

THE MISSING LINK IN THE INFRASTRUCTURE OF SCIENCE: AGRICULTURAL RESEARCH IN MALAYSIA

Szarina ABDULLAH
School of Library and Information Science
Institut Teknologi Mara
Malaysia

ABSTRACT

This paper analyzes the infrastructure of science development in Malaysia in an attempt to identify appropriate indicators comparable with those used in developed countries. The bibliometric indicators, widely used in the study of science in developed countries, had their origin in information-rich societies. The impact indicator by way of citation counts demonstrates that the Law of Cumulative Advantage has been in operation, thus perpetuating the slim chance of science in developing countries to have any impact internationally. This study contends that, though science is universal, the conduct of science is not. Therefore the indicators will vary according to the factors contributing to the infrastructure of science in each country. As a case study, agricultural research in Malaysia is explored, using bibliometric indicators as well as non-bibliometric methods. The results indicate that scientists in agricultural research place a high priority on quality scientists, funds, access to up-to-date information, and status of scientists as factors contributing to bringing agricultural research in Malaysia to the forefront of international science, while bibliometrics-related factors are considered of low priority. Malaysian scientists cite publications originating in Malaysia more than those published outside Malaysia. However as these journals are not covered by Science Citation Index, their visibility and availability to scientists in the developed countries are very poor, thereby eliminating the chance of being cited.

RESUME

Cet article examine l'infrastructure du développement scientifique de la Malaisie afin d'identifier des indicateurs appropriés comparables à ceux des pays développés. Les indicateurs bibliométriques ont été constitués dans les pays riches en information. Le facteur d'impact qui utilise les mesures de citations démontre que la loi de l'avantage cumulatif a largement fonctionné, perpétuant ainsi le faible impact international des pays en développement. Cette étude prétend que bien que la science soit universelle, sa pratique ne l'est pas. Ainsi, les indicateurs varient en fonction des facteurs qui contribuent à l'infrastructure de la science dans chaque pays. Le cas de la recherche agricole en Malaisie est examiné au moyens d'indicateurs bibliométriques et non-bibliométriques. Les résultats indiquent que les chercheurs en agriculture donnent une haute priorité sur la qualité des chercheurs, le financement, l'accès à l'information à jour et le statut des chercheurs comme des facteurs qui contribuent à placer la science malaisienne sur le front de la recherche mondiale, alors que les facteurs d'ordre

bibliométriques sont moins importants. Les malaisiens citent les publications émanant de Malaisie plus que celles publiées hors du pays. Cependant ces publications ne sont pas couvertes par le Science Citation Index, leur visibilité et disponibilité pour les chercheurs des pays développés est faible, diminuant ainsi leur chance d'être cités par des auteurs étrangers.

INTRODUCTION

It is generally agreed that science development and science productivity in any country do not exist in a vacuum. Several factors have been identified as contributing to the progress in science which in turn provides the impetus for the socio-economic and technological advancement of nations in the modern world. These factors differ in terms of quantity and quality from one country to another. They are not exclusive of one another and most often they create a chain reaction between and among themselves. These factors are summarized in Figure 1.

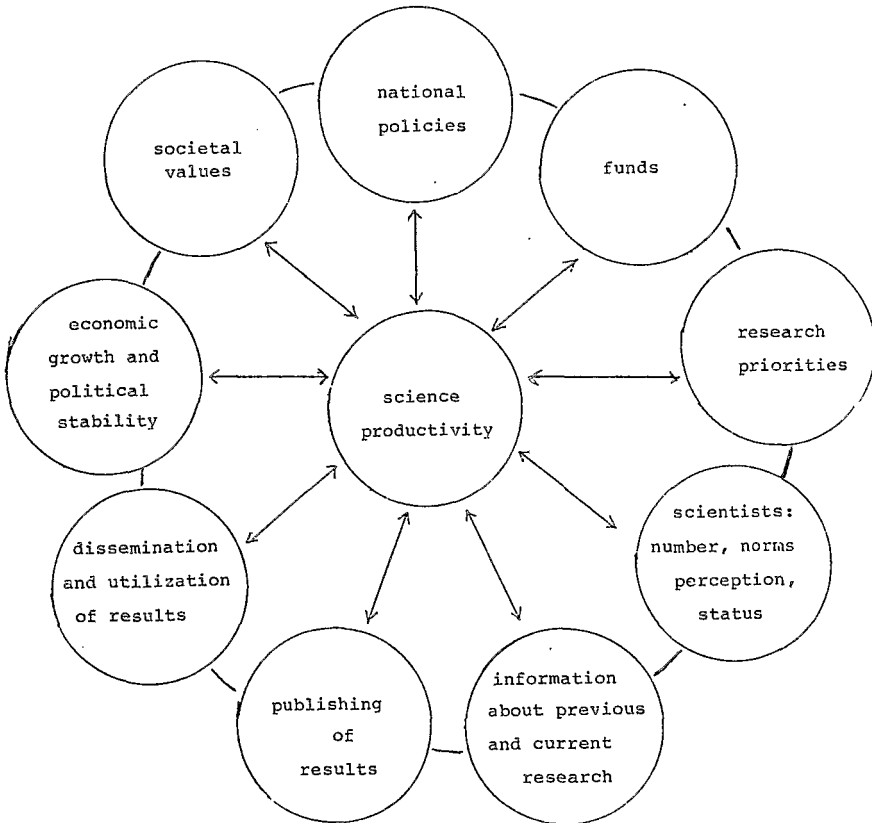


Figure 1. The interrelationship and chain reaction of factors contributing to science productivity (1)

Within the above framework, this paper discusses the state of science development in Malaysia in general, and agricultural sciences in particular.

SCIENCE AND TECHNOLOGY RESEARCH IN MALAYSIA: BACKGROUND

The research and development (R & D) in science and technology (S & T) in Malaysia have always had emphasis on improving the productivity and production of primary commodities which make the largest contributions to the Malaysian economy. Hence, the establishment of the Rubber Research Institute (RRI) in 1925, the Malaysian Agricultural Research and Development Institute (MARDI) and the Palm Oil Research Institute (PORIM) in 1967 and 1975 respectively. Another agriculture-based institute, i.e. the Forest Research Institute (FRI), established in 1929, is also of special significance as forest products are essential to forest-based industries of the country. It has been reported that "these R & D institutes have done exceedingly outstanding work as is evident from the highly competitive status enjoyed by Malaysia in the world market in rubber and palm oil" (2).

The establishment of the University of Agriculture in 1971 has provided for another major development in agricultural research as the university not only conducts research but also provides education and training for scientists, researchers, and field workers who are needed in the process of information transfer.

Besides these institutions, science research in Malaysia finds homes in the Institute for Medical Research, another one of the oldest research institutions established in 1900, the Tun Ismail Atomic Research Center (PUSPATI), and institutions of higher learning, such as the University of Malaya, the University of Science Malaysia and the National University of Malaysia. These universities were established in 1949, 1969 and 1970 respectively. The years of establishment of these research institutions reflect the very young age of science development in Malaysia compared to that of the developed countries. This factor has a very important bearing on the number of research activities, the publications in science and technology and the number of scientists and researchers.

SCIENCE POLICIES AND THE NATIONAL IDEOLOGY

The RUKUNEGARA (The National Ideology), adopted since 1969, contains a declaration dedicated to "building a progressive society which shall be oriented to modern science and technology" (3). In addition, in 1983 the Prime Minister, in his address to the National Council for Scientific Research and Development, gave specific guidelines for R & D as follows :

- (i) Research carried out in Malaysia will have to be applied research;
- (ii) It must be relevant to the social, cultural and economic needs of the country;
- (iii) Research should be conducted in applied fields in which Malaysia is already competent, such as in agriculture;
- (iv) Linkages between public and private sector research agencies have to be increased to ensure that research results are fully utilized;
- (v) The development of appropriate technology is of high priority particularly in areas where the development of design and fabrication is appropriate to Malaysia's climate and cultural practices;
- (vi) The utilization of wastes or byproducts has to be intensified so that these byproducts will not be polluting but will result in higher economic value (2).

From the above statement, it is very clear that applied sciences and technology, not pure sciences, have been given priority for the country's R & D. Since then, the government has taken several steps to accelerate its machinery and programs to fulfil the country's aspirations. Hence, the National Science and Technology Policy was formulated and approved by the Parliament in 1986, which provides another major landmark for R & D in science and technology in the context of the overall national development plan. The Policy places emphasis on: "1.(...)the utilization of science and technology as a tool for economic development, the improvement of human physical and spiritual well-being and for the protection of national sovereignty being an integral part of the socio-economic development policy of the nation. 2. (...) the promotion of scientific and technological self-reliance in support of economic activities through the upgrading of R & D capabilities by the creation of an environment conducive to scientific activity and the improvement of scientific, educational and other relevant infrastructures". (4)

PRIORITIES

The Policy specifically lists, among others, the following areas to be given priority in R & D:

- (1) the utilization of agricultural and other resources and the development of appropriate production and processing technologies.
- (2) health and primary health care.
- (3) the establishment of an efficient research management system and the development of research infrastructures such as science information centres, technology parks, patent offices and other institutions involved in research, design, consultancy and information.

In the area of scientific research, emphasis is on applied and adaptive research. Basic research is undertaken when necessary in order to develop specific areas important to the country.

FUNDS

The National Science and Technology Policy recognizes the importance of funds necessary to materialize its implementation. Thus, the national expenditure on R & D has been increased from around 0.5% of the GNP prior to 1986 to almost 1% in the vote for projects during the Fifth Malaysia Plan of 1986 - 1990 (5). Though this increased budget allocation for R & D in Malaysia is still lower than that of many developing countries (Table 1), it is a clear indication of the country's commitment to R & D. Compared with another developing country, for example Thailand, Malaysia's expenditure on R & D almost doubled that of Thailand in 1984.

TABLE 1 : EXPENDITURE ON R & D BY SELECTED COUNTRIES

Country	Unit (Million)	Amount	As% of GNP
Malaysia (1982)	Ringgit	290 - 295	0.5
Korea (1982)	Won	457,688	0.95
Japan (1982)	Yen	5,881,539	2.78
U.S. (1980)	US\$	62,220	2.36
U.K. (1975)	Pound	3,622	2.47
W.Germany (1977)	DM	41,320	3.04
*Malaysia (1984)	Ringgit	n.a.	0.66
**Thailand (1984)	US\$	122	0.34

Sources: * Medium and Long Term Industrial Master Plan. Malaysia, 1986-1995, page 26; ** Y.Yuthavong. Basic Issues and Recent Development in Science and Technology Policy in Thailand. ASEAN Journal of Science and Technology Development 4, no. 1 (1987) 2 - 11.

And, if the latest report is accurate, the government has allocated 614 million ringgit (6) for R & D under the Sixth Malaysia Plan of 1991 - 1995. Compared to the 400 million ringgit during 1986 - 1990, the budget for R & D in 1991 - 1995 has increased by 50%.

Besides funds, some other important steps taken by the government to accelerate R & D in science in technology are as follows. The Ministry of Science, Technology and the Environment (MOSTE) has been strengthened with full authority and resources to ensure effective S & T policy formulation, research, coordination and monitoring. The MOSTE has been adopting since 1987 a strategy called "Intensification of Research in Priority Areas (IRPA)" in coordinating research activities and funds in line with national development needs. A permanent Cabinet Committee on S & T, headed by the Prime Minister, is to be set up in mid-1990. An Advisory Council on S & T with membership from the government and research community with 50 percent of its membership

from the private sector is also being set up. The establishment of an effective and vigorous national S & T intelligence and information system to be operational in 1991 has also been recommended (7).

PUBLIC AWARENESS OF S & T DEVELOPMENT

The successful implementation of any development plans ultimately falls back on the citizens and residents of the nation. With that realization, the government has embarked on several undertakings aimed at educating and creating public awareness of the significance of S & T in nation building, and encouraging innovation and participation in S & T programs from the public. The National Science Week and the Malaysian Invention and Design Exhibitions have been held annually since 1987. The establishment of the Science Center, Technology Park, and Agriculture Park is yet another implementation of the S & T plans of action. The Agriculture Park, in particular, is reported to be the first of its kind in the world. During its preparation and after its official opening in August 1990, it has continuously been visited by an overwhelming number of people from all walks of life, including visitors from other countries.

Thus far, it can be seen that the Malaysian National Policies have played a very important and crucial role in S & T development in Malaysia. The above policies, funds, and machinery indicate a very positive direction the nation is taking on the path to development. They dictate the directions appropriate for a developing country to follow, i.e. emphasis on the applied sciences, not basic sciences. The results of R & D must also be reflected in the improvement of the socio-economic well-being of the nation. The above factors are important "Input Indicators" for science productivity.

SCIENTISTS AND RESEARCHERS

Another input indicator which is difficult to measure, yet plays a similarly crucial role, relates to human resources, i.e. scientists, researchers, their quantity and quality, their status and perception towards S & T development within the context of the overall national development.

The number of science and technical manpower of a country is not easy to come by, what more to compare it with that of other countries. Unless there is an agreed-upon definition of scientists and researchers to be employed in a systematic and consistent manner, the comparison is subject to further scrutiny and clarification. As a rough guide, the population of Malaysian scientists and researchers has been culled from two sources. The NSTP (4) estimates the number of full time research scientists and technologists in Malaysia in 1986 to be approximately 3,300. This gives a ratio of 236 S & T personnel per million population, compared to 1982 per million as reported in Japan, 2464 per million

in the US, and 1100 per million in West Germany. In 1988, another authority reported that Malaysia had 10,000 personnel qualified in science and engineering in government and statutory bodies (8). This figure brings the ratio of S & T personnel to 583 per million population. (The population of Malaysia in 1988 was estimated at 17.150 million (9). Relatively speaking, the number is still much lower than that of developing countries.

The number of scientists, accurate or inaccurate though the case may be, needs to be balanced with the quality. The latter is indeed very difficult to measure. If the Nobel Award in science signifies the utmost excellence of its recipient, then it is clear that developing nations possess none of the quality scientists. This fact speaks for the slow progress of science in developing countries.

SCIENTISTS' PERCEPTION ON AGRICULTURAL RESEARCH IN MALAYSIA

In the absence of previous studies on Malaysian scientists in all fields of science and technology and the nonexistence of a directory of Malaysian scientists and researchers, it is not possible to estimate a suitable sample size of scientists for sociological studies of science in Malaysia. However, this paper takes agricultural research as a preliminary case study of scientists' perceptions due to the fact that agricultural research has been identified as the most developed field of science in Malaysia for which bibliometric data are more readily available compared to other fields. The results of the findings therefore are not representative of scientists' perception as a whole.

In order to have some idea about the scientists' perception on the state of development of agricultural research in Malaysia, a questionnaire was sent to 200 scientists working in the six major agricultural research institutions, namely, University of Agriculture, Malaysian Agricultural Research and Development Institute, Palm Oil Research Institute, Rubber Research Institute, Forest Research Institute, and the Ministry of Agriculture. Eighty respondents (40%) returned the questionnaire (Table 2).

Results of the data analysis indicate that the majority of scientists rank "quality scientists devoted to research" as the most important factor contributing towards bringing agricultural research in Malaysia to the forefront of international science.

It should be noted that although the ranking by means and the ranking by frequencies do not produce identical results, the data from Table 2 are indicative of scientists' perception about their priorities in science productivity. It is definite that they consider "quality scientists" and "funds" the two most important factors. The "status of scientists" is almost equally spread out among rank 1 to 3; nevertheless it ranks high and competes with another factor "access to up-to-date information" for no. 3 and 4 position. The important conclusion that can be drawn from this group of data is that these factors which are ranked high (1-4)

by scientists are non-bibliometric, while factors that are bibliometric, i.e. "quality journals", "visibility of journals" and "publishing in international journals", receive low rank (5 - 8) . This finding has implications for our definition of "science indicators" for developing countries.

TABLE 2. FACTORS CONSIDERED IMPORTANT IN CONTRIBUTING TOWARDS BRINGING AGRICULTURAL RESEARCH IN MALAYSIA TO THE FOREFRONT OF INTERNATIONAL SCIENCE

Rank by Frequencies	1	2	3	4	5	6	7	8	Mean s	Rank by Means
Factor										
Quality scientists devoted to research	36.7	19.0	13.9	11.4	10.1	5.1	2.5	1.3	2.70	2
Funds for research	33.3	24.4	17.9	5.1	10.3	3.8	2.6	2.6	2.69	1
Access to up-to-date information	2.6	18.2	22.1	20.8	11.7	11.7	6.5	5.2	4.15	3
Status of scientists	15.6	16.9	15.6	10.4	5.2	11.7	11.7	13.0	4.19	4
Quality journals to disseminate results	3.9	10.5	10.5	14.5	27.6	19.7	11.8	1.3	4.64	5
Applications of research findings at large scale	7.9	2.6	7.9	11.8	19.7	21.1	13.2	15.8	5.27	6
Visibility of Malaysian journals among international scientists	3.8	7.7	3.8	11.5	9.0	16.7	25.6	21.8	5.75	8
Malaysian authors publishing more in international journals	9.2	3.9	10.5	15.8	6.6	10.5	18.4	25.0	5.36	7

Other non-bibliometric indicators that are investigated are the education and qualifications of scientists and the proportion of time they spend on research. The quality of scientists may be associated with the former while science productivity may be associated with the latter. In this study all 80 scientists (100%) possess Bachelor's degrees, while 65 (81.25%) and 46 (57.5%) hold Master's and Doctorate degrees respectively. These figures may be compared among scientists across countries in the same field of research. In developing countries, with the exception of research assistants, one would expect all scientists to have Doctorate degrees.

It cannot be denied that science productivity depends on the time spent on doing research. In this study the proportion of time for research is compared with that for teaching and administration. Data indicate that only 50% of scientists spend between 70 - 100% of their time on research. And if 70 - 100% is considered full time research, then it may be desirable to have more scientists devote their time to research.

BIBLIOMETRIC INDICATORS

What has been discussed so far centers around non-bibliometric indicators, namely national policies, funds, scientists, their number, quality and their perceptions related to science development. The next elements in the infrastructure of science (as shown in Figure I) deal with bibliometric indicators derived from the analysis of literature generated and literature used by scientists.

INFORMATION INFRASTRUCTURE

It has been established that progress in science is dependent upon the free flow of scientific information, that the rate of scientific advance is determined in large measure by the speed with which findings are disseminated among scientists who can use them in further research. The basic premise of research is the advancement of existing knowledge. Thus the scientist must investigate what has been done in his particular area of research before he proceeds with his investigation. The practice of "literature search" is both a norm and a requirement in science. This requires that the scientist has at his disposal information and data on previous and current research relevant to his work.

Unfortunately, in many developing countries including, Malaysia, science information systems seem to be the weakest, if not the missing, link in the infrastructure of science. At least two previous studies testify to this phenomenon. Inman's study (10) found that poor access to major international publications had serious implications for the research effort of scientists in developing countries. The inadequate access to current information may be associated with (a) their failure to refer to relevant literature, (b) duplication of research already carried out elsewhere, or (c) work falling outside the mainstream of current research interests. These three factors are major reasons for criticism or rejection of papers submitted by scientists from less developed countries (11) .

Such a situation creates a vicious cycle whereby the scientist's paper has no chance of being studied or cited by other scientists. The "Matthew effect" in science ultimately creeps into operation and scientists seek their retirement in the unproductive state of science. Velho's study (12) of Brazilian scientists in agricultural research also pointed out that the inaccessibility of Brazilian journals and their inconvenient locations contributed to the poor use of Brazilian journals

by scientists. The journals are not abstracted and made available to increase the scientists' awareness of research work done in Brazil.

In Malaysia, scientists face the same problems as their colleagues in Brazil. As recently as June 1989, an authority at the University of Agriculture stated, "though much research has been carried out ..., information pertaining to these research activities is fragmented and its retrieval not adequately coordinated. We still do not have comprehensive data on who is studying what, when and where. The gap in information about agricultural research programmes, projects, institutions, researchers and their research experience will surely have to be filled before major programme changes in research strategies can be contemplated" (13). The significance of access to information on previous and ongoing research has been given third rank by scientists in this study (Table 2).

AGRICULTURAL INFORMATION SYSTEM

The above statement prompted an investigation by this study. Since Malaysian agricultural research is said to be the most developed, it follows that proper systems for managing information in the field have been established. As a matter of fact, the agricultural information system (AGRIS) is the first and so far the most comprehensive system, covering agricultural and related disciplines in Malaysia. No other science or technology discipline in Malaysia has a well-developed information system comparable to agriculture. Coordinated by the University of Agriculture library, the database receives inputs from various institutions dealing with agriculture all over the country. Inputs from Malaysia are sent to the regional center in Manila (AIBA), which in turn forwards all Asian entries to the headquarters in Rome (FAO). At any point in time, scientists may browse through the printout of bibliographic information or enquire from the library about the items they need. It was reported that entries from Malaysia numbered 8,826 during the period 1976 to 1989. Another sister system to AGRIS, called CARIS, which deals with agricultural research projects in progress and coordinated by MARDI, lists 466 projects in Malaysia (14). Besides, MARDI has also established two inhouse databases covering abstracts of research and theses completed by its officers.

Unfortunately, perhaps the existence of such a system is not commonly known to scientists. Data from this study indicate that 50% of scientists do not use the AGRIS service for accessing information, and 18.8% of scientists use AGRIS only 10% of the time, while 9.4% of scientists use it 20% of the time. The most frequently used method of accessing information is via references from the articles they read. This method may, no doubt, lead the researcher to a selective list of relevant items, but it suffers from comprehensiveness and exhaustiveness of information search. It has yet to be confirmed also whether the literature search service provided by their respective libraries is efficient and meets their needs, because 48.5% of scientists use the service only 5-10% of the

time, 14% of scientists use it 20% of the time while 18.8% of scientists do not use the service at all.

CITATION ANALYSIS

Though quality agricultural journals in Malaysia have been in existence since the early days of establishment of RRI, MARDI, PORIM, and FRIM, none of these journals have been covered in Science Citation Index (SCI). Reputable journals such as the Journal of the Rubber Research Institute, MARDI Research Bulletin, The Planter, Pertanika, are covered by Biological Abstracts, and/or Chemical Abstracts and/or Bibliography of Agriculture. Malaysian authors and their papers appear in the SCI only when they publish in international journals which are covered by SCI. This again may be associated with the low citation rate and the low impact of Malaysian science in the international scene.

In order to investigate the characteristics of citations in Malaysian publications, a total of 848 citations from source articles from the above five major agricultural journals published in 1984 were analyzed. The results indicate that publications generated in Malaysia receive the highest number of citations (Table 3).

Data from the survey complement this bibliometric data, as 57.5% of scientists consider journals published in Malaysia of similar standard compared to those published in developed countries. This is a healthy situation for a country relatively young in science development, unlike Brazil, where scientists cite 80% of publications originating in the US (12).

Another source of data for comparison is the input statistics from AGRIS database. During 1975-1981 Brazil input 10,342 items, while Malaysia input only 3,809 items into the AGRIS database (15). This means that Brazil scientists have more chances of citing Brazilian items than do Malaysian scientists citing Malaysian items. Scientists' attitudes, non-bibliometric by nature, as pointed out by Velho influenced the pattern of citation.

Though the information infrastructure for agricultural research in Malaysia is well-established, that of other branches of science and technology is not. The National Plan of Action for industrial technology development, 1990, reports: "The information infrastructure is out-dated and ineffectual, unable to support technology development. Information, particularly documents containing technical facts and figures, appears to be held in low esteem. Accumulated knowledge and the vast experience within the industries of the country are very rarely documented for systematic use due to the inadequate appreciation of the value of documented facts. Even available documents from abroad are not properly disseminated and used by local industries ..." (16). The above statement very well sums up the generally poor state of information management in technology, which also applies to other branches of science. Steps have been taken by the Ministry of Science, Technology, and the Environment, to establish

a coordinating body with a view to managing, acquiring and disseminating science information both for researchers and the public. Without this systematic science information management, the missing link in the infrastructure of S & T development in Malaysia will continue to exist.

TABLE 3. COUNTRY OF PUBLICATIONS OF CITATIONS

Country	No. of Citations	%
Malaysia	245	28.89
USA	226	26.65
UK	134	15.80
Australia	28	3.30
The Netherlands	24	2.83
India	23	2.71
Japan	15	1.76
The Philippines	14	1.65
France	14	1.65
International Organizations	14	1.65
FRG	12	1.41
Canada	9	1.06
Nigeria	8	0.94
Brazil	7	0.82
Costa Rica	6	0.70
Kenya	5	0.60
Singapore	4	0.47
Belgium	3	0.35
Colombia	2	0.235
Denmark	2	0.235
Ghana	2	0.235
Indonesia	2	0.235
Italy	2	0.235
Thailand	2	0.235
Yugoslavia	2	0.235
*Unidentified	32	3.77
Total	848	100

*The inconsistency of citation formats, i.e. abbreviations of titles, missing dates or volume numbers contributes to the items being unidentified. This reflects in a way the quality of the journals.

BIBLIOMETRIC INDICATORS AND THE INFORMATION POOR NATIONS

The appropriateness of using bibliometric data as science indicators needs to be viewed from another angle. "Bibliometrics" had its origin in the information-rich nations. It was employed as a method for measuring certain characteristics of

written communication as has been well defined by Pritchard since 1969 (17). The early studies of literature in science such as that of Bradford (18), Price (19), and Groos (20) emerged due to the phenomenon common to all information-rich countries, i.e. "information explosion". The citation analysis studies have all pointed to the fact that scientists' must publish in a number of journals that are made visible to other fellow scientists. Due to the information explosion, citation studies have also been used to gauge a selective list of journals that are considered highly used that are most appropriate for subscription by research libraries. Results of citation studies have also been associated with quality science and quality scientists (21).

In most developing nations, the publishing and the information industries are in the infant stage of development so much so the countries may be considered "information poor". In such a situation, bibliometric data are scanty, scattered, if not difficult to locate. Therefore they may not be valid as a tool for measuring science for comparison with developed nations.

CONCLUSION

The present study is a preliminary investigation and is considered a step towards a more systematic and continuing effort in assessing science and technology development in Malaysia. Several science indicators have been described as having impact on science development, namely national policies, funds, and scientists themselves. The starting point should come from the national policy that will provide the framework for the science development, R. & D, education, human resources, and other infrastructures needed to implement the policy. It can be seen that all the elements shown in Figure I are cause and effect to each other. For example, scientists themselves are users and generators of information infrastructure in science; the proper system for information dissemination leads to more research and more publications and wider use of research results. For Malaysia, the utilization of research products is of prime concern due to economic values expected from R & D. The wide acceptance of economic benefits derived from R & D by the public at large will also lead to policies and funds that will stimulate more R & D activities.

Bibliometric indicators can only be used in areas of research where a systematic body of literature and information system has been well-established, such as agricultural research. Other areas of S & T in Malaysia are still out-of-bounds for bibliometric analysis. In these areas, a proper system for information creation, acquisition and dissemination is needed.

Acknowledgement

The author thanks the following individuals for their cooperation and assistance which have contributed to the completion of the study: Syed Salim Agha, University of Agriculture Malaysia; Fuziah Abdul Rahman, Rubber Research Institute; Khatijah Ibrahim, Malaysian Agricultural Research and Development Institute; Mardhiah Zain, Palm Oil Research Institute, Siti Zakiah Aman, Ministry of Agriculture; Kong How Kooi and Nor Hayati Nordin, Forest Research Institute; Dr. Mohd Khanif Yusof, University of Agriculture; Normah Mohd. Dali, Jamilah Md. Saat, and Mohd Najib Othman, Statistics Unit, Institut Teknologi Mara; Dr. Mohd. Mansor Salleh, Institut Teknologi Mara; A. I. Lebowitz, AGRIS Coordinating Centre, Rome; and all scientists who responded to the questionnaire.

REFERENCES

- 1) Major papers that discuss various factors for consideration as science indicators are such as
 - a) **Moravcsik, M.J.** Applied scientometrics : an assessment methodology for developing countries. Scientometrics. Vol. 7 no. 3 - 6 (1985) 165 - 176.
 - b) **Smith, D.C.** et al. National performance in basic research. Nature vol. 323, 23 October (1986) 681 - 684.
 - c) **Stolte - Heiskanen, V.** Evaluation of scientific performance on the periphery. Science and Public Policy vol. 13, no. 2, April (1986) : 83 - 88.
 - d) **Garfield, E.** Third World research : mapping science in the Third World. Science and Public Policy. June (1983) 112-127.
- 2) Medium and Long Term Industrial Master Plan Malaysia 1986 - 1995. Volume III, part 6. R & D and Technology Policies. Malaysian Industrial Development Authority and United Nations Industrial Development Organization. August, 1985. p. 16-18.
- 3) Information Malaysia 1988 Yearbook. Kuala Lumpur, Berita Publishing, p. 30.
- 4) Malaysia. Ministry of Science, Technology and the Environment. The National Science and Technology Policy. 1986.
- 5) **Omar, A.R. and Smith, M. Y.** IRPA as a strategy for S & T development in Malaysia. Seminar on Strategic R & T Planning and Management. Kuala Lumpur, Malaysia, 8 - 11 August (1988)15.
- 6) New Straits Times, 21 August 1990, p. 12.
- 7) Industrial Technology Development Plan : A National Plan of Action. A Report of the Council for the Coordination and Transfer of Industrial Technology, Ministry of Science, Technology and the Environment, Malaysia. Kuala Lumpur, 1990. p. 63.
- 8) **Sallehuddin Mohamed, Tan Sri Dato'**. Keynote address Science and Technology in National Development. Seminar on Strategic R & D Planning and Management. Kuala Lumpur, 8 - 11 August (1988)p.8.
- 9) Malaysia. Kajian Separuh Pengqal Rancangan Malaysia kelima 1986 - 1990. Kuala Lumpur, Jabatan Percetakan Negara, 1989. p. 87.

- 10) Inman, C.R.H. Scientific publications in English and developing countries; A report of a survey of scientists, experiences. Journal of Information Science no. 6, (1983) 159 - 164.
- 11) **Gordon, M. D.** Deficiencies of scientific information access and output in less developed countries. Journal of the American Society for Information Science. 30 no. 6 (1979) 340 - 342.
- 12) **Lea Velho.** The meaning of citations in the context of a scientifically peripheral country. Scientometrics Vol. 9, Nos. 1 - 2 (1986) 71 - 89.
- 13) **Mohd Ariff Hussein.** Some reflections on improving research contribution to Malaysia's agricultural and rural development performance. Berita Penyelidikan/Research News, Universiti Pertanian Malaysia, Jilid 3, Bil. 2, p.3.
- 14) **A.I. Lebowitz** of AGRIS Coordinating Centre, FAO, Rome, provides this data on 14 September 1990.
- 15) "AGRIS Input Statistics. Agricultural Information and Documentation Systems (AIDS) no. 1, p. 13. (1982).
- 16) Industrial Technology Development: A National Plan of Action. A report of the Council for the Coordination and Transfer of Industrial Technology, Ministry of Science, Technology and the Environment, Malaysia. February, 1990. p. 23.
- 17) **Pritchard, Alan.** Statistical bibliography or bibliometrics? Journal of Documentation. Vol. 25, no. 4 (1969) 348-349.
- 18) **Bradford, S.C.** Sources of information on specific subjects. Engineering 137(1934) 85-86.
- 19) **Price, Derek.** Citation measures of hard science, softscience, technology and non-science. In Communications Among Scientists and Engineers. Lexington, Mass, Heath. 1970.
- 20) **Groos, O. V.** Citation characteristics of astronomical literature. Journal of Documentation vol. 25 (1969) 344-347.
- 21) See for example **Zuckerman, H.** Scientific Elite: Nobel Laureates in the United States. New York, Free Press, 1977.