vision. It is the responsibility of these institutions to take maximum use of these equipment to justify the cost incurred in purchasing them. Otherwise these equipment would be considered as wastage of public funds.

It is worth recording here another major issue the researchers are facing; not receiving chemicals, at the time they need them for research work. Calling quotations and purchasing take a long time and some time the chemicals purchased are not the brand/quality they required. If the chemicals are received late, there is no use and sometimes the whole research has to be repeated. The government should consider introducing a mechanism, different from the usual government regulations, for S&T institutions to purchase consumables.

However, with all these limitations these institutions are functioning at their maximum capacity. If these institutes are provided with better equipment and a more conducive mechanism for purchasing consumables, they would be able to excel in their performance.

5.3. IT infrastructure

Almost all S&T institutions have their own websites. The institutions functioning under the Department of Agriculture have their websites connected to the main website of the Department of Agriculture. However, these institutions, especially agriculture-based research institutions can use their websites more effectively in providing information such as pest and disease outbreaks, weather updates and market prices to farmers and consumers.

Some institutions have specific databases to maintain records of their services. However, these databases are only for the use of the institution and not open to public. There are very few institutions such as NSF who has given access to their research grants outputs database to the public through their library.

The scientific staff in all these institutions have a total of 1362 computers. This is not a bad situation as the total number of research staff in these institutes is 897. It would be better if there are more computers available for the use of scientific support staff also, which is 1287 in number.

Computers with Internet facility is an essential and basic facility required by scientists. Although majority of the institutes have adequate number of computers, certain institutions do not have adequate number of computers for scientific staff. This is a barrier for staff to perform their work efficiently as the ROs have to share computers with each other.

Although Internet facilities are provided to scientific staff, some institutions receive poor connectivity. This is a demotivating factor as extracting scientific information from the web has become a tiresome task. This prevents Researchers' exposure to external world and make them frustrated. These factors work as barriers to performance and affect job satisfaction of scientists.

6 Services Provided by S&T Institutions

Almost all S& T institutes are mandated to provide different services to different groups such as farmers, industrialists and the general public. Some services are unique to that particular institute, (e.g. SLSI, SLAB) and function as the only authority available in Sri Lanka for providing that service.

Table 6.1: Some specialized services provided by S&T institutes

Institute	Services provided
AEA	Nondestructive testing, testing radioactivity of imported products, Water chemical analysis, Dosimetry calibration service (ISO 17025), Accreditation of laboratories
ACCIMT	Testing of batteries, surge testing
CRI	Fertilizer analysis, virgin coconut oil analysis, issuing fertilizer recommendation certificates, issuing certificates for exporting coconut-based value added products
FMRC	Test certificates for farm machinery
ITI	Water testing, fertilizer testing, calibration of equipment, product and process certification
NERDC	Noise level measurement, ambient air quality measurement, soil block testing, wastewater testing, boiler testing, tuning and flue gas monitoring in stationary combustion systems, cement block testing, consultancies on environmental emission control systems, energy audits
Seeds certification Centre	Registration of seed importers
SLAB	Accreditation of laboratories, certification bodies and inspection bodies
TRI	Soil testing, fertilizer testing, leaf testing
VRI	Microbiological quality of milk and milk products, Soil sample testing, Water samples testing, Field disease investigation

Table 6.1 clearly shows that S&T institutions make a valuable contribution to the agriculture sector, industrial sector, health sector etc. These services are essential in productivity improvement in agriculture and livestock sector, quality improvement of agriculture products, quality assurance of products for the import and export markets, as well as consumer safety assurance.

Table 6.2: No. of clients served/ services provided by some selected institutes during year 2013

Services	No. of clients served	Highest contributors
Testing services	64,749	TRI – 19,191 ITI- 18,730 Seeds certification centre – 16,431 AEA- 10,071
Calibrations	672	ITI - 600
Products and Process Certifications	1,773,488	CRI – 900,619 Seeds Certification Centre – 872,796
Training programmes	34,486	CRI – 8385 HARTI – 6897 PGRC – 6585 Field Crop Research Inst. – 3000 NBRO – 2985 SRI – 2451

Table 6.2 is only a simple indication of the contribution form the S&T institutions to industrial sector. Most of the services provided by agriculture-based research institutes are free of charge.

However, this contribution is not much felt by the decision makers, mainly because their contribution is intangible and cannot be measured. These services are not measured as outputs of the sector, although they contribute indirectly to increase the GDP of the country. Some industries cannot export their products, without obtaining a quality assurance certificate from a government-authorized body. Agriculture research institutes play a huge role in introducing new varieties with high productivity, high nutritional values with pest and disease tolerant qualities, and pest and disease management through extension services. All these contribute to increase agriculture productivity, improve quality of agriculture products as well as save money spent in importing agriculture products, including rice.

Due to invisibility of the contribution made, the S&T sector attracts less funds compared to road development, education, health etc. as the significance of the sector is not felt by the decision makers. This is a matter of concern, because these institutions are functioning on very tight and limited budgetary allocations from the government. Furthermore, these institutions cannot be expected to be income earning entities as most of the services provided are free of charge, especially in the agriculture and livestock sector. There are institutions such as ITI, NBRO, AEA who earn income through the services they provide to the industrial sector.

In addition to above mentioned services some S&T institutes provide specialized trainings to farmers, industrialists, agriculture extension officers etc.

Table 6.3: Trainings provided by S&T institutes

Institute	Trainings provided
ACCIMT	Modern power electronics
CRI	Extension/research dialogues, training of trainers, coconut-based value added products, organic coconut growing
FCRDI	Fruit cultivation, home gardening, tissue culture, nursery management
NERD	Energy and environmental issues, wastewater treatment, improving engineering maintenance performance
HARTI	Trainings on planning and management of rural/community development projects, social mobilization, marketing extension, farmer empowerment
Seeds certification Centre	Quality seed production, product and process certification, ,

However, these trainings are provided with limited resources, such as lack of auditorium capacity, inadequate funds allocated for training programmes etc. It is necessary to improve the human resource development capacity of these institutes as it has a trickledown effect in transferring benefits to the society.

All these factors indicate that S&T sector is a significant contributor to economy and human resource development of the country. This should be realized by the decision makers and consider thoroughly when making budgetary allocations.

7 The Way Forward

It is a well-known fact that developments in science and technology have intense effects on economic and social development of a country. This affects agriculture through increased productivity and nutritional value of food, increased longevity through improvements in health systems, increased living standards through new products and technologies etc.

The extent to which developing countries achieve the status of development depends on their ability to create new knowledge, adopt and apply technologies developed by other technologically-advanced countries and use them effectively.

By looking at other countries that reached higher levels of development, it is clear that rapid and sustainable economic development is possible through advances in S&T, innovations and successful commercialization.

Capacity of a country's S&T sector, especially its R&D to generate new knowledge and appropriate technologies depend largely on several factors including:

1) Adequate and stable investment in R&D
2) A well-established network of research and development
3) Clearly defined priority areas for research based on national needs to make maximum use of limited resources
4) Proper institutional facilities to conduct research work, which includes standard laboratories well-equipped with modern equipment, continuous supply of consumables needed for research, and autonomy in decision-making relevant to work by scientists/ researchers.
5) Human resource development; updating knowledge of scientists through continuous education and production of highly competitive graduates for needs of the country.
6) Adequate remuneration and facilities for scientists/ researchers to prevent them moving in to non-science employment and leaving the country.
7) A well-established system for commercialization of new products and technologies

This report clearly indicates the following issues in the S&T sector in Sri Lanka.

1) **Low levels of investment in R&D,** which is approximately 0.16% of GDP. This is extremely low when compared to other countries in the region where India spends 0.8%, Malaysia -0.6%, Pakistan- 0.67%, Japan – 3.4%, South Korea – 3.47%.
2) **Limited involvement of private sector in R&D and partnership with the public sector R&D institutes,** which has led to failures in product commercialization and technology transfer.
3) **Inadequate human resource base** to undertake R&D work that address industrial and national needs. Sri Lanka has very low number (93) of researchers per million inhabitants. This figure is 137 for India, 152 for Pakistan. The reasons may be; not producing adequate number of graduates according to needs of the country, low remunerations that scientists are given, inadequate recognition for 'scientists' as a profession.
4) **Lack of facilities in R&D institutions** including laboratories and modern equipment. This is a long-term result of low investments in R&D during the past several decades.
5) **Low number of scientific publications and patents.** According to UNESCO Science report Sri Lanka had only 400 publications in SCI journals in year 2008. This number was 729 for Bangladesh, 36,261 for India, 2,994 for Pakistan. This is a quantitative indicator of R&D work in a country and number of patent applications is an indicator of the dynamism of innovation. We lie far below in this aspect also with a total of 201 resident and 264 non-resident patent applications in year 2008. India has a total of approximately 28,000 patents while Pakistan has 1,700.

All these factors impose a challenge to S&T sector and the higher education sector of Sri Lanka. If we are to benefit from advances in S&T the sector itself needs increased investment, capacity development through institutional development and human resource development, while introducing conducive management strategies with less bureaucracy. At the same time the education sector needs proper identification of human resource needs of the country, improved access to higher education, improved quality and relevance of tertiary education.

Even if all these challenges are met, there would be no use if the Government does not consult scientists to find solutions for burning national level issues. As a country we should be able achieve socio-economic equity and move forward faster, if the scientists are consulted by the government and involve them in national level planning, policy making and implementation of plans and policies.