The diversity of experiments that have been conducted long term almost precludes a simple summary. The preceding papers attest to that diversity, but some valid observations can be made despite the diversity.

Increases in food and fiber production have occurred. A clear, unrefutable conclusion is that many of the crop yield increases of the past century have been due to improved cultivars. However, the various interactions within the soil-plant-environment continuum often are not clearly discernable. It is only through long-term observation and measurement that some of those interactions are unraveled.

For example, Fig. 3 in Dr. Jenkinson's paper illustrates a fertility-manure-cultivar interaction, which likely would have been undetected had not the Broadbalk Classical Study been in place (3). Thus, one justification for long-term field studies is to provide information on the interactive effects that can occur in the soil-plant-environment continuum of a field or forest. The large surface area exposed by soil to active plant roots in a field or forest tends to serve as a buffer for many of the reactions that occur as the soil is used for plant support and sustenance. The fact that the soil is a buffer implies slow change which must be monitored over time to measure the net effect of soil manipulation.

The nature of growth of perennials, including forages and trees, makes long-term field experiments essential to better understanding of the influence of management practices. The use of crop rotations, considered as a vital requirement for good soil stewardship, necessitates several cycles before the complete influence of the rotation is understood. A 2- or 3-yr study on a 4-yr crop rotation would be valueless in determining the contribution of the rotation.

Thus, logic dictates that there are aspects of agromonic research on the soil-plant-environment continuum that must be long term. This symposium started with that assumption and our task was to extract some nuggets of knowledge that will help us do better work in the future. In some cases, these nuggets were not new but have aged to perfection.

For example, A.E. Brandt in 1945 stated at an earlier symposium three musts for a long-term rotation experiment which were: "1: provide for all crops and treatments each year; 2. replicate; and 3. randomize." Earlier, W.G. Cochran (1939) had written "The standards of amount of replication are of course not necessarily the same as in single annual experiments, because in most experiments ... there is a certain amount of replication provided by the results in different years (2)." All are likely to agree that a good statistician is essential in planning any experiment.

This 1989 symposium pointed out three essential features of long-term experiments:
1. Several disciplines must be involved.
2. Communication is essential among those who carry out long-term experiments (a symposium every 45 yr is not sufficient).
3. A minimum set of measurements and modelers can utilize data. This set of data should include:
   a. Weather records
   b. Management activities
   c. Soil parameters
   d. Unusual events
   e. Crop measurements

Dr. Army, in his presentation, gave little encouragement for continual or new funding of studies. Modern science was called "short-term." Dr. Cady pointed out that young scientists are interested in long-term studies, but funding and publication requirements preclude actually doing them.

When initiating new long-term studies, some provided some musts for the new work: plots must be large so that soil creep does not become a factor and so that the plots may be split in the future. This limits the number of plots, which requires a clear statement of the objective and decision on design, data management, and statistical analysis prior to initiation of the study. Dr. Mensel pointed out that long-term studies on water quality must include both watershed sized studies as well as long-term monitoring. Thus, Dr. Army's comments concerning limitations on funding are especially alarming; coming at a time when the need for long-term studies seems especially great.

In conclusion, this symposium has been a blend of what has been done, what is being done, and what could be done. The current emphasis on sustainable agriculture should enhance the value of these long-term sites. Will it?

REFERENCES