Agricultural Biodiversity and the Role of Research and Development

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Introduction

In October 16, 1993, FAO selected the theme "Harvesting Natures Diversity" for the World Food Day, hoping to draw the worlds' attention to agricultural sustainable development and to mobilize action to halt the continuing loss of biodiversity.

In contrast to natural systems, where species diversity and persistence are more or less the focus of concerns for system stability, agricultural production stabilities fluctuate from year to year. Variable weather, weeds, diseases, pests and markets are among the major sources of risk which farmers face. In regions with large variations in rainfall, such as semiarid regions, dryland farming outputs vary annually. Variations in yield however, are becoming lower than they were in the 1800s and earlier, perhaps due to technological developments and farmers experiences. It is not clear however, which technological changes should be given credit for this reduction in variability. Fertilizers, biocides, drainage and machinery technologies have progressed dramatically, but so has disease resistance of modern cultivars as well as other components of genetic stability.

The future holds numerous uncertainties for farming. Climatic change, future restrictions on the use of biocides, and increased demand due to population growth will perhaps continue to have the greatest impacts on production. While it is certain that people will continue to need food, much of the future stability of farming will depend on the natural and magnitude of these factors, and on the ability of farmers and supporting services to respond to such changes.

Research and development in agriculture provides techniques and know how to advance food production. But training and education of farmers and the existence of competent programs in all aspects of agricultural developments such as plant breeding, entomology, plant pathology, soils and others are equally important. Both research and development and farmer education however, should be directed towards the genuine understanding of development in terms of finite resources and sustainable yield.

This paper presents the concepts of diversity in agricultural systems and the role of technology and research in advancing agricultural production with particular emphasis on the role of research institutions in agriculture and related fields in Kuwait. Throughout the discussion, agricultural research refers to crop and livestock production. Research and technologies in fisheries are excluded.

Biodiversity in Agriculture

According to Shan (1993) biological diversity is made up of all species of plants and animals, their genetic material and the ecosystems of which they are a part. Ecological systems or ecosystems are defined as assemblages of living organisms in association with their physical and chemical environment (Heitschmidt 1991). The components of the ecosystem (biotic and abiotic) interrelate and interact among each other forming complex mixes in diversity between and within species. Agricultural ecosystems, while depending on human activities for their existence and maintenance, also have characteristic assemblages of plants and animals (Shan 1993).

In agriculture, genetic diversity is defined at several levels. At the species level, thousands of plant species have been cultivated by humans and several hundreds are currently employed as crops, yet the great majority of crop production is derived from only a small number (Loomis and Connor 1992). Table 1 shows that from the family Gramineae, wheat, rice, maize and barely, account for more than half of the total world principal crop production. Very great diversity however, is available in horticultural species. Fruits and vegetables are important sources of vitamins, and minerals, as well as roughage, and they add desirable diversity to our tables, but their place in agriculture and their contribution to food supplies on international bases.

Limited species diversity is not a recent phenomenon in agriculture. The archeological evidence is that domestication was a gradual process and that a small number of crops have long satisfied basic food needs within each of the regions where agriculture developed (Smith 1990). Loomis and Conner (1992) indicated that movement of species around the globe has resulted in a much greater diversity of crops for each region than was previously available to earlier cultures. For example, the cultivation of maize, sorghum, wheat oats, barley, rice, beans, potato , sugarcane and sugarbeet now exist in the USA, whereas native Americans cultivated mainly maize, beans and squash.

The genetic structure of agricultural species populations is defined by particular genes, their relative frequency in the population, and by their combination with other genes. Structure of genes is subject to change during reproduction through natural or induced mutation of genes. Plant breeders artificially select plants through identification of phenotypes that possess certain traits. Selection also takes place in nature. Phenotypes that are well suited to a particular environment achieve a greater reproductive rate than poorly suited phenotypes, and therefore their genes increase in frequency in the population over generations. The successful genotypes generally become more adapted to local conditions such as climate, disease, soil pH, heavy metal toxicities, nutrient deficiencies and other (Loomis and Conner 1992).

Biotechnological methods, new methods for gene transfer based on a variety of molecular techniques, are now being used to supplement traditional methods of plant breeding. Advances in plant breeding methods have made farmers' choices of genetic material increasingly important. Modern cultivars are generally greatly superior to earlier cultivars and they also may differ greatly from each other in adaptation to local conditions and to the quality of their yield.

Food Demand

A number of factors exert a profound influence on food and agriculture. Rapid population growth continues in some regions of the world. As compared with the situation in 1990, by the year 2010 there will be an extra 1900 million people to feed, an increase of 36% from 5300 to 7200 million people (Table 2). Ninety percent of the entire projected growth over the next 20 years is expected to take place in the developing countries (WHO 1992, Wright 1992).

A 36% increase in the amount of food, other agricultural products and potable water needed will be required over the next twenty years simply to match the anticipated rise in population (WHO 1992). The pressure for agricultural and food production will lead to a greater burden on the environment, especially in poor nations.

Each country should formulate and implement policies and programs to ensure that all households have access to an adequate and affordable diets which will alleviate energy and nutrient deficiencies, while promoting long-term sustainablity in food production. At the same time, excessive consumption of certain dietary components, such as fats, oils and sugars, which contribute to overweight and some chronic diseases, should be discouraged.

Recognition and acceptance of the need for a healthy, robust agricultural sector makes it all the more important that we look to the future of this vital industry.

Agricultural Research and Development

Based on WHO (1992) analysis, an hour of farm work today produces 14 times as much as it did in 1919-21. Just in the past 50 years, both crop and livestock production have more than doubled, with close to the same amounts of cropland, breeding animals, and total inputs.

Agriculture is an increasingly sophisticated business. Tomorrow's farmers will be better businessmen, as well as better production technicians. They will benefit from a rapidly growing array of electronic technologies which will provide more information on a more timely basis, with more analytical capabilities. How well farmers manage this information will be an important factor in business success.

It was projected that by the year 2000, agricultural production will have grow substantially, and that many technologies will be used by farmers to enhance crop yields and reduce their variabilities from year to year (Battelle 1983). Questions are constantly raising such as: What size are farms and ranches? How are they managed? Who works on them? How are producers taking care of the environment, especially soil and water? What about farm income and inflation? How will government policies on credit, conservation, subsidies, land tenure and labor affect the future?. Questions like those just mentioned, frequently need answers. To answer such questions research is needed.

Agricultural research is a scientific activity classified as descriptive or comparative at either the basic or applied level (Bender et al. 1989). Problems may be addressed and data collected through a survey of existing conditions or with controlled, planned experiments. CGIAR classified agricultural research into basic, strategic, applied and adaptive. Basic research is designed to generate new understanding, Strategic research is designed for the solution of specific research problems, whereas applied research is designed to create new technology. Adaptive research is designed to adjust technology to the specific needs of a particular set of environmental conditions (ISNAR 1993). Research is a continuous process as new findings often require evaluation or description of new attributes of the resource, or as conditions are modified by changes in economics or public values. All biological research is conducted in an environment of inherent variability. Information generated is only as valuable as the care which goes into defining the hypotheses, and planning and implementing the data collections.

Agricultural technologies are usually location specific and sensitive to agroecological and socioeconomic constraints. They may not be directly transferable from one country to another. Hence, technologies transfer are usually subject to testing, improvement or modification. Also, new agricultural technologies cannot be developed without sufficient funding for agricultural research, which often must wait many years for a payoff. Even after development of a successful technology under experimental conditions, the technology may not be employed on a widespread commercial scale if economic conditions do not warrant its use. Ultimately, any new practice which conserves energy and labor, increases production, improves product quality, etc. must return the user a higher income than might be achieved from the conventional, perhaps less sophisticated, practice. Technology extension is an important element in securing proper technology transfer. In the middle East, efforts are exerted to link research and extension at all stages of technology development (ICARDA 1993).

More recently, there is widespread recognition within the agricultural research community of the problems associated with desertification, characterized by soil erosion, low water availability, and loss of farmland for nonfarm purposes. Therefore, steps are now being undertaken to plan and develop agricultural sectors based on the concept of sustainable developments. Moreover, FAO has reformed its program to place a central emphasis on the sustainablity of agricultural and rural development (Shand 1993).

In the USA, European countries and other countries thousands of agricultural research projects were directed toward discovering new and better ways to grow crops, to manufacture more efficient tractors and farm machinery, to produce superior livestock and poultry, and to more effectively communicate and manage agricultural information.

Substantial resources are already employed in the development of new technologies to enhance the productivity of resources used in food and agricultural production, processing and distribution, and such research should continue.

Agricultural Technologies and Their Potential

A technology description by itself overlooks the synergistic effects of these technologies on the quantity and quality of farm output, and on the mix of agricultural inputs used for production. In other words, the total effect of combining two or more new technologies may be greater than the sum of each technology considered on an individual basis. For example, fertilizer consumption could be affected by the ability of genetic engineers to create crop varieties that fix their own nitrogen from the atmosphere. Also, less fertilizer could be needed when water conservation technologies save nitrogen by reducing leaching and runoff. Similarly there is a relationship between potential developments in seed treatment and fertilizer use, since seeds may be treated with nitrogen fixing bacteria in addition to using the techniques of genetic engineering. Also, the potential use of nitrogen fertilizer will involve other factors beyond nitrogen fixation and water conserving technologies, such as controlled nutrient release mechanisms and nitrification inhibitors.

Thus, it is impossible to take one specific technology, such as genetic engineering, and determine its potential implication on agriculture since its commercialization will be closely related to developments in seed treatment, water conservation, plant growth regulators, etc. Considering the wide range of technologies now under development, there are many ways to increase plant and animal productivity. But at what price such increases will come and whether or not the farmer's income derived from the use of a new technology will pay for its investment and cost. Another critical factor is the ability of public institutions and private industry to provide research funds for agricultural technology development.

Water is a prime resource for agricultural development in any region. Many techniques were developed to improve and reduce irrigation water losses. Irrigation technologies advanced drastically in the past few years focusing primarily on water conservation. Water conservation technologies, such as drip or trickle irrigation, are increasingly used on high value specialty crops. In addition, field crops that use flood irrigation, are using surge-flow irrigation techniques to produce water savings up to 50% over conventional practices (Battelle 1984). Infrared guns are being employed to measure plant temperatures as indicators of water stress. Irrigation scheduling are being developed based on the evapotranspiration rate of individual crops under particular environmental conditions. Field conditions are being monitored by sensors, and tied in with satellite weather forecasts, to aid in irrigation scheduling.

Conventional plant breeding and genetic engineering technologies would help crop farmers in many ways, such as by making it possible for them to use plant varieties with disease, insect and salinity resistance. Tissue culture development is being used to quickly develop disease resistant varieties that would take years to produce via conventional plant breeding. The development of crops with improved salt water tolerance such as wheat and barley, will have particular importance in arid regions. Improved salt water tolerance coupled with trickle irrigation, will allow irrigation with high saline water and will also extend the geographic range for commercial crop production.

Genetic engineering is capable of altering plant structures and shapes to enhance mechanized harvesting. It will be especially valuable in introducing new genes with desirable characteristics from wild plant species. Genetic manipulation may, for example, be able to improve the rate of photosynthesis in the less efficient C-3 plants, thus resulting in faster growth rates and greater yield increases. Genetic engineering technologies will also advance livestock production primarily by shortening the time span needed to upgrade the population of cattle and poultry. Lean and nutritious meat products are focused upon to provide low fat, high quality and nutritious diets.

The use of nitrogen based fertilizers may be significantly affected in the future by developments to come. Inoculations of seeds (wheat and barley) with nitrogen fixing bacteria or genetically altering the plants in other ways would reduce the use of nitrogen based fertilizer and hence reduce cost of production. However, research is continuing on this regard especially in corn due to its complex combination of 10,000 genes. Plant growth regulators can control weeds, hasten crop maturity, enhance yield and reduce biological environmental stress. The use of controlled release fertilizer and nitrification inhibitors prevent nitrogen loss.

Controlled environment agriculture is mostly used in areas having limited productive land, severe environments, or rapidly rising population. Because the expense of producing crops in the controlled environment atmosphere is normally higher than under ordinary field conditions, its use has been limited to the high value crops such as vegetables and other nursery products. The higher plant yields obtained under environmentally controlled conditions may, in some cases, offset the higher production costs. Hydroponics (cultivation of plants without soil) technology is used in controlled environment agriculture. Many techniques were developed to advance hydroponic systems such as aeroponics, nutrient treatment films, pullulator systems and others (Battelle 1984).

Mechanization reduces time and labor in the field, increases crop yield, improves crop quality, controls application of pesticide and fertilizer quantities, and speeds crop, grain and fruit harvesting. Microcomputers could be used to determine proper machinery and system operations. Field conditions could be monitored by sensors and tied with satellite weather forecasts to aid in irrigation scheduling.

Poultry and dairy industries have led the way in the adoption of new technologies that are based on controls associated with management practices. Frozen embryo transfer and the more widespread use of artificial insemination in beef cattle are some of the technologies used in intensive livestock production. Cross breeding of domestic and exotic sheep increased reproduction rate which have been great deterrents to efficient sheep production. Poultry waste is an excellent protein supplement, superior to alfalfa crude protein and contains both calcium and phosphorus. Research for better animal health is well established and vaccine control provides the protection needed against many diseases.

Remote sensing satellite technology has been used ,for example, to predict wheat crop yield; to give advanced warning of freezes; and to monitor surface water supplies, irrigation practices, soil erosion and vegetative stress from blight, insects or drought. The use of remote sensing technologies will make data more available, more timely and be of higher quality.

Agricultural Research in Kuwait

This part provides a general review of the research institutions engaged in or are directly serving crop, livestock and fisheries production in Kuwait.

Agricultural Research Institutions

The Public Authority for Agricultural Affairs and Fish Resources (PAAF) is the center for agricultural development in Kuwait. PAAF, previously a department in the Ministry of Works, is frequently referred to as an autonomous authority. It has a board and a Director-General, who also acts as Chairman, and is responsible to the Minister of Public Works rather than the Ministry itself. The total staff of PAAF amounts to less than a thousand personnel of whom more than 50% have degrees in agriculture or related subjects. PAAF has an important role to play in promoting agriculture, livestock and fisheries. It supports the needs of producers and workers in the agriculture sectors. Fig. 1 outlines the structure of the organization showing the number of departments in the organization. 'In October 1992, PAAF requested the assistance of FAO representatives to evaluate and modify its organizational structure and to define its role in the agricultural development.

Kuwait Institute for Scientific Research (KISR) has a major role in conducting agricultural research. Under the umbrella of general research in Life and Environmental Science, a position held by the Deputy Director General, the institute carries out research related to the environment and agriculture under three divisions: Division of Environmental and Earth Science, Division of Water and Resources and Division of Food and Biological Resources (Fig. 2). A large portion of KISR's efforts is directed to plant, livestock and fisheries primarily in the Division of Food and Biological Resources (FBRD). The FBRD currently has more than a hundred staff, with plans to employ more. Of the Division of Food and Biological Resources, more than 30% of its projects are in the Aridland Agriculture Department.

PAAF, the Kuwait Foundation for the Advancement of Science and the Environmental Protection Council sponsor many projects at KISR that are directly or indirectly related to agricultural development. A high level committee drawn from PAAF and KISR exists to deliberate upon the research proposals put forward by KISR's technical sub-committees dealing with plants, animals, fisheries and the environment. Many projects are conducted at KISR that also consider conservation of renewable resources such as the flora and fauna of the country. KISR in collaboration with the Kuwait Municipality recommended establishment of National Parks for the conservation of species diversity in the desert ecosystem. Like wise projects were conducted to evaluate establishment of wildlife sanctuaries and marine parks. Other projects are more oriented to agricultural research in plant/crop production, greenery, agricultural master plan development, fisheries master plan development and others.

The two institutional sources of finance for agriculture and fisheries are the commercial banks and, of particular importance, the Industrial Bank of Kuwait (IBK). The bank provides loans to capital projects covering crops, fisheries, poultry, sheep production, dairying, and agro-processing. The IBK collaborates with PAAF on an informal basis, as well as through an ad hoc consultative committee including both the Bank and PAAF, together with the Kuwait Investment Authority.

There are a number of local companies involved in agriculture livestock and fisheries with varying amount of Government involvement and shareholding. The companies are: Kuwait Flour Mills and Bakeries Company, Petrochemical Industries Company (KSC), Kuwait Farmers Federation, Agricultural Food Products Company (K.S.C.), United Fisheries of Kuwait, United Agricultural Production Company, United Poultry Company, Mubarakiya Poultry Company, Palms Agro-Production Company, Bubiyan Fish Company and The Kuwait Supply Company. Research in the companies is rather limited as most of the companies are engaged in marketing and processing food commodities. KISR aims to serve as the sectors research arm.

KISR Research activities and Findings

Kuwait, like the other GCC countries, is generally food, water and arable land deficient and hence agricultural research is primarily focussed on the production of food crops, fodder, livestock and fisheries with prime consideration of the limiting factors (water and soil).

The pre-war research activities at KISR were focused on range and ecology, livestock production and environmental tolerance, plant production and environmental tolerance, bio-conversion research, genetic engineering, tissue culture, aquaculture fish and shrimp development, live food fish production, fish health management, fisheries management, biology and oceanography studies and food technology studies.

The agricultural research is supported by other studies conducted on water resources, erosion control and soil improvement. In the post war period. Research in agricultural developments continued at a lower pace with more emphasis on greening/landscaping aspects and resource management and conservation.

Research within PAAF is limited under each department except in the case of fisheries, in which applied research is virtually undertaken by KISR. More collaboration and interaction is needed between the two organizations (PAAF and KISR) in order to define research priorities.

Summary and Conclusions

Biodiversity awareness is the theme of the 1993 World Food Day. In agriculture, genetic diversity is defined at species levels, as thousands of plant species have been cultivated for years. Biotechnology developed molecular techniques for gene transfer to alter the general characteristics of plants and animals. Species that are more tolerant to stress and environmental conditions are being selected and tested for commercial production.

Rapid population growth in the world continues and food demand is continuously increasing. More pressure is being exerted on land, water and other resources. Research and technology development activities are essential in order to develop and sustain our agricultural resources. Many technologies for example, have been developed to improve and reduce irrigation water losses. Conventional plant breeding and genetic engineering technologies have been applied in developing plant varieties that are more tolerant to disease, insect and salinity problems that exist here and other arid parts of the world. Tissue culture techniques have also been developed to speed the productivity of more adaptable and useful species. Poultry and dairy industries have developed technologies that are based on controls associated with management practices. Electronically-controlled machinery, Controlled Environment Agriculture techniques and Remote sensing are among the more advanced equipment technologies used by farmers to enhance agricultural development. Research and Development in agriculture takes into account sustainable developments and farmers are trained to use more sophisticated equipments in order to speed crop production and minimize labor and cost.

In Kuwait, research on agricultural developments are primarily conducted in two institutions: Kuwait Institute for Scientific Research (KISR) and the Public Affairs for Agriculture and Fish Resources (PAAF). Other institutions that indirectly contribute in agricultural research are Kuwait Foundation for the Advancement of Sciences (KFAS), the Environmental Protection Council (EPC) and others. The paper highlights research activities of KISR and PAAF.

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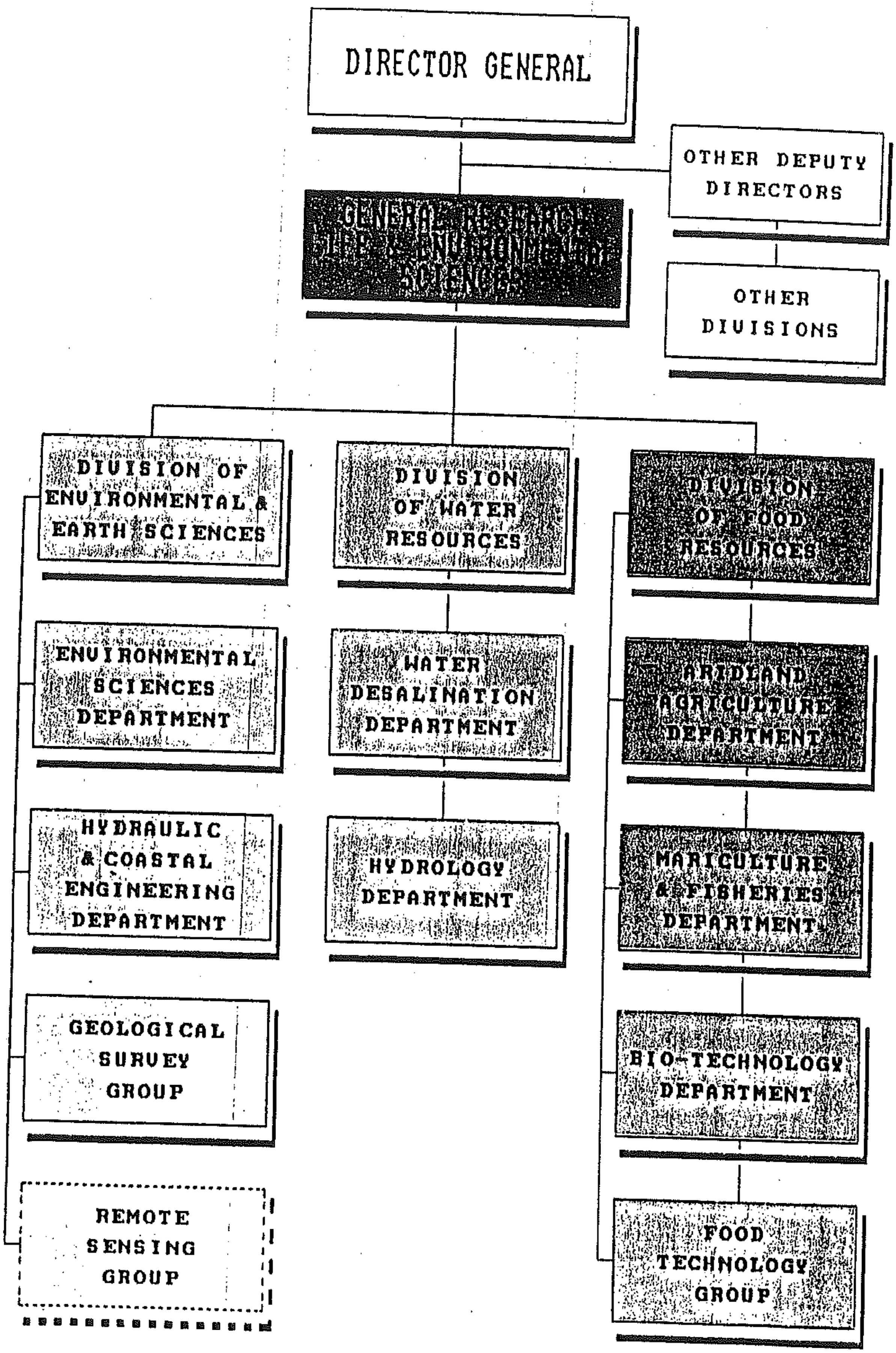

Fig. 1 - The organizational structure of the Life & Environmental Sciences at Kuwait Institute for Scientific Research. KISR/Food '93

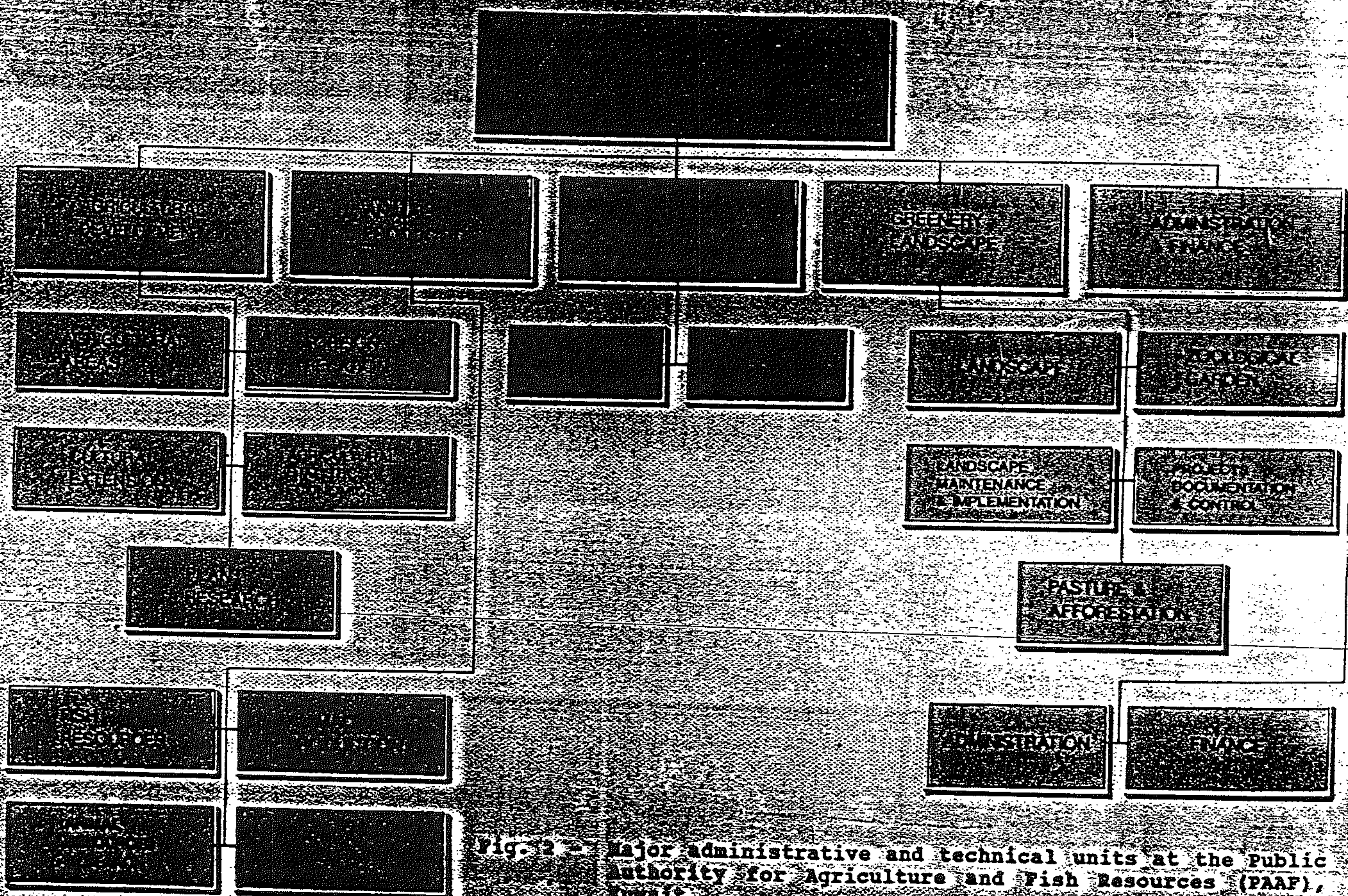

Fig. 2 - Major administrative and technical units at the Public Authority for Agriculture and Fish Resources (PAAF), Kuwait.