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*Report of*

*the*

# Colombia-U. S. Workshop on Science and Technology in Development

February 26-March 1, 1968

FUSAGASUGA, COLOMBIA

*VOLUME I*

NATIONAL ACADEMY OF SCIENCES
In Cooperation with the
COLOMBIAN MINISTRY OF EDUCATION

This report records the topics discussed and conclusions reached at the Colombia-U.S. Workshop on Science and Technology in Development held in Fusagasugá, Colombia, February 26-March 1, 1968. It is compiled from reports of session rapporteurs, as well as staff notes. The workshop was jointly sponsored by the National Academy of Sciences and the Colombian Ministry of National Education, under contract AID/csd 1122. This report will be presented to the Science Organization Development Board of the National Academy of Sciences and to the Agency for International Development, as well as to interested institutions in Colombia. This workshop is part of a continuing study and program of science organization and development in a number of countries, undertaken by the National Academy of Sciences.

Report of the

# COLOMBIA - U.S.

# WORKSHOP ON SCIENCE AND TECHNOLOGY IN DEVELOPMENT

Fusagasugá, Colombia
February 26 - March 1, 1968

Volume I

Report and Recommendations

Office of the Foreign Secretary
National Academy of Sciences

In Cooperation with the
Colombian Ministry of National Education

NATIONAL ACADEMY OF SCIENCES
Washington, D. C.

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Dr. Josué Muñoz (Administration), Director Institute of Sciences, Bogotá
Ing. Faustino Martínez (Reports), President, Colombian Association of Electrical and Mechanical Engineering Bogotá

# A G E N D A

## Monday, February 26

**SESSION I**
**4:00-8:00 p.m.**

**Chairman:** Minister Betancur
**Rapporteurs:** Dr. George Waggoner
Dr. Oliverio Phillips

Science Policy and Economic Development
**Speakers:** Dr. Harrison Brown
Mr. Carroll Wilson

## Tuesday, February 27

**SESSION II**
**8:30 a.m.-12:30 p.m.**

**Chairman:** Dr. Carl Djerassi
**Rapporteurs:** Mr. Keith Glennan
Dr. Jaime Sanín

The Need for a Colombian Science Policy for Science and Technology
**Speaker:** Minister Betancur

Current Educational Research in Colombia
**Speakers:** Dr. Aurelio Céspedes
Dr. Enrique Ruffat
Dr. Javier Arias

**SESSION III**
**3:00-8:30 p.m.**

**Chairman:** Dr. Stanley Cain
**Rapporteurs:** Mr. Hans Landsberg
Dr. Norton Young

Technological Problems in Agricultural Development

**Speakers:** Dr. Guillermo Guerra
Dr. Canuto Cardona

Non-Renewable Resources in Colombia
**Speaker:** Dr. Dario Suescún

Problems in the Development of Research

**Speakers:** Dr. Zven Zethelius
Dr. Ramiro Tobón

**SPECIAL SESSION**
**9:30 p.m.**

Advanced Technological Approaches to Education
**Speaker:** Dr. William Bollay

Wednesday, February 28

| | | |
|---|---|---|
| SESSION IV<br>8:30 a.m.-12:30 p.m. | Chairman: | Dr. Oliverio Phillips |
| | Rapporteurs: | Dr. Dwight Brothers<br>Dr. Faustino Martínez |

Technological Problems in Industrial Development

| | |
|---|---|
| Speakers: | Dr. Gabriel Poveda<br>Dr. Manual Carvajal<br>Dr. Rodrigo Uribe<br>Dr. Karl Folkers |

WORK GROUP MEETINGS
2:00-8:30 p.m.

1. Education

Dr. George Waggoner (Chairman)
Dr. Gabriel Betancur
Dr. Aurelio Céspedes
Dr. Carl Djerassi
Dr. Gerardo Eusse
Mr. Keith Glennan
Ing. Alberto Ospina
Dr. Jaime Sanín
Dr. Edward Schten
Dr. Ramiro Tobón
Dr. Zven Zethelius

2. Agriculture and Natural Resources

Dr. Joaquín Piñeros (Chairman)
Dr. Harrison Brown
Dr. Stanley Cain
Dr. Canuto Cardona
Mr. Hans Landsberg
Dr. Tulio Marulanda
Dr. Foster Montgomery
Dr. Jesús Ramírez
Dr. Dario Suescún
Dr. Norton Young
Dr. Robert Waugh

3. Industry

Dr. Rodrigo Botero
Dr. Dwight Brothers
Dr. Manuel Carvajal
Dr. Karl Folkers
Dr. Faustino Martínez
Dr. Luis Ospina

3. Industry (cont'd)
Dr. Gabriel Poveda
Dr. Rodrigo Uribe
Mr. Carroll Wilson

4. Policy for Science and Technology
Dr. Gabriel Betancur
Dr. Harrison Brown
Chairmen of work groups

Thursday, Febr ary 29

| | |
|---|---|
| 8:30 a.m.-12:30 p.m. | Preparation and Discussion of Work Group Reports |
| SESSION V | Chairman: Dr. Harrison Brown |
| 2:00-6:00 p.m. | Discussion of Work Group Reports and Approval of Recommendations |
| CLOSING SESSION | Chairman: Minister Betancur |
| 8:15 p.m. | |

Friday, March 1

| | |
|---|---|
| 11:00 a.m. | Meeting with President Lleras, San Carlos Palace |
| 6:30 p.m. | Reception by the Minister of Education |

# INTRODUCTION

The possibility of holding a series of science workshops in Colombia, similar to those sponsored by the National Academy of Sciences in Brazil, Peru, the Philippines, Nigeria, and Taiwan, was initially discussed in July 1967, when Dr. Harrison Brown, Foreign Secretary of the National Academy of Sciences, and Miss Theresa Téllez, Head of Latin American Affairs for the Academy, met in Bogotá with Ambassador Reynold Carlson, Mr. Harry Martin, Jr., Acting Director of the USAID Mission for Colombia, and other Embassy and USAID personnel. Subsequent talks were held with Minister of Education Gabriel Betancur, Minister of Agriculture Armando Samper, Dr. Edgar Gutiérrez, Director of the Administrative Department of Planning, as well as with scientists at some of the universities and members of the "MIT Club of Colombia" which included: Mr. Rodrigo Botero, Economic Adviser to President Lleras, Ing. Alberto Ospina, Director of the Foundation for Educational Development, and Dr. Oliverio Phillips, former Director of the Technological Research Institute.

All these persons emphasized the need to improve Colombia's scientific and technological capabilities. The Minister of Education offered to collaborate in the organization of a meeting of U.S. and Colombian scientists to discuss the problems and potential of science and technology in Colombia's economic development.

Ing. Alberto Ospina coordinated the arrangements for the Colombian participants, and in this connection was financially supported by

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Reference Center
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# SCIENCE POLICY AND ECONOMIC DEVELOPMENT

Harrison Brown
Foreign Secretary, National Academy of Sciences
and
Division of Geological Sciences,
California Institute of Technology

## Why Science and Engineering?

It is becoming increasingly clear that research and development have for a long time played an important role in the economic and social development of the technologically more advanced countries. The scientific-industrial revolution carried Europe far ahead of the rest of the world economically. More recently, we have seen industrialization and high per capita levels of production and consumption spread to the United States, to the U.S.S.R. and to Japan. In this process, research and development have given rise to a continuous flow of improved ways of accomplishing tasks.

The agricultural sector of the United States economy provides an outstanding example of the extent to which research and development can give rise to economic gains. Recent studies have demonstrated that returns on investments in agricultural research in the United States have been very high, averaging something like 100 percent per year over the last century, with returns on research on hybrid corn alone averaging perhaps as much as 700 percent annually. Over the last century Japan, also, has realized very high returns on agricultural research expenditures.

The rapid growth of the non-agricultural sector of the United States economy can by no means be explained satisfactorily solely on the basis of the accepted classical ingredients of economic growth: capital, labor and land. The missing ingredient is an element which has variously been called "innovation," "technical change," "scientific and engineering advance," "research and development," and "advances of knowledge" and almost certainly includes increased understanding of management methods and improvements in the education and training of labor. Although economists disagree among themselves as to the importance of this element, recent studies indicate that it has contributed over the years perhaps as much as 50 percent of the annual growth of the United States economy and possibly even more.

The poorer countries of the world have been slow to share in the flow of wealth which the scientific-industrial revolution has made possible. The reasons for this are complicated and only poorly understood, but it now seems likely that one of the reasons lies in the failure of the poorer countries to develop an adequate scientific base. The late Homi Bhabba, who did so much to develop science in

India, summarized the situation forcefully in 1966 when he said: "The problem of developing the underdeveloped countries is the problem of establishing modern science in them and transforming their economies to one based on modern science and technology."

Most of us recognize that the problem of the economic development of the poorer countries is enormously complex, requiring a multiplicity of actions. Agriculture must be modernized, roads must be built, resources must be surveyed and analyzed, factories must be designed and built, distribution systems must be established, schools and universities must be built, teachers must be trained, health services must be established and social and political institutions must be modified. Throughout the process leaders are called upon to make a diversity of complex and difficult decisions. All too often they lack the combination of wisdom and knowledge which is necessary if the correct decisions are to be made. Frequently the required knowledge, itself, is simply not available.

An economy which is based upon technology must be backed up by a substantial "problem solving competence" covering a broad spectrum of activities ranging from management to economics to engineering and science. This competence is necessary if solutions are to be obtained to development problems as they arise. All too many development plans either ignore or give low priority to this need.

The creation of an indigenous "problem solving competence" really means the creation of an ability to undertake research and development. It means creating the cadres of engineers and scientists who can apply their talents to development problems. It means creating the institutions which will enable the scientists and engineers to work effectively.

It is often stated that while it is true that research and development have contributed substantially to the economic development of the richer countries, the poorer ones can now solve most of their technical problems of development simply by importing the necessary technology from the more technologically advanced countries. If this were true, it would be unnecessary for the poorer countries to attempt to build up their own local scientific-technological competence. It is sometimes argued further that at the very least the poorer nations should postpone attempts to establish sophisticated national scientific establishments, including adequate research facilities and post-graduate training, until the development process is well under way.

The evidence speaks strongly against this view. For example, if technologies are to be imported, persons must be in the position of making informed, wise decisions as to the technologies which are most appropriate. Rarely are foreigners as familiar with the

problems of a country as are its citizens. Further, a given technology is usually designed for a particular physical-economic-social environment and is often inappropriate when transplanted to other environments. Under the circumstances it is frequently desirable to modify technologies as they are transferred. In addition, many of the problems encountered in the development process simply cannot be solved outside the environment in which the problems arise.

Here, agriculture provides us with the most obvious illustrations. The problems involved in learning how to grow crops in the Amazon basin cannot be solved in Europe or the United States. They must be solved in the Amazon basin. The Rockefeller Foundation recognized this principle when it assisted the Mexican government to establish a long range program aimed at increasing Mexico's agricultural production. The Foundation recognized that American technology could not be transferred directly to solve Mexican problems. However, agricultural problem-solving techniques which were developed in the United States could be transferred to Mexico and over a period of twenty years the joint effort contributed to an increase in average wheat yields from 11 to 37 bushels per acre. In the process, a cadre of outstanding young Mexican scientists and leaders was developed which now carries on a well-organized national agricultural research program.

In part as a result of the Mexican experience, it is now well recognized that an essential element of well-conceived national programs of agricultural improvement in developing countries is a program of agricultural research. This necessitates training agricultural scientists at home or abroad. It necessitates providing research institutions with adequate equipment and supplies. It necessitates the development of research leadership and the creation of an intellectual environment within which research can flourish.

These principles have been applied successfully to agriculture in a number of countries, yet, their application to other sectors of the economy has come about very slowly. In part this omission has resulted from an implicit faith on the part of planners that technology can be transferred intact successfully. In part it has resulted from a failure on the part of leaders to recognize that in such sectors as resources surveys and evaluation, industrial development, urbanization, transportation, communication and public health, problems will inevitably arise which must be solved locally and which are too numerous to permit them to be solved by specialists brought in from the outside.

It is often stated that the inadequate rates of per capita economic growth which are currently characteristic of the underdeveloped regions of the world arise primarily from inadequate domestic savings and inadequate transfers of capital from the richer countries to the poorer ones. In a very real sense this is correct. Yet we must recognize the fact that if by some miracle

the private and public capital available for investment in developing countries were suddenly greatly expanded (for example, doubled) there is serious question that the additional funds could be quickly put to effective use. As we have seen, there simply are not enough persons in these countries who possess the training and experience necessary to make the difficult decisions, to solve the large numbers of complex problems and to carry out the work of development itself. The extent to which this deficiency can be alleviated by utilizing trained persons from the technologically more advanced countries cannot be ignored, yet it is limited. We must face the fact that one of the most important rate-limiting factors in the development of the poorer countries will be the rate at which adequately trained persons can be produced. In the long run it seems likely that development rates will be limited more by shortages of the right kinds of people than by shortages of money.

## How many Scientists?

The present state of our knowledge does not permit us to estimate on an *a priori* basis the optimum numbers of scientists a given country should have as a function of time. Nevertheless it is possible to establish some principles to guide us in our estimates. Further, we can make use of the experiences of recently developed countries, in particular the Soviet Union, Japan and the United States.

Basically, the numbers of scientists and engineers needed can be estimated in terms of the development problems faced by the country. Here it is assumed as a working principle that *virtually all research and development efforts in a developing country should be aimed at solving problems closely connected with the economic development of the region*.

In the agricultural sector an estimate of the number of scientists required should take into account the area of arable land (including the area of potentially arable land, given irrigation, fertilizers and pesticides), the diversity of conditions of soil and climate, the population density (in terms of the area of arable and potentially arable land), the relative contribution of agriculture to the GNP, and the importance of agricultural exports to the economy. The agricultural research experiences of recently developed countries over the past century can be utilized to assess roughly the relative importance of these various factors and to estimate the number of agricultural scientists needed if the pace of research is to be commensurate with the need. The estimate obtained in this way will, of course, usually be very much larger than the number of agricultural scientists currently available. The next step is to assess the means by which the necessary numbers can be produced. In doing this three important questions must be answered: What resources can reasonably be allocated to this task?

What assistance can reasonably be expected from the outside? What is a reasonable time scale for achieving the goal?

Similar estimates can be made in other sectors. The numbers of scientists needed for fisheries research will depend upon the length of coastline and upon the need for products of the sea. The numbers needed for health research will depend upon the population, the diversity of serious health problems and the relative importance of health problems as inhibitors of economic and social development. The effort that should be placed upon industrial research will depend upon the total capitalization and diversity of industry in the country.

It is perhaps useful to consider a specific example, geology, in more detail. The number of geologists, geophysicists and supporting professional workers should be roughly proportional to the area of the country, modified of course by the diversity of geological conditions. In 1966 there were approximately 20,000 geologists in the United States, corresponding to about 2,600 geologists per million $km^2$. Experience indicates strongly that this is not a "luxury" population. Since 1952 the "doubling time" for geologists has averaged about 18 years.

Let us now compare the U.S. population density of geologists with population densities in selected Latin American countries:

| Country | Number of geologists per million $km^2$ (1966) |
|---|---|
| Brazil | 94 |
| Mexico | 127 |
| Chile | 143 |
| Peru | 240 |
| Colombia | 254 |
| U.S.A. | 2,600 (1966); 1,500 (1952) |

Without refined corrections involving the geological complexities of the regions, it seems that in most Latin American countries, the numbers of well-trained geologists should be increased 10-20 fold. Clearly such a great increase cannot be achieved instantaneously. When we consider that a generation is required to educate a scientist, it would appear that a doubling time of ten years is not unreasonably long. This would mean that times of the order of 30-50 years might be required to increase the number of geologists to adequate levels.

It is important to note that, using the guidelines discussed above, as development progresses the total research effort will increase and the relative research emphasis will shift. In a nation which is predominantly agricultural, most research effort would be directed at agricultural problems plus health, public works and resource surveys. As capitalization of industry increases,

investment in industrial research and development would predominate when the country becomes highly industrialized.

How Many Engineers?

Needs for engineers, like needs for scientists can best be estimated in terms of problems and requirements in individual sectors of the economy such as agriculture, food technology, transport, communications and industry. As in the case of estimating needs for scientists, good use can be made of the experiences of recently developed countries.

The number of engineers in the United States has increased from about 50,000 at the turn of the century to over 800,000 in 1960 and to an anticipated 1,100,000 in 1970, corresponding to about one engineer for every 200 persons in the population. Until the middle of the century the ratio of engineers to scientists remained remarkably close to three. Since 1950 the ratio has been dropping and is now approaching two, a phenomenon which requires careful analysis, but might indicate that in the earlier years the amount of research being undertaken was below that required for optimum progress in terms of the total available technically-trained manpower. In retrospect, it seems extremely unlikely that the United States had an overabundance of engineers.

The total population of scientists and engineers in the United States increased from about 0.4 percent of the non-farm labor force in 1900 to about two percent in 1960 and the proportion is still increasing exponentially, a clear indication of the rapidly increasing technological complexity of our society. There appears to be a marked relationship between this proportion and the proportion of the labor force engaged in non-farm activities—also an indicator of the level of technological complexity of the society.

Were developing countries to attempt to follow the U.S. experience, the "required" numbers of engineers and scientists would amount to no more than about 0.1 percent of the non-farm labor force, considering the relatively small proportion of the labor force which is engaged in non-farm work in most of the areas. This almost certainly should represent a lower limit for the immediate goals of such countries. In the first place, the levels of technology which developing countries are attempting to deal with are considerably more complex than the United States had to cope with in mid-nineteenth century. Secondly, the poorer countries hope to develop at a more rapid pace than did the United States. Thirdly, we must remember that the scientific-engineering establishment in the United States "just grew" without any effort being made to plan for its growth. In retrospect it seems likely that prior to World War II we had too little research. Had we had more research and development, there would probably have been a correspondingly greater demand for engineers to transform laboratory and pilot-plant findings into economic reality.

In view of these considerations, it would appear that reasonable immediate goals of the poorer countries should be to create cadres of engineers and scientists corresponding to about 0.5 percent of the non-farm labor force, with the longer-range goal being to increase this proportion to about two percent. The precise goals would, of course, be determined by a careful sector-by-sector analysis.

Finally, we should note another development in the United States and elsewhere, which is of particular importance to developing countries. During the last few decades there has been a marked increase in the proportion of business executives holding degrees in science and engineering. In 1900 only seven percent of executives were scientists and engineers. By 1964 this figure was 33 percent, almost a five-fold increase. As a corollary there has been a marked decrease in the proportion of executives with backgrounds in banking and law—again, an indicator of the increasing technological complexity of the decisions which must be made.

Clearly, developing countries should train scientists and engineers not only to engage in research and development and in traditional engineering activities. They should also train them with the idea that a significant proportion will eventually hold executive positions in industry and government.

## How Much Research and Development?

The total cost of a nation's research and development effort, both private and public, can be estimated in terms of the estimated numbers of scientists required. The total cost will depend upon a number of factors, the most important of which are:

1. Salary, which is related to the salary structure of the country.
2. Cost of research assistants and other helpers. Again, this is related to the salary structure of the country.
3. Cost of the physical plant, which is again in large part related to the salary structure of the country.
4. Costs of equipment and supplies, which are proportional to the numbers of scientific workers. In view of the fact that most supplies and equipment, including books, must come primarily from outside the country the question of foreign exchange and foreign assistance will be an important one.

The problem of salary scales of research scientists and engineers is of the utmost importance. Salaries should be high enough to make it unnecessary for research personnel to hold more than one job. Salaries should also be high enough to make the research profession a prestigious one, thus stimulating qualified secondary school and university students to elect science or engineering as their professions. Lastly, salaries should be high enough to

discourage emigration of highly trained scientists and engineers to the technologically more advanced countries.

There is little point in going through the expensive process of training research scientists unless there is a clear-cut policy to support their research adequately. They should be provided with adequate laboratory facilities and help. Foreign exchange should be made available for the purchase of equipment and supplies. Facilities and personnel should be available for equipment maintenance. Well-stocked and well-run te hnical libraries are essential. Administrative help should be available to expedite orders, repairs, deliveries and to minimize, simplify or circumvent "red tape" which all too frequently slows or even stops research progress.

In the United States a useful "rule of thumb" is that an annual expenditure equivalent to a research scientist's salary is required to pay for his equipment, supplies and general support. This does not include the cost of the physical plant or the initial cost of the technical library. This proportion might well be considerably larger in developing countries primarily because most of the equipment and supplies must be purchased overseas.

Once a total research and development budget has been estimated using guidelines such as those discussed above, it should be modified to take into account the diversity of competition for scarce resources. Even when the severe demands placed upon the available resources by the various sectors of the economy are considered it seems unlikely that a knowledgeable evaluation of research needs will give rise to a recommendation for research and development expenditures much less than one percent of the GNP, at least in the majority of the poorer countries.

Today the more technologically advanced countries spend between one and three percent of their GNP's for research and development. The proportion currently spent by the underdeveloped countries is generally at least ten-fold less.

## How Much Basic Research?

The experiences of recently developed countries indicate that if applied research is to flourish a finite porportion of the national research effort should be devoted to "basic research," i.e., to research which is undertaken for its own sake and not oriented to any particular practical goal. If it is agreed that this principle is a sound one, the question then arises as to what proportion of the national research budget should be allocated to such activities. At one extreme there are nations in which basic research is looked upon as a luxury and practically no support is given. At the other extreme there are some nations in which considerable high quality basic research is undertaken but where there

is virtually no research aimed at solving the problems of the country. Both extremes are unhealthy.

It almost goes without saying that the quality of applied research, no matter whether it is sponsored by government or industry, is dependent upon the quality of education received by the research scientists. An integral and essential part of the education of a scientist is active participation in research of high quality and in its corollary activities: the free interchange of exciting ideas, exposure to uninhibited criticism by one's peers, exposure to criticism by the international scientific community. Even at the undergraduate level it is important that students be exposed to the excitement of research.

During the initial phase of the development of a viable national research and development activity, young scientists-to-be will receive their graduate education outside the country, perhaps in Europe or in North America. But every effort should be made to establish indigenous programs of graduate education as quickly as possible. This means that research programs of high quality must be started in the universities.

Generally speaking most basic research should be undertaken in the universities. There is nothing against applied research being undertaken in the universities also, but the greater part of a nation's applied research efforts will take place in government and industrial laboratories established for this purpose. But one of the primary responsibilities of the university is to nourish basic research so that it truly flourishes.

With respect to basic research activities in the universities of developing countries, it is important to remember that the world scientific community does not tolerate a double standard in science: one standard for the advanced nations and another for the underdeveloped ones. In basic science there is only one standard: a world standard. So when a program of basic research is started in a university, it is important that it be of as high quality as a comparable program in any of the advanced countries.

In general if a given program of basic research in a university is to be viable and of high quality it must be provided with a number of elements:

1. There must be a "critical mass" of scientists of high calibre who can interact with one another.
2. The scientists should not be isolated from the outside world. There should be frequent contact with scientists in the same field from the technologically more advanced countries.
3. There must be adequate, steady, predictable support for help, equipment and supplies.
4. There must be adequate research facilities.

If any of these elements are missing, the program in all likelihood will fail. But by far the most important ingredients will be the scientists themselves. Some of them might be young persons who have been sent abroad for their graduate training. Others might be young scientists from the more advanced countries who are willing to spend a few years in a developing country under the right circumstances helping to build a research program.

From the point of view of maintaining contact with the outside world, in many cases it will be desirable for a research group to establish a long term working relationship with a corresponding group in one of the more advanced countries with which it can exchange professors and graduate students on a continuing basis. In the few cases where such relationships have already been established the programs have been very successful.

Confronted by scarce resources available for basic research it is essential that great selectivity be exercised in choosing the universities and the research areas in which graduate education will be developed. Initial efforts should be concentrated on a very few institutions of highest quality. With respect to areas of effort it would appear desirable to avoid fields of inquiry which have particularly high capital costs per unit of research output (e.g., high-energy physics). Some preference should be given fields where the environment in the country offers unusual research opportunities (e.g., geophysics in Peru or the chemistry of natural products in Brazil). Also, preference should be given fields which have some relevance to development efforts (e.g., solid-state physics if an electronics industry is being planned; organic chemistry if pharmaceuticals are to be manufactured; geology if mineral potential is high).

Concerning the level of support of basic research activities, we should take the view that, in the light of their importance for the development of higher education, they should be given all possible support consistent with the concept that the prime national research and development objectives are practical ones such as agriculture, resources, health and industry. In other words, as many high quality research persons as possible should be permitted to devote themselves to basic research without greatly detracting from the needs presented by the major practical problems. Reduced to quantitative terms, an allocation of one percent of the total national research and development budget for basic research would be too little. An allocation of 50 percent would be too large. Something in the neighborhood of 10 percent would appear to be about right.

How Large the Growth Rate?

Since the beginning of this century the population of scientists and engineers in the United States has doubled about every 15 years. In the U.S.S.R. by using planning coupled with rigid controls, research and academic personnel increased at about the U.S. rate between 1940

and 1950, in spite of the disruption of war. Between 1950 and 1955 the doubling time was 11 years and between 1955 and 1960 the doubling time was eight years.

The reduction of the long-term doubling time for the production of well-educated research scientists to much below the ten-year level appears to be an extremely difficult task. One can conceive of short-cuts, particularly in the early stages when a fair proportion of the graduate training can be obtained overseas. But in the long run, it could appear that a doubling time of about ten years is about the minimum that should be considered for planning purposes.

We must keep in mind that it takes about 25 years to produce a competent scientist or engineer, for the process really starts in the home. Psychological studies of successful scientists and engineers suggest that such factors as the parents' occupation, the socio-economic status of the family, the attitudes of the parents toward intellectual knowledge and the parent's own educational attainments are significant in determining whether a child will be inclined to enter science as a profession.

Given a family environment conducive to science, other influences which lead to success or failure in the making of a scientist or engineer include early identification, encouragement and training. The child's interest can be deflected at many points in his development. The way in which science and mathematics are taught at the elementary and secondary school levels, and the enthusiasm and understanding of the teachers can have tremendous influence. Often teaching procedures and course requirements deaden any interest the student might once have had.

These difficulties are cited in order to emphasize that a government which desires to expand rapidly its cadres of scientists and engineers will be confronted by problems which greatly transcend those of developing post-graduate education in science. Competent teachers must be trained to teach science and mathematics in the primary and secondary schools. Effective course curricula at those levels must be formulated. Extracurricular activities, designed to excite the interest of young people in sciece must be developed.

When we examine these requirements it becomes clear that the creation of a substantial research and development competence in a less developed country necessitates a long term, sustained program at all levels of education. Great effort must be expanded if doubling times as short as ten years are to be achieved and maintained.

## Government Organization

If science and technology are to grow in the less developed countries at rates commensurate with the needs, it is essential that

governments establish policies and mechanisms which will provide for adequate scientific-technological advice at the highest levels, which will also provide for the necessary financial support and which will facilitate adequate coordination between responsible agencies of the government and the sectors of the economy. We have seen that the problems of developing a national scientific-technological competence are so enormously complex that virtually all levels of government as well as a substantial part of the private sector must be involved. Under the circumstances, except in the situation where the development of science is but in its infancy, no single governmental mechanism will be adequate.

It is essential that whatever the form of the governmental mechanism, it provide for:

(a) Advice at the highest levels of government concerning the problems and opportunities involving scientific-technological development.

(b) The means whereby science and technological change can be adequately taken into account in national economic planning.

(c) Mechanisms which will enable each government agency to undertake or sponsor research which is relevant to its mission.

(d) Mechanisms which will ensure that industrial research of importance to the national economy will be undertaken either within the private sector or by government-operated laboratories established for the purpose.

(e) Means for ensuring that the results of applied research are used to improve the effectiveness of operations and the efficiency of production in the various sectors of the economy.

(f) Means which will enable adequate government funds to be channeled selectively to scientists in the universities for the support of their research activities, both basic and applied, on a continuing basis.

(g) Establishment of post-graduate education in all areas of science and engineering relevant to national economic and social development.

(h) Strengthening of science and engineering education in the universities at the undergraduate level.

(i) Development of adequate curricula and teaching methods in science and mathematics in the primary and secondary schools.

(j) Means which will ensure that the limited available resources are allocated to these various activities on a national basis and which will enable the multiplicity of efforts to be coordinated.

(k) Mechanisms which will enable the non-governmental scientific-engineering community to criticize government programs constructively and advise the government about needs and opportunities in research and education.

A wide variety of governmental organizations can be conceived which, at least on paper, will fulfill these needs. The choice of the most suitable will, of course, depend upon many factors including the size of the scientific establishment, the level of scientific development, the nature of the economy, the nature of the university system and the basic organization of the government itself. The ways in which these problems are handled in the U.S.S.R. are not necessarily the most useful approaches in the United States. The most appropriate science organization for Brazil is not necessarily the best one for Peru.

Above all it does not seem likely that any one organization can fulfill the total needs of a given country for very long. Something like a "research council" which can channel government funds to worthy research projects would appear to be essential. Some kind of a scientific advisory committee at the highest government level would also appear to be essential. It is important that there be a governmental group which can coordinate research undertaken or sponsored by government agencies. Some group must pass judgement on the distribution of allocations to agencies for research and development.

Often the most important governmental functions with respect to science can be combined in a single agency. But other essential activities simply cannot be undertaken within the framework of government. In some cases an "Academy" which is close to government but not a part of it, and which can criticize programs and make suggestions for future activities freely, is desirable. In some cases an "Association for the Advancement of Science" can effectively undertake programs which educate the public as to the importance of research and development.

The most effective "mixture" of organizations will vary greatly from country to country and will also vary with time. Each nation must select and support that mixture of governmental and non-governmental structure and activities which it believes will come closest to fulfilling its needs.

# COMMENTS ON THE NEED FOR AN OVERALL POLICY FOR SCIENCE AND TECHNOLOGY IN COLOMBIA

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## Introduction

The scientific and technological development of a country has been established worldwide as one of the key elements to the achievement of an accelerated economic and social develcpment. It is, therefore, quite obvious why the countries of the world are now devoting so much attention to the internal promotion of science, and why efforts are being made to analyze ways of speeding up the organization of science and technology.

In view of the shortage of trained personnel and adequate financial resources in the developing countries, it is obvious that government participation must be provided for in order to coordinate all of the efforts being made in connection with the development of such important sectors as agriculture, industry, services and utilities, etc. This basic problem was stated by the U.N. Advisory Committee on the Application of Science and Technology to Development. ". . . Every government must have a clearly defined policy in matters of science and technology. This policy must be geared to the achievement of an autonomous and self-sustained national scientific growth and it must also be directed toward the organization and planning of national scientific activities, in support of economic and social development, through the application of science and technology. . . ."

On this basis, we would like to present some comments on what the science and technology policy of Colombia should be and on the way in which the scientific and technical effort can be developed in this country.

## Definitions

We might begin this presentation with some general definitions to which we will refer later. By "scientific policy" we mean all of the measures taken by a country in an effort to develop and strengthen its skilled and trained scientific manpower, its institutions of research and higher education, and its scientific and technological information and dissemination system. By the term

"human resources"—for the purpose of this discussion—we mean personnel including scientists, engineers, and technicians and, especially, persons in full-time research. The group of research institutions includes here any group of qualified individuals engaged in a continuous and organized effort. Finally, by "information systems" we mean professional societies, technological institutions, agricultural technology or industrial extension organizations, documentation centers, and technical libraries. We will consider not only the technical and scientific activities carried out by personnel within the particular agency or organization but also their functions as dissemination media with respect to the external (foreign) community.

Status of Scientific and Technological Development in Colombia

Through each of the factors mentioned above, it is possible to establish what might be called the development of science and technology in a country. The number and the quality of scientific personnel, the proportion involved in research, the articles published in international journals, the level of university education, the equipment available for research, the general investments in research, the status of scientists, the level of professional activities in the country—these are the indexes which can be used to measure the country's scientific and technological development. In addition, the annual or longer-term variations in these indexes are a clear indication of the quality of the general system.

In the case of Colombia, these indexes are unknown mainly because no one has made an exhaustive analysis of the entire scientific and technological situation. Moreover, we have not carried out a thorough analysis of all research institutes, all of the personnel of these institutes, nor have we gone into long-term research program planning or projects.

Internationally, an attempt has been made to establish a correlation between the indexes of scientific development and the economic indexes. It is now rather commonly accepted that investments in research can be correlated with the GNP of the particular country. A number of regional meetings has emphasized the need for establishing a minimum initial investment of 0.7-1.0 percent of the GNP for the development of a scientific policy. (Personal estimates of the case of Colombia indicate figures of slightly over 0.1 percent of the GNP.) Even if we do not go into a thorough discussion of the real significance of this broad range or difference, it seems clear that there is a critical deficiency between the current effort and the levels in countries with a similar development condition.

A second general index involves the number of professional men per 1,000 inhabitants. In the case of Colombia, this ratio is

8/1,000, compared to figures of 2 for Argentina and 1 for Brazil. Although these indexes are rather sketchy, they tell us very clearly that the scientific and technological development situation in this country still leaves much room for improvement. I do not want to go into an analysis of the number of articles published by Colombian authors in foreign journals of recognized international prestige since we would find only a few, in a few fields, perhaps in the medical sciences, in botany, and biology, where a few individuals turn up in the scientific literature each year.

I have tried to outline this situation because I believe that the best thing this meeting can do is to analyze the situation as it really is at this time and to discuss ways of altering this situation in a minimum period of time, in accordance with our capabilities. We do have trained people in this country, and we also have a younger generation that is full of hope. If we organize ourselves properly we will be able to establish means to facilitate the accomplishment of a true scientific effort in our country. Furthermore, the current situation underscores the urgent need to launch a government and private policy aimed at this objective.

Organization for a Science and Technology Policy

Two essential elements are necessary for the implementation of an effective policy. One is that the country must have an organization that will establish the general foundations for the personnel to be trained, the research activities to be developed, the financing required, and the institutions that must either be created or strengthened. It will be the mission of that organization to cover the entire national scene in terms of science and technology and to contribute to the definition of specific programs. The second element comprises the groups that must carry out the research, obtain the necessary funds, and implement prior recommendations. This element will include not only the scientific community but also the industrialist, the farmer, and the researcher.

The first element is generally developed through a centralized group in the form of a science and technology council, a government division, or, in some cases, even a science and technology ministry. In the case of Colombia, the government is studying the establishment of a council which might consist of executive representatives from the government, leading researchers, university representatives as well as representatives from industry and agriculture. This group would not be very large in terms of numbers and it could be advised by specialized groups for each of the disciplines that might be required to prepare a realistic analysis of the country. Obviously, if it is to accomplish anything positive, this council must have a limited but highly capable structure so that it will be able to coordinate the information obtained. In addition it will have to obtain the basic data to enable it to adopt the necessary decisions.

In general, these councils in Latin America have concentrated primarily on training scientific personnel abroad and subsidizing of national research. In our case it would also be necessary to analyze the future development of the country and work out solutions for gradually closing the technological and scientific gap in our development. In addition, it will be necessary, in conjunction with the national economic planning group, to carry out studies which define new fields of technology in which activities should be initiated in this country, in accordance with economic and social development programming. ICETEX is doing tremendously important work in Colombia in connection with training and could assume a large portion of the administrative management of studies abroad. However, the council will have to recommend fields in which a major intensification of the training effort may be necessary and it would have to establish priorities among those fields.

Finally, the council will have to perform a function which will become increasingly important as regional integration progresses; it will have to act as a channel for relationships in the field of science and technology with the countries in our own area and with countries on the other continents. The exchange of trained professional men among our Latin American countries, visits by professors from more developed countries, and contacts with engineers and scientists throughout the world will increasingly constitute the key element in the achievement of true progress. On the other hand, we must keep in mind that such integration can be achieved not only through commercial agreements and the movement of physical products, but also through very close contact among Latin American leaders among whom professional men in sciences and engineering will perform an important mission. This council will also serve as a liaison between the professional communities of countries such as the United States and our own country, through a continuous effort along these lines.

## Implementation of a Science and Technology Policy

The second element of the program, the performance of research work, training, the dissemination of information, will have to be handled by the existing institutions in the country. However, the experience of various countries has shown that the government must give direct aid in order to speed up the rate of scientific and technological growth. Even the United States requires government assistance in this respect, although for reasons different from those that obtain in Colombia. In the United States this aid amounts to something like 50-60 percent of all of the research work being done. For this purpose, it is necessary to establish a fund through international credit institutions. The initial amount of this fund would have to be discussed with the institution. The fund would of course be used for the development of programs which, in the judgment of the national council, have a critical effect upon the establishment of an effective research and expansion effort in the country.

If the council consists of a majority of individuals with proper training and prestige throughout the country, we can be sure that the use of these funds will accelerate our scientific and technological development to an extent that we currently cannot imagine.

A periodic program review, conducted by independent individuals and an analysis of results obtained in the various programs and projects will make it possible to judge the quality of the decisions that have been made. If the program is sufficiently flexible to allow the introduction of changes which are considered necessary, it will then be possible to speed up the action of existing groups, without any need to introduce substantial modifications into the long-range plans.

In Colombia we now have institutions such as the Technological Research Institute (IIT) in the field of technology, the Nuclear Affairs Institute, the various research departments of the universities, medical research institutes, and the research sections of some of our industries. One of the concerns of our future scientific policy will be the best possible utilization of this existing complex of facilities. However, we must keep one thing in mind that is often overlooked, that these institutions cannot take action far beyond the capacity of the persons who constitute them. It is therefore essential to establish measures which will permit scientists to devote their time completely to their work, in an independent fashion, free of economic worries. Society must therefore give recognition to those who have contributed to the development of a better country through their efforts. It is necessary to analyze the salary levels, to promote subsidies for researchers and professional men who carry on programs of great importance to the nation, and finally, to avoid a situation in which our scientists are more or less cut off from worldwide science and technology development. Only through a comparison of our knowledge with that of the more developed countries and other developing countries will we be able to determine which new elements should be adapted in the country and what modifications we must make in our systems of operation. In recent years, limitations on travel have affected participation in international meetings and contact with foreign scientists, with the result that the professional community, with some exceptions, is losing contact in rapidly changing fields.

All the measures mentioned above will, of course, have to be integrated with the country's economic and social development plans. For this reason, joint groups of scientists and economists should analyze the primary requirements of research to determine which fields should be given major attention in terms of research, which institutional elements should exist, and what kind of cooperation we should have between science and technology, as well as university planning.

To date, the country has not included in all of its plans sufficient elements capable of relating science and technology to development in general, in other words, capable of presenting science and technology as an integral element of planning. Over the next several years, it will be necessary to carry out studies covering all of the activities of our scientific supporting structure as well as of the plans presented by the Planning Department. Here we should discuss the general outline and scheme to be followed as well as the possible utilization of the results obtained. It is necessary to have a general frame of reference within which we can establish priorities, either in terms of fields or in terms of economic and social objectives.

It should be stressed that through this kind of planning effort, the government attempts only to achieve general coordination between the official research agencies and to define the aspects that should be promoted specifically, with respect to direct financing. This policy is not presented as a straitjacket for science or for the researcher, who must of course maintain his independence to pursue research in various fields. However it is the obligation of the government to channel its limited resources to those fields and projects which offer the greatest possibility for social and economic improvement.

We must also establish a research methodology. The true study of research procedures, administration of research, and selection of research projects in accordance with the goals to be achieved was launched only about a decade ago. We must analyze ways to promote seminars on these aspects in the country, in order to eliminate costly errors in studies whose importance may appear very great, but which, in fact, would not have a genuine impact upon our national situation.

## Financing

We are quite aware that one of the decisive elements in the success of the activities proposed here will be the adequate financing of these activities. The government is prepared to study its participation in this undertaking in conjunction with private initiative, with the international credit organizations, and with the contribution of the necessary counterparts. But the government is also aware that a major aid program must be based on prior studies that justify it; and these studies must indicate clearly the reasons for the selection of the various projects to which major attention is to be given. We believe that research, like education, is an investment; and we are prepared to evaluate means whereby we could promote an expansion of the private effort, either through tax incentives or through special financing terms, which you may indicate.

In view of the limited resources, we believe it will be necessary to analyze the way in which research activities can be

concentrated in specialized units or institutions so as to cover a specific field in sufficient depth. We must avoid duplication of effort and excessive dissipation of research, and we must not in any way interfere with the individual creative spirit. For this purpose, we must analyze the systems that presently exist in the country in order to establish contact between researchers in a particular field, in order to determine what information in scientific or technical magazines provides knowledge on the activities of the various institutions, and to determine how we could create or supplement this communication in the country. One of the most effective elements in speeding up the scientific advance of countries such as the United States has been the close connection between men of science and the "cross fertilization" action between groups with different interests. Modern science cannot be conceived as a series of compartments; we must recognize its universality and tackle problems through the combined efforts of the natural and the social sciences. How to achieve this goal will be one of the points we must discuss here.

We must also study together the experience of Colombia and other countries with systems that assure continuous and growing financing for science and technology programs. The success of SENA in obtaining funds through fixed contributions by Colombian enterprises is well known. Argentina has been able to obtain adequate financing for its agricultural research programs through a 0.2 percent tax on its exports in this field. Argentina has also developed one of the broadest networks of technological assistance through fixed participation from all industrial loans granted by the industrial bank, amounting to 0.25 percent of these loans. We would also like to see voluntary private participation in our scientific policy programs because that contribution must supplement official funds. The experience in the great country to the north will be very important in casting further light on this point.

We have great hopes for the Inter-American Science and Technology Program to be developed through the OAS, as direct aid to research and development and to scientific policy in the various countries of the region. This program was created by the presidents at the historic Punta del Este meeting, and will be carried out with the help of the government of the United States, which is a member of the OAS. We believe that other private and official sources throughout the world will channel their resources toward this program when it is launched. With the approval of President Lleras, the government has submitted the proposal of the Institute of Scientific and Cultural Integration, which is presented to this meeting as one of the working documents. This program will be developed in conjunction with the Colombian university and with other countries in the area, and constitutes one of the first steps in our national scientific definition efforts. The government has already pledged a sum of US$387,500 to support the Inter-American

Science and Technology Fund and we are confident that we will receive the necessary support for our proposals here in the near future.

Scientific and Technological Information

One of the aspects to which we must pay special attention is the establishment of efficient mechanisms for access to the accumulation of existing knowledge, primarily in the developed countries. This information, both in science and in technology, must be within reach of investigators and researchers, industrialists, as well as higher education centers, etc. The country must develop a scientific information and technological data transmission center. It must have centers specialized in scientific information, facilities which will be able to supply rapidly photo copies or microfilms of international literature. Several international documentation centers have offered us their collaboration but so far we have not had a nucleus through which this effort could be channeled.

This function must be more than a passive one. It should be promoted among possible users of these services, either through translations or in the form of copies, abstracts, proceedings, patents, etc. Some of the centers now existing in other countries have specialized in the industrial sector, as a service for those institutions without enough information of their own, such as small industries, individuals, and so on. It would certainly be worthwhile to try to determine whether Colombia should also consider the agricultural sector and perhaps others.

Parallel to this information function, we must have a coordinated effort aimed at the adaptation of foreign technology to Colombian conditions. Very frequently, industries developed in this country are copies of other industries that have sprung up in entirely different economic and social environments. The difficulties in these cases are frequent and lead to appreciable economic losses. Do we have a suitable mechanism working in this direction in Colombia? The work done by the IIT, the university research sections and the industry research facilities have been decisive factors in our incipient national technological development. We must ask ourselves whether this is sufficient, whether this ought to be modified, and whether we are actually covering all of the areas that are really important to the country's future. Perhaps we might also ask ourselves whether we are making adequate use of what we now have, whether we might find some of the previously-mentioned institutions among the possible users. The country is now beginning to see the benefits of agricultural expansion all over the nation, an expansion which has been achieved by the Ministry of Agriculture, the ICA, and private and semi-official agencies, but we cannot yet see a similar effort in the field of industry.

Finally we must analyze the obstacles to the adaptation and employment of knowledge in the country. We frequently note that

the patent system prevents many processes from being utilized for the benefit of national industries—but has anyone studied this problem thoroughly? Should we modify our attitude in this respect? The government has carried out various studies, particularly in the chemical and pharmaceutical field but this has not been a broad effort. In this sense, we must remember that the country requires specialized groups which work on the threshold of scientific and technological development. In the beginning this will not be large-scale; but it is the only way in which we can develop a future system which will be homogeneous and which will not depend on foreign sources for its vitality.

In carrying out these functions, we will depend to a decisive extent on the collaboration of professional, scientific, and engineering associations, through their specialized groups, through the dissemination of knowledge, as well as the promotion of activities that will keep our scientists and technologists up to date. In this respect, there has been an erosion of knowledge, characteristic of a time in which the average life of a product is perhaps no more than 10 or 15 years. The basis of any policy will depend on the effectiveness of the means which we will develop in order to avoid professional obsolescence in the country.

Utilization of Colombian Manpower

This is one of the most important elements in any science and technology policy. We must determine not only whether all of our professional men trained at the universities meet our requirements for development but also whether the professional graduate is offered sufficient opportunities in the country to expand his knowledge effectively.

It is here that the government sees a need for preventing, to the greatest possible extent, the emigration of our best trained scientists abroad after we have made a tremendous economic sacrifice in terms of foreign currency. The strengthening of our institutions that could absorb these graduate scientists, the continuity of our research programs, and the recognition of research quality are some of the aspects we must discuss here. We would like to hear your recommendations on the creation of personal motivation systems, such as subsidies, national prizes in sciences and technology, and perhaps, most important, the creation of a national awareness that the entire field of science is one of the most important weapons in the struggle for development.

## WHAT IS THE STATE OF EDUCATIONAL RESEARCH IN COLOMBIA?

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### The Concept of Education Research

In order to narrow the terms of reference of this theme, we will try to establish a specific definition of what is understood by education research.

It can be noted that, in general, there has been a change of attitude towards research. It is recognized today that research is a necessary element in every process of production, distribution and consumption. The industrially-advanced countries have introduced new productive technologies, thanks to a permanent process of scientific research on methods and procedures of production. Administrative organization, public and personnel relations, procedures and machinery, market analysis and time and motion studies are all areas in which scientific investigation has a formidable field of application.

In the area of social advancement, a process of experimentation, similar to that in the fields of technology and production, has been occurring. It would take a long time to enumerate all the studies of national and international agencies which have already been made, or those done in the social sciences where research is considered of enormous importance in the formulation and evaluation of social advancement policies.

Social progress and research can no longer be conceived as isolated concepts. On the contrary, the process of social change is being observed scientifically, with the objective of identifying its direction, dynamics and meaning, as well as the variables of major importance which affect its evolution.

Consequently, it seems quite natural that education research should also undergo profound change, expanding its areas of investigation and refining the methodological analysis of educational problems. This has motivated a change of attitude in the educational investigator and has enlarged his functions.

Education research in Colombia has been characterized by the study and presentation of quantitative data, such as the actual characteristics of the population: number and distribution of ages, sexes, principal occupation, and level of education and illiteracy. Similarly, the buildings and school services, the school population, matriculation, absenteeism and promotion, data

about the number of teachers, their level of training etc., have all been studied; and we know, in general terms, their magnitude and deficiencies.[1]

Administrative and budgeting aspects are also equally important in education research.

This analytical examination of the major "microeducational" variables has been in certain cases complemented by future projections, including estimates of deficits and the level of resources needed to satisfy demand.[2]

What seems debatable is whether this type of educational research, "descriptive" or "informative," has produced changes of plans, programs and major directions in education.

The compilation of data to determine the efficiency or inefficiency of educational changes, or to investigate the variables which intervene in the process of education can hardly be called "research." Although there has been some attempt to understand the state of education research in this country, and some concern about research on the part of various high-level educational institutions, education research is still clearly in an embryonic stage in Colombia.[3]

Analyzing the problem further, it could be said that the scientific study of the nature, and of the real technical value of the relation between educational services, their administration and function, and the general aims to which they are addressed, have been underestimated. It has not been scientifically determined whether education is responding to the actual needs of the country in its rapid technological and cultural advance.

Nevertheless, some scientific works must be mentioned, despite the fact that this investigation cannot be included within the context of education research concept that we are attempting to analyze here.

The analysis of the correlation between the socio-economic levels of pupils and their academic performance, and the performance of the university student based upon his admission examination, has been accomplished by two independent researches.[4]

Consequently the necessity arises to elaborate studies which transcend the descriptive area and introduce analytical research on education, converting it into an integral instrument of economic and social growth, and assuring a high quality system which can adapt the educational process to the needs of the country.[5]

In summary, one can tentatively define education research as a process which includes, not only descriptive analysis of variables

which influence education, but also systematic study of the effects of other variables which are part of the curriculum, such as methods of teaching, contents, audio-visual aids, attitudes of the teachers, the learning of the pupils in accordance with the objectives of education, and their standards and aspirations.

The scope of this definition is easy to appreciate: based on results already obtained it is possible to establish simple methodological bases for education planning with a direct correlation between educational activity and the goals of a social, political, cultural and economic advancement to which the nation aspires.

Conceived in these terms, education research appears as an integral and complementary activity of educational statistics, and its function goes beyond the simple descriptive concept previously mentioned.*

Obstacles and Limitations in the Advancement of Education Research

Education research has been restricted in underdeveloped countries. It is said that there has been little imagination in the advancement of methods, curriculum, equipment, texts, buildings and administration, required to meet the challenge of the rapid and sustained demographic growth of the region.

In the case of Colombia, this phenomena is explained when one realizes that the rapid process of social and economic advancement of the country involves the formidable problem of adapting to new national circumstances totally different from traditional ones.

This means that major attention has been given to the most urgent problems, such as the demands of matriculation, building

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*It is interesting to note that the Office of Planning Coordination and Evaluation of the Ministry of Education created by Decree No. 206-2351 of 1957, and reorganized in Decree No. 1937 in 1960, within the Section of Institutes of Scientific Research, would have initiated an inventory of scientific investigations underway in Colombia, and for which it intended to organize the National Council of Scientific and Cultural Investigations, and a National Center of Scientific Documentation. Similarly, they intend to publish annually a Guide of Institutions of Scientific and Cultural Investigations and the names of researchers. (See: Jaime Posada, Una Politica Educativa para Colombia, Vol. I, National Printing, Bogotá, D.E., 1963, p. 1)

Apparently this intention has not, till the present moment, been realized. (See: University of Antioquia, Escuela Interamericana de Bibliotecología, Investigaciones en Proceso en Colombia, Vol. I, 1966. Acumulación - Medellín, 1967, p. 3.)

and equipment of classrooms, accelerated training of teachers at all levels, and the implementation of an organizational structure for educational administration. The analysis or evaluation of learning through experimentation has not, accordingly, received similar emphasis.

As to curriculum, it was not until the end of 1967, during the fourth Seminar of Faculties of Education, held at the Universidad del Valle, that such themes as "types of research which must be advanced in order to coordinate the area of each institution into works as a whole," were formulated. The elaboration of new curriculums was not mentioned, the theme being focussed on an analysis of the administration of the actual curriculum.

Another important limitation in the advancement of education research appears to have been the lack of a policy of mutual collaboration in formulating themes for investigation, including the assignment of specific responsibilities.

The result has been a proliferation of studies of uncoordinated educational researches.

We must also note the lack of specialized personnel as one of the most serious limitations of educational research. This deficiency is seen not only in the elaboration of the curriculum, but also in its administration.

Finally, it has been difficult, at times impossible, to carry out pedagogical experiments because of the lack or technical materials and educational aids.

In sum, limitations have existed not only in formulating new curricula but also in their administration and evaluation.

## Conclusions and Recommendations

It seems clear that the methods, techniques and objectives of education, formulated in a previous era, are no longer adequate for the prevailing conditions and characteristics of this country. In our opinion, the effectiveness and legitimacy of the educational role at all levels (primary, secondary, technical and superior) rest upon a dynamic correlation between the technical transformation of the modern world and the response of the educational system to satisfy the quantitative and qualitative demands of the developmental process.

Before there can be any adaptation of teaching content, programs and methods to the new needs brought about by cultural progress, there must first exist the concept that education research is basic to the modernization of teaching and of methodology. The application of scientific research to teaching, the formulation and

administration of the curriculum, and to the study of educational administration should be a systematically coordinated activity.

It would be desirable to assign specific tasks of education research to specialized personnel. Faculties of education should have sufficient financial backing for the formation of major groups of professionals dedicated to the pursuit of education research.

We recommend the acquisition of technical materials and elements for the development of education research.

It is hoped that the answers to such questions as: How many resources are needed for educational distribution? At what levels? Which educational techniques should be selected?, etc., can be answered through education research.

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A brief, selected bibliography is included here in which one can find mention of the topics discussed in this paper, relating to the theme, "What is the state of education research in Colombia?"

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# PROBLEMS OF A TECHNICAL NATURE WHICH INFLUENCE THE DEVELOPMENT OF THE AGRICULTURAL AND LIVESTOCK SECTOR

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## Introduction

Problems of a technical nature are those generated by factors other than land, labor and institutional structure which limit the growth of agricultural and livestock production. In other words, problems of a technical nature refer to forms and services of capital resources known as agriculture and livestock technology.

The problems analyzed here as problems of agriculture and livestock technology are those referring to deficiencies in: (1) research, (2) production, (3) dissemination and (4) adoption of (a) forms of capital such as machinery, improved seeds, fertilizers; and (b) capital services such as the knowledge necessary to increase production. The redistribution of public resources for priority areas of research, production, and dissemination of technology is suggested as solutions to the deficiencies analyzed. Mention is also made of the need for new investments combined with policies of incentives for agriculture and livestock producers.

## Problems of a Technical Nature

Technical problems can be grouped under the categories of problems relating to research, production, dissemination and adoption of agriculture and livestock technology.

Among the research problems in agriculture and livestock technology is the relatively limited attention to the study of ecology and agricultural production in the country's hot tropical zones. These zones cover 83 percent of the country and encompass 40 percent of its population.[1] Cattle raising, promising export crops such as cotton and bananas, and crops for import substitution such as cacao, sesame, African oil palm, etc., are concentrated in the humid tropics. These zones have rainfall, temperature and sunlight conditions which favor vegetable growth to a higher degree than in the temperate zones of the world. It is calculated that the vegetation incorporated into the soil in tropical areas can be as high as 150 tons/hectare/year in contrast to 60 for temperate climates.[2] However, research has been concentrated mainly on cold and temperate climate crops, which occupy only 15 percent of the area of the country.

Another problem is the very limited attention given to industrial transformation and commercial processing of agricultural and livestock products. It has been calculated that aggregate value generated by processing can be as high as 10 billion pesos,[3] but the budget and personnel involved in the study of commercial processing represent less than one percent of the resources dedicated to the agriculture and livestock sector.[4]

Problems in the production of forms of capital (fertilizers, machinery and such) refer mainly to high costs due to causes such as the following: (1) Great proportion of imported materials and rise in the costs of such materials; (2) Inadequate structure of the sales markets for such products, which is translated into high commercialization margins[5]; (3) Low quality of some products due to the fact that the necessary government control has not as yet been developed.

The problems regarding dissemination of agriculture and livestock technology are also numerous. For one thing, there is a lack of sufficient technical personnel to reach a "reasonable" proportion of the country's farmers. The scarcity of such personnel can be measured in terms of active agricultural population, number of farms, and number of cultivated hectares in the country. Thus, in 1960, an active agricultural population of 2,650,000 people was calculated for the country;[6] an area of 4,817,000 hectares of land being permanently or temporarily cultivated or lying fallow in populated regions;[7] 1,437,410 farms[8] and a total number of 877 technicians,[9] which gives the following relationships:

| | |
|---|---|
| $\frac{\text{active population}}{\text{number of technicians}}$ | 3,030 persons/technician |
| $\frac{\text{number of farms}}{\text{number of technicians}}$ | 1,640 farms/technician |
| $\frac{\text{number of hectares}}{\text{number of technicians}}$ | 5,700 hectares/technician |

If we agree that one technician can attend directly to one farm per working day (that is, 250 farms per year), or an extension of up to 1,000 hectares, we would conclude that technical assistance reaches about a sixth of the total number of farms and/or area cultivated in agriculture.

Other problems related to dissemination of technology are the inadequate training of a considerable number of the technical personnel for disseminating knowledge among farmers and the lack of integration between the different State programs providing complementary forms of capital such as credit, education and technological inputs.

Finally, concerning problems related to the adoption of agriculture and livestock technology, we could include (1) low level of adoption by the mass of Colombian farmers; and (2) unfavorable incidence (reduction) in the use of hand labor resulting from the use of certain forms of capital, such as agricultural machinery indiscriminately applied.

Suggestion of Possible Solutions

In the case of research, the unbalance seen in the insufficient attention to problems of the hot tropical zones can be corrected by dedicating more resources to the study of ecological conditions, and to crops and cattle suitable to these zones. These increased resources would have to be obtained, at least in part, at the expense of cold-climate crops, of which certain varieties with remarkable resistence and productive capacity have been developed. Research on commercial processing and industrial transformation would also require additional resources, in relation to the economic importance of these processes.

An increase in technological inputs requires several measures in the public and private sector. For one thing, it seems necessary to give further study to the economic feasibility of developing mineral resources for agricultural use. For another, additional financial resources should be dedicated, and compensation balances utilized for the importation of machinery to transform these mineral resources and for the production of capital goods for agriculture (motors, pumps, equipment). Also required are infrastructure investments to improve external economies, thus reducing costs and prices, and increasing demand. Perhaps it would be advisable, also, to adopt the experiences of other countries where State-owned firms or those of farmer organizations are involved in the production and/or transformation of technological inputs to make the markets for these products more competitive.

The deficiencies in the field of dissemination of agriculture and livestock technology can be lessened through greater use of sub-professional personnel and young farmers or peasant leaders to transmit information to the farmers. The utilization of such personnel decreases the social distance between the professional technician and the peasant, thus facilitating communication. Furthermore, it reduces the quantitative deficiency of personnel without great additional budget allocations.

In addition, the deficiencies in the dissemination of agriculture and livestock technology can be reduced through closer programming and coordination between various State organisms, mainly between credit and marketing organisms and technical dissemination organisms. Proper training of personnel on how to transmit information requires intensification of social science

courses in the agriculture and livestock faculties or schools, or training through special courses; likewise, extension personnel should be trained in rural administration so that they may give an economic dimension to their technical recommendations.

The application of solutions such as those set forth for the problems of research, production and dissemination of agriculture and livestock technology, should contribute towards raising the level of adoption of certain capital forms and services among a greater proportion of the rural population. But changes are required in land tenancy and price policy in order to provide incentives for the farmer to adopt new technologies and increase agricultural and livestock production. In this sense, technical solutions are a necessary but not a sufficient factor in promoting development of the agriculture and livestock sector.

Inadequate planning in the use of other forms of capital, such as agricultural machinery, gives rise to unemployment of farm workers. Thus, it is necessary to concentrate these capital resources in activities which increase the productivity of other resources. In a country like Colombia where there is a large labor force but scarcity of capital, it is generally not desirable to have capital replace human labor indiscriminately, as this increases unemployment. Thus, use of machinery should be concentrated in opening new areas which may increase job opportunities and in those tasks which cannot be carried out economically with hand labor.

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# ANALYSIS OF THE TECHNICAL PROBLEMS THAT COLOMBIA FACES IN THE DEVELOPMENT OF ITS CROPS AND LIVESTOCK SECTOR

Colombian Agropecuarian Institute

## PART I

Colombia possesses a diversity of climates and soils which makes it possible to cultivate and produce nearly all the species of plants and animals useful to mankind. However, in the modern competitive world, optimum production and development of both animals and plants requires a great deal of technical know-how, as well as economic knowledge and enlightened systems of regulation.

This paper deals broadly with a number of unanswered questions which presently prevent high productivity in terms of land, labor, and capital. In general terms, the following are the most common technical problems experienced in crop and livestock production:

1. Although improved crop varieties have been developed for most of the basic food crops, several species still require improvement.

2. For certain crops, improved methods of soil management, fertilization, supplementary irrigation, weed, disease and insect control are lacking. Improvements are required in plant population density, harvesting, and port handling of crops.

3. Improved methods are needed for proper management of certain classes of livestock, specifically with respect to infectious diseases and parasite control, and the use of balanced rations to achieve efficient, intensive production. Such production would be possible with existing breeds, if presently-known systems of nutrition and management were applied.

4. Technical assistance is lacking, particularly in the form of agricultural extension programs for application of known techniques.

5. There is a general lack of education at all agricultural levels.

6. Marketing systems for agricultural products are deficient in quality control, packaging, transportation, storage and distribution, financing and market support.

7. There is a general lack of adequate national planning in zoning areas for crop production, government policies on prices

and production costs, infrastructures, substitution of imported products, and promotion of specific agricultural crops for export.

8. Many problems of a national, cultural and legal nature exist. Examples are land tenure systems, water rights, land inheritance systems, and lack of community pride and spirit.

These problems are clearly complex. The first four points mentioned are directly concerned with plant and animal production, and the need to educate farmers on improved methods, aiding them to obtain increased productivity. The problem of technical assistance and agricultural extension, listed as Point 4, is considered of primary importance. Although the information necessary for increased productivity of basic crops and livestock is already available, it is not used by the majority of farmers and livestock producers. A massive education program is needed to assist them in making decisions on questions of production and marketing.

There is a need to substitute domestic production for the present system of importing such products as wheat, fats and vegetable oils (African oil palm, coconut, olive, sesame, soybean, peanut, cottonseed, sunflower), wool, cocoa, and barley. Production problems and their solutions are either partially or totally known. The application of these solutions is difficult, however, because of credit limitations, lack of marketing systems, absence of crop controls, production cost controls, and absence of government agricultural policies.

The agricultural industry proposes solutions to these problems as follows:

1. Use all methods possible to place in the hands of all farmers the new agricultural information obtained by the Colombian Agropecuarian Institute (ICA), and other institutions.

2. Increase the research effort directed at technical problems of management and pest control with respect to plants and animals.

3. Set up work programs on fats and vegetable oils, crops on which the country lacks sufficient information, to insure an adequate technical foundation as soon as possible.

4. Increase specialized education programs and provide enhanced incentives to younger scientists to help overcome the shortage of specialized professionals in the various agricultural scientific disciplines.

5. Influence the government to assume the initiative in nontechnical problems that, in one way or another, obstruct agricultural development, delegating the problem of searching for solutions to the appropriate entities.

In the second part of this report, a critical analysis is presented of specific technical problems which currently obstruct the development of the following crops or livestock: rice, wheat, barley, corn, soybeans, field beans, potatoes, yucca, bananas and plantain, cocoa, sugar cane, fruits and vegetables, pasture and forage crops, soil management, beef and dairy cattle, sheep, swine and poultry.

## PART II

In this part, a general analysis by crop and livestock species is presented. The current status of each crop and animal species is described and evaluated, and pertinent technical problems, with their causes, are identified.

This includes:

1. Rice
2. Oats
3. Banana and Plantain
4. Cocoa
5. Sugar cane
6. Barley
7. Beans
8. Fruits and Vegetables
9. Corn
10. Potatoes and Yucca
11. Pastures and Forages
12. Soybeans
13. Soils
14. Wheat
15. Beef Cattle
16. Dairy Cattle
17. Sheep
18. Swine and Poultry

### Rice

In the technology of rice production in Colombia, very few technical questions remain unanswered. Nearly all of the problems are known, and usually the best solution in each case is available.

The productivity of the rice crop is directly proportional to the following factors: favorable environmental conditions (temperature, rainfall, soil, sunlight, relative humidity, etc.); quality and quantity of available varieties; degree of plant protection against insects and diseases; absence of weeds and other deleterious influences; and technical capability of those who handle the crop.

There are some technical problems yet to be solved, such as development of varieties resistant to diseases, especially those known as "hoja blanca" and "blast." The ICA is currently intensifying its study of the problems of fertilization, weed and insect control, efficient irrigation, as well as seeking improved management techniques.

Rice production technology is hindered by social and economic factors such as the land tenure system and the general lack of agricultural extension services.

The importance of rice in Colombia is evident from the fact that in 1965, 374,000 hectares were cultivated, producing 672,000 tons of rice, and in 1966, an area of 350,000 hectares, producing 680,000 tons of rice.

Oats

Under experimental conditions the production of grain oats varies between three to five tons per hectare; and the production of green forage oats (a separate crop) is about 40 tons per hectare. At the present time only 2,000 hectares are planted with oats in Colombia, making it necessary to import from abroad, both for human and livestock consumption. Imports total approximately $1 million per year.

The chief problem limiting oats production in this country is a fungus disease known as "stem rust," which effectively prevents establishing oats as a commercial crop. The climatic conditions necessary to develop stem rust epidemics are unfortunately ideal throughout the year. For this reason, early maturing varieties and varieties that are stem rust-resistant must be developed. Improved methods of crop management are also needed. The overall need to increase the oat crop, both for forage and for grain is clear.

Bananas and Plantain

Recent banana production in Colombia was approximately 630,000 tons, with an area of 58,000 hectares under cultivation. Of this harvest, 250,000 tons of bananas grown on 30,000 hectares was exported. The most serious technical problems in banana production are the "sigatoka" and "panama" diseases, produced by fungi, and a root rot caused by "nematodes." For many years the variety "Gros Michel" (Musa Sapientum L.) has been the only variety cultivated. The crop yield is not very large, but has been accepted in the international market.

Due to the serious threat of "panama" disease, the varieties "Valery" and "Poyo" (M. Cavendish L.) have recently been introduced. These varieties are disease-resistant and also have higher yields. Due to the size of the plants, these varieties are less affected by the strong winds that annually cause enormous damage. However, these varieties ripen very rapidly, and hence are susceptible to deterioration during handling and storage, resulting in considerable fruit loss in the international markets. Due to the tremendous fluctuation of international banana prices, the increased competition of various African countries, and the new banana plantations in Formosa, serious thought must be given to the industrial use of the banana surplus and of the lower quality fruit.

Plantain presents problems similar to those of the banana with respect to "sigatoka," and "moko," and other diseases. Moreover, plantain is cultivated by small farmers, rather than on large plantations. This makes it difficult to control "moko," which requires community action. Research on plantain has been initiated only recently.

Cocoa

Colombia was formerly an exporter of cocoa. It now imports the beans, with an average import level of $7.2 million over the last three years. Domestic production is approximately 17,000 tons, with 38,000 hectares under cultivation. The cause for the decline of this crop are disease and insects, which have decimated existing plantations. Some progress has been made in recent years, however, due to research carried on by ICA. A hybrid cocoa plant has been developed that matures rapidly, is resistant to disease, and produces a high yield.

A preventative for the disease "witch's broom" is available, and simple methods have been developed for the control of moniliasis, one of the most important fungus diseases from an economic standpoint. However, many problems requiring further investigation exit, such as prevention of stem-rot (Ceratostomella-Xyleborus complex) and gall disease; processing technology, including techniques for fermentation, drying, and cleaning; and development of specific insecticides for the control of insects that destroy the beneficial pollinating ones. Other problems include the dissemination of research results, and availability of adequate credit as an incentive to cocoa producers.

Sugar Cane

Many years ago, due to the presence of an infectious disease known as "mosaic," a resistant variety, P.O.J. 2878, was introduced from Java and has been cultivated extensively ever since, despite its susceptibility to insects and disease. Since that time, superior varieties, adapted to Colombian conditions, have been introduced; and new varieties developed here. In spite of these advances, it has not been possible to replace P.O.J. 2878 with the new varieties. Cane growers have not been receptive to them, nor have they been willing to adopt new management techniques. If they would use the hot air seed treatment recommended by ICA, it would be possible to increase yield by 30 percent, and in a few years the ratoon stunting disease, a virus, would be erradicated. Additional research is needed on cultivation techniques, and the development of varieties resistant to disease and insects.

Studies are needed on increased production of cane sugar for brown sugar production, specifically on adequate use of fertilizers and herbicides and development of high-yield varieties resistant

to insects and disease. The greatest problem affecting brown sugar production is the fluctuation of prices.

Although production statistics vary considerably, white sugar production totals about 485,000 tons for 85,000 hectares under cultivation. For brown sugar, the figures are 585,000 tons for 265,000 hectares under cultivation.

Barley

The barley crop of Colombia has fluctuated at about 105,000 tons per year, from a cultivation area of 63,000 hectares, a yield that was adequate for national needs only in 1962 and 1963. National demand has increased, with a 1967 estimated consumption of 145,000 tons. Assuming a domestic production of 115,000 tons, approximately $4 million worth of barley must be imported.

The country now has two improved varieties—"Funza" and "124," which are grown in 30 percent and 70 percent of the cultivated area, respectively. The "124" variety is moderately resistant to lodging (falling over and lying down), to leaf diseases and smut. The average yield is 2,000 kilograms per hectare, reaching 3,500 kilograms on some farms.

Technical problems still unsolved include development of resistance to smut, leaf rust, and dwarfing, common and yellow. There are also difficulties in introducing good malting quality into the varieties that have high yield.

Other factors that adversely affect yield are: lack of production programs; lack of adequate supplies of improved seed, insecticides, fertilizers, etc., plus the high cost of same; lack of comparative knowledge of the advantages of other cold climate crops, including livestock; low production in some areas; small size of production units; and lack of technical assistance and agricultural extension programs.

Beans

Most of the technical problems of bean production, as well as their solutions, are known. The most serious problems with this crop are related to disease, insects, and the occurrence of harmful atmospheric conditions which farmers call "bad weather."

National yields have fluctuated widely. In 1957, about 72,000 tons were produced from 130,000 hectares. In 1966, only 36,000 tons were produced from 52,000 hectares, according to I.N.A. figures. This indicates an apparent reduction in the consumption of this grain, or a change in eating habits, since imports of beans have been very low. The country has available efficient methods of cultivation and improved varieties which resist the most common

and destructive diseases. Using these varieties with improved methods of cultivation, it would be possible under normal conditions to obtain a yield of 1,500 kilograms per hectare. This compares very favorably with the average yield of 583 kilos per hectare and 692 kilos per hectare produced in 1957 and 1966 respectively.

Problems still to be solved include the following: production of varieties resistant to certain bacteria and root fungi that have not yet been controlled; introduction of varieties adaptable to hot climates (on the coast of Colombia there are 130,000 hectares of cotton for which there is no suitable rotation crop); production of varieties with higher protein content and better quality; development of storage conditions that will control insects, deter color change, and limit handling of grain which makes cooking difficult; low production in some regions; lack of credit available to small producers; and lack of technical assistance and agricultural extension programs. Improved varieties and technical assistance should reach the farmers through an enlarged agricultural extension program.

Fruits and Vegetables

Colombia has climates and soils suited to economic cultivation of numerous species of fruits and vegetables. In 1966, over 530,000 tons of fruit and 389,000 tons of vegetables were produced. Export of fresh pineapple, mango, papaya, grapefruit, tomatoes, melons, onions, and garlic has great potential.

Enormous quantities of tropical fruits are lost annually, due to the following technical factors; need for agricultural extension of improved production methods for the different species; lack of credit and technical assistance; lack of knowledge of standards necessary for commericial marketing of fruits, including such aspects as optimum harvesting practices, fruit preservation, processing, and overall industrialization; lack of nurseries well distributed throughout the country; and need for research on various species, expecially tropical fruits.

With respect to vegetables the problems are: development and adaptation of new varieties; lack of high-quality seed produced within the country (in 1967 over 67 tons of different vegetable seeds were imported); intensive study of improved methods of cultivation, including fertilization, use of supplementary irrigation, and control of weeds, diseases, and insects; establishment of quality control, plus better methods of commercialization, including transportation, conservation, processing, and distribution; efficient cultivation methods for various horticultural crops, of which several well-adapted varieties are available in the country.

Again, a program of agricultural extension and training of personnel in the management of the various crops is needed.

Corn

Corn, which accounts for 870,000 hectares, is one of the most widely cultivated crops in Colombia. It is easily handled, widely adapted to the different climatic zones of the country. Over the years, Colombia has improved 40 varieties of corn, as well as cultivation methods. The most efficient cultivation systems are known, and their application would permit a considerable increase in yield per hectare, even though the national average yield is currently one ton per hectare. Over 60 percent of the cultivated area is managed by subsistence farmers in cold and medium climates, and on hilly, marginal farms.

Technical problems are: introduction of varieties of medium height and low ear placement for easy mechanization and resistance to lodging, insects, and disease; improvement of the protein quality, particularly certain amino acids such as lysine and triptophane, to enhance its nutritive value; improved storage and marketing systems, including increase in national storage capacity; development of economical control methods for weeds in the hot tropical regions; and study of use of supplemental irrigation, plant density, fertilization, and also the interaction of these factors from an economic standpoint.

The major problem in increasing corn production is, again, the development of agricultural extension programs to inform farmers of current information and production techniques. Such programs must include the small grower in the mountainous regions as well as the large commercial farmer.

Potatoes and Yucca

For many years Colombia has produced enough potatoes to satisfy domestic needs. However, there are serious seasonal market imbalances every year, due to the difference between supply and demand for this crop, causing serious price fluctuation in the market. Several improved varieties and efficient cultivation methods are at the farmer's disposal.

Using these methods, 65 tons of the improved variety ICA-Purace were produced per hectare, near the town of Funza in 1967. Due to its geographical position, climate, and appropriate soil, Colombia is in an advantageous position to produce tuber for export, both for consumption and as seed.

The estimated 1966 average yield of potatoes in Colombia was 10 tons per hectare, from 80,000 hectares under cultivation. The average productivity is considerably lower than the yields in Funza

for several reasons: lack of timely credit, technical assistance, adequate marketing systems, and land tenure problems. In addition to these difficulties, which are common to other crops, there are other problems which must be solved if potato production is to be increased. These include: coordination of production cycles with market demand, certification of seeds, mechanization of production, storage, and industrialization of the export process.

About 142,000 hectares of yucca are cultivated in Colombia, with an average yield of six tons per hectare. There are great economic possibilities in an increased production of this crop, with respect to its use for animal feeds and industrial processing.

ICA began research work on yucca in 1967. The most pressing problems appear to be: storage, processing, industrialization, adequate growing areas, mechanization, determination of planting and harvesting cycles, planting densities, fertilization, control of weeds, diseases and insects and introduction of high-yield varieties of good quality, resistant to disease and insects, for higher yield of starch and flour.

Pastures and Forages

Results obtained in pasture research offer cattle growers production alternatives which, if applied, would substantially increase their incomes. These results have been channeled primarily through national cattlemen organizations and banks supporting this industry. To make maximum use of this knowledge, adequate supporting inputs must be available on a timely basis and at equitable prices to permit pasture improvement and efficient cattle management.

It is necessary to intensify studies concerning production of seeds of high-quality grass species better adapted to local conditions. Also needed are production and control of tropical legumes and detailed study of pasturing systems using them.

Soybeans

In 1967, 35,000 hectares were seeded in soybeans, with a resulting yield of 51,000 tons, most of which came from the Cauca Valley. ICA recently produced a new, high-yield variety that is resistant to downy mildew, a disease which causes serious losses in most commercial varieties in this Valley. Research on cultivation practices has led to recommendations on seeding densities and insect control methods that are being applied with good results. New genetic research has recently been started, with the aim of increasing yield and protein content. Early indications from this research are that these factors can be increased considerably.

Technical problems to be solved are: adaptation of varieties to hot climates, permitting their use in crop rotation with cotton and rice; mechanization of harvesting; establishment of agricultural extension and technical assistance programs to educate farmers in the production and use of the improved varieties now available.

Soils

The cultivated soils of Colombia vary from typically tropical to sub-tropical, due to the factors that controlled their formation, such as climate, topography, age, and type of parent material. Although, in general, the physical properties of these soils make them suitable for almost every crop, their chemical nature limits productivity in many regions. This is particularly true in regions where available phosphorus is insufficient.

Fertility problems are common throughout the country. In cool zones with acid and "alophanic" soils, there is excessive fixation of native phosphorus and phosphorus added in the form of fertilizers. Many of these soils are acid and low in exchangeable bases. There are also deficiencies in some micro-elements such as baron and molybdenum.

In low alluvial valleys there are areas low in nitrogen. In the eastern plains (LLanos Orientales) the soil is extremely acid and infertile, and responds particularly to lime, phosphorus, and nitrogen.

The solution of these problems should be sought in terms of the crops grown, production, regional ecological factors, and the availability of supplemental irrigation. In most cases, the solutions to the problems are known; however, the implementation of these solutions is often difficult, due to the lack of fertilizers, access roads, trained farmers, information and agricultural extension systems, and also to high tariffs.

Wheat

National wheat production is about 110,000 tons from 102,000 cultivated hectares. Wheat imports total about 200,000 tons per year. Improved varieties with high yields, disease resistance, good agronomic characteristics, and good baking qualities exist. Information is also available on different phases of production, including planting density, fertilization, and weed control. Yields of over seven tons per hectare have been obtained on fields where the farmers used the best-known methods of cultivation. However, wheat acreage has been decreasing in recent years, due partly to the following influences: deficiencies in marketing; high input costs raising production costs; lack of technical assistance and credit; and lack of agricultural extension services to disseminate the technical advances obtained by ICA.

Beef Cattle

The principal obstacle to increased productivity of beef cattle is the lack of application of known technology on different factors such as pastures and forage, nutrition, and animal health and physiology. Major problems in developing the industry are: low calving percentage (50 percent), the principal limiting factor in the increase of the industry; low rates of gain (calves are sold at approximately 3 1/2 to 4 1/2 years of age, which represents a low percentage of slaughter (13 percent); losses due to disease and parasites (aftosa, brucellosis, bronchitis, etc.), all of which produce death in approximately eight percent of the cases, and undetermined weight loss among those that survive; lack of better use of the 16,000,000 hectares of cultivated pastures and the 24,000,000 hectares of native pastures; and lack of adequate agricultural extension.

Dairy Cattle

In the high and temperate areas of the country, known techniques with respect to pastures and forage, nutrition, and animal health and physiology would eliminate many of the difficulties that prevent development of the industry. As it is, the industry suffers from these factors: low milk production; high cost of calf production; losses from diseases and parasitism; inadequate utilization of pastures; and lack of efficient balanced rations.

In the tropical zones the deficiency in milk production is due to the lack of development of appropriate breeds. Nonetheless, using the existing breeds, improved productivity could be attained by application of proved pasture and cattle management systems.

Sheep

Sheep production is mainly in the hands of a large number of farmers who maintain flocks for the sake of tradition, or out of affection, and not primarily for economic reasons. The flocks are mostly native, are not well managed, and meat and wool yields are low in quantity and quality.

There are vast areas of Colombia that should be utilized for sheep production. There is a need to develop programs to organize small farms into associations, federations, and foundations, with the goal of building a large industry. Furthermore, it is necessary to improve the flocks by utilizing proven sires, so as to increase and improve meat and wool production. The following problems require solution: low reproductive rates; low growth and low wool production; losses due to disease and parasites; lack of optimum use of pastures; lack of industrial and improved small flocks; improvement in wool utilization; and commercial utilization of lambs as a meat source.

Swine and Poultry

Improvement in this area of agriculture has been outstanding in recent years. There is still a need for economical sources of food, and protein. With the application of known management systems and introduction of existing improved breeds, many production problems would be eliminated, and the heavy losses caused by various infectious diseases and parasites would be reduced.

# COLOMBIAN NON-RENEWABLE NATURAL RESOURCES

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## Abundant Resources

Limestone rock: Limestone and marble of all ages, from Paleozoic to Pleistocene, are found throughout the country. Limestone is mined by 13 cement plants to produce 2,000,000 tons of Portland Cement a year. Some calcium carbide, white cement, and lime are also produced. Limestone is not very extensively mined for the production of agricultural lime, which is badly needed as a corrective of the acid soils.

Reserves of limestone are virtually unlimited.

Coal: Colombia possesses a reserve of 5,000 million tons of known, exploitable coal. It is very probable that this amount could be doubled if several unknown basins were explored.

Production is very small—3,000,000 tons per year.

Colombian coals range in age from Upper Cretaceous to Paleocene-Eocene through Oligocene. This means they are young coals but, due to the the intensive influence of tectonic forces, they have been transformed into rock coal. Some beds contain coking coal suitable for metallurgical purposes.

The best-known basins are: Cerrejon in LaGuajira; La Jagua in Magdalena Department; Amaga-Titiribi in Antioquia; Valle del Cauca; Sabana de Bogotá basin; Guaduas Formation Basin in Bogotá; and Eastern Piedemonte, in the Eastern Cordillera in Meta Department.

Phosphate Rock: During the period 1964-68, the Mineral Resources Survey, Division of the Ministry of Mines and Petroleum, in collaboration with the U.S. Geological Survey, found extensive, rich deposits of phosphate rock along the whole Eastern Cordillera of the Colombian Andes.

To date, reserves of possibly 100 million tons, with an average 20 percent $P_2O_5$ content, have been prospected.

This resource will be very valuable in the development of the mining, agricultural, and animal sectors of the economy, since the mining operation will provide a great deal of employment, and the subsequent application of phosphate to the soil will raise agricultural and animal productivity.

Building materials: Building materials are abundant and of excellent quality. Varieties include: foundation stone, graded materials, materials for concrete, aggregates of sandstones and sands, schists and serpentine for facing stone.

Igneous and metamorphic rocks of good quality and beauty for use as facing materials are abundant, but so far have not been exploited.

Salt: This resource is very important to the development of the chemical industry of the country, since over 120 products are derived from it.

Fortunately there are good reserves, both as land deposits, and as a product of solar evaporation of sea water on the Atlantic coast. The Mineral Resources Survey has located a promising new site in Tausa, north of Zipaquira. If this proves to be as large as presently estimated it will increase the salt reserves for the mediterranean area of Colombia enormously.

Sufficient Reserves

Petroleum and natural gas: This is a non-renewable resource of growing importance to Colombia.

With a reserve of 1,500 million barrels and an annual production of 75 million barrels, the deposits will be depleted in 20 years unless we undertake an intensive exploration program and also solve a series of problems that presently hold back the Colombian petroleum industry.

Colombia has 40 million hectares that are geologically favorable to the accumulation of oil. Of this area, only 5 million hectares have been drilled on an exploratory basis.

Natural gas production in the country is at present 100,000 million cubic feet. It is used as follows: production of gasoline, butane and propane (three percent); injection into oil fields to maintain pressure on crude oil (28 percent); a source of energy and raw materials (15 percent); as a source of fuel in the fields under exploitation (14 percent); and unused and burned in the air (34 percent).

Nickel: A large deposit of nickeliferous laterites has been found, studied, and evaluated in Colombia.

In Montelibano district, Cordoba Department, a topographic dome of a peridotite rock shows a rich nickel concentration, with a little over 60 million tons of measured mineral ore reserves, with a two percent content of metallic nickel. With an initial investment of US$44 million, $8 million for mining exploitation and $36

for metallurgical plants, 25 million pounds of iron-nickel can be produced per year, with a market value of US$18 million.

A deposit located 15 kilometers south of the one just described contains 20 million tons of nickeliferous laterites, with a one percent average metallic nickel content, which concentrated prior to treatment, will increase the reserves substantially.

Gold, silver and platinum: Exploitation of these resources has been traditional in Colombia. Gold production in 1965 was 9,838 kilos, with a value of US$11 million. Silver production in 1965 was 3,530 kilos, with a value of US$106,000. Vein and placer mining are used. Platinum is produced by placer mining only. The author could not obtain recent production figures for inclusion in this report.

Sulphides of base metals-Pb, Cu, and Zn: These minerals are not presently being mined for industrial production of base metals. However, prospects are known and are being evaluated by the Mineral Resources Survey, the National Geological Service, and the Medellín Metallurgical Promotors. These studies will permit economic mining operations from large and small deposits if this exploitation is encouraged.

Sulphur: A mine near the Purace volcano, with reserves of over 5 million tons, and a production of 20,000 tons per year, is the only one being operated at present. However, this plant could easily be enlarged to produce 100,000 tons a year if improved mining and extraction systems were used.

In the volcanic areas of the Central Cordillera, other sulphur deposits are being studied. Their exploitation would be difficult due to the lack of an adequate highway system.

Kaolin and feldspar: Recent official reports show that Colombia possesses sufficient resources of these minerals for domestic use in the ceramic and paper industries, provided small washing plants for these minerals are built.

Emeralds: Colombian emeralds are preeminent in the world market, due to their size and quality. However, this resource has developed problems in exploitation and marketing. The development of its possibilities deserves special analysis.

## Scarce Resources

We have classified as scarce, in terms of the economic development of the country, the following resources: iron, chrysotilic asbestos, gypsum, and manganese, since a detailed study of their potential is lacking. However, reserves adequate to the domestic demand may be found.

Problems and Solutions

Institutions: Colombia's major governmental agencies and the executive and legislative branches have lacked coordination with respect to the development of the country's non-renewable resources.

Ministries do not know the programs other agencies are conducting. Parallel programs have thus resulted, each with its own unilateral criteria. This situation discourages, dilutes, and inhibits general development.

The legislative branch pays little attention to the need to expedite modernized legislation. The executive branch lacks skilled technical personnel, instead is burdened by incompetent personnel with excellent lobbying, social, and political capability. This is true with respect to most government programs.

It is important to create a permanent Coordinating Committee responsible directly to the President of the Republic, to oversee establishment of new programs, select competent executives and experts, provide assistance for the solution of problems already identified, and generally to oversee the dynamic development of the mineral wealth of the country.

Legislation: Legislation has been a traditional problem in Colombia, since no legislature to date has become concerned about modernizing the Mining and Petroleum codes, which are inadequate for the needs of the country.

For example, the Mining Sector is governed by the Mining Code of the Sovereign State of Antioquia, which has been in force since the 19th century, with only slight modifications made by law or by decree as special problems requiring urgent solution have arisen.

The Petroleum Code is the only one in the world that still grants 30-year concessions, although modern technology can deplete primary and secondary petroleum deposits in one third of that time, and then no benefit is received by the country.

Since the legislative aspects of the non-renewable natural resources area is so important in Colombia, it requires extensive and intensive discussion. I will present here only some significant examples of questions that require solution:

(a) Why are petroleum contracts signed before Law 10, 1961, became effective not adjusted to the provisions of this law? There are cases such as the Putumayo oil fields where only a three and one-half percent royalty is paid on the petroleum recovered. How is it possible that from a production of 100,000 barrels per day the nation receives only 3,500 barrels?

(b) Why are oil fields that produce less than 1,000 barrels per day, or in some cases, only 19 barrels per day, permitted to retain areas as large as 50,000 hectares? In these cases the leaseholder should be limited to the drainage area of his two or three producing wells, or sell them to the State oil enterprise, in order to liberate the large area of land that is currently frozen under this unfair system.

(c) Why is a term of 50 years granted to a petroleum concessionaire by executive decree, whereas the law allows a 30-year term only?

(d) Why has the Adnian's pipeline, instead of reverting to the State in 1971 after 50 years use, received a change in the legal reversion clause to one of "purchase option"? Why does the Congress not correct this?

(e) Why does our legislation not provide that the State Petroleum Enterprise be granted the right to an initial share of at least 49 percent of all exploration, exploitation, refining and transport investments, with a future purchase option of refineries, pipelines, and chemical plants, after the foreign investment company has received a just profit?

(f) Why does the Mining Code legalize the blocking of exploitation of rich mineral deposits badly needed by the country as a source of employment and wealth, while two or more companies are involved in civil quarrels and lawsuits, lasting ten years, over which one has the right to exploit these deposits?

Lack of investment capital: A financing agency is required to launch the development of the Mining Sector. It is well known that the Agrarian Industrial and Mining Credit Association, which has a lending capacity of over two thousand million pesos, allots only 50,000 pesos to the support of the mining industry.

The Industrial Development Institute (IFI) may be willing to help in the development of the Mining Sector; but its scope is industrial only, that is, concerns transforming raw materials into finished products.

Mining has specific fields, such as prospecting, exploitation, and concentration of minerals. This requires the creation of a Mining Bank that would lend funds and control investment in exploitation. We already have Colombian geologists and mining engineers,

qualified to develop mining prospects basic to the Private Sector, who would apply for loans. In the Public Sector they could review, approve, and supervise the use of such loans in the technical exploitation of the mines.

Scarcity of Technical Personnel: Proper development of the mining sector for the foreseeable future requires personnel such as engineers, technicians, and qualified skilled laborers sufficient to take care of building, maintaining, and operating processing plants.

Universities, polytechnic institutes, and SENA must contribute substantially in meeting the keen demand which will develop for these specialties. This should be done via scholarships, modern laboratory equipment and ample budgets.

The country requires that a group of geologists, mining, metallurgical and chemical engineers obtain fast specialized training to the master's and Ph.D. level, since we cannot expect to move ahead without such competent professional staff with maximum scientific and technological knowledge.

Poor knowledge of Colombian underground resources: Despite the efforts made by the National Geological Service, the Mineral Resources Survey, the Mining and Petroleum Divisions of the Ministry of Mines and Petroleum, the Geographic Institute, and the universities, we have a systematic study and data to date of only about 10 percent of the underground resources of the country.

It is necessary to supply the agencies just mentioned with modern laboratories, adequate budgets, and needed personnel so that the systematic investigation of the entire national territory can be made in the least possible time.

# ANALYSIS OF THE PROBLEMS THE COUNTRY FACES IN THE DEVELOPMENT OF RESEARCH

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Although Colombia's research problems are many, they can be reduced to three major areas.

## Problems of Personnel

Scientific personnel capable of performing research which will accelerate our development are very scarce. Those who are capable frequently dedicate themselves to other activities, mainly administrative if they go into industry, or lecturing. Although industry recognizes the fundamental importance of research, it tends to weaken the university by luring away the best-trained professionals with higher salaries. As very few industries have real research sections, this scientific talent is wasted.

The university, confronted with an increasing student body and shortage of funds, overloads the professors with classes leaving little time for research—in spite of the theoretical admission that teaching and research must go together to create in the student the interest and motivation to become a useful element in the country's development.

The unfortunate personnel situation could be improved by ways we will suggest below.

## Research Elements and Atmosphere

Though it seems that research equipment problems are different from those related to the research atmosphere, I have united them, since very often a good research atmosphere is destroyed by the difficulties of acquiring the elements required for research.

These difficulties—in addition to the lack of stimulus and recognition of the value of research evidenced by the low salaries (insufficient for the peace necessary for this work), and the lack of a national policy to support research—are frequently the reasons why good and capable people go to industry to do routine work or escape to foreign countries where, with less work, they can have better salaries and working conditions.

The Problem of the Lack of Motivation

Not only is there a lack of motivation; frequently we are unaware of the existence of the problem.

In general, we do not know Colombia scientifically; we do not know the tropics and, consequently, we do not know what problems will be encountered if we were to study the world in which we live, nor what the value of the solutions to these problems might be for our progress. A clear vision of our possibilities, together with the motivation which would be created by a policy to support "science for development," would surely induce many Colombians to remain in their country and seek solutions to our problems.

Unfortunately, we ignore the tropics and their resources and, therefore, lack the necessary data to develop efficient, appropriate and economic technologies competitive with imported technologies which are frequently unsuited to our problems, having been developed for different ones.

Solutions to these problems might be summarized as follows:

1. The shortage of research personnel could be solved by providing the necessary stimulus and conditions to allow present scientists with proven capabilities and dedication to conduct research directed toward the development of Colombia.

These first researchers must recognize the existing problems and resources and seek solutions for real and present problems, using the most advanced scientific methods. This research must be of the highest level, but also very practical.

Funding research projects through a development policy with a minimum of administrative difficulties could accomplish this purpose.

Foreign scientists could help us study the tropics and develop our technologies, and adapt imported technologies very carefully to our possibilities and needs. Joint projects for postgraduate tropical research could be very useful.

But the best solution is to train our own high-level research scientists here in Colombia, immersing them in our problems from the beginning of their graduate studies, or even before. In this way, they would feel fully involved with the country's problems, supported by an appropriate national policy, and benefitting from the direct collaboration of the industrial and agricultural sectors and their fellow citizens.

2. As the working conditions are improved and appreciation for scientific work increases, the proper scientific atmosphere

will develop. The beneficial results of research will justify the high cost of these labors.

3. When the scientist realizes his efforts are benefitting his fellow Colombians and receives their appreciation, support, and collaboration, he will be fully motivated for his work and will not consider leaving his country.

I hope the solutions coming out of this workshop will help us create, in as short a time as possible, the conditions and atmosphere essential for the scientific handling of our enormous tropical resources and, hence, for Colombia's development.

# ANALYSIS OF THE PROBLEMS WHICH CONFRONT COLOMBIAN UNIVERSITIES IN THE DEVELOPMENT OF RESEARCH

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## PART I

### Introduction

Although the analysis has been limited to the universities, the majority of the problems encountered are also present in research institutions. The situation in which the universities find themselves presents some particular problems and it is convenient to analyze them in a broader context. In order to maintain the brevity of presentation necessary in these seminars, a reaccounting of the breakthroughs made in the field of research will not be attempted. The work which has been done is in no sense being overlooked; on the contrary, an attempt is made to analyze the problems whose solutions would make the investigative effort developing in various universities and research centers within the country more effective.

### Problems

The fundamental problem is the lack of adequate environment necessary for research. By environment is meant a combination of those factors which provide the investigator with facilities, exchange of ideas, and any necessary technical aid. The following aspects should be emphasized:

1. The lack of highly qualified personnel in sufficient number and with complementary specialties which permit an effective exchange; in other words, the investigator is still too isolated in his work, and must possess a high degree of self sufficiency in order to be able to work within the country. Specialization in other countries causes problems in adaptation, because it is not fully appropriate to the needs of this country. It is necessary to continue specializing our personnel in other countries; but special care should be given to these problems and top priority assigned to the development of our own graduate programs.

2. Physical facilities now exist at some sites but they must be enlarged, and new facilities developed where none exist. It is generally easier to finance the investment needed for adequate equipment and facilities than to obtain adequate funds to meet

day-to-day needs and to hire auxiliary personnel. The problems associated with importing necessary equipment are excessive.

3. In general, libraries in university and research institutions are not equipped to provide adequate service for research needs. The money required to bring them up-to-date is beyond the financial ability of most of these institutions.

4. Only now have graduate programs been initiated which will begin to make qualified persons for group research available. Technical assistants able to do routine work are scarce. The investigator accordingly has many trivial chores which lessen his effectiveness and create frustration in his work.

Possible solutions

In order to create an adequate environment for investigation, means must be provided to solve the fore-mentioned problems. The following approaches are suggested as a basis for discussion. They are not the only ones possible.

1. Create a "Fondo Nacional" (National Fund) which, through existing institutions, will encourage and finance research programs, especially those which will give rise to the establishment of graduate programs or fortify existing ones. Such programs should have maximum priority.

2. Stimulate a greater exchange of ideas and information among investigators within the country. Such an exchange would naturally result in more coordination and less duplication. The creation of a coordinating institution at the national level is not adequate.

3. Strengthen existing libraries and establish a system to supply them with photo or Xerox copies. To this end, financial aid is required in addition to that contributed by the universities or institutions.

4. Seek solutions to the problem of technical personnel. The universities alone do not have the means to finance such programs, but should be academically involved in them. Collaboration between SENA (National Service of Apprenticeship) and the universities is suggested.

The preceding points will be elaborated upon in the second part of this paper.

# PART II

## Introduction

In this short paper, an attempt has been made to enumerate and analyze the principal problems confronting the investigator in a university. And, as is natural, in trying to discuss the overall picture of the country, general situations are presented which some groups may have partially resolved. Many of the problems to be analyzed are also present in institutions carrying on research which are not connected with education. This paper has been limited to educational institutions; an analysis of the achievements made in the field of research has been deliberately avoided. For this reason, this presentation may give the impression that the author looks pessimistically upon the development of research within the country, but this is not the case. On the contrary it is believed that the country has the ability to solve these problems in a relatively short time, depending on the energy with which they are attacked and the resources which are made available.

## Background

Traditionally, Colombian universities have limited themselves to professional preparation at the undergraduate level, with major emphasis on the application of knowledge and techniques developed in Europe and North America. In general, this preparation has been well founded, and the students have developed and are developing valuable research within the country. To date the accomplishments of Colombian professional personnel have not been underestimated nor overlooked. But it should be noted that, until relatively recently, the universities have not been developing personnel in the basic sciences at the undergraduate level, nor engineers at the graduate level. Only in the past few years have curricula in the basic sciences shown considerable increase and graduate programs in the sciences and engineering been initiated.

The research and development of the majority of educational programs have been the charge of professional people who specialized in other countries and by those who, thanks to their own efforts and perseverance, have achieved an equivalent level and have the benefit of much experience.

The lack of research programs, professional personnel and scientists prepared at the highest academic and technical levels has been such that the industrial development of the country was based largely on adaptation of foreign techniques and, at times, were simply a transplant of these techniques. In the last few years industry has begun its own research, and has thus brought about a demand for people prepared at the graduate level.

The universities have begun to change their traditional structure of professional studies and to organize themselves along departmental lines. At the same time, they have introduced Estudios Generales (General Studies) into their plans of study, more or less following the "liberal arts" philosophy of the United States. This break with tradition has made necessary the reassignment of personnel in the basic sciences utilizing those (doctors, engineers, certificated educators, etc.) who have a scientific vocation. This should only be an emergency solution; to continue such a pattern would surely result in a tremendous waste. In order to turn a doctor or engineer into a scientist, it is necessary to go through an extensive process of reorientation and training in scientific disciplines of which they have acquired only a limited knowledge during their professional careers. This process requires too much time, and for this reason is not the most efficient way of solving the problem.

## The Problems

For the purpose of focusing the discussion, the problems considered most important have been selected. It is not intended that this paper contain an exhaustive list of all current or potential problems in the field of research.

1. The facts noted above have produced a great demand for qualified persons in the field of the basic sciences the country did not have the capacity to meet. There is also a scarcity of personnel with advanced degrees in engineering. In the sciences, even at the undergraduate level, trained personnel have been practically non-existent. Only in the past few years have people begun to earn degrees (B.A. or B.S.) in the sciences; the country must therefore depend heavily on specialized training in other countries, a process too slow and expensive.

The need to develop teaching in fields where there was no previous experience results in a reduced number of qualified personnel to handle the multiple administrative and planning responsibilities, thus limiting time available for research. These individuals have to worry not only about development problems in their own areas, but must also search for more efficient educational methods which would permit the university to handle the ever-growing number of high school graduates. They must plan the development of programs of study at the undergraduate level, structure the corresponding courses, and collaborate in planning the physical and academic university expansion.

In short, it is necessary to increase the number of qualified personnel available in science and technology considerably in order to handle the combined demands of the different factors just enumerated.

In developed countries, the investigator benefits from adequate academic and scientific environment and planning. In the universities the teaching load is light, and the rewards are competitive with industry. There are opportunities to discuss and analyze problems with colleagues and specialists in other fields. Research has become a team activity with interdisciplinary participation. As a logical consequence of this state of affairs, education at the graduate level is oriented to produce a scientist, highly specialized in a limited field, who will be able to do team work with researchers who are more advanced in his or related fields. It is becoming increasingly common for post-doctoral work to be done before "independence" of research is achieved by the young Ph.D.

This state of affairs creates serious problems in adaptation and limits the research possibilities open to Colombians specializing in other countries who return to universities and institutions here. This is one of the factors contributing to the "brain drain" which has been discussed extensively in recent times. It is not meant to discourage specialization in other countries. This is necessary and should be increased in quantity as well as quality. But one must remain aware of the problems created and be prepared to handle them. It might be recommended that the Colombian specialist's stay abroad be extended so that he will become more familiar with techniques and problems in fields related to his specialty and thus obtain a broader basis of knowledge which would allow him to achieve more upon his return.

Although exceptions can be made, in general it is fair to say that in Colombia the universities and research institutions have not been able to create an environment or "climate" adequate for research. This is due not only to the lack of personnel, but also to other problems that will be discussed later.

There is also great scarcity of technical assistants capable of handling routine chores of service and maintenance. Another important aspect is the lack of graduate students. This will be discussed in point 4.

2. The need to teach science to greater numbers of students, and the increasing demand for more and better science courses to train professional personnel has involved a large investment in teaching equipment, thus limiting the money available for advanced and, consequently, more expensive equipment that might be used for teaching and research. This investment has also diminished the amount of money available to cover sustenance costs necessary to research for supplies, reagents, etc., and to pay assistants. In spite of the difficulties, great efforts have been made to increase facilities in the universities and institutions, and investments have been made or plans exist for the improvement of local facilities. These efforts have carried some universities to the point

at which a relatively small stimulus can produce a large impact, making the investment in research productive. But when one says productive here, intellectual rather than economic productivity is meant. By its very nature, basic research is essentially a long-term investment. Applied or technological research may give short-term benefits but, of course, this should not be the only criterion governing a policy of investment in research.

It is impossible to evaluate economically the long-term contribution a research program will make to the economic development of a country, though a program is not initiated with economic success in mind. Gains resulting from such research programs in the confidence of a research team and in the development of human resources are not easily measured. Dr. Frederick Harbison[1] of Princeton University, in his book "Economic Development and Educational Investment," sets forth some interesting and appropriate facts and opinions. He says:

> According to the opinion of eminent economists less than one-third of the increase in the Gross National Product in any country can be directly explained by substantial increases in factors of production such as capital and available qualified personnel. The "remnants" could be explained as qualitative betterment of these factors including such things as more productive capital, more productive human resources, scaled economies and others. An analysis of the "remnants" has not been done yet, but the most important factors seem to be the betterment of human resources by means of education, training, better health, etc., as well as development of knowledge and technology which, of course, are causally related to education. It could thus be said that the wealth of a nation depends on both development of human resources and institutions and on the growth of capital.

He concludes that nothing would be gained by discussing whether material or human capital is more important. To achieve a rapid economic growth, both must be accumulated at an enormous rate.

3. Another factor which has been brought to light about the development of research in universities and in institutions is insufficient library materials. The growth of the student population and the opening of new professions has made the investment of considerable resources in the acquisition of library materials necessary.

The cost for periodicals is constantly rising and their number increasing at such a rate that it will be difficult to keep our libraries supplied with current publications and much harder to acquire complete collections.

4. In developed countries, the productivity of research is much higher than that in our country, because of better scientific and technological environment, better physical and financial conditions and, of no less importance, the existence of graduate students who save the investigator much work. The problem of the unadaptability of Colombians who specialized elsewhere and have received a preparation not totally adequate for our necessities and work conditions has already been mentioned. In connection with this problem, Dr. Jerome Daen[2] of the National Science Foundation of the United States has stated:

> Progress towards the long-term meeting of this goal is being made through programs of master's and doctor's level education at foreign universities. Though this is an effective method it does have disadvantages, among them their expense, the fact that they provide a form of advanced training not fully appropriate to the Colombian situation, and, the fact they do not develop independent strength in Colombia sufficiently rapidly....
>
> and later he adds: "Many of these defects will be remedied as the local graduate programs become established and grow in extent and quality."

The establishment of graduate programs demands the existence of research programs which can be used to adequately prepare graduate students; and conversely, effective and productive research programs demand graduate students. It is therefore necessary to promote and stimulate research, especially when it will lead to the establishment of graduate programs. It is important to realize that there is a need to accumulate more experience at the undergraduate level, and that a substantial investment must be made in support of research as a necessary preparation for the establishment of graduate studies.

There is already experience at the undergraduate level in technological fields, but it is necessary to give research a push in order to reach the master's level. Some graduate programs have already been initiated in engineering and science fields where a greater preparation and maturity had been reached previously. The development of these and other fields is of the utmost urgency, since only in this way can an environment or "climate" adequate for research be established.

It is occasionally stated that, due to a lack of funds, research should be developed by selectively strengthening different fields in the different cities and universities. There exists the danger of not achieving the "minimum" necessary to create the "climate" in any one of these universities and of not reaching the

"critical mass" needed to start the reaction. Maximum care must be taken in planning for this important objective.

The establishment of graduate studies in the country is the only real solution for the problem of providing higher education to a greater number of Colombians. University education demands people at least at the master's level. The country will not be able to create a sufficient number of these people through specialization in foreign countries alone. This specialization should be intensified while a solid basis for more and better graduate programs is built. On this point Dr. Daen[2] has warned that: "Before starting graduate studies it is mandatory to anticipate and meet the multitude of hidden human costs that are not evident. Unless such cautions are observed, the expansion will be disruptive and injurious to the institution for many years in both its undergraduate and graduate efforts."

Once the master's level is reached within the country, training of people at the doctorate level should be intensified and investigation strengthened even more to provide a step leading to the establishment of doctoral programs. This process could be accelerated, but time must be allowed for maturation and careful evaluation before the new program is embarked upon, for the reasons stated above. More and better science professors in the universities will permit the training of more and better secondary school teachers not only through regular courses, but through in-service training programs as well. Although various universities have advanced in-service training of secondary school teachers, they have met with difficulty due to lack of qualified personnel in sufficient numbers to adequately handle them. A greater number of university professors would enable them to present more ambitious programs in this field, making a real impact on secondary education. This is impossible at the present time due to the lack of personnel.

The process must begin with better preparation in high school, which would make it possible to perepare better professional people, including future secondary teachers who would be able to complete and enlarge the cycle. The tremendous number of high school graduates unable to enter the universities for lack of space is somewhat misleading since a large percentage of them are incapable of handling university-level work and should look more toward a "junior college" type of education. The experience of various universities indicates that only in the last few years has the university been forced to turn away students meeting minimum entrance requirements, and that when they have had the space and admitted students who fell below this minimum, the results were disastrous.

5. The creation of organizations to coordinate research with the object of avoiding duplication has been discussed frequently. The need for better communication between institutions carrying out or planning research and for greater exchange of information

about the programs in progress within the country is very great. It is therefore important to promote periodic and frequent meetings, visits, etc., which would allow greater contact between the investigators, giving them the opportunity to help each other.

It is necessary to create greater stimuli for research and for the study of basic science, since this is a totally new and little-publicized field. The idea of creating an organization or foundation charged with this task at the national level has been put forth; but one must be extremely careful that it does not in practice become a regulatory institution, fixing priorities which appear reasonable but go against the freedom of research and tend to inhibit it. It is appropriate to repeat what was said before: a research program geared to the conditions of the country, even if only having the effect of increasing the confidence of the investigator, convincing him that the obstacles which are posed to development are not insolvable, giving him experience and allowing gifted youth to begin research work, would be an excellent investment in the future of the country.

6. Much has been said about the need for a greater number of technical institutions at the intermediate or "junior college" level to absorb the overflow of students from the universities and would not demand as high requirements for admission. Some universities have already created such schools themselves and the results have been very attractive; but the lack of necessary resources makes it quite difficult to enlarge these programs. It is valuable to have the universities participate in the training of these personnel, also establishing mechanisms for transfer between the intermediate and university levels, since in this way the failures and frustrations of many students can be avoided. Moreover, this would make it possible for students at the intermediate level to continue with studies up to the professional level when they show sufficient ability.

These people are fundamental to the development of the country in all aspects and much has been written about the necessity of giving them junior college training; but financial difficulties and inherent problems of motivation and prestige have limited the establishment of these programs.

The importance of such technical assistants for better development of research is no less of primary importance. SENA and the Universidad del Valle are initiating joint programs which may produce useful experience in this field.

Some suggestions for solutions to the problems stated

Some of the problems discussed, and the situation of the universities to solve them, may suggest the possibility of increasing the number of institutions dedicated to research, and of concentrating

within them the research efforts of the country. This would be a grave error since the absence of research at the universities would make it impossible for them to attract and retain qualified personnel and would produce sterile teaching. Under these circumstances, the teacher would be converted into a transmitter of information and would lack the enthusiasm, mysticism and the satisfaction of the investigator who trys to discover this knowledge for himself. Moreover, it would impede the development of graduate programs which, as was said earlier, will have a snowball effect upon the entire process.

The solution of the problems can be summarized in the necessity to create the environment necessary for research. The following suggestions would contribute to this end:

1. The national government should allocate funds annually to further research and to create stimuli for science study. These sums could be channeled through the universities and institutions which could use them more effectively, and should be sufficient for scholarships, investments in equipment and maintance of research programs at the universities and institutions. The criterion should be encouragement and promotion, not control. A law earmarking a small but fixed percentage of the national budget to this effort would be quite useful.

2. This fund should also contemplate giving special assistance to the universities, whose budgets are not sufficient to retain valuable personnel required to start graduate programs in a given field. Emphasis should also be given to supporting library expansion.

3. A special statute to reduce to a minimum the amount of "red tape" involved in importing necessary research equipment and materials would alleviate much frustration since it would help avoid interruptions in the research.

4. The problem of libraries merits special attention. To raise them all to the level necessary for research would require too great an expenditure. Each library should have sufficient funds to complete basic collections of periodicals starting five or ten years ago and to maintain these collections up to date. One or two libraries should be brought up to date in all the necessary collections, or they should be able to specialize by fields in different parts of the country. The universities and institutions could provide part of the funds needed, but on a national scale, an efficient photo or Xerox copying system should be established and put at the disposal of all interested people. In order to make this effective, periodical distribution of complete revised indexes is indispensable. Funds should be allocated to this end as a support to research.

5. Coordination and exchange of information can be organized through existing institutions which in many instances are ineffective because of lack of funds. The Association of Universities, for example, has created some committees which could lend their services to this field if additional funds were made available for their operation. The creation of a national organization charged with encouraging research presents many problems, some of which could have a negative effect. Many times we have seen how new national organizations are born but cannot, for well-known budget limitations, function efficiently. It is better to extend and strengthen the capacities of existing organizations.

This would also permit more effective use of present investments and expenditures.

6. The universities should give more attention to training technical assistants, needed not only in industry for normal production work and research, but also in the universities and research institutions. This is one of the responsibilities of the university to the community. It must be realized that the universities do not have at their disposal the financial resources necessary to adequately take care of all levels, but they do have human resources whose experience and dedication to education is fundamental to achieving adequate programming of these plans of study. SENA's financial resources and experience in the lower levels is certainly the needed element and it is most logical to make joint plans which benefit both entities and, more important, the country.

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# PART I

## Introduction

Scientific and technological research in Colombia is defined in relation to the reality and needs of the country. A factual diagnosis of the present status of scientific and technological research is set forth, with special emphasis on matters of interest to the manufacturing, mining, and construction industries. Specific subjects of scientific research are described for these industries: coal, ferric and other minerals, sulphur and sulphuric acid, fishing canning, dairy, food oils, mills, baking, sugar chemistry, beverages, textile, lumber, paper and pulp, leather, rubber, mineral chemicals, organic chemicals, cement, glass, nonmetallic minerals, metallurgicals, and metal-mechanics. Other more general research fields of interest to industry (natural resources, zoochemistry and phytochemistry, mechanics of materials, oceanography, hydrography) are also described. Mention is made of the problem of the lack of scientists and the emigration of many. Finally, recommendations are made regarding the creation of graduate-level educational institutions and scientific research organization in Colombia and Latin America, international cooperation in this field, coordination between Government and private enterprise, and centralization and distribution of information.

## The Problem

Scientific research of a general character, and especially that related to industrial problems, is characterized by the following essential factors:

1. It is sporadic, limited in its capacity, and represented by very few concrete efforts, and these are dispersed and uncoordinated.

2. To all intents and purposes, it lacks any firm and fruitful connection with the social and economic reality of the country and our people.

3. In many cases it responds to research requests from abroad, and the results do not remain at the country's disposition but at

that of foreign governments or enterprises.

4. It does not have firm, continuous and efficient support from either the Government or from industry.

5. It lacks coordination, is not organized at the national level, and has no plan or central purpose.

6. The number of scientists and engineers is less than 0.1 percent of our labor force, and is completely insufficient both in number and in adequate preparation.

7. Apart from some four or five isolated individuals we have no investigators of international reputation.

8. Many scientists and technicians who have had advanced education are not associated with science or with jobs which utilize their training—some because they enter other fields—and others because they cannot find appropriate occupations, or because the university atmosphere does not allow them to develop their possibilities.

9. For this reason and due to lack of community responsibility many have already emigrated, continue to abandon the country, creating a heavy loss of valuable human resources.

10. Industry depends entirely on foreign technology, paying enormous royalties (sometimes for trivial brands or patents), instead of going to the universities for scientific help, or utilizing or patronizing high-level investigators. The valuable, although incipient, effort made by the Institute of Technological Research (IIT), and the Colombian Institute of Technical Norms (ICONTEC), has not had enough support from the nation's industries.

11. The universities, with their personnel and laboratory resources, are unaware of and isolated from the concrete and specific needs of industry with regard to technical development and economically applicable research, and do not generate or facilitate contacts between professors and the problems of industry.

12. Scientific and technical exchange with the rest of the world is very limited, existing with only three or four countries. There is no exchange with nations which have made important scientific discoveries, such as the Soviet Union, Sweden, Israel, Canada, West and East Germany, Poland, and Italy. There is almost none with England or France.

13. There are no research services or adequate means of instruction, and access to scientific literature is extremely difficult because of the lack of communication and indexing.

14. There are very few valuable scientific publications, and these receive no financial assistance.

This situation has resulted in, or contributed to, the following problems in Colombian industry:

1. The contribution of factory-type industry to the economy of the country is less than it should be, considering our population, our level of economic development, and natural resources.

2. Industrial growth is very slow, well below that required to support adequate economic development. Moreover, the rate of industrial production has been deteriorating in recent years, and in 1967 reached its lowest point since 1952.

3. Exaggerated productivity differences exist between industries (e.g., between textile and lumber), and even between factories in the same industry.

4. The development of some basic industries that require a definitely advanced technical level (i.e., the metal-mechanics and the basic chemical) is considerably less than it should be in a normal, balanced system of factory-type industry. The same is true of certain traditional lines such as the lumber industry, where practically no technical innovations have been made.

5. Without exception, the technology of our industry (materials, processes, equipment, work methods) is foreign. Almost all of it has come (historically and financially) from the United States and England, with a small part originating in France, Germany, and Sweden.

6. The growth of Colombian industry has declined almost to the point of paralyzation. Many companies previously owned by Colombians become foreign-owned in order to be modernized and technically developed. As a result, the level of industrial financial autonomy in the nation has decreased.

7. As in the originating countries, the technology used here leans heavily toward saving on manual labor (much more costly there). Our industry is accordingly opening up very little new employment, and the additional markets it creates are smaller than they should be in relation to the annual increase in population. This phenomenon has existed since 1962 and persists as a chronic problem.

8. In the new areas (paper, chemistry, non-ferrous metals), a strong dependence on important investments is being created, understandable in a technology that has been created in convertible and hard-currency countries, but not appropriate to Colombia. Moreover, in some instances expenditures are made under the pretext

of technology importation which would not be necessary if we had our own technology.

9. Vitally important industries connected with the exploitation of natural resources, such as fishing, mining, lumbering and non-metallic minerals, which could be a large source of employment, and contribute appreciably to the balance of payments, are still way behind in their economic development.

10. Productivity and competition between many industries is very low, compared with other Latin American countries.

11. The possibilities for economically viable import substitutions appear well nigh exhausted in the intermediate goods sector and very limited in the capital goods sector, because of the ever-growing size in scale and capacity of minimum-size plants produced abroad (which is our necessary source of supply), making them increasingly too large for the size of our markets.

12. Agricultural and mineral products found in our country are exported with little or no processing. Examples are: coffee, bananas, emeralds, cattle, lumber, tobacco, leather and precious metals. Thus, a considerable margin of added value is lost that could remain within the country if we knew the methods by which to improve these products.

13. Domestic industries and handicraft, which could be a very important source of employment, and in which 700,000 people work already, remain stagnant in some areas and are slipping backward.

14. Colombian professional and technical people in industry are not often stimulated to make scientific innovations but rather limit themselves to the application of foreign processes and standards. They usually do not even participate in serious studies of design, operational problems, materials, and processes, because these problems have been solved abroad or are always sent abroad for solution.

## Bases for a Solution

The approach to these problems should be on the following bases:

1. It is necessary to reduce or control the technological dependence of Colombian industry and mining on other countries. This involves the adoption of a definite and systematic policy covering use of foreign technology, patents, and payment of royalties, and also providing for the encouragement of original research in Colombia.

2. Research in technology and science must be actively promoted, extended, and expanded, with emphasis on research leading to industrial development. Expansion should begin with the universities that are in a position to do so; and a plea for the necessary financial support should be made to the various entities of the country that can afford to provide it.

3. Colombia must start an effective and vigorous interchange of personnel and information with the most technologically and scientifically advanced countries of the world. With the exception of one or two, we are completely isolated from them at present.

4. National scientific and technical progress must be adjusted within the Latin American frame, within which it is necessary to form a common, free market for the technology originated in this region. Only in this way can the emigration of the most valuable scientific men be stopped, and those who have already emigrated be recovered. This is also the way to acquire the financial resources needed for further research, and to take advantage of our very limited material and scientific resources. It would be extremely profitable to guide the vocations of advanced students in these fields toward Latin American countries.

5. In order to keep research in proper perspective, it is necessary to establish a national organization, duly instituted by the Government, which would guide official and private efforts in the national interest, on a high scientific level, befitting our conditions and efficiency.

6. Positive scientific and technological policy should be adopted, in keeping with the geographical and economic diversity of the country, so as to encourage each region to support research directly connected with local problems, without losing sight of the universal aspect of scientific knowledge.

7. It is necessary to awaken and stimulate the interest of the private sector in becoming involved in scientific and technical research, in terms of donations of equipment, financial support, training of qualified personnel and, especially, its own problems to be studied.

8. As an indispensable aspect of policy aimed at fuller employment of the country's human resources, it is necessary for us to create a new technology of our own in all economic sectors, given consideration to our population and our lack of capital and foreign currency. This is a difficult task which will take a long time. It is one which must therefore be started at once, in an ambitious way, asking for the scientific and technical help of all foreign entities and countries willing to assist intelligently and without self interest.

# PART II

## Introduction

If "research" means "search for the truth," it would seem that research in Colombia would not be anything other than a search for truth as it relates to Colombia. This consideration is valid for any area or academic discipline, but it is even more significant in scientific and technological fields of research, probably because the "immense ocean of unknown truth" of which Newton spoke extends over a much larger area than we Colombians have yet realized; even less do we know how to take advantage of it in order to benefit our own country.

Therefore, it is clear that scientific and technological research in Colombia should take into account the great Colombian truth, which can be summarized under three headings: economic underdevelopment, technical-cultural backwardness, and social inequality. The concept of the researcher in his "ivory tower" cannot be tolerated in this century in a nation which suffers these diseases and needs to be developed. We must recognize that the scientist has a responsibility to the community, and that his most urgent and most important task is to contribute to the solution of mankind's vital problems.

Accordingly, scientific and technical research in Colombia can be defined as a systematic search to enlarge and implement our scientific knowledge and technical experience, in order to improve living conditions for Colombians. For this reason our research cannot be reduced to the routine and subordinate task of solving sub-problems assigned to us from abroad, within programs not prepared in this country, but inspired by outside interests. One example of what we should not do is the study assigned by a foreign government to various Colombian unversities looking for vegetable steroids in species of the solanacease family. Assuming the research is successful, the results will serve other countries without any real benefit to our own.

This paper details various subjects or problems of Colombian industry, which might form the basis of fruitful research activity, especially in the natural science fields, the so-called technical sciences and the basic sciences. We do not include the many social and humanistic sciences (i.e., demography, social anthropology, human ecology, sociology, etc.), in which extensive research is required in order to obtain a valid picture of the problems inherent to industrialization of Colombia, because this subject is too vast for this paper, and because such research is outside of the author's professional field.

It is universally recognized that industry is the economic sector that contributes most effectively to technical progress and that also most easily takes advantage of it. However, this remark is subject to exception in a country such as ours, that has created an industry based completely on imported technology (in its equipment, processes, operations, etc.), and whose activities are primarily those of transportation or processing of natural raw materials, with a rather low proportion of added value. In Colombia, many manual forms of industry have disappeared which, although rudimentary, contributed to the handicraftsmanship and small-industry activity which is important. In their stead we have been adopting industrial processes with increasingly greater capital-labor ratio, since the systems come from countries where financial resources abound and labor resources are scarce and costly.

The primary means by which Colombian industry has supplied itself with foreign technology has been via acquisition of patents on a royalty basis, sometimes on unfavorable terms. The annual royalty cost is currently an estimated $3-4 million per year. This figure does not include other amounts paid for fees and technical services, which bring the annual total above $4 million. This has been happening to such an extreme extent that the Government recently discoved a foreign country was paying royalties to its home office abroad for the manufacture of a popular foodstuff that every Colombian housewife knows how to make!

In order to obtain a minimum of autonomy for our technological capacity, Colombian industry requires a great deal of work, with the following objectives. We must (1) adapt technologies from abroad to our national situation in order to facilitate the adoption of exogenous knowledge; (2) create and develop genuine Colombian production techniques, that is to say, we must make endogenous innovations in existing industries; and (3) identify Colombian processes and materials which would create new industries in our country, using our own resources. This is an urgent task, to which highest priority must be given in any industrial promotional program. It is a task of such crucial importance that the Colombian government should be made aware of it.

## Scientific and Technological Problems in Industry

There is no more eloquent and serious sign of our backwardness in the scientific field than our appalling ignorance of the country's basic natural resources. Only in recent years has a mining inventory for some regions of Colombia been made available. We do not yet know the true ichthyological potential of our two seas, despite the fact that they are being exploited and pilfered by foreign flags. We lack a forest inventory, so we cannot talk wbout the relative abundance of Colombian tree specimens. Although a few individual studies of considerable merit have been made, our plant life is still unknown, and yet it contains enormous possibilities for

industrial exploitation. For example, it is deplorable that a rich caffein source found exclusively in our forests, the "yoco" (Paullinia yocco), was identified and investigated by Professor Schultes, who came from Harvard University for this purpose. We still do not know the physical, chemical and pharmacological qualities of the Tolú Balsam, a Colombian product par excellence whose name is perpetuated in that of the toluene. In general, we have abandoned or neglected (for someone else's benefit, in some cases) the efforts made by the Botanic Expedition, and more recently, some great Colombian naturalists (Zea, Triana) to improve our national patrimony with resources whose scientific and economic value is within our arm's reach.

Practically speaking, there is no industial research at a company level in Colombia. It is true that a few firms and institutions, such as Bavaria, The Coffeegrowers' Federation, the Technological Investigation Institute, the National Chemical Laboratory, the Nuclear Affairs Institute, and the Augustin Codazzi Institute have made valuable studies. But their work suffers from a lack of coordination and joint programming, and from confidential handling of the topics and results. The lack of support given to technical research by entities which should provide assistance, such as banks, the financial corporations and the Bank of the Republic, is notorious. It is incredible, for example, that the latter does not conduct or sponsor research in Colombia on gemmology or natro-chemistry, which could contribute to Colombia's exclusive benefit.

In the following discussion concerning possible technological research themes, we have purposely omitted the huge field of agropecuarian research: botany, zoology, geology and mineralogy, since these are areas in which the study possibilities are innumerable and are a little more recognized. We have concentrated, instead, on the examination of the methods, materials and processes of manufacturing industries which have been studied in Colombia in only a fragmentary and limited manner.

Fishing

Fishing is undoubtedly an industry with great possibilities for Colombia, as a work source, as a basic, essential and economic food producer, and as a source of exports. However, very little can be done in this field without ichthyological and ecological studies of our marine platform. As to the fishing resources in the sea, an ample program of studies is required, analogous to those made by the Magdalena and Sinu Valleys Corporation (CVM) in the biology of fresh water specimens (i.e., in ecology and reproduction of the "bocachico"). These studies should be extended to other types of warm water and cold water rivers and lakes of the country. The recently-signed agreement between the Government and FAO offers the possibility of pursuing this very important line of industrial development.

Mineral Technology

Coal is one of the most abundant natural resources of Colombia. This reserve, measured as more than 20 thousand million tons, puts us in first place in South America, as the largest and almost the only coal-producing country. The economic usefulness of coal as a fuel is certainly decreasing, but the obvious advantages of economy and exploitation techniques that we have indicate clearly that we must improve our geological, mineralogical, physio-chemical and economic knowledge of hard coal, aiming at utilizing it as a possible raw material for an eventual large-scale carbochemical development in the country.

Given our abundance of bituminous coal, the extensive knowledge of the technology and chemistry of hard coal distillation, and the diversity and importance of its potential products, optimum means of exploitating this resource could be determined as we develop carbochemical industrial complexes of economic dimensions.

Dr. Bruno Leuchner, in his study for Cepal on "Technological Research in Latin America" gives a prominent place to the study of coal coking in this continent. Especially recommended as studies which Colombia could make are: purification for phase separation; briquetation of preformed coke; distillation at low temperature; coking of coal mixtures (alone or with tar and asphalt); and the petrographic characteristics of hard coal and its influence on coking. The study of the coking conditions of coal mixtures would be of special interest for the possible exploitation of coal in the Cauca Valley.

Colombian reserves of economically exploitable iron known at present are very limited and are, of course, very inferior in quantity and quality to those of Venezuela, Brazil or Argentina. However, large ferruginous formations of low content are present. Utilization would be possible if we could develop exploitation techniques, with emphasis on low caliber metalic minerals such as, for example, the laterites and pyrites abundant everywhere in the country. It should be remembered that the "Strategic-Uddy" iron reduction process was specifically developed for use on Venezuelan minerals of low content, and that in principle, the chemistry of minero-metallurgic process for iron exploitation is well known. In this field, the most important requirement for technical advancement is the application of intelligent and imaginative ideas to elemental resources. It is worth noting that Austria, a minor country in the world steel industry, is today earning substantial royalties from big industrial nations for the use of its oxygen-injection patent for manufacture of steel by the so-called LD process (Linz-Donawitz).

Apart from geologic explorations and the search for new metallic mineral deposits of all kinds, which we should be making

in this country, better studies of their characteristics are needed to determine the reduction and exploitation processes best suited. We also need pilot-plant-level experiments of the processes that offer the best possibilities. Recent failures in the exploitation of phosphoric rock stemmed from a lack of adequate geological and geochemical investigation.

Without pretending to cover all the metals and chemical elements which we could look for in our mineralogical world, we should mention the great importance of a systematic and profound search for potassium reserves in our soil. This element, the basis of the kalio-chemical industry, which as one of the three fundamental elements for chemical fertilizers has extensive technical and agricultural possibilities and would open up a wide variety of industrial possibilities for the country. The fact that potassium deposits have already been found in quite a few places in the world, including Canada, where a deposit has been found that could presumably supply the world market for centuries, should not stop us from trying to make the most of the availability of our own supply. The case of phosphoric rock, which has also been found in several regions of the world, and which has been discovered recently in Venezuela and Colombia in large quantities, demonstrates that one should not lose sight of the possibilities for success in such an important enterprise.

The example of mineralogic studies serves to emphasize the importance of having our scientific and technological centers and institutions duly informed of the work being done in other countries (including Latin America) and of the results of these studies. For example, an important collection of works on mineral potential made by the Institute of Technological Investigations of São Paulo, by the Mexican Institute of Technological Research (IMIT), and by the National Institute of Technological Research (INTI) of Argentina, would be very important to Colombia.

The extraordinary development of solid-state physics during the last ten years has generated extensive interest in the study of glasswork. Scientific interest has been revived in natural crystals, macro-crystals and gems (i.e., the ruby as central element of laser). The proverbial wealth of Colombian minerals and gems should spur us at least to participate in studies on the application of these minerals and in basic research on the chemistry of ceramic materials, especially those which contain heavy metals. In this scientific field it is worth mentioning that today a country cannot expect to have an electronic industry that is not subject to foreign technology and interests, unless it possesses scientific knowledge and technical experience in solid-state physics.

Sulphuric acid production in Colombia is very low in terms of our level of industrial development. Our production is much lower than that of countries such as Peru and Chile, whose industries are comparable or smaller than ours, and we are forced to import

this essential product. This deficiency is due fundamentally to the small amount of sulphur production in the one deposit being exploited today in Colombia. We need to increase sulphur production, and to do so, we can turn to the extensive volcanic sulphur formations in the Colombian Andes, particularly the Central Range. However, we must first create an adequate technology, the development of which will require study of various basic problems of this industry. Among them there are: types of concentration of the volcanic sulphur mineral, refining of concentrations, extraction of solid sulphur from pyrites, extraction of sulphur and sulphuric acid from combustible gases, and the floating and extraction of sulphur from the mud of lakes, etc.

Food Technology

Despite the fact that the manufacture of dairy products continues to be largely an art based on centuries of experience, with empiric practices and manufacturing secrets, we in Colombia do not know or apply universally known fundamental aspects of milk chemistry and technology. For this reason there is hardly any Colombian investment* The simple fermentation process by B. Acidilactici, his chemical kinetics and the variables which affect it in our climate, with our cows milk and our soil, need more study if we are to begin to give the vigorous push to dairy products manufacturing—that is indispensable to better feed our population. It should be recognized that this industry is still afflicted with deficiencies, and that its variety of products is very limited. Simple techniques such as evaporation and pulverization had to be set forth by a foreign company at a high royalty cost. Even for geometric packing design, such as the one called "Tetrapak," our country pays royalties that could be saved by the simple application of a well-known, elemental geometric theory of space.

More ambitious development of Colombian dairy industries requires that we create and perfect disposable packaging materials, new kinds of products, and new processes for the use of by-products. We should also investigate more fully the physical, chemical and bromatologic qualities of the milk of other ruminants, such as sheep and water buffalo, whose development in Colombia is imperative for strong economic reasons, such as the substitution for cattle meat which should be used for exportation in the future. It is interesting to note that large buffalo milk cooperatives (Bubalus bubalis) in India have developed their own large plants, with extremely high productivity, thanks to the systematic application of the basic principles of genetics, zoophysiology and dietetics.

The processes of the milling and bread-making industries, characteristically traditional and elemental industries, are

*Except in pasteurization and in some small factories for derivatives.

generally on a low technical level in Colombia. The grain crushing operation should be studied in the light of the known technology on reduction of sizes of solids. To solve the numerous every day problems of the mills and threshing companies, studies of the mechanics of pulverulent (dusty) and granulated materials should be made. A challenging problem to technical investigation in Colombia is that of maximizing the possibilities of the machinery installed in the milling and baking field. Normally this machinery stands idle 80 percent of its time-capacity. This problem involves means of using it in other industrial processes that may require similar processes or operations,as for example minerals.

The major problem of the bread-making industry is the limited supply of the raw material, wheat. In 1967, Colombia imported 270,000 tons, and produced slightly over 100,000 tons. We need to undertake a methodical, large-scale program to analyze and evaluate the flours and grits from other plants (corn, yucca, rice, millo, rye, etc.), to design blending processes, to study its bread-making qualities, and to develop appropriate industrial processes.

The bromatological research field is another one so vast that we are forced to leave it out of this presentation. However, we cannot pass over it without mentioning that we, in Colombia, have done nothing to formulate a rich, balanced and cheap universal food, while more than 6,800 Colombians die of starvation every year. The Nutrition Institute of Central America and Panama (INCAP) has shown that, based on high-level research, such a food can indeed be developed, thereby providing for the vital and social necessities of the population. They produced the "Incaparina" formula, for the manufacture of which we must also pay royalties today, although the ingredients are produced exclusively in Colombia. Here, too, is a possible area for technical research, drawing on rudimentary and domestic food-manufacturing processes which are well known to us and could be examined from the standpoint of technology, mechanization, and industrialization.

The edible fats industry also poses problems of scientific interest in the areas of technological, botanical, and zoological research.

First of all, there is a need to identify new sources of oils and edible fats, and to establish their chemical, nutritional and biochemical qualities. An example of the important problems of this industry, and one that is vital to health in Colombia, is the matter of saturated acids content (the monoetenoides acids, and dietenoides acids in vegetable fats, with their different effects on the colesterol level of the blood). We still do not have complete and exact analyses of the raw materials used by Colombian industry (soy, cotton, african palm, sesame, etc.).

In a country that until recently was a large-scale importer of edible fats and that still imports great quantities of fish oil, it is indispensable that we make a serious effort in the field of botanical, zoological and biochemical research in order to identify and evaluate animal or vegetable specimens which could constitute new sources of fats and oils, and to accurately determine their biochemical and nutritional characteristics. Materials such as the coffee bean, cereal chaff (other than rice), cucurbitaceous seeds (such as cucumber, Cucurbita pepo; and melon, Cucurbita gratíssima) and the rhizomas of some amaryllidaceous specimens, have not yet been evaluated as to oil content, nutritional value, and industrial possibilities.

Other specific tasks for investigators in this field include: an inventory of Colombian oil-yielding plants; determination of ecological conditions influencing vegetable oil characteristics; the control of extraction processes; physicochemical qualities, and the behavior of oil mixtures; quantitative effect of the physical variables in hydrogenation, oxidation and saturation, industrialization of autochthonous seeds and materials; industrialization of by-products such as lecithin, and search for important chemical substances such as steroids and vitamins.

Animal fats offer another group of important subjects for research. Among them the following deserve mention: the possibility of increasing the edible percentage of animal fats materials; industrial hydrogenation and oxidation, the inter-esterification of animal fats, analysis of fish fats and of different specimens of beef, industrial use of by-products; and industrial separation of pure chemical substances from natural fats.

The entire sucro-chemical field is yet to be developed in Colombia. Current literature shows that a variety of rich products could be derived from sugar or its by-products. The decline of the world sugar market and the increasing pressure from the major producing countries make it advisable that, in a country such as Colombia which has the economic and technical advantages needed to produce sugar, the technical and industrial possibilities of developing this manufacturing field be exhaustively explored. The country's recent experience in using a patent for the manufacture of critic acid using molasses has been fraught with difficulties showing the necessity for greater care in selecting foreign technologies, and careful evaluation of those adopted.

If we were able to remove the chemical, bacteriological and economic unknowns, the country could meet its domestic needs via sucrochemistry and by means of acetone, butanol, acetic acid, citric acid, lactic acid and its esters and salts (which are at present imported in great quantities), and still export to some neighboring markets, with obvious advantages for our balance of trade. However, the problems require extremely careful microbiologic

research, specifically in genetics, on the metabolism and microbian ecology of the stumps required for these fermentation processes. The studies should be aimed at identifying adequate nutrients in order to determine the chemical kinetic mechanism of these reactions and the best conditions for industrial development. Comprehensive pilot-plant experiments are also required. Although these could be very costly, they are feasible. This is a promising industrial field that should be promoted by entities interested in its development and financing (Institute of Technological Investigations, Bank of the Republic, Financial Corporations, Sugar Cane Association, etc.), considering the favorable factors (low raw material cost, availability of local capital, the possibility of manufacturing equipment in this country, the possibility of building plants in accordance with our markets, etc.).

For the development and diversification of the sugar industry, the country also needs complementary knowledge and industrial know-how in the uses of bagasse and sugar cane peel for the production of cellulose and its derivatives (waxes, furfural, etc.).

The technical level of a great number of the country's canning industries is only slightly ahead of domestic methods, explaining their limited economic dynamics. The Ten-Year Plan for Economic Development had had great hopes for the canning industry which were never realized. It consequently faces possible competition from other LAFTA countries. One or two companies has achieved modernization at the cost of being transferred to foreign ownership. This is an industry whose technology is based on unitary operations of all kinds, which could be greatly improved in our factories. Possibly the most important area for fundamental research in this field is the physio-chemical process of cellular dehydration—the main problems in its industrialization, and the saving of materials that would result.

In the alcoholic beverages industry, the country is depending more and more on foreign sources, which contribute only the mixing formula, and cost a considerable amount of foreign currency. It is strange, with the variety of fruits, nuts, flavors, berries, resins and vegetable extracts that exist in our groves, meadows and forests, the country should use so much foreign exchange for mere soft drink formulae based on foreign investment. We pay some US$200 thousand per year in royalties to manufacture caffein stimulated soft drinks, yet we have our own vegetable products with which to manufacture them (i.e., in the specimens of the Paullinia gender) but we have not duly studied the problem.

Brazil has set us an example with the industrialization of a caffein-type, soft drink based on seeds of its native "guaraná" (Paullinia cupana, of the Sapindácea family).

## The Textile and Clothing Industry

The textile industry—certainly the most developed, modern and efficient in the country—is also based on English, North American and European technology, as is that of the whole world. There are not many alternatives to choose from in textile machinery and processes, but we could try to increase our list of utilizable raw materials, in the potentially rich area of liberian fibers for hard fibers for example. The extremely interesting work of the Institute of Hard Fiber Research in Poznań (Poland), shows how much can be done in this field. With regard to natural and artificial soft fibers, there is probably no more comprehensive study than the one made by the Textile Institute of Łódź in Poland, which unfortunately is unknown to our textile industry.

Two specific lines of research and technical development can be outlined for the Colombian textile industry, in accordance with our specific needs. One of them is the design and development of machinery for semi-manual operations, to create a domestic handicraft knitting and clothing industry similar to that developed by India with Poland's help. We could thus establish a technically well-equipped, high-quality handicraft industry, widely distributed throughout the country to give employment to rural and semi-rural population. The technical problems posed are similar to those solved in India.

Another extensive line of textile research and development would be finishing processes and auxiliary materials, for which the country now depends entirely on foreign techniques and suppliers. For instance, in spite of the extraordinary development of dye industries in the world (but not in Colombia), the possibility of re-discovering and utilizing natural dyes should not be ignored. Reference is made to the many natural dyes the world has known which come from Latin America (i.e., cochineal, Brazilin, hematoxilin, Nicaragua blue wood, brazilwood, purple violet). Vegetable dyes are still used in Guatemala for the manufacture of popularly-used materials. From the economic viewpoint and within the concept of "shadow costs" and "opportunity costs," it would seem that extensive possibilities exist for redeveloping the use of natural dyes. Chemical research in this field would be of great interest and have high scientific value.

The clothing manufacturing industry involves high foreign-exchange expenditures, simply for the use of foreign trademarks. However, it can be said that in this industry there does not exist, at world level, any extraordinary or patented originality, with the exception of some minor details of design and sewing. Actually, in the manufacture of clothes the most advanced technical knowledge consists only of a little descriptive geometry, some anatomy, and a few statistics—apart from which only imagination is required.

Therefore, although there are no specific areas of major importance to investigate here, the textile industry clearly illustrates that, in addition to encouraging research to accumulate our own stock of technical knowledge, we must discourage the easy (and sometimes futile) recourse to foreign "know-how" which seldom, if ever, makes an effective contribution to technical progress and yet must be paid for with costly and limited foreign exchange. Technical development, and control over indiscriminate incorporation of foreign technology must be the two fundamental principles of Colombia's technical-scientific development policy.

Forest Products

It is no exaggeration to say that lumber technology has changed little since the Neolithic Age. Only during the thirties and forties were some elemental treatment processes invented and adopted (for immunization, impregnation and aglutination), greatly extending the uses of lumber, which continues to be the construction material of greatest demand in the world. However no fundamental changes have been introduced in the industrializable forms of lumber, to diversify its utilization extensively and make it competitive with other, more costly, structural materials. In fact, little has been done to develop industrial processes which would give permanent qualities of incombustibility, mechanical resistance and homogeneity. Studies during the last ten years of natural and artificial compound materials open vast areas for progress. One can readily appreciate the enormous economic importance to a country like Colombia, which has very limited basic metals but a great supply of forests of a capability of giving lumber hardness, rigidity, mechanical resistance, elasticity, impermeability, foldability and incombustibility, whereby it could become a great iron, aluminum and copper substitute—materials that we presently consume at a great rate and for which we will probably never be able to supply our needs.

The first task of forestry and xylotechnical research confronting us is the preparation of an inventory of Colombian lumber specimens and a determination of their qualities and possibilities for industrial use as sources of alphacellulose, tannin, gums, oils resins, edible fibers and other materials. Bamboo cane, for instance, needs a systematic study of its industrial possibilities and characteristics as a structural material.

Another area of interest, due to the great importance any technical advance would have, is that of new designs and construction procedures, including pre-fabrication, and lumber modules, especially those used in buildings. Positive results would greatly increase the productivity of the construction industry which, in general, is very low at present especially in the home building field. For this reason, agencies, such as Cinva, ICT, Camacol, and IIT should support such a research program of taking advantage of the very interesting experience already gained by INTI in Argentina, the

Institute of Industrial Research (III) of Monterrey, Mexico, and Catholic University in Chile.

The lumber industry of Denmark demonstrates that innovations requiring only creative thinking and intelligence can be as fruitful as complex technological research. The originality and simplicity of the Danish furniture design has gained a world market and also a great deal of income from royalties.

The invention and industrialization of the process of paper manufacture from sugar cane bagasse (a typically tropical product) by a North American company is another illustration of how we Latin Americans (and especially Colombians) have ignored the possibilities of economic utilization of our own resources. This example should lead us to examine carefully other potential resources (which may be plentiful) that we could utilize to obtain pulp and cellulose in Colombia. The possibility of utilizing materials or by-products such as chaff of cereals, coffee pericarp and seed, bamboo cane, numerous specimens found in trees in humid forests, hemp fiber and other liberian fibers for this purpose is clearly established. In this field it would be very important to have the collaboration of IMIT of Mexico and of INTI of Argentina. However, it should be recognized that research in this area can wait for a while until more urgent problems such as those mentioned previously relating to the food industries, are taken care of.

## The Leather Industry

In the leather industry, centuries-old techniques and processes still prevail, preserving this activity as a handicraft guided largely by empiric practices and established customs. This means that great advances and innovations in leather preparation and fabrication can be made in the decades ahead. This supports the idea that research should be started in Colombia to increase productivity and improve the technico-economical state of the leather industry. This industry is still very backward, in spite of the effort made by the IIT, Leather Technological Center to raise its technical level. A possible field for study is the examination and development of new methods to preserve, tan, and modify leather qualities by X-ray, gamma radiation, exposure to neutrons, electrophoresis, electro-coagulation, and dielectric chaldaic. There is still much to be done in the area of traditional technology, with respect to new dyes and tanning, optimum conditions and tanning control, improvement of mechanical qualities of leather, and increasing the resistance of leather to abrasion, wear and splitting.

Possibilities for leather industrialization are also offered through industrial utilization of wasted products by hydrolysis, unfolding and other chemical treatment processes, provided that we first obtain the necessary chemical knowledge and techniques. If, as is presently intended, the country prepares itself for a

great program of cattle development and exportation, it must begin studies now to evaluate and diversify the use of leather.

Rubber

It seems that Colombia is not presently able nor feels any immediate urgency to initiate vast scientific and technical studies on rubber, its manufacture and processing. However, we would benefit greatly from X-ray study of the internal structure of natural and artificial elastomers thereby determining the influence of materials such as lamp-black and kaolin, used as filling in rubber manufacture and appraisal of the possibility of using economical substitute fillings, such as the local clay.

The Chemical Industry

The chemical industry of Colombia has innumerable problem areas in which it is necessary and possible to carry out autochthonous fundamental research or technological development. This is a field in which the country has created a more subordinated industry, from the technical and financial standpoint. The complex technology required has been obtained completely from other countries, where it was developed under very different economic and social circumstances, without the studies necessary to adapt it to Colombia. Nonetheless, we would like to point out two problem areas to which major, immediate efforts should be directed. The first is the search for native raw materials to substitute for those which are imported. This is especially needed for the inorganic chemical industries. The second is the necessary revision of "classical" technologies for totally new ones which would permit us to diversify our production of organic chemical products.

The problem of raw material substitutes has two aspects. One is the need to find in Colombia the natural raw materials we are currently importing, so as to obviate the need to make changes in processes or equipment. For example, we should make an effort to find potassium, sulphur, nickel, chrome, and boron in Colombia.

The other problem, still more complex, is the study of domestic substitute materials, possibly of a different chemical and physical nature, from those we import. This would mean changes in the processes and equipment used in order to continue producing or to begin the manufacture of material and chemical products necessary for the country. This requires that we initiate fundamental studies on the physio-chemistry of the processes, so that we can eventually substitute different materials for the conventional ones at an industrial level. As examples, the following studies can be mentioned: use of national kaolins instead of aluminum hydroxide to produce aluminum sulphate; use of laterites to produce oxide, chloride and iron pigments; use of different types of

national calcium derivatives to produce cynamid; and the industrial development of our barium minerals.

The organic chemical industry in Colombia, which is in its infancy, requires a new and original approach to encourage it, thereby permitting us to make the importation substitutions that are extremely necessary today.

One of the possible approaches, obviously, should take into consideration the fact that much of the technology by means of which this industry developed and progressed in Europe and North America was based on natural-resource development, and that a great deal of relatively unskilled labor was available. The abandonment of this kind of process in favor of others involving much greater investment and less unskilled labor—such as in the petro-chemical industry—was due to the dwindling of the original natural resource, the scarcity and diminution of labor, the extraordinary development of internal capitalization, and the necessity of planning for future oil demands.

The development of the modern petro-chemical industry in Colombia is very difficult because the conditions of this country are different from those under which this industry has usually developed. It would be a very good idea, therefore, to carefully revise the "classical" technology, which up to 1940 allowed Europe to create a very advanced chemical industry, based largely on natural resources (lumber, agricultural products, coal, natural gas), and was superceded by new industrial processes based on the chemistry of organic synthesis only when the natural resources disappeared when war absorbed and destroyed most the young men, when post-war demand enlarged the international market and when the United States' military triumph allowed them to impose their technology on Europe through their investments.

Colombia has abundant natural resources still to be inventoried and utilized. It faces the enormous problem of absorbing an increasing labor force. It lacks big capital, and is obligated to economize its limited internal savings. It has domestic markets that are small (and will be for a long time) in comparison to the minimum size of an economical, internationally predominant plant. And it needs industries whose inputs are totally or primarily domestic.

We enjoy the important advantage that we have abundant natural and economic resources such as molasses, starchy agricultural products, lumber and arboreous vegetation, natural gas, ethyl alcohol, autochthonous flora, salt, sulphur, coal, leather, calcium derivatives, phosphoric rock, and many possibilities of developing new lumbering specimens. We should remember that from these prime natural resources many chemical products are (or were) made industrially in several countries of the world, by simple reduction

processes, dry distillation, solvent extractions, and oxidation, using relatively elementary equipment.

Among those products are some industrial chemicals that are very important, and yet are not produced in Colombia today; for example, many industrial sodium and potassium salts, sulphur and phosphoric acids, and salts; calcareous cyanamid and its derivatives; carbonic bisulfate and tetrachloride; silicates and silicones; amonium salts; methanol and formaldehyde; glycerin; acetic aldehyde, chloral and chloroform; furfural;acetone and butanol; formic; acetic, benzoic, oxalic, lactic, and citric acids, their esters and their metallic salts; cellulose and its numerous derivatives; ether, trimetilamine, cyanide and Prussian and Turnbull blues; coal tar and its endless series of industrial derivatives; phenol; pyrrol; pyridine and quiboline; alcaloids, antibiotics and hormones; edible and industrial gelatine, etc., etc.

Basic research could be done on the cinetic and the thermodynamic chemistry of these processes, to adapt them to our conditions and our raw materials, to perform technological studies on their industrial implementation, and to make technical economical evaluations of the feasibility of supplying the Colombian and/or LAFTA markets.

Construction

The cement industry is one of the oldest and most important in the country, and has reached a technical level at which it should already have started a research program on cement manufacture, use, and qualities. This is done at research centers and institutes in many countries.

It should be remembered that, with the exception of what has been achieved in recent studies made in the United States, very little is known about the basic nature of the physical, chemical and mineralogical processes which take place during the calcination and forming of cement.

In Colombia we do not use the dry process to manufacture cement, although this would permit a great saving in production cost. This is because, on the one hand, our factories were built many years ago and, on the other, because we do not know the necessary technology and have not identified the materials that can be used since studies have not been made on this point, and international patents are very limited and costly.

A basic study should be made of the nature and qualities of metal-ceramic interfaces. This knowledge is very important to progress in the design of reinforced, pre-tensioned and post-tensioned concrete. Also to be investigated are the potentially

interesting prospects of mixtures with fiberglass, metallic fibers, metallic granulates, artificial fibers, etc.

The extraordinary experimental work on glass done recently in England, United States and Germany could make this one of the most diversified of materials with incredible application, including the possibility of its becoming a construction material competing with steel. For Colombia, which produces glass entirely from national raw materials, and which is poor in metals, these developments could have extraordinary economic consequences. However, we are doing nothing about this. As has happened so many times in the past, when these developments are perfected abroad we limit ourselves to buying patents, paying royalties, punishing our balance of payments and continuing to be technologically subordinate.

One of the more common and plentiful natural resources in Colombia is clay. Up to the present time clays have been used almost exclusively to make basic construction materials such as adobe and more or less primitive ceramic articles. However, the complex chemical compositon of clay leads one to contemplate the possibility of using it as a source of inorganic chemical products, especially those derived from iron, aluminum, calcium, and magnesium—several of which are consumed in great quantities by Colombian industry. Three years ago the organization of a joint research program on industrial clays was recommended among technical study centers of several Latin American countries. The progress and results of this study would be very important to Colombia.

Metallurgy

Like the food and chemical industries, the metallurgic and metal-mechanic industries constitute one of the principal branches of our manufacturing activity. But they have reached a point where future development is seriously limited by lack of technologic innovation and modernization. Research and technical progress in these fields is therefore not only very urgent, but also extremely promising. The field of mineralogical, metallurgical, chemical, metallographical and physical research required by this industry is so vast that it is impossible to mention it briefly. All the activities of this industry need perfecting and technification: casting, tooling, die-making, cutting, finishing, etc. The assistance the Institute of Technologic Research is giving to the foundries has been valuable and useful, but it must be extended to other manufacturing operations all over the country.

Due to the relatively limited metallic minerals in Colombia, the country should invest in studies on the possibilities of using low-content ores to produce iron, copper, aluminum, lead and zinc, by means of simplified processes that do not require big installations or heavy investment.

The efforts of the principal metallurgic industries in this area could be combined with those of the Institute of Industrial Development, the Institute of Technological Research, and other entities engaged in the study of the industrial development of minerals.

Important Areas for Research

Colombia has numerous other problems that, whether or not they directly affect existing industries, clearly are related to the development and industrial diversification possibilities of the country, in one area or another. These problems are so numerous and so different, that we can only present an incomplete list of the more important and more promising themes. Among these are:

1. Studies for the elaboration of metal-genetic map of the whole country.

2. Search for natural substitutes of ions for use in chemical, petroleum, soft drink, water-treatment industries, etc.

3. Geographical, geological and geophysical research to determine the possibility of using solar, eolic and geothermic energy in rural areas or regions isolated from centers of electric generation.

4. Studies on the production of basic pharmaceutical products (antibiotics, hormones, opotherapeutic, esterols, etc.), based on Colombian vegetable and animal materials, to relieve the stress these products are currently placing on the balance of payments, due to royalties, patents and over-invoiced raw materials.

5. Phyto-chemical and zoo-chemical studies of Colombian flora and fauna, to evaluate their immense possibilities for industrialization.

6. Solid-state physics research on our minerals.

7. Basic studies on the mechanics of the fluid movement of granulated and pulverous materials, which frequently cause problems in our factories.

8. Manufacture of standard and economical construction materials for houses and the development of simple and efficient construction techniques.

9. Research in soil mechanics, a science which could furnish information of interest for the solution of problems that are appearing in the design and construction of foundations for industrial buildings.

10. Oceanographic and hydrobiologic studies and research required for better knowledge of the country and the industrial development of the incalculable economic potential of our seas.

It is impossible not to mention, if only briefly, the question of the personnel required to do this vast work, and of its scarcity in Colombia (see Appendix). This has been discussed in great detail in other works and documents. Here we wish simply to emphasize the fact if we do not take definite and effective steps to end this shortage, it is useless to think of the possibilities for technical and scientific progress in Colombia.

One of the most serious aspects of this problem is the emigration of technicians and scientists. Colombia shares with Argentina the dubious distinction of being a Latin American country that exports free of charge large numbers of this precious human resource, with great detriment to itself and profit to countries that are already highly developed. ICETEX estimates that about 900 professionals emigrate abroad every year, causing serious damage to Colombia (to say nothing of the capital which goes with them), because of what they are not doing for the country, increasing our technical and cultural backwardness.

Although several reasons have been given for this exodus, I believe that it has not been clearly explained that it is fundamentally an ethical problem, attributable to a deficiency in Colombian education, which does not give the student or the university graduate a sense of responsibility toward his country.

It is also undoubtedly due to the fact that because of the negligence of both the public and the private sectors, or to the impossibility of affording such opportunities, our technicians and scientists are denied careers in their fields and the opportunity of making contributions to the progress of the country. University professors, for example, are confined to their teaching or laboratory work. Although they make up our most valuable and qualified reserve of scientific knowledge and technical competence, the nation fails to take advantage of them for its social and economic development.

Recommendations

With reference to technological studies for industrial use and the various general measures which must be adopted if we are to advance science and technology in Colombia, the following steps should be taken:

1. It is necessary to create a Latin American Institute of Science and Technology that would coordinate and centralize all of these activities in Latin America, taking maximum advantage of the limited equipment and personnel in our countries, that would recover

and integrate the Latin American scientists who have emigrated, and would establish liaison with all similar institutions in the world. The Conference on Science and Technology in Latin America (Santiago de Chile, September 1965) recommended: the creation of such an entity to UNESCO. The Inter-American Development Bank, LAFTA, the Latin American Iron and Steel Institute and other entities concerned with Latin American industrial development should also contribute to its formation.

The Institute should investigate all scientific and technical possibilities available in the world today, especially those which appear to be most applicable and adaptable to specific Latin American conditions.

2. In its efforts toward the creation of a common market of science and technology in Latin America, Colombia should initiate steps for the adoption of inter-government agreement for scientific and technological reporting and exchange among the major Latin American countries, especially in the fields of agriculture, mining and industry.

3. It is necessary to create a Colombian Council of Scientific and Technological Research composed of a small number of distinguished persons from the scientific and technical community and reporting to the President of the Republic. Only an entity such as this can coordinate the incipient and diverse research work carried out in the country, organize and channel state support to them, supervise the incorporation of foreign technology and the use of patents, concentrate resources for research and promulgate a serious and consistent policy for scientific development.

4. It is necessary to organize a concrete research program on industrial technology, especially for the chemical, food and metallurgical industries, through the joint action of private industry and taking advantage of the means and experience of universities, official and semi-official institutions, and industrial laboratories.

5. It is necessary to strengthen the Institute of Technological Research, opening it to the patronage and participation of private industrial companies, to coordinate its activities with those of industrial financing entities and universities, and to create dependencies in Medellín, Barranquilla and Cali.

6. It is necessary to establish and strengthen permanent and active cultural and scientific relations with the countries that are today the main protagonists of scientific and technical development, such as the Soviet Union, France, Japan, Sweden, Canada, Poland, South Africa and Israel.

7. It would be advantageous to establish bilateral agreements for the exchange of personnel and work with industrial research

centers in various countries, such as the Portland Cement Institute of the United States, the Central American Institute for Technological and Industrial Research (ICAITI), the Textile Institute of Lódź (Poland), the Butantan Institute of São Paulo (Brazil), the Metallurgical Studies Center for the National Commission of Atomic Energy of Argentina, etc. At the same time, it is necessary to institute permanent cooperation and interchange with the Latin American national research centers, such as the INTI of Argentina the IMIT of Mexico, the Institute of Technological Research of São Paulo, the INVESTI of Venezuela, and the III of Monterrey, etc.

8. To take advantage of the possible creation of a Latin American Institute of Science and Technology, it would be a good idea to define and start research programs in specific academic fields or areas (i.e., chemistry of metals, mineralogy, vegetable esteroids, metallography, etc.), to be carried out by Latin American scientists in Colombia and with assistance of the foreign institutes or countries, selected exclusively for their scientific competence.

9. It is necessary to create a Colombian fund to develop specifically Colombian new industries which would be financed by the National Government, Bank of the Republic, financial corporations, governmental and private industries, IFI, banks and other voluntary contributors, and which would take charge of the design, development and industrialization of technologies adaptable to the specific requirements and possibilities of Colombian industry.

10. A Center of Documentation and Information would be an invaluable instrument for the organization of research in Colombia. Its constitution and operations should be under the control of the Colombian Scientific and Technological Research Council previously recommended. A task of industrial interest which could be achieved by this entity would be to obtain and disseminate information on expired industrial patents in the United States, Europe and other countries, many of which could undoubtedly be used.

11. ICETEX should guide its loan programs toward the more advanced Latin American countries, such as Mexico, Brazil, Argentina, and Chile, which have the high-level teaching institutes and programs in scientific fields that are so important for technical progress, such as mathematics, physics, chemistry, biochemistry, metallurgia, statistics, hydraulics and pharmacology.

12. The most important thing of all is to stimulate and unite the Colombian scientists, to repatriate those who have already emigrated, give them honorable and challenging conditions under which to do high-level scientific research which will benefit Colombia. At the same time, we must promote interest in scientific vocations among our university youth, stimulating their intellectual curiosity, respecting their freedom of opinion, guiding their deep and sincere concern with Colombia, opening the country to scientific

currents and world thought. The essential ingredient for science is scientific manpower and to have scientists we must create young scientists.

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APPENDIX

PROPORTIONS OF SOME KINDS OF SPECIALIZED PROFESSIONS WITH RELATION TO THE LABOR FORCE, 1959

| | | Scientists and Engineers | Doctors, Dentists, Pharmacists and Veterinarians | High School Teachers and College Professors | Total of the Three Columns |
|---|---|---|---|---|---|
| DEVELOPED COUNTRIES | France | 0.8 | 0.4 | 0.6 | 1.8 |
| | Italy | 0.9 | 0.6 | 1.0 | 2.5 |
| | United Kingdom | 1.0 | 0.3 | 0.7 | 2.0 |
| | United States | 1.7 | 0.7 | 1.0 | 3.4 |
| | Canada | 1.3 | 0.5 | 0.9 | 2.7 |
| | USSR | 1.2 | 0.4 | | |
| DEVELOPING EUROPE | Greece | 0.4 | 0.5 | 0.4 | 1.3 |
| | Spain | 0.3 | 0.6 | 0.3 | 1.2 |
| | Turkey | 0.2 | 0.1 | 0.2 | 0.5 |
| | Yugoslavia | 0.5 | 0.2 | 0.3 | 1.0 |
| AFRICA | Ginea | 0.002 1/ | 0.007 | 0.016 | 0.025 |
| | Nigeria | 0.01 | 0.01 | 0.05 | 0.07 |
| ASIA | India | 0.05 | 0.1 | 0.3 | 0.45 |
| | Iran | 0.16 | 0.1 | 0.2 | 0.46 |
| | Pakistan | 0.05 | 0.03 | 0.2 | 0.28 |
| | Philippines | 0.24 | 0.42 | | |
| | Formosa | 0.1 | 0.2 | 0.6 | 0.9 |
| | Thailand | 0.01 | 0.03 | 0.1 | 0.14 |
| LATIN AMERICA | Argentina | 0.2 1/ | 0.4 2/ | | |
| | Brasil | 0.1 1/ | 0.2 | 0.4 | 0.7 |
| | Colombia | | 0.1 | 0.5 | |
| | Perú | | 0.2 | 0.6 | |
| | México | | 0.2 | 0.4 | |

1/Engineers only
2/Doctors and dentists only
Source: OECD Observer

# SOLUTION OF THE PROBLEMS OF INDUSTRY AND GOVERNMENT THROUGH A RESEARCH INSTITUTE

Karl Folkers
President, Stanford Research Institute

The Stanford Research Institute (SRI), is a problem-solving organization that conducts research and development generally not suitable for a university. SRI extends the research and development of the government, and it performs objective-oriented studies and research for business and industry lacking appropriate research staff and laboratories. Business and industry often cannot build up an extensive research and development staff so they contract SRI to conduct needed research on their problems. SRI and similar institutes in the U.S. fill a gap, particularly between the university and the industrial and business world. Also, SRI provides a greatly needed facility for the government. In fact, SRI is about 75 percent governmental and 25 percent nongovernmental, including industry.

Other countries have recognized their need for such a gap-filling institute for research and development. Japan now has one of its own, dedicated in 1966, and continuously assisted by SRI in planning and on an advisory basis over a period of several years. Today, the Japanese Nomura Research Institute is operational and is successful. This Japanese institute and SRI are independent and separate but each can, and does, subcontract the other to do studies and research.

SRI has divisions for economics, management sciences, systems sciences, engineering, physical and life sciences. The latter two divisions include agriculture. SRI has the unique capability of being able to form teams of investigators to solve problems. For example, economists, physicists and engineers can team up to solve a client's problem. Chemists, biologists, and agriculturalists can join forces to solve problems on insecticides or nutrition. Economists, management, and systems people with computer-based experience can work together on problems of transportation, post office operations, urban life or education.

SRI is particularly outstanding among its kind of research and development institutes in the U.S. by virtue of its unique strength in economics and management and the combination of these disciplines with science and engineering.

SRI generally declines routine testing of products for composition and quality, and other functions which involve mere assembly of information with little or no sophisticated research input.

SRI generally does not become involved in pilot plant operations in technology, but does a little such larger scale development in the transition of a problem to the industrial client.

SRI can conduct research on new products and new processes for an industry in order to circumvent a patent position of a competitor in the field. This is frequently normal industrial research, and SRI normally solves typical problems for its industrial clients.

I know that Colombia has several research institutes, including ones for technology, cancer, health, and nutrition. However, let me extrapolate the nature and purpose of SRI to the needs of Colombia, and propose for consideration a similar institute for Colombia as a "model." The name of this "model" organization could be "Colombian Institute for Research and Development" (CIRD). "Research and Development" is a meaningful expression in the U.S. I understand that Colombia is greatly concerned with the difficulties of adapting existing technology to its needs. Adaption is a part of research and development. The building up of technical staff and skills to perform research and development locally is very important to Colombia.

The Instituto de Investigaciones Tecnológicas in Colombia, whose Director is Dr. Norton Young, already fulfills some of the needs today in Colombia for such research and development. Dr. Young's Instituto de Investigaciones Tecnológicas could be expanded in the future to fulfill all of the functions described for the "model" as "Colombian Institute for Research and Development."

A Spanish expression which clearly translates "Colombian Institute for Research and Development" is important for the policy, nature, image, and operation of the organization.

The existing Instituto de Investigaciones Tecnológicas could be expanded by consolidating with a few, but not all, of the other existing institutes. Alternatively, the Instituto de Investigaciones Tecnológicas could be expanded as fast as new research and development business and staff are obtained. The consolidation of a few existing institutes into a new organization as a nucleus would probably save money and, in addition, facilitate interdisciplinary research that is probably not now very feasible.

"CIRD," or an expanded Instituto de Investigaciones Tecnológicas, should be organized and managed by modern concepts of management sciences for maximum contribution to the nation. The institute could have a Board of Directors of 24 members. The number of members should be rather large so that many Colombian organizations are represented on the Board for greater guidance and help. The tenure of Board members could be for three years,

so that rotational representation is possible from business, industry and government.

The policy of the institute could be primarily to solve problems on a contract basis for clients in Colombian industry and government. Contracts could be for weeks, months or years.

The institute might have the following divisions: (1) Economics, (2) Management and Systems Sciences, (3) Life Sciences, (4) Physical Sciences, (5) Engineering, (6) Central Administration and Finance. The first five divisions would do the research and development; the sixth would support the five research and development divisions. The interdisciplinary approach to problem-solving should be emphasized. The Economics and Management staffs and the Life, Physical and Engineering Sciences staffs should work together with a sense of urgency and a sense of profit on the practical problems of industry and the government. Perhaps 20 percent of the staff's time could be devoted to their own research and development of new ideas.

The entire staff of the institute must respect the confidentiality of the clients' projects, and not disclose information of one client to another.

Financial support for the institute could come partially from the Colombian government and partially from Colombian business and industry, on an annual and rotational basis. All Colombian business and industry could look to this institute to solve its problems. Since Colombian business, industry and government would help support the institute, all of these sectors would feel responsible for its success.

Contracts awarded to the institute could provide the balance of the financial support. The contracts could be obtained in two manners: (1) The staff originates a proposal and "sells" it to a client; or (2) The client approaches the staff, asking the staff to solve a problem. The first approach is by far the most important. This means that the professional staff must be innovative, aggressive, and possess a sense of urgency. Therefore, the selection of professional staff is a very important responsibility of the president of the institute. Of course, not every professional staff member will be an ideal entrepreneur but, as Professor Djerassi told us yesterday, a few dynamic entrepreneurs can promote an entire organization. A few dynamic entrepreneurial economists, management experts, chemists, geologists, biologists, and engineers can have great impact upon the entire staff of the institute.

I am confident that such an expanded institution could start contributing immediately to the progress of Colombia—not years

from now but in 1968, 1969 and onwards. The necessary knowledge is available to Colombia, and the success of the American institutes such as SRI, Battelle and others, illustrates the fundamental value of such institutes. The establishment of the new Japanese Institute is also significant.

SRI would be glad to provide guidance and assistance to Colombia in developing an expanded Colombian-owned and -managed Institute. In the meantime, SRI would be available to help Colombia solve its problems, as it is now doing in 25-35 other countries of the world.