THE CONDUCT OF FIELD INFESTATION SURVEYS AND THE ECONOMIC USE OF THEIR RESULTS

C. P. F. DE LIMA
National Agricultural Laboratories
P. O. Box 30028
Nairobi, KENYA

INTRODUCTION: In many developing countries today, the rate of population growth is such that these countries face difficulties in producing sufficient food for their people. Agricultural practice is still subsistence in nature and the little that is produced is inadequately stored with the result that a significant proportion of the harvest may be lost in storage. Many attempts made in the past few years to improve the extension of good storage practice to farmers in these countries have met with poor success, mainly due to the ad hoc nature of these projects and an absence of the background scientific and socio-economic information.

An attempt is made here to present a balanced approach to the problems of improving grain storage at the subsistence farmer level in developing countries, and to construct from first principles, a framework for their study.

SURVEY PURPOSE: In tropical countries, agriculture is the principal occupation of most of the population. Every farmer stores grain to sustain himself and his family throughout the year. Attempts to monitor and assess losses in food grains from any cause in so many stores requires extensive field surveys. The purpose of these surveys will determine to a large extent the manner in which the planning authorities in a given country are prepared to tackle the problems. In the context of the title of this paper reasons for conducting surveys may be examined in the following sequence:

A. The need to obtain accurate estimates on the storage losses (quantity and quality) in food grains suffered by the farmers and the nation.
B. The need to evaluate the importance of the principal pest organisms and the effects of secondary pest organisms (in the existing pest complex) under different ecological conditions and at each level of storage technology within the country's storage system.
C. The need to identify the importance of grain storage in the rural agricultural system and to study the effects of its improvement on the socio-economic pattern within that system.
D. The need to develop and evaluate a set of general strategies for use at the national level to achieve improvements in grain storage; and sub-sets of alternative specific strategies for improved storage at regional levels.

In most countries, estimates of loss in grain storage are

usually available (even if "dirty" [1]) as starting points for planned investigations into the magnitude of the losses and their causes. Pests and storage methods need to be examined scientifically but the social consequences of the losses and of methods of over-coming them must also be studied before any changes are made. Solutions developed should be tested for relevance in the rural system, and examined for suitability for inclusion in appropriate strategies for the advancement of rural welfare.

IDENTIFICATION OF SURVEY OBJECTIVES, PLANNING AND EXECUTION: Problem specification generally requires the definition of a set of qualifying objectives. The identification of these objectives will determine the type of data collected, the analysis and subsequently the development of solution strategies. More generally, while grain storage problems may be of national importance, problem solution, for its effectiveness, calls for local or community participation. Adequate planning for survey objectives requires primarily a proper identification of the nature and magnitude of the problems in terms of the demand for their solution. In rural areas the objectives should be the ones that the farmer recognises as necessary for improving his welfare.

Socio-economic and Ecological Conditions - The basic problem (within each objective) is to define what information is required from the study and the kind of data needed to provide that information, given the practical limitations of field work. The ecological conditions of production and storage vary considerably from region to region, and besides having an effect on the rate of development of the pest population [2,3] , they also, in conjunction with several sociological and economic factors, affect the type of storage technology employed by the community [4]. Adequate attention should be given to the nature of these ecological and socio-economic conditions to obtain a picture of the differences that exist in the production/storage cycle between regions in a country, so that areas of priority may be established for investigation and a sampling frame and sampling programme developed.

But first, we should review the information already available. This would include altitude, mean monthly temperature, relative humidity and rainfall [5]. We may then examine the potential effects of these conditions on the rate of development of the pest organisms by using simple diagrams (Fig. 1), and from this, decide how to progress with survey plans. In a similar manner, socio-economic strata may be characterised (Fig. 2) and plans made on the nature of the data required and the development of relevant questionnaires, etc.

Very often a "preliminary" field survey [6], carried out after the initial planning studies mentioned above, (but before statistical designs for the "main" survey are finalised) will provide information to improve the definition of objectives, and the design of the survey.

The Sampling Programme - Naturally the kinds of storage affect the sampling programme; for example, sampling techniques

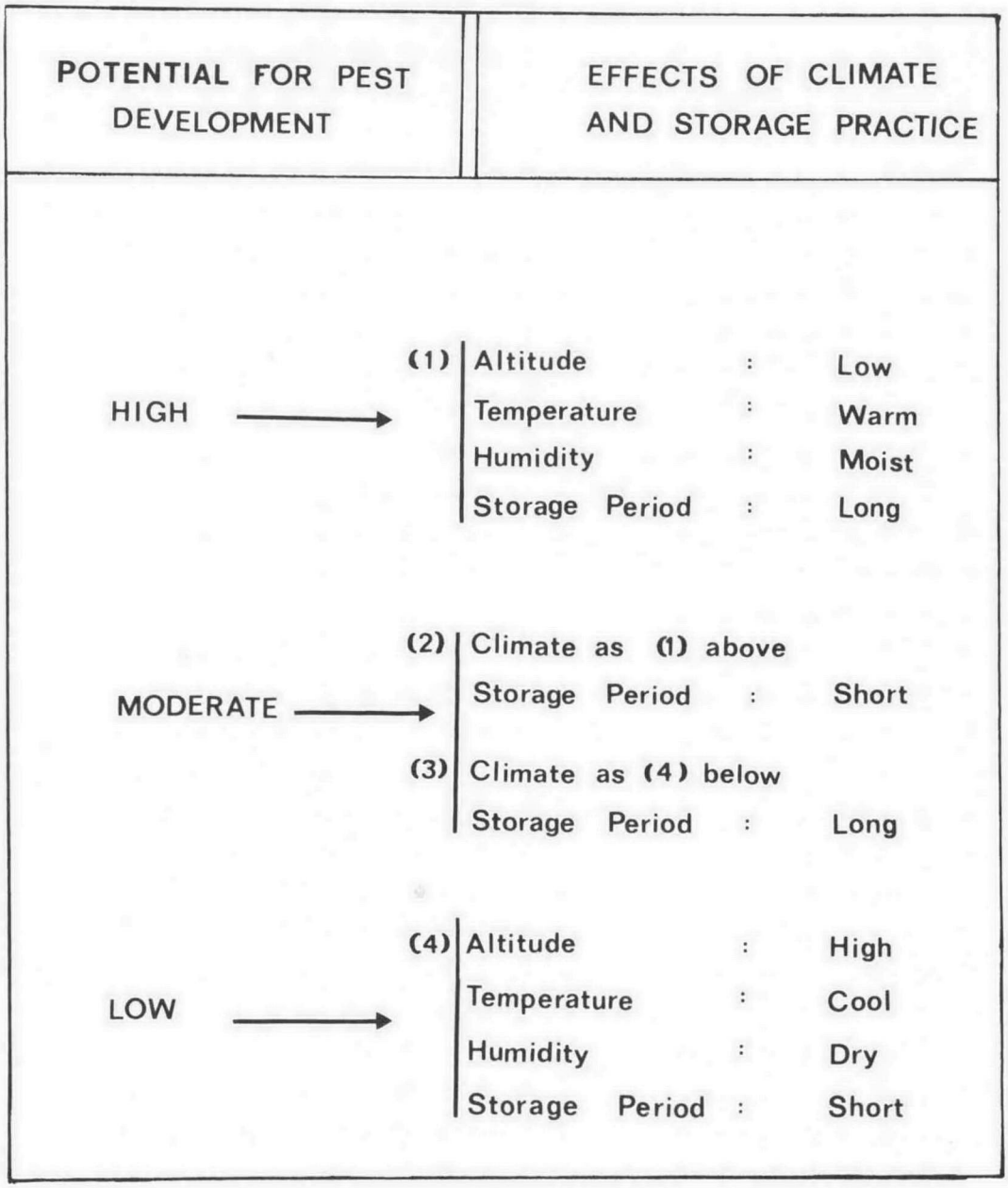

FIGURE 1. Storage/Climatic Factors For Pest Increase.

for maize cobs stored on trees would differ from techniques used for maize cobs stored in a crib. The sampling programme must take account of variations in sampling technique which in itself may depend on ecological and socio-economic conditions. Several excellent accounts of the statistical designs applicable to scientific, sociological and economic surveys are available [7-13]. In general surveys must be objective and samples truly random; and there must be replication within allowable costs related to the variation in the population being sampled. Stratification is likely to be required in the sampling design but depends on prior knowledge of the sampling sites. Sequential sampling [14] makes it possible to

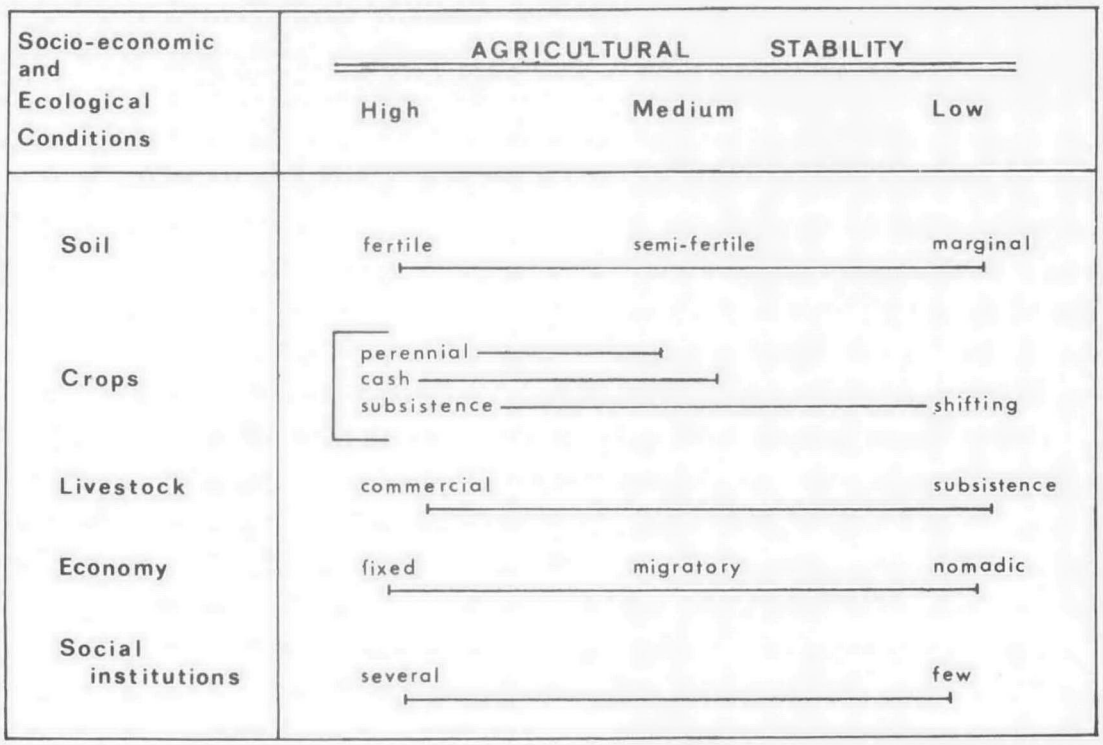

FIGURE 2. Characterisation Of Ecological and Socio-economic Strata

follow the pattern of loss, and data collected from any survey should be used to draw up sequential sampling plans for future surveys [15].

Areas of priority for sampling must be established. These should be areas where (a) grain storage makes a substantial contribution to self-sufficiency in the rural economy; (b) stored grain forms a substantial part of the food source available to the farmer for the major part of the year; and (c) food grains, although not making a substantial contribution to the diet of the rural population never-the-less makes a significant contribution to the nutritional status of their diet in the annual cycle.

Loss Assessment - The most suitable way of assessing loss for a sample may not necessarily be the most efficient. Thus, for example, if time or transport is limiting, counting damaged and undamaged grain may be preferable to a better technique which requires a number of instruments for taking bulk density measures.

To estimate losses to a community or region from sample losses, we need also to know the date of harvest, total grain harvested and the expected storage period. To judge its social repercussions we should know also the number of family members and the per capita consumption. Observations on complementary and alternative sources of food that become available during the storage period of the main cereal, will enable an evaluation to be made of the actual nutritional loss to the community as a consequence of infestation. The samples obtained must be analysed to estimate loss and notes made about the insects and moulds found. Thus, the possible savings of food can be estimated. The wider implications of these

savings are more complex as their consequences may extend beyond the individual farmer to the nation at large.

If the likely savings of food are worthwhile we may proceed to carry out a more scientific study of the causes of loss. If there is a close relationship between pest intensity and weight or nutritional loss then control measures may be economically feasible. The aim should be to demonstrate whether or not ecological conditions, cultural practices and technological differences influence pest abundance. The conclusions based on the analysis of this data should make it possible to propose solutions to the problems, and assess their social significance.

Evaluating Solutions and Developing Strategies - Once solutions have been specified they should be tested, initially on a pilot scale, bearing in mind the opening remarks of this section. A farmer, no matter how poor, is basically a manager, and the solutions must be to his advantage. The farmer will devote work and money to protect his stored grain only to the value he places on it. Solutions must therefore fit his personal priorities and the community pattern to gain acceptance. We now reach the point where an evaluation of the various strategies is required with respect to the country's own economic priorities and in terms of investment areas for the farmer and the government. Thus improvements that require public investment will need to be judged at the national level in relation to opportunity cost of the investment and in terms of improved social welfare; and necessary data for decision-making on these aspects should be collected during the survey if possible. At the national level these strategies will affect teaching, agricultural extension, rural marketing requirements and policies for communications, loans and subsidies.

Mention may be made here of management techniques like systems analysis in initial planning and in subsequent guidance of field operations [16,17]. The provision in project control, of periodic revision can lead to much saving in cost and time and to greater viability of project planning [18]. A simplified account of project planning for improved grain storage using the Critical Path Method has been discussed elsewhere [15].

DATA ANALYSIS: Once one has finally obtained the grain sample, the basic work of extracting as much information from it as possible begins. Each sample must be examined for free-living insects, mites, mouldy and punctured seeds. This might be done partly by passing it over a series of sieves and partly by spreading it on a tray, which is less likely to kill insects or mites. Loss assessment may be made by counts of damaged and undamaged grains and by bulk density criteria before subdividing the sample into enough weighed sub-samples for incubation and to permit other destructive analytical operations (e.g. moisture, nutrition, immature stages, etc.).

The analysis of the pest population complex will proceed by means of species counts obtained from the samples. Examination of sub-samples for immature stages will give a clearer picture of the pest population. Samples collected at regular intervals in

time will enable studies to be made on the rate of increase of the pest populations, the effects of climate and other factors influencing mortality. Analysis may be made of life tables and key factors and of processes like, intra and inter-specific competion, density dependent and independent factors, etc., [19].

These basic data may then be subjected to statistical analysis. Studies of functional relationships by regression [20] generally provide a considerable amount of insight into the relationships between two variables when both are subject to error. Thus for example we may examine (Fig. 3) the relationships between the rate of the decrease in a unit volume of grain over time with an increasing pest population (3a,b). Also we may see how pest population, grain damage and loss in weight increase with time (3c,d,e). Finally we may look at the relationship between pest numbers and grain damage and loss in weight (3f,g). For further examination we may put these data into a multiple regression equation (Table I) and study the decrease in weight per unit volume sample with increase in insect numbers, loss in weight and damage (Eq. 1), and sample loss in weight with increase in insect numbers, damage and time (Eq. 2).

As can be seen from the foregoing, the variables studied are interrelated and some advantage may be obtained from examining them in terms of a simpler set of uncorrelated components. Here the principal component analysis (Fig. 4) can be useful for example as a means for providing clusters which show areas of similar pest species and damage relationships 4-8, and 20-24 weeks after harvest. For field use all these scientific data must be digested into simpler form, taking into account economic aspects. Thus to convert our data for use of extension workers we may attempt a bayesian approach [21] using loss functions based on the opportunity cost of alternative decisions; calculations from this [15] for different regions in Kenya (Fig. 5) based on whether the posterior mean (after an insecticidal treatment) is greater than the break even mean (mean without treatment plus the cost of the insecticide) may reveal areas in which the optimal decision would be to treat grain if storage is for more than 8, 12, 16, 20 weeks after harvest.

ECONOMIC USE OF RESULTS: When planning to put to economic use the results of the surveys, it is useful to bear in mind, as a first principle, that the results of the surveys create (in the solution - strategies developed) a "collective good" in the sense that the farmer is not the sole beneficiary, but society as a whole benefits [22] and so it is socially desirable to provide the solutions.

To begin with it is necessary to examine the role of the food grain harvest in the rural economy. A specification of inputs invested to produce the harvest, in terms of the farmer's total available resources for agricultural enterprise is required. From this an assessment can be made of the importance the farmer places on protection of his stored grain as part of his earnings from investment and the benefits that result from prevention of storage loss. These benefits may be expressed in terms of actual cash to

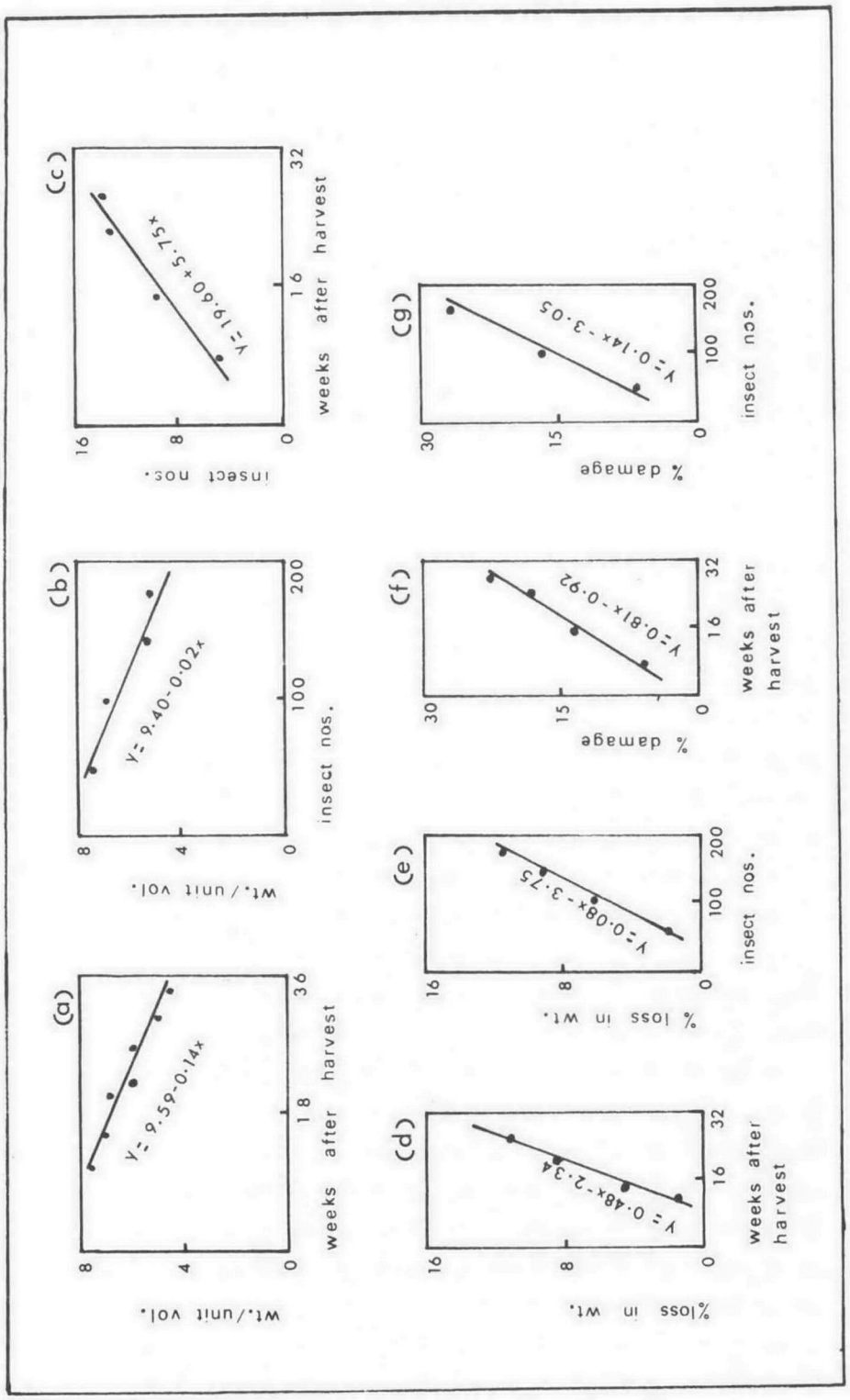

FIGURE 3. Functional Relationships Of Data Variables in a Single Stratum

the farmer (in case he would be able to sell the grain saved) and in terms of the actual value of the grain to the farmer if he had to buy it. Further extension could be made to the local farming community and the nation in terms of self-sufficiency in grain production, export value of grain saved, potential foreign exchange

TABLE I. Multiple Regression Analysis Using Variables From Figure (3).

$$Y_a = 0.66x_d - 1.54x_b + 3.13x_c \quad \text{.....Eq. (1)}$$

$$Y_b = 2.36x_d - 1.28x_c - 0.10x_c \quad \text{.....Eq. (2)}$$

a = weight/unit volume; b = loss in weight; c = damaged grains; d = insect numbers; e = weeks after harvest

savings and earnings [23] general social benefits to the nation from better nutrition, [24]; and general benefits from stability of urban food supply to economic development [25-27].

The costs and benefits of the solutions produced will depend on their nature - for example (Fig. 6) in insecticidal applications, after determining specific points in time at which decisions for a control action may be taken [28, 29] it may still be necessary for the economists to determine whether, at that specified time the farmer is indifferent to the infestation level as it affects his output. Thus there is a need to estimate at the farm level, the consumers surplus, in relation to costs of, (for example) a grain drying process, a pesticidal application, or a structural improvement. We may then decide whether there is need to subsidise the input and if not whether to leave things as they are (the null strategy). Alternatively if a consumers surplus exists, we need to find the opportunity cost of the subsidy and decide whether to continue the strategy or examine an alternative.

The development of general strategies at the community and national level requires cost-benefit analysis in terms of certain analytical techniques [30] economists have developed like net present value, internal rate of return, and pay-back. The main problem in the use of these methods is of deciding on the appropriateness of discount rates to be used in the calculations [31,32], especially as we are concerned here with a "non-productive" sector of the economy [33]. Notwithstanding this, however, we should keep in mind the fact that we are more concerned with the welfare of society as a whole (in terms of the national and international grain storage situation) and it is more appropriate to adopt the concept of a potential Pareto improvement [34].

A PLACE FOR SOCIOLOGICAL ANALYSIS: Sociological analysis has the primary role of shaping the solutions derived from scientific and economic investigation into strategies for the improvement of rural welfare. In tropical countries strategies for rural advancement depend to a large extent on the priorities established by local leadership, and planning for development with the support of external sources will only go as far as the limitations of the basic political, social and economic forces allow [35]. The development of strategies for social improvement of the poor is dependent to a large extent on the degree and nature of participation and is limited

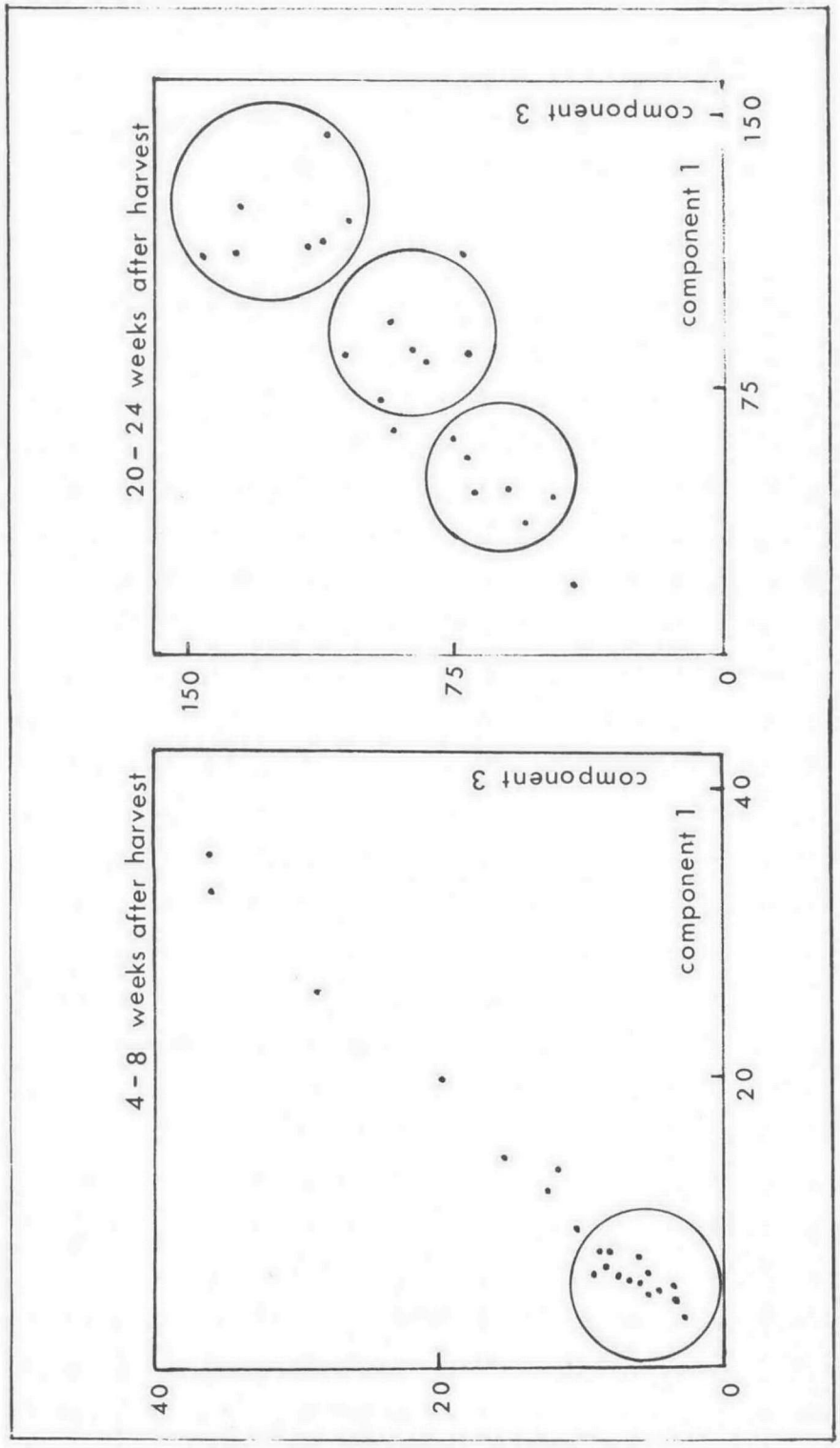

FIGURE 4. Principal component analysis of data variables for 22 strata.

by several basic sociological characteristics [36,37]. Thus we depend on sociological research for a diagnosis [38] to tell us first how important the problems are to the farm community and next how to produce solution strategies that will gain community acceptance and thereafter community participation.

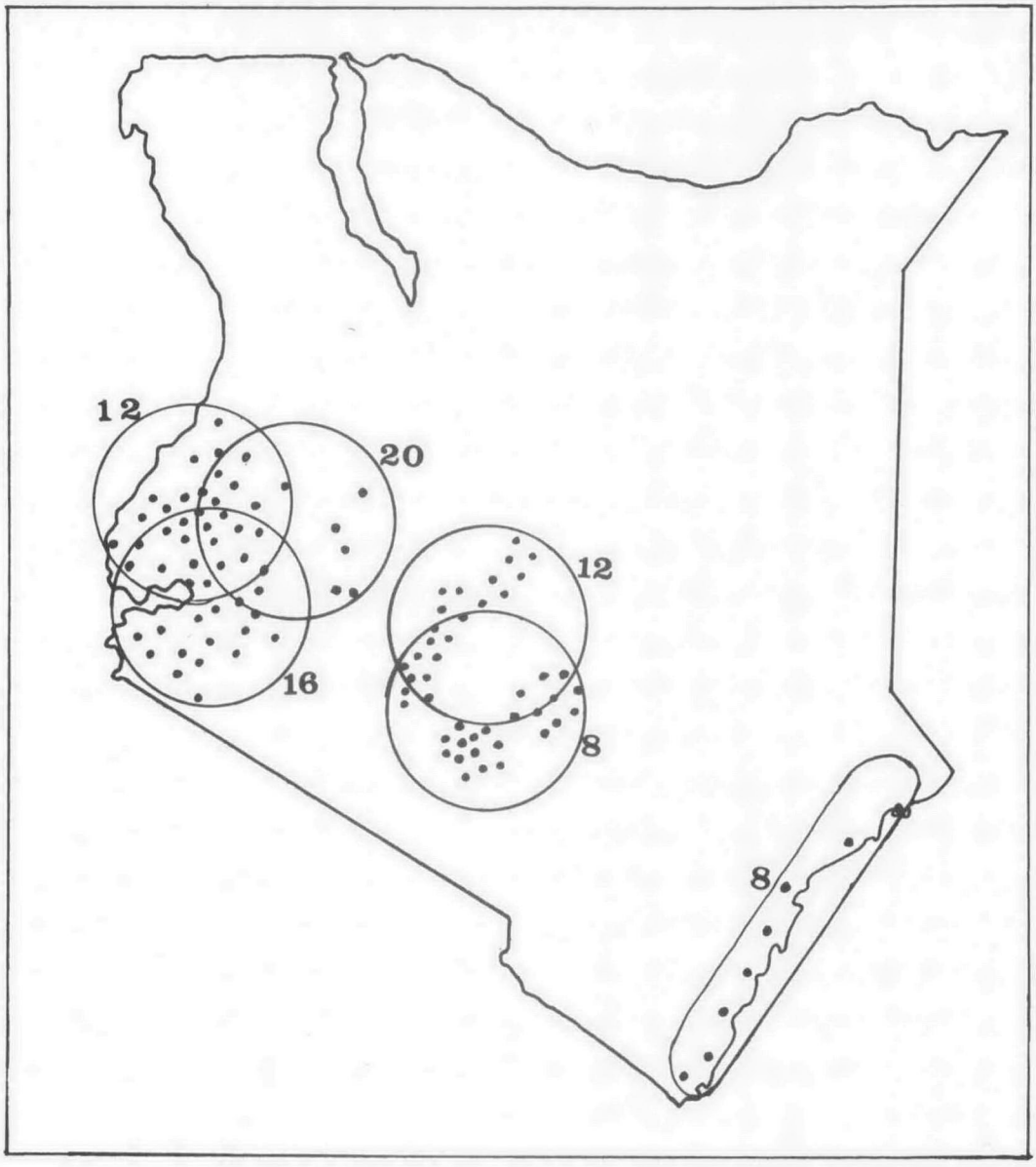

FIGURE 5. Optimal decision - treat if storing more weeks than figures for circled areas show. (Each dot = 10,000 Ha. maize - source: Allan, A. Y., thesis, Nairobi Univ.).

CONCLUSIONS: For decision-making at the national level to have the required degree of balance, it is essential that decision makers are made aware of the extent of the problem. A balanced picture of the problems in the field can be obtained by the process of systematic research and evaluation of information discussed so far. This process is essentially long term, and subject to a large number of constantly changing variables. Thus strategies evolved during one decade may be totally inappropriate in the following decade. This is true especially of tropical countries where political and economic changes have created a state of flux and the stabilities

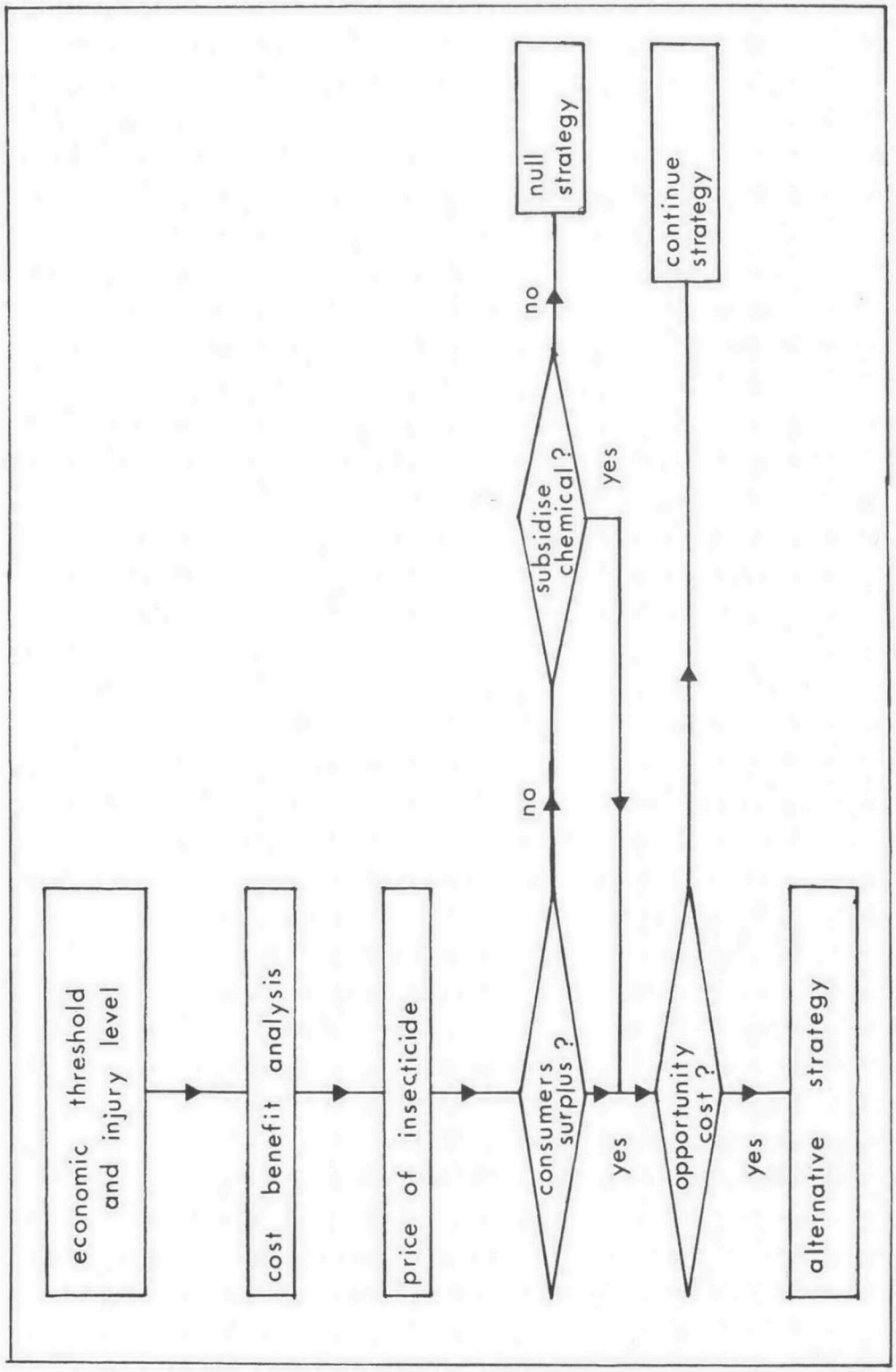

FIGURE 6. Strategy development for grain storage improvement

of rural and regional populations are extremely relative [39]. Failure to take these considerations into the development of national and regional strategies often results in either poor consideration of alternatives to investment [40] or failures to achieve

specified goals [41].

Agricultural systems in tropical countries vary remarkably from region to region and even within regions themselves [42,43]. As a result, different communities have differing values and priorities and although personal values may vary from individual to individual, individual values seldom differ markedly from group values. Successful development will therefore need to take account of these and other sociological aspects of the community in the general consideration of national achievement. It is therefore essential for national progress, that more emphasis in development is placed on improving the self-sufficiency and self-fulfilment components of community welfare [44]. Therefore, solutions to storage problems that require a change in the farmer's priorities are less likely to succeed, than those that fit into his world. One can get a farmer to protect his stored grain only to the extent that he is willing to. Once suitable solutions have been found they should be tested for their acceptance and accordingly modified. This is a long and continuous process, but it is useful to bear in mind that the innovations being motivated are required to be introduced into systems that are centuries old, and that have already arrived at a degree of stability.

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