

Editorial Section. This section publishes articles on issues and topics affecting the statistical profession in the Philippines.

STATISTICAL SCIENCE AND THE ENVIRONMENT*

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Abstract

The nature of the environmental problem is examined from the point of view of Statistical Science and a more active role that a statistician should play in environmental research is proposed. The intersection between Environmental Science and Statistics is described and Environmental Science in the University of the Philippines is presented.

Keywords: uncertainty, Statistical Science, environmental statistics.

INTRODUCTION

In a series of articles in the Philippine Daily Inquirer, Yasmin Arquiza of the Philippine Center for Investigative Journalism painted a grim ecological picture of the Philippines, a picture marred by widespread pollution and rampant environmental degradation and destruction.

Mindless deforestation has caused the rapid loss of habitat thereby posing a threat to the diverse wildlife of the country. No wonder the Philippines appeared among the top ten "hot spots" or most endangered ecosystems in the world.

However, with the recent environmental and ecological disasters to which this country has played host such as the Mt. Pinatubo eruption, the Ormoc tragedy and most recently, the Mindanao power crisis, public awareness has expanded and more and more pressure from various sectors is being exerted on the government to deal with these problems. Some animal and plant life have already been eliminated and places of natural beauty have been destroyed. Many more will die if the pollution and destruction of the environment by greedy, thoughtless and careless people continues.

Environmental issues have indeed become enormously important for this country. It has now become imperative that rational and scientific measures be effected before the environment is irreparably

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damaged. However, scientific facts related to environmental issues are complex. Understanding and solving environmental problems require insights from many disciplines. Its complexity dictates that specialists from relevant disciplines go beyond the boundaries of their own fields to communicate with others, to share what they know and to discover what they do not know, to talk and to listen. In the United States, the American Statistical Association and the National Academy of Sciences have, for the past twenty years, been sponsoring the Symposium on Statistics and the Environment. This symposium series over the past years has provided a forum for the exchange of ideas concerning environmental matters among statisticians, scientists, lawyers, and other professionals.

Statisticians can and do make important contributions to the solutions of environmental problems. Unfortunately, the nature of these contributions are not widely appreciated due mainly to the fact that statisticians themselves do not seem to realize the extent to which they can help in solving these problems. For instance, statisticians are none too visible in other disciplines in colleges and universities, and much less to the public. It is not uncommon for faculty researchers to assume that statistical advice and services can be obtained from computer programmers. Most of the statistics being practiced today in many researchers is carried out without professional statistical assistance.

We hope that the formation of a group on environmental statistics at the Statistical Center, will stimulate interest and participation of statisticians in environmental studies. The group hopes to accomplish this by introducing a new area of research in Statistics; by developing a "research culture" among statisticians; and by helping upgrade statistical methodologies currently in use in environmental studies.

This paper examines the nature of the environmental problem from the point of view of Statistical Science and presents a more active role that a Statistician should play in environmental research and related activities. Section 1 discusses the problem of the environment and provides a definition of Environmental Statistics. The intersection between Environmental Science and Statistical Science is presented in some detail in section 2 and in section 3 Environmental Science in the University of the Philippines is described. Finally, the last section addresses the question what should be done from here.

1. WHAT IS ENVIRONMENTAL STATISTICS?

Environmental statistics has indeed come a long way since the First Symposium on Statistics and the Environment sponsored by the American Statistical Association and the American Academy of Sciences in the early seventies. The rapid development of various statistical techniques as applied to environmental studies has not only advanced the field of Environmental Statistics but has also emphasized the wide applicability and utility of Statistical Science in the solution of real-life problems. The advance of Environmental Statistics owes much to the innumerable symposia and fora held where interdisciplinary communication and discussion were made possible. These experiences underscore the need for an interdisciplinary approach to environmental problems.

Notwithstanding the plethora of researches abroad dealing with environmental statistics, a reasonable definition of this emerging field in Statistics has yet to be formulated. William G. Hunter (1982), instead of defining Environmental Statistics, identified the central problem in Environmental Statistics. According to him, the central problem of Environmental Statistics is "to determine how our quality of life is affected by our surroundings, in particular by such factors as air and water pollution, solid wastes, hazardous substances, foods and drugs." Specifically, Environmental Statistics is involved with the analysis of quantitative data with relevance to the two fold problem of determining whether a particular substance or situation represents an unacceptable risk to public health; and if so establishing appropriate regulatory policy that will satisfactorily deal with the problem.

The only science that deals with phenomena involving uncertainty is Statistics more aptly called **Statistical Science**. It goes beyond the definition found in outdated textbooks which says that *Statistics is the collection, presentation and analysis of data*. It is an exciting and rapidly growing field and appears in various names such as Biostatistics, Geostatistics, Econometrics, Psychometrics among others. It has found usefulness in forensics and the Courts, in business, in the Sciences and in all the other disciplines because the element of uncertainty permeates almost all known phenomena in the real world. Statistical Science involves decision making under uncertainty based on available information or evidence. It is a mathematical science dealing with risks and is distinct from mathematics. The interested reader is referred to J. Durbin (1987), M.J.R. Healy (1978), Moore and Olkin (1984), C.L. Chiang (1985) and M. Zelen (1983) for information and insights into the nature of Statistical Science.

ENVIRONMENTAL STATISTICS DEFINED

We now propose the following definition of environmental statistics:

Environmental Statistics is the area of statistical science which is concerned with the development and application of statistical theory and methods for the study of environmental phenomena which have direct or indirect effects on the quality of life.

Hence, the study of environmental statistics involves the study of various subject-matter fields with emphasis on the use of statistical methodologies to advance our understanding of these fields. In particular, the domain of environmental statistics covers such diverse fields as agriculture, genetics, demography, epidemiology, and many others. Any probabilistic or statistical advancement in these disciplines, both theoretical and methodological, may be classified as environmental statistics. Implicit here is the view that statisticians must possess subject-matter knowledge; otherwise, his ability to contribute to advancing the subject matter is greatly constrained.

It is with this view that the participation of statisticians in environmental researches as full partners and not just as consultants should be encouraged. C.L. Chiang (1985) wrote, "it may not be sufficient merely to advise scientists to design their experiments and collect their data to suit the established statistical methods of analysis." Statisticians should develop models and provide appropriate techniques for estimation and other related problems when the required statistical theory is still nonexistent. These we cannot afford to delegate to non-statisticians. Hence, the work of an environmental statistician is not limited to applications like the calculation of regression coefficients. His work involves learning the underlying mechanism of environmental phenomena and using his expertise to describe them mathematically. It must be remembered that it is the development of probability and statistical theory, concepts and methods needed in many areas of research that has enriched Statistical Science.

2. THE ROLE OF ENVIRONMENTAL STATISTICS IN ENVIRONMENT STUDIES: THE INTERSECTION BETWEEN ENVIRONMENTAL SCIENCE AND ENVIRONMENTAL STATISTICS

The main concern of environmental statistics is to determine how our environment affects our quality of life. Environmental statisticians in collaboration with other researchers attempt to explain how factors like air and water pollution, solid wastes and hazardous substances cause degradation to our surroundings. We summarize below how Statistical Science have been and can be used in the major areas of environmental studies, namely pollution, forestry and marine resources, hydrology and ecology.

POLLUTION

The first step is of course to identify the pollutant in a certain environment. Once a pollutant has been identified, a measurement is made about its concentration. One major statistical problem that will arise is in determining the value of the concentration that would be dangerous to the environment. The mere presence of air or water pollutants may not necessarily cause harm. For example, it has been shown in the laboratory that chloroform can cause cancer. However, traces of it is present in our water supply as a result of chlorination. The question then reduces to how much chloroform is acceptable in the water supply. In a more general setting, it is our objective to determine a nonzero "threshold" concentration of a pollutant at which no consequential harm may occur.

Another major area of statistical concern is on "Risk Assessment and Analysis." There are many approaches to risk analysis. From a statistical viewpoint, risk analysis in the context of pollution control will involve three phases:

- _ model building for the concentration of a pollutant;
- _ model building for the hazardous effects that may result from exposure to the pollutant; and
- _ estimation and diagnostic checking for the above models.

In the analysis phase, alternative risk must also be considered and benefits and risk must be balanced. Risk assessment provides a useful input in decision making. In the United States, risk assessment provides valuable information to regulatory agencies and policy makers.

FORESTRY & MARINE RESOURCES

Forest and marine ecosystems provide renewable living resources that have important social and economic values on both global and national settings. They share the common trait of relatively rapid and sustained renewability. It is very important to monitor the changes and trends in these natural resources. Statistics plays a key role in the monitoring of these resources. Most of the statistical methodologies, from sampling to forecasting, will be useful in the different phases of preserving a favorable inventory of these fast dwindling resources.

Innovative sampling methods, data gathering and management, accurate model building and reliable forecasting are but a few statistical concepts that need to be developed. The area of sampling alone can provide challenging problems. Stochastic processes are relevant to model building and inferences on these stochastic processes are but one of the open fields in this area.

In summary, most natural resources surveys involve:

- _ area classification or stratification;
- _ field measurement; and
- _ model-based estimation.

Although current survey methodology is workable and effective, there is room for improvement in all aspects of survey operations through research.

ECOLOGY

Ecology, broadly defined, is the relationship of organisms to its environment. It is desired that a happy balance is maintained between a community of organisms and their nonliving environment. when pollution enters the scene, the conditions will not be the same. Statistics is used in the anlysis of community

structure. Anent to this, the concept of a Balanced Indigenous Population (BIP) is defined as an ecological community that exhibits characteristics similar to nearby communities living under unpolluted conditions. Based on a number of biological variables and indicators, statistical analysis is applied in testing differences between sites. Multivariate methods are also frequently used but other parametric and nonparametric methods are useful as well.

Ecological degradations can also be measured by some socially relevant indices like the reproductive failure of birds or mortality of eggs or larvae of fish. These indices should have tractable sampling distributions and an area of statistical research is the discovery of such distributions. Studies on the utility of various robust procedures are also worthy subjects of research.

HYDROLOGY

Broadly defined hydrology is the study of water. More specifically, an adhoc panel on hydrology of the Federal Council of Science and Technology of the USA offers us the following definition of hydrology: *"the science that treats of the waters of the earth, their occurrence, circulation, and distribution and their reaction with their environment, including, their relation to living things. The domain of hydrology embraces the full life history of water on earth."* Historically hydrology began with the study of the "rainfall-runoff process" and with the rise and fall and flow of rivers. Both deterministic and stochastic models have been employed by hydrologists to solve their problems. Most hydrologic processes are stochastic processes. The water level in a dam has been modelled as a Markov process. Many hydrologic data are in the form of time series. Hydrological research should be a priority area in the Philippines in view of the worsening situation caused by drought, flooding and the ensuing energy crisis. In this area Statistical Science will play a major and crucial role.

3. ENVIRONMENTAL SCIENCE IN THE UNIVERSITY OF THE PHILIPPINES

Environmental Science in the University of the Philippines is an uncoordinated and often sporadic effort among units and individuals often depending on persons and foreign funding. For example the College of Arts and Science in UP Diliman offered a Ph.D. in Environmental Science but this was gradually phased out in spite of its modest success. Now it is being reinstated without a Social or Statistical Science component. The other constituent universities of the U.P. System have their own environmental programs. These programs are all in their infancy and need nurturing and encouragement by central administration. A brief description of these efforts are given below.

UP DILIMAN

The College of Science and its institutes engage in some kind of environmental research. Among these is the National Institute of Geological Sciences (NIGS). Most researches are funded by the National Research Council of the Philippines (NRCP) and the Philippine Council for Advanced Science and Technology Research and Development (PCASTRD). Many of these researches are centered on the effect of mining activities on development in terms of national concerns, as well as on local impact of mining in the communities. Other units of the College of Science that engage in the environmental research are the Marine Science Institute (MSI), the Institute of Biology (IB) and the Natural Science Research Institute (NSRI).

The Chemical Engineering department of the College of Engineering offers graduate degrees in Energy and Environmental Engineering. This program was established in response to the need for high-level manpower requirements in the energy and environmental sector. It is also envisioned to become a center for excellence in energy and environmental engineering training, research and development, as well as a focal point of a network of energy research development and information in the country. The

department offers a Ph.D. in Energy Engineering, a Master of Science in Energy Engineering, and a Master of Science in Environmental Engineering.

The Institute of Science and Mathematics Education Development (ISMED) did some research which involved evaluation of the suitability of some textbooks for environmental education in elementary education.

The Statistical Center has been involved in several environmental researches with other UP units and some agencies of the government, one of which is a study on statistical modelling for risk assessment on Philippine volcanic hazard zone. Also, the Statistical Center has recently formed an Environmental Statistics Group (ESG) whose objective and activities we have mentioned earlier.

UP MANILA

Of the six departments of the College of Public Health in UP Manila the Department of Environmental and Occupational Health and the Department of Epidemiology and Biostatistics have engaged in environmental research. Their researches dealt with effects of changes in the environment on health. The main philosophy of this college is to provide the country with capable individuals who can assume greater responsibilities for the improvement of people's health and quality of life.

UP LOS BAÑOS

At UP Los Banos, one can find the Institute of Environmental and Management Studies (IESAMS). It is a unit of the College of Arts and Sciences and its programs are funded by a Canadian funding agency. Besides offering a Master of Environment Management, it also engages in research and serves as the permanent secretariat for the Environmental Education Network of the Philippines (EENP).

THE ENVIRONMENTAL EDUCATION NETWORK OF THE PHILIPPINES (EENP)

Population growth, the high incidence of poverty, and decades of misuse of the environment have contributed to the serious resources and environmental problems of the Philippines. The ecological and cultural diversity of the country indicates that a decentralized approach to these problems and a more coordinated and unified strategy towards human resources development in promoting environmental awareness must be the order of the day.

Having identified these problems, a network of over 16 university environmental study centers and a few non-government organizations (NGOs) have taken steps to arrive at some doable solutions that led to the formation of an Environmental Education Network of the Philippines (EENP). The EENP is a network which covers regional colleges and universities, research centers and non-government organizations working with programs and projects that promote environmental education and awareness.

The birth of the EENP is an attempt to provide coordination and assistance to these various institutions. The network intends to bring together these institutions and the government's Department of Environmental and Natural Resources and other agencies in promoting the advancement of environmental education in the Philippines and to develop collaborative activities that will lead towards a sustainable management of the country's natural resources. It is also the goal of the EENP to coordinate researches and initiatives among environmental and educational institutions in the country and to provide a linkage for these initiatives with global and regional (Southeast Asia) environmental programs.

The Network also provides assistance - financial and technical - to its member institutions. Financial assistance is in the form of small research grants, ranging from P50,000 to P100,000, for research proposals approved by the EENP Research Review Committee. The EENP also grants scholarships for the Master of Science in Environmental Studies at U.P. Los Banos to member units.

Technical assistance comes in the form of lectures and discussions of the existing environmental courses, formulation of an environmental curricula and training programs and seminars on environmental education and awareness.

The EENP, through its permanent secretariat based at the Institute of Environmental Science and Management (IESAM), also provides a mechanism of information through a newsletter and data bank.

4. WHAT CAN AND SHOULD STATISTICIANS DO AND WHAT NOW?

The need for close scientific cooperation among the different disciplines undertaking environmental researches need not be overemphasized. While there may be some difficulty in setting up a mechanism for smooth interaction, the joint undertaking of researches results in a better quality of output.

The Environmental Statistics Group of the Statistical Center took the liberty of going around and talking to people who are involved in environmental researches in the University of the Philippines (UP). We found that while there is a consensus in the research community for an interdisciplinary approach to environmental problems, this has not yet been done and only a handful considered or thought of including statisticians as part of their team. It even chagrined us to hear something like "we already have people who know how to use the statistical softwares." This limits the role of a statistician to that of data analyst. Oftentimes he is called upon to salvage a poorly designed study.

This is certainly not what statisticians are trained for. This also reflects how people in other disciplines understand and view Statistics. Many of the studies undertaken by researches in UP involve simple descriptive statistics and on a few cases which look promising, the statistical analyses lack sophistication.

At present, Statistics plays a supportive role in research, whereby it contributes to substantive discoveries only as one element of good research. In reality, its role is more extensive than that, Statistics being intimately involved in the logical design and planning of research, in the clarification to the researcher of his assumptions, in the saving of money, in the acceleration of the rate of discovery of new knowledge through efficient statistical design, in the accounting of the role of variation and the role and logic of probabilities, and so on. But most researchers are not aware of this fundamental role of Statistics in the intellectual part of research, as distinguished from the more mechanical problems of computation.

There are many ways in which statisticians can make a significant impact in making quality researches. As such, they should serve as advisors in the planning of scientific investigations and researches. On a higher level, statisticians should serve as consultants in the formulation of public policies. There is a need to educate the academic community on the valuable contributions statistician can make toward meaningful research.

The problem of the environment is of such complexity that to understand its nature and extent the various viewpoints offered by the Law, the Sciences, and the Professions should be considered together. The urgency of finding solutions to the problem and implementing those dictate concerted effort on the part of all us environmental workers and scientists. We should be able to communicate with one another and we ought to be familiar with each others work and above all we should work together. The last year was a good one for us. Three fora were made available to us: the National Conference of the Philippine Academy of Science, another by the Institute of International Legal Studies of the Law Center of the University of the Philippines and the United Nations Conference on the Environment and Development. Now we are in this symposium offered by the Philippine Social Science Council. We need at least three things now: a directory of environmental workers and researchers, a regular symposium and a journal. We are proposing that a national committee be created tasked with looking into these matters.

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