THE WIDER ASPECTS OF STATISTICS*

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Mr. Kidwai, Mr. Damle and Gentlemen,

I am greatly honoured by being asked to deliver this address to you at your inaugural session. I am particularly pleased to have this opportunity to talk to you because I have had such long contacts with Indian Statistics and particularly with Indian agricultural statistics. It was my misfortune not to visit India until last year, but for many years before that, indeed ever since I have been in agricultural research at Rothamsted Experimental Station, I have had the pleasure of meeting Indians engaged in the various branches of statistics, particularly agricultural statistics, who have come to Rothamsted to study and exchange views. Many of the people I am meeting out here, who are now in leading positions in statistics, I have had earlier contacts with in that way and know personally very well.

I have always been greatly impressed by the high standard of statistics in India. The way you have built up statistical science in this country, and the way you have applied it to the task of carrying out agricultural experiments and developing sampling methods to determine the yields of agricultural crops, is something of which you can well be proud. You have also made very great contributions to pure statistical science. It is a record any country can be proud of.

This occasion is, I feel, particularly auspicious because this year marks the re-establishment of the Indian Region of the Biometric Society. As you know, the Biometric Society is an international society; it is *the* international society which represents the modern trends in statistics. I am very glad to see that it has been decided to re-establish a Region in India. I hope that you will all give it strong support. I am sure those of you who do won't regret it.

I feel this occasion is a suitable one for considering the wider aspects of statistics. You probably know of me as a person who has been concerned with rather complicated experimental designs and the rather complicated analytical processes appropriate to those designs, and as somebody who has been concerned with the special techniques appropriate to sampling methods in various fields. But I have as well,

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particularly in recent years, been concerned with trying to see the part that statisticians ought to play in the life of a country. What I have seen and what I have done myself in England has convinced me that statisticians have a most important part to play.

I want to take specifically the case of agricultural research statisticians, because this is a society of agricultural statisticians. A young agricultural research statistician, when he finds himself entering the field of statistics, usually has some training in complicated experimental designs and in sampling methods, and at first he feels that his main duty (perhaps his sole duty) is to evolve such designs, to analyse them and pronounce on the significance of the results. And on the sampling side to evolve sampling methods, see they are carried out properly, determine the accuracy attained and whether it is adequate, and increase the efficiency of the methods in use.

Those are technical problems. They are highly specialised technical problems. The evolution of the science behind them—I won't say it's difficult—but anyhow it does present certain difficulties. And the basic science which has caused such a great increase and advance in these more technical applications, namely, the reordering of the science of mathematical statistics, has certainly demanded intellectual effort of a high order. There I think we must recognize the work of Sir Ronald Fisher, who is quite the outstanding man of the age in this field. It is on the basis of his work that the whole of the modern development of statistics and the modern trends of statistics have been built. But the technical application of these modern techniques, when they have been evolved, and their further improvement in detail, is not in itself an inherently difficult task, as indeed is very apparent since you find that quite a number of biologically trained people, who are not themselves trained or indeed particularly skilled in mathematics, have become extremely able and competent statisticians.

But there is a wider task for statisticians which they should be prepared to play. Let us first take the statistician in an agricultural research station. I have said already that he has to design experiments and that he has to analyse them. He will also of course have to advise biologists, entomologists and so on on observational data—what observations are to be taken and what conclusions should be drawn from them. But before the statistician comes to design a specific experiment somebody has to decide what experiments should be done and what treatments should be included. Now I want to see the statistician taking part in those deliberations. I want to see him sitting down with the other scientists, in a small group interested in the

specific problems at issue, where he can contribute his quota. I have found as a matter of experience that most biological scientists are not quantitatively minded. If they were they would probably be physicists or mathematicians or engineers. Therefore the statistician or the group of statisticians in a biological or agricultural research station is usually capable of handling the quantitative ideas in a way that the other workers are not. And quantitative ideas play a large part in the planning of experimental programmes. So I want to see the statistician co-operating at that level in the actual drawing up of an experimental programme—suggesting what things are worth testing and in what combinations and at what levels. My experience is that provided they recognize that they are collaborators with the other scientists and not their masters they have a great deal to contribute.

When we have designed scientific experiments, carried them out, analysed them and reported on the significance of the results, the statistician often feels his duty is then done. I would submit that it is not. He has to be concerned with their wider interpretation; he has to be concerned with putting the results of different experiments on the same subject together and making a coherent story of them. That is itself a very difficult task. It is easy enough to analyse one experiment. It is very much more difficult to take a heterogeneous mass of experimental data—different experiments conducted by different workers, very often with somewhat different objectives in mind—and put them all together, fit them into a proper picture. My experience is that that can only be done, if it is done at all, by people who are statistically trained and quantitatively minded. Even then it is a skilled job which the statistician will have to learn as he goes along. He doesn't at present get training in this job when he takes his diploma either in this or in any other country. Again he must be the collaborator, not the master. He must work in conjunction with the other scientists, discuss his conclusions step by step, discuss the procedure, find out what questions are important, find out the whole background and the scientific principles involved, if he is going to do a good job.

Then, apart from this putting together of the scientific picture, there is also the economic interpretation of what the results mean. Scientific research workers, particularly biological research workers, have a fine indifference to the economic implications of their results; agricultural economists, I have found, have a fine indifference to the science of agriculture. As a result, we find that the research scientists put forward proposals which are hopelessly impractical economically, and the agricultural economists put forward proposals which will not

bear close scientific examination. Now there again I submit that a statistician can often act as a bridge between the two. His own training, his mathematical background, and his ability for quantitative thought should make him at home in the field of economics. He will have to learn some economics, so that he can understand what economists are driving at and the economists can understand him, but that should not be difficult for him. In the same way he has to establish wide contact with the agricultural scientists, so that he can understand what they are driving at. Then he can act as the bridge between the two groups, and show how the scientific conclusions can be translated into economic terms so that they can be put to practical use.

Take the very simple example of fertilizers which Mr. Kidwai has mentioned in his inaugural address. He has pointed out (very rightly) that it is no good telling farmers to use fertilizers unless you can tell them that in fact it is profitable to do so from the point of view of the farmers. But many of the fertilizer experiments conducted in this country in the past have been conducted with the idea of finding out what is the maximum possible yield that can be obtained with any amount of fertilizer you care to use. I submit that, that is rather an irrelevant question. What we want to know is what are the economic levels to use.

There are other problems of the same kind in the use of fertilizers which are not entirely economic. They are more concerned with national planning. If this present campaign for greater use of fertilizer catches on, if these experiments on cultivators' fields that we have been discussing in our meetings here and to which Mr. Kidwai has referred are carried out, and that if cultivators see—as I have been told they already see in Bihar—that fertilizers are actually a profitable thing to use, then in two or three years time you will not be confronted with the appalling prospect of overfull warehouses at Sindri that cannot be emptied. You will be confronted by a real and genuine scarcity of fertilizers. You have not got anything like enough of fertilizers to go round, if people use them as they should use them. And if this scarcity of fertilizers develops, the question becomes not solely one of how much a farmer can economically place on his fields but how the nation can best use its limited supplies of fertilizers so as to get the maximum return—and that is not quite the same question, because it may still pay farmers to put on larger dressings but they may be getting smaller returns for the additional unit they put on than might be obtained if it were used elsewhere.

So there the statistician comes into the national planning picture and it is there that I have found that it is most essential that the

statistician should play his part. You may say that national planning is already full of statisticians. That everybody agrees that they should play their part. They are playing a part; yes, that is true. The point that I want to make is that there are different types of statisticians—the economic statistician who is already fully involved in national planning, and the research statistician whose primary job is to find out facts like how much yield you are going to get from additional supplies of fertilizers and what dressings to use and so on. Now at present the link between the two is very bad. The research statisticians don't assemble their data in a way which is useful to the planning experts. They should try to think what the planning people want to know, and contact them and discuss their problems with them, and then go away and get out their data in the form that is required for that purpose.

So far I have dealt chiefly with the experimental side of scientific research. I would like to turn now for a moment to the observational side. A lot of scientific research has to be observational. If you can make experiments, it is always a good thing to do so, because then you have the treatments under your control, you get rid of extraneous variation and the part you cannot get rid of you can assess by calculating the experimental error. But you can't do all science that way. We should never have had a science called astronomy if we had insisted on doing all astronomy by experimentation. In the same way we cannot have a science of economics merely by relying on experimentation. There is very little we can do by experimentation in the economic field. The same is true of the other sciences concerned with human beings. In human medicine and sociology we can do a certain amount of experimentation, but not very much. In human genetics we can do none. Therefore observations are always vitally important and must not be lost sight of.

Here again the statistician has the same sort of role to play. He should be in at the planning stage when what is worth observing is being discussed, and he should help in designing the scheme of observational work. Surveys are a form of observational work—a particularly refined form—and there the importance of the statistician in designing the sampling scheme has been recognized. But when I look at the questionnaires used in surveys, and particularly in sociological surveys, I often feel that the statistician must have had mighty little to do with their planning. Then comes the analysis of surveys and other observational work. This is more difficult than the analysis of experiments. There are all sorts of cross-influences and cross-

currents which have to be sorted out. You can never be certain of your conclusions. Therefore the analysis of observational data is fraught with much greater dangers, and demands a much higher degree of skill, than does the analysis of the results of a well designed experiment. But that this is so is not fully recognized, even by many statisticians. Frequently, also, a synthesis of experimental and observational data is required—another highly skilled job.

I have already mentioned that statisticians should play a part in planning at the State and Central level. There is another way in which they can help in national affairs. That is in what is called operational research. If we are going to get more fertilizers used in this country we require not only to know how much return the farmer would get from a given amount of fertilizer if he does what we tell him to do, we require to know also how individual farmers are using their fertilizers. They might be putting it all in very heavy dressings on a few cash crops and neglecting their food crops. In such a case the country might be getting poorer returns—perhaps considerably poorer returns—than could be obtained with a better distribution. Again, we may find in spite of our advice that for a given crop the farmers are putting the same amount and type of fertilizer over the whole of a State, or the whole of India, regardless of soil types and other factors that are known to affect requirements. For instance we can show from experiments already completed that with adequate water-supply nitrogen gives a fairly constant response over most of India. I won't say absolutely constant, certainly not, but reasonably constant. Consequently we are reasonably safe in recommending a general small dressing and we can be confident that all farmers will get a profitable return and that the fertilizer won't be misused. But with phosphate just the contrary holds. For a long time it was said that phosphate was not worth putting on in India. Now, thank goodness, some trials have been done on cultivators' fields and as might be expected it is being found that there are plenty of regions where phosphate in fact is required and is profitable. But this is not true of all regions and if we recommend phosphate for universal adoption it will be used much less efficiently—a large amount will in fact be wasted.

And Potash ! Take potash ! There we have it held as a tenet of faith that there is no soil in India that requires potash. Indeed, that tenet of faith has been so strongly held that in recent years practically no experiments have been done on potash. So it is very difficult to say whether it is a true tenet or not. But only to-day I have seen the results of some 150 experiments in three districts of

Bihar on cultivators' fields in which for the first time potash was included; and those districts did in fact show as good a response to potash as to phosphate, in fact a highly profitable and highly useful response. How far that is widespread, we do not yet know—it has got to be tested out. But it agrees with the soil analyses. The soil analyses show that these soils are deficient in potash, the experiments show that the crops respond to potash. The moral of all this is that we must not prejudge these issues. And here again, I think statistician, with his in some ways broader outlook and his feeling for the quantitative situation, can help the agricultural scientist.

I am afraid I have been talking very much about fertilizers. I do not want you to think that fertilizers are the only important subject in agricultural science at the moment, but I took fertilizers as an example firstly because they are of immediate topical interest—there is a national campaign, quite rightly, to get them used—and secondly because during this visit to India I have been looking at the experimental results obtained on their responses—a task for which I personally am particularly qualified since Rothamsted is a fertilizer research station.

But there are many other fields of immediate practical importance where the statistician has a great part to play. Plant breeding is one of them. It is interesting to note that Sir Ronald Fisher has never been a professor of statistics. When he left Rothamsted, where he was Head of the Statistical Department, he became Galton Professor of Eugenics at London University, and he went from there to become Professor of Genetics at Cambridge University; I think that shows the close link between statistics and genetics.

Then irrigation; there is a big quantitative field which wants watching there. You are installing tube-wells in many parts of the country. The water-supply for those wells must be watched. You must see that you are not merely putting out of commission the older wells, Persian wheels and so on which are already, if not very adequately, serving their purpose. Irrigation engineers, of course, are more aware of these problems because they are engineers and therefore are used to thinking quantitatively. But irrigation engineers are apt to make mistakes on the biological side and there again well designed experiments are required on such problems as the amount of water, whether continuous irrigation is going to cause trouble in destroying the soil structure or depositing harmful salts in the soil, and so on. All these are problems in which the statistician can be of real help.

Finally, I want to consider an even broader aspect of agriculture—namely the Indian food problem as a whole. Here the agricultural statistician who deals with the food production side and the vital statistician who deals with the population side must meet together and pool their conclusions. At present I feel there is some lack of liaison between these two groups. Let us look at it from the broadest possible angle. Lord Boyd Orr, who was over here recently, made a statement—if he was correctly reported in the press—that with the proper application of science everyone in this country could in 20 years time be well nourished and there would be no food scarcity and no food problem. On the other hand an equally eminent scientist, Sir Charles Darwin, grandson of the great Darwin, has recently written a book entitled *The Next Million Years* where he prophesied that the sad lot of humanity was for all time to be continuously starving. I do not want to discuss the long term issues to-night. I want to discuss the immediate future. But I would emphasise the importance of looking to the more distant future; if we are going to develop fertilizer use in this country, for example, we are going to create a drain on raw materials such as phosphate, sources of energy for the manufacture of nitrogen and so on. And other forms of industrialization will make similar demands on raw materials. If the whole world is going to be industrialized—and it is perfectly reasonable ambition, I do not see why Western Europe and America should have a prerogative of industrialization—the raw material situation will have to be looked at very seriously.

But that is not an immediate problem. What is the prospect for the next 20 or 30 years? I merely want to emphasise from the statistical point of view the magnitude of the immediate problem with regard to this country. According to the last census the increase in population is now 4·2 millions per year. That means that there are 8 more mouths to feed every minute. In rough general terms about 25 people are born and 17 die every minute.

Now I have been talking about the value of fertilizers and how their proper use can increase food production. Let us look at this matter quantitatively. From a study I have just completed, in collaboration with Dr. Panse and Dr. Finney, I came to the conclusion that the whole production of Sindri if properly used on paddy will give somewhat over half a million extra tons of rice a year. That, if I have got my calculations right, will provide food for $2\frac{3}{4}$ million people, that is it will take care of less than one year's population increase. If that is so you should be putting up a new Sindri every year.

That is if you depend solely on nitrogen. Of course actually we can look to phosphate and potash also to provide increases. But that is the sort of increase in fertilizer plant which is required if the present population increase is going to be looked after by greater use of fertilizers.

Of course there are a number of other ways in which—very sensibly—you are increasing agricultural production. Irrigation and improved varieties are two. To make a quantitative guess at possible improvements on these lines, if we have 15 fertilizer plants of the same magnitude as Sindri, and parallel increases in phosphate and potash supplies, and if improvements in varieties, in irrigation and in other miscellaneous directions, each produce improvements equal to that resulting from fertilizers we shall be able to take care of an increase in population of about 200 million. That sounds very satisfactory but it will require a lot of capital investment, and hard and quick work which cannot be delayed. Nor can we go on indefinitely in this manner. One reason why increased agricultural production in this country is relatively easy is because the present level of production is very low. The so-called law of diminishing returns will operate as the level of production is pushed up.

But the situation is not really as satisfactory as this. We know, only too well, that the people at present alive are not getting enough food and are not getting the right kind of food. The infant mortality is at present 13%, that is one out of every 7 babies born die in their first year, many of them because of malnutrition. According to the latest figures the expectation of life at birth is only 32 years. That is a situation that must be set right, and the medical people are working hard to set it right, but every success they achieve makes the population problem worse because every step they take to combat diseases like typhoid, small-pox, cholera, malaria and so on means that fewer people die of those diseases and therefore if the birth rate remains where it is population increases more rapidly.

We must recognize that in any given country over a long period of time the death rate must approximately match the birth rate. If you suddenly improve the conditions of health and so on without simultaneously lowering the birth rate you will inevitably get a rapid increase of population and this will result in more and more trouble from malnutrition, and an increase in the death rate from this cause. Therefore you have got to take steps to get the birth rate under control, and I think that the statisticians have a really great part to play both in bringing home this problem to the country and in helping

to solve it. This country, I believe, has a distinction of being the only country in the world that has officially recognized the population problem. It is written into your 5-Year Plan as one of the important problems that has to be tackled. But I have not in my present stay here seen much evidence that it is being tackled with anything like the same vigour that the food problem is being tackled; it is a much more difficult problem to tackle, as we know, but it must be tackled. If it is tackled, then in a very short time this country will be able to reap the fruits of science in better nutrition, better health and better living standards generally.

And on that thought, gentlemen, I would like to close and express my thanks for being invited here to-night to give this address and my very great appreciation of the honour you have done me by so inviting me.