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RESEARCH AT BENCHMARK LOCATIONS

REPORT OF WORKING GROUP 3

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THE NEED FOR BENCHMARK LOCATIONS

The SAT contain a complex array of diverse environments for crop growth due both to the range of soils and climates and to the wide variations in weather, especially rainfall, that may be experienced at any one location. This environmental diversity creates special problems for agricultural research, particularly in the application of results from one experimental site to other locations.

Research resources are insufficient to attempt studies of even a small fraction of the total number of environments. Some of the diversity arises because of sensibly continuous variation in environmental characteristics across a region; temperature and rainfall are good examples. Simulation models could substantially assist in describing the effects of soil variation on crop yields; however, these models have not yet been developed to the stage where they can predict crop productivity at various locations from the basic characteristics of the location. As a result, much farming systems reseach is location-specific.

Nix (1968) has described two methods other than simulation modeling by which results at one site may be applied to other locations in a region: the site-factor and the analogue method. The site-factor approach is suitable where relationships exist between crop productivity and one or more of the key factors determining productivity, e.g., soil moisture, available nutrients, soil texture, etc. Where research results are empirical, the analogue approach is more appropriate; this involves conducting experiments at a site chosen to be representative of soils and agroclimate of that area. This is known as a benchmark site. If the benchmark site has been correctly selected, then the research results may be fairly well applicable to areas with similar soils and agroclimate in the region. Empirical approaches involve a heavy input of resources, especially in the SAT, where experiments may need to be conducted for several years to ensure that they experience a range of seasonal conditions. The selection of benchmark sites therefore requires critical attention to ensure that each accurately represents an agricultural area and serves as large as area as possible; however, these aspects have so far received little emphasis, despite the need for benchmark sites stressed by others (Norman and Wright 1975; Dillon et al. 1978; Evans et al. 1978).

BENCHMARKS

The term benchmark originiated as a surveying term to describe a reference or

datum point, especially for elevation. Its use has spread so that it is now synonymous with a reference or standard. However, in agricultural research, there has been little attempt to define what is meant by the term "benchmark site." There is considerable variation in the use of the term and in the nature of the sites used as benchmarks. Four examples can be given.

1. Benchmark villages. The Economics Program at ICRISAT is conducting socioeconomic surveys in a number of villages, selected to be representative of a major cropping area. Some selection criteria used were: village size (population), major crops, general agroclimate, and soils.

2. Ecological-zone centers. In West Africa several broad ecological zones have been identified, mainly on the basis of agroclimate, especially rainfall. Two of these zones are of particular interest to ICRISAT, because of the strong crop orientation of our mandate: the sub-Sahelian zone, in which the rainfall is marginal to moderate for cropping, and millet is the major cereal, and the Sudanian zone, in which the rainfall is higher and more assured, and sorghum is the major cereal. Sadoré, near Naimey in Niger, and Kamboinsé in Upper Volta, have been designated as benchmark centers for these regions.

3. Benchmark locations for the FSRP at ICRISAT. The Norman and Wright (1975) report recommended that the FSRP establish additional benchmark locations in India to provide more extremes in environmental conditions than are provided by ICRISAT Center. The suggested criteria for these locations were: Vertisols under low rainfall (500 mm/yr), Vertisols under high rainfall (1000 mm/yr), and an Alfisol under low rainfall (500 mm/yr); these complement the medium rainfall (750 mm/yr) locations for Vertisols and Alfisols at ICRISAT Center.

4. Benchmark Soils Project (BSP). The BSP has been conducting experiments for some time to test the hypothesis that the soil family, a classification unit in the fifth tier of subdivision in the US Soil Taxonomy, provides a reasonably homogenous soil taxonomy unit for the transfer and application of results of agricultural research (see Swindale 1978). Climatic as well as soil physical and chemical characteristics are used to classify soils. The BSP has defined primary and secondary benchmarks as follows.

a. Primary benchmark sites are used for the detailed research needed to establish concepts. They are located on the most important soil families, with perhaps only one site per family.

b. Secondary benchmark sites are used for testing the transferability of results obtained at primary sites. Fewer research inputs are made than on primary sites, and the sites are intended to be used for perhaps 2 to 3 years. It seemed obvious to our committee that these sites should be located at research stations of the national programs (in India).

The committee recognized the usefulness of the BSP's concepts of two levels of benchmark locations and the defining of an environmental unit (i.e., the soil family in the BSP). However, the identity of this environmental unit was the subject of much discussion. This unit should not be selected only on the basis of soil taxonomy but should perhaps include other criteria, e.g., agroclimate. It was considered desirable that a much larger soil taxonomic unit than the soil family be used.

The soil component of an environmental unit must be much larger than the soil family, solely on the basis of practicability. The soil family is too small a unit for use in the field; even detailed soil maps produced by soil surveyors will usually use a mapping unit of an association which consists of a group of several families with similar characteristics. Larger units should be satisfactory for farming systems research—for example, the present transfer of technology testing involves the "deep Vertisols in assured rainfall areas."

SELECTION OF BENCHMARKS

Selection Criteria

The first stage in this selection of SAT benchmark sites is the consideration of the global geographical SAT requirements. The needs of each region for research to improve production need to be assessed by a number of criteria, e.g., population size and density, economic needs, production levels of major crops, trends in production and population, etc. On the basis of these criteria, the priority of each region for a benchmark site will be decided.

The location of the benchmark site within a region will depend on the major crops, soils, agroclimate, and biological factors (e.g., pests, diseases, etc.). A benchmark site may have more than one benchmark soil; for example, ICRISAT Center at Patancheru is a benchmark center with at least two benchmark soils—Vertisols and Alfisols. To classify, we can list the existing benchmark sites and their major soils as follows:

Benchmark site	Benchmark soil
ICRISAT, Patancheru	Vertisols Alfisols
Sadoré	Psamments
Kamboinsé	Alfisols (toposequence)

Other sites that would perhaps be considered in the future are those to serve the SAT in southern Africa (Entisols, with a higher temperature) and in northeastern Brazil (Oxisols, with a particularly long but erratic rainfall season).

Within a region, there may be need for additional soils outside of the benchmark site to cover known variations in particular environmental aspects, e.g., agroclimate, soils, disease incidence, etc.

Implications

To determine the best location for benchmark sites, there is a need for good resource inventories. These in turn require good soil and agroclimatic surveys. Some compilation and interpretation will be needed for West Africa, because soils were mapped there in a system different from the US Soil Taxonomy. But, for India, the completion of mapping of the country in much more detail than previously, and using the US Soil Taxonomy, will result in a very marked improvement in the soils resource inventory. One aspect of direct relevance to ICRISAT's FSRP work is that we will be able to select benchmark sites for FS1 and FS2 much more critically than on the very broad basis used in the past (i.e., rainfall and soil order, with an additional qualifier of soil depth). The more important sites, out of the 23 originally used, are listed in Table 2. (For descriptions of FS1 and FS2, see Table 4, page 42.)

Table 2. Important benchmarks in India for FS1 and FS2.

Soil order	Benchmark site	Mean length of growing period (weeks)
Vertisols[a]	Indore	16.4 ± 3.1
	Akola	14.0 ± 3.7
	Patancheru (ICRISAT)	12.9 ± 5.8
	Sholapur	11.3 ± 6.4
Alfisols	Ranchi (?)	16.4 ± 3.8
	Ramanathapuram	13.4 ± 5.2
	Patancheru (ICRISAT)	12.9 ± 5.8
	Anantapur	
Entisols	Agra	13.3 ± 3.6
	Hissar	

a. Vertisols are deep at all sites, except at Akola (medium).

Investigations are also needed to determine the size of the environmental units used for selecting benchmarks. Of particular importance is the fact that there has been very little critical work done on the transferability of research results. The BSP studies have provided useful leads. However, it must be kept in mind that the BSP was mainly testing the transferability of the results of component research (e.g., responses to nutrients), whereas we are interested in the development and transferability of farming systems.

RESEARCH AT CENTERS AND BENCHMARKS

The aim of research centers is primarily to develop concepts and technologies. Because of permanent facilities, and the concentration of workers from several disciplines, research centers are best placed for conducting detailed and interdisciplinary research. The establishments at Sadoré and Kamboinsé are considered to be benchmark (regional research) centers, serving as a focus for research for the sub-Sahelian and Sudanian zones. A research center must contain at least one primary benchmark site and possibly several. For example, we must regard ICRISAT Center as having at least two benchmark soil sites—Alfisols and deep Vertisols. The Vertic Inceptisols, or shallow Vertisols, provide a third benchmark.

For the FSRP, it is appropriate to elaborate on the characteristics stated earlier of the different categories of benchmarks.

Primary benchmarks

Detailed basic studies to establish concepts.

Applied and multidisciplinary studies to test applicability of disciplinary concepts under field experimental conditions.

Operational research to provide provisional testing of concepts and new technologies in farming "systems" or "practices."

Secondary benchmarks

Evaluation of transferability of technologies.

Evaluation of validity of concepts (both farming systems and component research).

Involvement of national programs (partial test of transferability).

Primary benchmarks located away from the center will still be occupied with multidisciplinary and detailed research, with the marked constraint that inputs may be limited by the logistical problems created by distance from base.

The distribution of research effort between the centers and the two levels of benchmarks will vary with the attributes of a particular improved technology. However, some speculation can be made (Table 3) to indicate a possible distribution of efforts within each of the five categories of research outlined by Working Group 2.

Table 3. Relative emphasis of farming systems research areas at centers and benchmark locations.

Kind of research	Center	Benchmark	
		Primary	Secondary
Base-data analysis	XXXX	XX	X
Single-component research	XXX	XX	X
Multicomponent research	XXX	XXX	X
Integrated operational research	XXX	XXX	XX
On-farm research			XX

ORGANIZATION OF RESEARCH AT CENTERS AND BENCHMARKS

The organization required for research at benchmark sites will necessarily be specific to location and purpose, but in all cases there will be different requirements at primary benchmarks operated wholly by ICRISAT as compared with the secondary benchmarks operated offsite with other collaborating institutions. Within ICRISAT, there will be a major emphasis on coordination of team efforts, both for concept development and logistics; with offsite work, there will be need to assess the constraints placed by travel, and the constraints and advantages of working with collaborating institutions.

These comments are made especially in the context of ICRISAT in India and West Africa. With current staffing allocations, buildup of centers staffed by ICRISAT in eastern and southern Africa, and South America, is precluded. For these, different staffing and organizational arrangements will be necessary; nevertheless, many of the principles involved in the use of centers and benchmarks will still apply.

One aspect that requires discussion is the extent and nature of interaction between centers in India and Africa. Programs at each center will obviously differ from the others because of differences in the major problems to be researched in each agricultural environment, but there is need for interaction for sharing of resources, ideas, and research methodologies.

CONCLUSIONS

Relatively little critical attention has been given in the FSRP to the criteria to be employed for defining benchmark locations. This has been partly due to lack of resource classifications and inventories in the past, but the basic information required for these is becoming increasingly available. The current developments, within the FSRP, in agroclimatic classification are an example of additional resource descriptions that will improve our ability to select the best.

SUMMARY OF DISCUSSION--SESSION 3

Use and Concept of Benchmarks

Those involved in farming systems research at ICRISAT need to develop technology and to test, evaluate, and distribute it on the basis of a number of sites relevant to ICRISAT. Moreover, farming systems research involves the development of a methodology for selecting benchmark sites.

The concept of benchmarks is extremely useful and should be developed at ICRISAT. Benchmarks help us in stratifying the environment; the more finely stratified, the more they will apply, and the farther we move from the fineness, the less they will apply. Further, we must know the confidence limits for generalization at various levels. These concepts are well understood and can be handled provided that (1) we have well-defined benchmarks that have sensible relationships to each other and encompass the populations, soils, and climates with which we must work; (2) we attempt to spread the information from those locations in a regular, methodological way.

The overall concept is one of understanding and defining the environment for crops, so that we can predict more acurately the areas over which new research findings will be applicable.

Criteria for Benchmark Selection

Similar soils and climate. We should consider not soil alone, but an ecological unit of soil plus agroclimate.

Toposequence. There should be an effort to combine the concept of toposequence with benchmark location. In Australia the concept of landscape units has been developed and used fruitfully by the CSIRO. In West Africa, we have started a systematic use of toposequence for agronomic studies on the adaptation of new varieties and some management techniques, e.g. planting date, soil tillage, etc. We have three sequences in Mali and two in Upper Volta. At ICRISAT there is a special type of toposequence consisting of Alfisols, Vertic Inceptisols, and Vertisols occurring over a short distance. If we consider the Sahelian zone, toposequences are of little value, since we can identify only one, or perhaps two, soil families there. However, in the Precambrian shield areas in Upper Volta and Mali, toposequences are very important.

The toposequence can be considered as a tool to observe the relation of crops to a number of factors, especially if observations are well made and supported by complementary measurements.

Biological parameters. Since we are dealing with biological systems, some aspects that must be taken into account in crop production—in addition to climate and soils—are latitude, altitude, and various insect-cum-disease parameters. These biological parameters, unfortunately, are not stable— they vary considerably from year to year, and a site that is a good benchmark one year may be an appalling one in another year.

Sociological aspects. The benchmark idea is a good one. However, in practice we have human beings in the system and, given a certain socioeconomic setup, we may have to allow time to elapse before adapting technology to suit the socioeconomic conditions.

Regions selected by ICRISAT crop improvement programs. We should take note of the regions identified by our crop improvement programs. Benchmark sites must fit into those regions so that there is congruence between the two sets of objectives. From the cropping point of view, the benchmark regions have already been identified.

Number of Benchmark Sites

T.S. Gill of USAID has calculated that there are about 240 agroecological units for all climatic zones in the world and has posed the question: can we reduce the number of important units to, say, 15?

For the grouping of smaller units into larger units, we have to consider the number of units and variations within them. There is a compromise between the size of the unit and the degree of accuracy. The penalty for failing to characterize the agricultural environment correctly may be the failure of the technology.

We must be careful to identify those particular units that have some significance for our work at ICRISAT.

Existing and Future Benchmarks

We all agree that we must spend most of our efforts on well-chosen and well-characterized major sites that are to be under our own control. This has already been done. We will not have research centers at more than three locations in the world for a long time to come. These locations—two at Patancheru, one at Sadoré—are, in fact, primary benchmarks, well chosen with some scientific logic in mind, and represent a conceptual framework within which we can interpolate and not extrapolate from our current results.

We ought to have at least one more location in Brazil, the fourth and very necessary corner point in our particular sphere of soils and environment, and we hope to arrange this. We are not only choosing our sites very carefully but we are also considering methodologies to extend from them to more finely defined sites around the world.

Possible Assistance in Benchmark Selection

We must look to other people to work on benchmarks when this becomes necessary. Such external work might include the services of an experienced person to identify 15 sites that are of concern to ICRISAT.

Relative Emphasis at the Primary Benchmark Locations

The two ICRISAT centers at Patanheru and Sadoré have provided sites for attacking major agricultural problems within farming systems research in each region. Each center serves a region with its own individual problems; since we have many more scientists at Patancheru, we will be able to study many aspects in greater depth than can be done at Sadoré. Soils at the two sites differ appreciably. At Patancheru we do not have deep sandy soils containing highly weathered clay. The Sadoré site consists of only sandy soils, with no Vertisols. But there is a need to intercommunicate in respect of field and laboratory techniques and methodologies. The effective working relationship between the Indian and the West African centers has received only limited attention so far.