41942 PN-AAT-649

Agricultural Systems 15 (1984) 101–123

Stratification: An Approach to Cost-effectiveness for Farming Systems Research and Development

W. W. Shaner

College of Engineering, Colorado State University,
Fort Collins, Colorado, USA

SUMMARY

Farming systems research and development is a new approach aimed at meeting the needs of farmers with limited resources in the less developed countries. The cost-effectiveness of the approach rests with identifying enough farmers operating under similar conditions who will adopt the proposed technological improvements. An important way of doing so is through stratification of environmental and farmers' conditions to develop what is called a recommendation domain. This paper reports on current stratification efforts, involving (1) descriptive schemes (classification of farming systems, agricultural growth stages, and an ecological systems approach), (2) stratification by components (agroclimatic zones, soil and land classifications, cropping and biological environments, farmers' cultural practices, and economic and socio-cultural conditions), and (3) stratification strategies used by four major research centers. The paper closes by asserting the need for further methodological work and offers some suggestions.

INTRODUCTION

Within the past ten years an approach to agricultural research and development of technology aimed at helping farmers with limited resources in the less developed countries (LDCs) has gained considerable attention and support. This approach, called farming systems research and development (FSR&D), brings various disciplines to bear on farmers' problems in a systematic way by identifying problems and conducting

Agricultural Systems 0308-521X/84/$03·00 © Elsevier Applied Science Publishers Ltd, England, 1984. Printed in Great Britain

research on the farmers' fields in collaboration with farmers. While many of these characteristics are present in other approaches to agricultural research in the LDCs, the combination and systematization of procedures sets FSR&D apart from the others.

More specifically, FSR&D is an approach that 'views the whole farm as a system [and] focuses on (1) the interdependencies between the components under the control of members of the farm household and (2) how these components interact with the physical, biological, and socioeconomic factors not under the household's control'. The approach 'can be summarized as being farmer-based, problem solving, comprehensive, interdisciplinary, complementary, iterative, dynamic, and responsive to society. The approach is:

—farmer-based because FSR&D teams pay attention to farmers' conditions and integrate farmers into the research and development process;
—problem solving in that FSR&D teams seek researchable problems and opportunities to guide research and to identify ways for making local services and national policies more attuned to the farmers' needs;
—comprehensive in that FSR&D teams consider the whole farming activity (consumption as well as production) to learn how to improve the farmers' output and welfare, to identify the flexibilities for change in the environment, and to evaluate the results in terms of both farmers' and society's interests;
—interdisciplinary in that researchers and extension staff with different disciplinary backgrounds work with farmers in identifying problems and opportunities, searching for solutions, and implementing the results;
—complementary because it offers a means for using the outputs of other research and development organizations and for giving direction to others' work;
—iterative in that FSR&D teams use the results from research to improve their understanding of the system and to design subsequent research and implementation approaches;
—dynamic in that oftentimes FSR&D teams introduce relatively modest changes in the farmers' conditions first and the favorable results encourage more significant changes later;
—responsible to society in that FSR&D teams keep the long-run

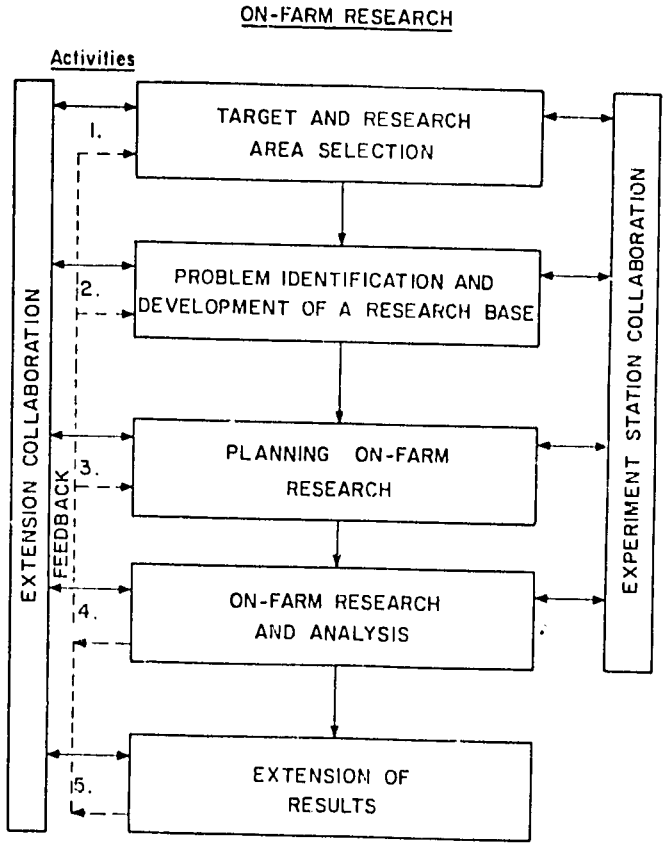

Fig. 1. The five basic activities of FSR&D (Shaner *et al.*, 1982).

interests of the general public—both present and future—in mind, as well as those of the farming groups immediately affected' (Shaner *et al.*, 1982).

While the foregoing may be implemented in various ways, FSR&D programs generally embody the five activities shown in Fig. 1. These activities are (1) target and research area selection, (2) problem identification and development of a research base, (3) planning on-farm research, (4) on-farm research and analysis, and (5) extension of results.

The basis for selecting the target area is generally a combination of policy objectives and the area's potential. Once selected, the area is stratified according to sub-areas of commonality. FSR&D teams next select areas of research to include at least one of these sub-areas in a way

that conforms to their research objectives and the relative importance of each sub-area. Interdisciplinary teams then study secondary information and conduct field studies to identify problems justifying their attention. In the process, the FSR&D teams organize the information collected and begin to gain an understanding of the area's characteristics. That is, the teams develop a base for implementing their research programs. Research activities are planned during the third phase. During the fourth phase, research is carried out and the results analyzed. Finally, successful results are turned over to the implementing agencies for broad-scale dissemination of improved technologies.

Completing the activities shown in Fig. 1 are the collaboration with extension and the experiment stations, and the feedback of results. Such collaboration demonstrates FSR&D's complementarity with other research and development activities in the region; and the feedback demonstrates the iterative process of progressively improving the research approach by using the results previously attained (Shaner *et al.*, 1982).

Because of the general difficulty of monitoring and evaluating agricultural research in the LDCs and the newness of FSR&D programs, some still debate FSR&D's cost-effectiveness. A common criticism runs as follows: (1) FSR&D devotes too many scarce resources to helping too few farmers, and (2) by following an FSR&D approach, other research activities are cut back thereby limiting the country's total research program. This has been termed FSR&D's site specificity problem.

In defense of the FSR&D approach, Harrington (1980), among others, argued that FSR&D *can be* cost-effective. His reasoning contains the following points. First, the rather obvious costs of transportation and *per diem* associated with FSR&D may not be greater than the less obvious costs of experiment station research, when consideration is given to the costs of facilities and the more highly skilled specialists. Secondly, rates of acceptance of improved technologies must also be taken into account. By identifying problems of concern to farmers, the FSR&D approach is expected to yield a high rate of acceptance. Thirdly, FSR&D staff have developed survey and research procedures for reaching targeted farmers and producing improvements quickly. For example, interdisciplinary teams conduct rapid reconnaissance surveys (Hildebrand, 1979) and attempt to implement on-farm trials during the first available season (Zandstra *et al.*, 1981). Finally, FSR&D researchers are urged to identify improvements to farmer's conditions that are *better* than their current

practices, not necessarily the *best* that can be offered. Thus, some degree of improvement is often possible without long delay. Such improvements are contrasted with cases in which station researchers spend years perfecting a technology that farmers ultimately reject.

While admitting that FSR&D costs may not be greater than alternative forms of research and that high rates of technology acceptance may be accomplished because only marginally better improvements are sought, still FSR&D may remain too expensive if the numbers of farmers affected are small. Thus, a key factor in the FSR&D approach is the team's ability to identify enough farmers operating under essentially similar conditions so that the benefits from research on new technologies justify the costs. Here this process of identifying such farmers and their conditions will be called *stratification*.

The following sections contain a review of current literature and practices. They begin by first dealing with the way stratification fits into FSR&D methodology. Then, three approaches to stratification are described. The paper closes with some ideas about further research opportunities.

STRATIFICATION

Stratification can take on two connotations: that relating (1) to the characteristics of the area (and those within it) and (2) to the likelihood that farmers will react similarly to proposed changes in technology, otherwise known as *recommendation domains*. These two concepts are discussed below.

Area characteristics

Stratification of the target area is part of the first FSR&D activity (see Fig. 1), whereby the area is partitioned according to its commonalities. This commonality refers not only to the range of physical, biological, economic, and socio-cultural factors that farmers face but also to the FSR&D team's evaluation of the opportunities for identifying technologies and policies beneficial to the farmers.

Because of the heterogeneity so common within agricultural areas, these sub-areas refer to the general conditions prevailing there. Actually, conditions within a sub-area can be quite diverse because of differences in

terrain, soil fertility, farm size, farmers' resources, cropping patterns, and other factors. As a result, to be fully useful, farmers in the sub-areas need to be further screened according to their commonalities. This further division of the sub-areas yields what CIMMYT (International Maize and Wheat Improvement Center) calls *recommendation domains*.

Recommendation domains

According to Byerlee *et al.* (1980*a*), a recommendation domain is a 'group of roughly homogeneous farmers with similar circumstances for whom we can make more or less the same recommendation. Recommendation domains may be defined in terms of both natural factors (e.g. rainfall) and economic factors (e.g. farm size)'. While the concept of recommendation domains is appealing, some have found difficulty with it because of the heterogeneity of farmers and farmers' conditions and because of having to define the domains before the recommendations are made. For example, Zandstra asserts that a domain's characteristics depend on the nature of some future recommendation and that these characteristics cannot be fully known until the research has been carried out (personal communication). Nevertheless, researchers have applied the essential features of recommendation domains in a variety of forms, as will be shown in subsequent sections. A technique followed by CIMMYT (1981) is to identify the domain first on a preliminary basis and then to modify the domain as further investigation proves necessary.

On an abstract level, a recommendation domain can be considered as that group of farmers to the left of the intersection of the curves representing the 'profitability' to individual farmers and the minimum 'profitability level' (see Fig. 2). The shaded area (recommendation domain) in Fig. 2 represents the conditions whereby the net benefits of an improved technology exceeds the farmers' demands of a new technology. The heterogeneity among the farmers and farmers' conditions explains the divergency in net benefits. Notwithstanding this diversity of results, researchers will have succeeded in identifying the recommendation domain if most of the farmers who find the new technology acceptable were previously identified as those being within the domain. A point brought out by Byerlee *et al.* (1980*a*) is that these farmers can be scattered throughout the target area.

Returning to Zandstra's argument, one could expect a different set of curves (Fig. 2), and thus different domain parameters, for each

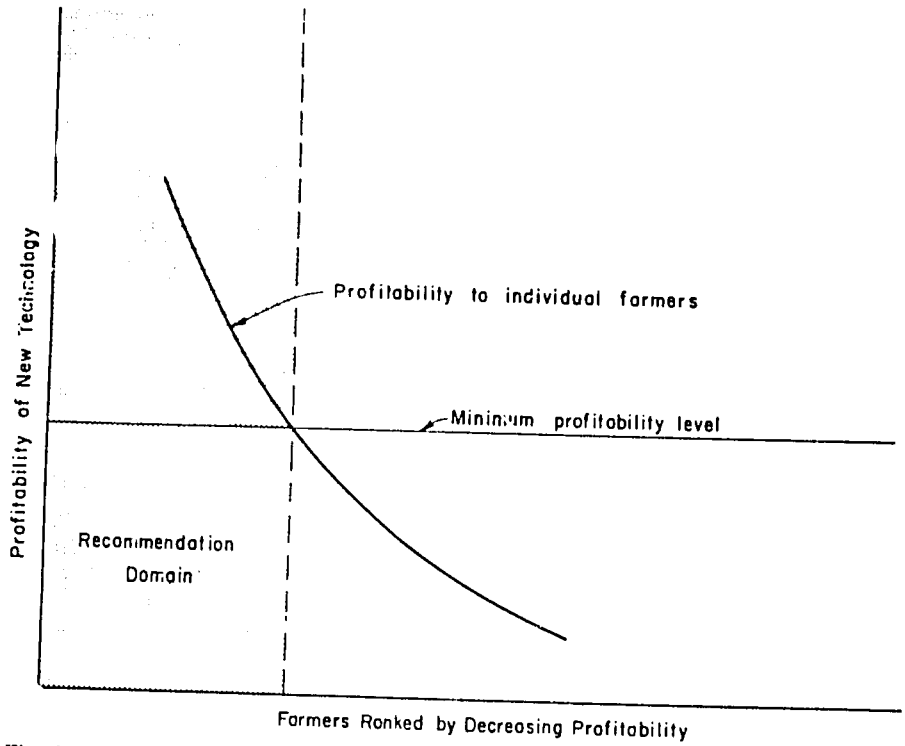

Fig. 3. Recommendation domain defined as the set of farmers who would find a new technology acceptable.

technology. This reasoning leads to the conclusion that recommendation domains take on two characteristics: first, they can be used to set broad conditions for research, such as fundamentally different soil types; and secondly, the more specific the domains become, the more frequently they need to be redefined as the technologies change or as more is learned about the domains. Some examples of recommendation domains follow.

Norman and Gilbert (1982) suggest that research strategies need to be appropriate for each recommendation domain. Thus, 'families in a particular subgroup will tend to have similar farming activities and include similar social customs, similar access to support systems, comparable marketing opportunities and similar present technology and resource endowment'. After considering such a range of activities, the Kansas State University (KSU) team decided that the critical factors on which to base its initial research effort could be reduced to three major domains: (1) relatively wealthy farms with a distinct emphasis on

livestock, (2) marginal mixed crop and livestock farms, and (3) submarginal mixed farms with a crop emphasis (Bussing *et al.*, 1981). The distinguishing factors in identifying these domains were the power source (i.e. size of the livestock herd) and the size of the families' holdings.

In a study of a maize-producing valley in one of the South American highlands, CIMMYT (1981) identified four recommendation domains according to altitude, irrigated or rainfed agriculture, main planting dates, vegetative cycle, incidence of disease, and disposal of the maize crop. In another example, this same report identified two basic recommendation domains: one on flat lands and another on steep lands. Using these two divisions, major differences were found in the way farmers prepared the land, in their choice of plant varieties, and in their weeding practices. More recently, Byerlee *et al.* (1980*b*) hypothesized that tractor ownership – i.e. those who owned tractors and those who rented them—was the distinguishing factor on which to stratify farmer types within a highland valley of Mexico. Their reasoning was that those who owned tractors could prepare the land and plant their crops at more appropriate times than those who had to wait until tractors were available. This hypothesis was then tested for statistical significance according to cropping patterns, farmers' resources, and land preparation practices. While the results showed a number of factors as being significant, such as dates of land preparation and the number of times a field was harrowed, the authors concluded that these differences were not significant enough to warrant separate recommendation domains when planning experiments. Clearly, this was a matter of judgement that needed testing as that research program progressed.

APPROACHES TO STRATIFICATION

The foregoing suggests that a variety of approaches can be taken in stratifying farmers and farmers' conditions. Moreover, while differences in conditions can be identified, the researchers ultimately must decide on the degree of homogeneity to capture within their stratifications. Their choices depend on their ability to identify key factors influencing farmers' decisions and on their anticipation of the types of improvements that can be developed. Approaches to stratification, divided into descriptive schemes, stratification by components, and strategies for stratification, are described below.

Descriptive schemes

Several authors have studied farmers' systems with the intent of gaining a better understanding of a family's activities and its means of production. Below are brief accounts of three descriptive approaches.

Classification of farming systems

Writing on tropical agriculture, Ruthenberg (1971) comments that some form of classification of farming systems is necessary for devising meaningful agricultural policies even though no two farms are organized exactly alike. By focusing on farm management characteristics, he divides farming according to whether its functions are primarily collecting, cultivating, or using grasslands. Within cultivation systems, which have been FSR&D's primary focus, Ruthenberg distinguishes among activities according to type of rotation (e.g. ley systems, field systems with one crop following another, and perennial crops), intensity of rotation (e.g. number of crops per year), water supply (e.g. irrigated or rainfed), cropping pattern and animal activity, implements used for cultivation, and degree of commercialization.

For a particular farming system, insight into farming activities can be gained by studying the system's natural environment and the critical aspects of the socio-institutional setting. MacArthur in Ruthenberg (1971) looks at climatic influences, soils, and biological conditions within the natural environment. He mentions that critical problems may relate to soil fertility, cropping with risk and uncertainty, low labor productivity, and seasonality of water supply. In closing his description, MacArthur reminds us of the dynamic nature of tropical farming. Even though farms can be classified and described, farmers continually make minor adjustments to their production processes because of changing conditions. The need for such adjustments provides researchers with the opportunity to introduce improvements to the farmers' systems.

Agricultural growth stages

Harwood (1979) expands on Ruthenberg's classification by noting that agriculture progresses through a series of stages: namely, hunting and gathering, crop and animal husbandry subsistence, consumer orientation, early commercial orientation, mechanical power for tillage, and finally mechanical power for additional farming activities. While researchers often use the last stage as their ideal on the assumption that increases in labor productivity through mechanization are the objective,

Harwood suggests that such an ideal is inappropriate for subsistence farmers. Rather, Harwood suggests that FSR&D teams should spend part of their initial efforts in identifying the farmers' stage of growth. Such an understanding helps set the direction of research, since labor productivity, number of farming enterprises, and cash and skill requirements depend on the development stage.

Harwood (1979) uses the following factors to identify a farmer's stage of development: degree of commercialization, predominance of labor activities, cropping systems, use of draft animals, untended pigs and chickens, complementarity of interactions between crops and between animals, and the contribution of family production to its own nutrition. For example, permanent agriculture with low commercial activity typically supplies most of its own food and relies heavily on the complementarity between crops and animals. Farming becomes complex owing to 'intensive intercropping, nutrient cycling, diversified and highly developed mixed-planting of homestead areas, and a delicate crop–animal balance [that maximizes] productivity in an environment where external resource use is being minimized . . .' (Harwood, 1982).

An ecological systems approach

Hart applies an ecological systems approach to understand better the interactions within the farm household and between the household and its environment. Using this construct, the farming system is both part of a larger system and in turn made up of cropping, livestock, or mixed subsystems. These subsystems are broken down into individual crops and types of animals.

With this systems approach Hart studied individual components of the farming system. For instance, for a cropping system he studied the 'arrangement of crop populations that process energy (solar radiation) and material inputs (soil nutrients and water) to produce outputs (crop yield). The crop population can be arranged both spatially (planting distances) and chronologically (date of planting)' (Hart, 1982*a*).

Hart's use of an ecological approach provides insight into a farmer's activities and the degree to which the farm is in physical, biological and economic balance. In another of Hart's studies (1982*b*), he began by identifying a representative farm within a region. The principal farming activities and interactions were next shown graphically. Then, data on inputs and outputs were gathered weekly for an entire year to quantify the graph.

This year-long study provided Hart with a means for (1) adapting Odum's ecology principles (1971) to FSR&D, (2) analyzing the interactions of complex farming systems, and (3) training students in FSR&D methodology (Hart, 1979). His approach is therefore investigative and pedagogical, rather than applied. More direct approaches to FSR&D are described below.

Stratification by components

Some of the approaches to stratification by components are described below under the headings of agroclimatic zones, soil and land classifications, cropping and the biological environments, farmers' cultural practices, and economic and socio-cultural conditions.

Agroclimatic zones

Agroclimatic zones are distinguished according to their suitability for generally broad categories of agriculture. Rainfall and temperature (especially in mountainous areas) are widely used in evaluating an area's agricultural potential. Also, measures of potential evapotranspiration have been used to classify arid and semi-arid areas according to 'homoclimates' (Chang, 1980). However, Chang suggests that such broad classifications are usually inadequate for research purposes because (1) the annual data so often used are too gross for cropping purposes, (2) the climatic boundaries are seldom appropriate for specific crops, and (3) mean values of temperature, precipitation, and potential evapotranspiration are seldom sufficient by themselves. Instead, Chang calls for greater attention to the phenological requirements of specific crops, solar radiation, photoperiod, temperature extremes, and wind.

At a more applied level, Hargreaves (1977) derived a moisture availability index for identifying water deficiencies and excesses. This index is computed by dividing the dependable (75% probability) precipitation by the potential evapotranspiration. According to Hargreaves, 'monthly indices are fairly adequate for most planning and development needs. However, whenever serious doubt exists relative to the validity of the use of monthly values, daily data can be used to estimate daily, 5-day, 10-day, or 15-day values and indices. Use of comparisons between monthly values and those for shorter time periods has added confidence in the use of monthly indices.

Where research extends across areas with different climates, Lawson,

of the International Institute of Tropical Agriculture (IITA) in Nigeria, would have researchers plan their experiments by taking the region's climatic variability into account. By selectively placing experiments and recording climatic data, experimental results can be more adequately interpreted in the light of actual conditions; and yield responses under different climatic conditions can be better understood (Lawson, personal communication; see also IITA, 1977, for an annual account of its farming systems program).

Soil and land classifications

Considerable work has gone into classifying soils and land types for agricultural purposes. Examples include The Food and Agriculture Organization's (FAO's) framework, The International Rice Research Institute's (IRRI's) land types, the soil temperature and moisture regimes of Van Wambeke, and Cochrane's work at The International Center for Tropical Agriculture (CIAT).

FAO (1976) proposes six principles for classifying land for agricultural use. These are: (1) lands should be classified for specific kinds of use; (2) different types of land require comparisons based on the potential benefits and cost of their use; (3) the evaluation process requires an interdisciplinary approach; (4) evaluations should take account of the areas's physical, economic, and social conditions; (5) an area's suitability should be based on its long-term use; and (6) alternative uses for an area require investigation. In going through this classification process, researchers will be able to compare actual with potential land use.

Zandstra *et al.* (1981) provide recommendations more specifically to the physical characteristics of an area. They explain that land types 'must be sufficiently different to merit the development of a different technology for each . . .'. Their classification of land types considers terrain (e.g. plain and bottomland), major soil type (e.g. balo loam and loba clay), water table depth during the rainy season, hydrology (e.g. pluvic and fluxic), flooding hazard (e.g. absent and 1 in 10), major present use (e.g. rice fallow and tree crops), and potential use (e.g. rice rice and 'as is').

More narrowly related to soils, but for broader application, is the work of Van Wambeke (e.g. 1982) on soil moisture regimes of Africa. This approach combines soil temperature and moisture regimes to classify soils. Van Wambeke states that the 'reason for using soil climates is that they are the causes of many other properties, . . . some soil characteristics are only meaningful when they are considered in a limited area restricted

to a defined soil climate . . . [and] major soil limitations for plant growth are implied' by the classification. Such broad-scale classifications as Van Wambeke's are primarily useful in (1) grasping an area's general soil and climatic characteristics, and (2) comparing the area's agricultural research and production results with the results from other areas.

While working with CIAT in Colombia, Cochrane *et al.* (1979) extracted data from reports, transferred these data to computer storage, and then produced computer-aided maps of soil characteristics. Data on climate, soils, and landscapes were then correlated with crop production and the results used to locate areas of major importance for CIAT's cropping and livestock research programs.

As another application of soil and climate classification, Palmer *et al.* (1978) mapped the six ecozones in Kenya in studying the potential of the so-called marginal lands in the Machakos-Kitui area. These six zones were divided according to the ratio of rainfall to potential evapotranspiration. Overlays were placed on these six zones to account for soil characteristics and for slope. The resulting classifications were then used to search for improvements in agricultural technologiés suitable for semi-arid conditions.

Cropping and the biological environments

Crops, cropping patterns, and pests are commonly used as a basis for characterizing farmers in an area. Several of the International Agricultural Research Centers have a commodity focus. Also, national agricultural research programs often build on experiment station activities centered on specific crops. Another reason for focusing on specific crops is that farmers with limited resources often do not change from their basic subsistence crop. For instance, most highland farmers of Guatemala develop their cropping patterns around maize and the lowland farmers of the Philippines typically develop their cropping patterns around rice. Consequently, in stratifying agricultural areas, attention needs to be given to the stability of existing cropping patterns.

Problems with insects, diseases, weeds, and other pests also deserve attention. Research areas were zoned in Sumatra on the basis of the particularly troublesome grass *Imperata cylindrica*. Winkelmann and Moscardi (1982) report that the insect pattern (which was closely related to altitude) was one of the factors in establishing recommendation domains in Ecuador.

While working with CIAT in Colombia, Jones (1979) conducted an

agroclimatic survey of bean production in South America. The objective of the survey was to identify the climatic conditions of the region's major bean producing areas. Disease and pest problems, yields, and other relevant characteristics of bean production could then be correlated with climatic characteristics.

In contrast with Jones' approach, which notes the interaction between crop and agroclimatic data, the FAO study of Africa (1978) identifies locations in which environments are suitable for producing particular crops whether they are grown there or not. Knowledge of potential production areas according to crop requirements can be used as a starting point in searching for new crops or cropping patterns.

Farmers' cultural practices

Farmers' cultural practices offer a variety of opportunities for classification, as illustrated earlier when discussing the work of Ruthenberg and Harwood. Characteristics to consider include ownership and use of animal and mechanical power, communal and individual activities, use of purchased inputs, and knowledge and use of available technologies Farmers sometimes differ in their choices of land and seedbed preparation, planting dates, plant populations, spacings, row geometry, variety selection, maintenance of soil fertility, pest management, and harvesting and crop storage.

The extent to which the foregoing are important in dividing farmers into separate groups depends largely on the strength of their customs. Hildebrand warned against experiments that jeopardized the maize crop of the highland Indians in Guatemala. Some of these farmers' planting practices are tied in closely with their beliefs and customs, such as their resistance to thin maize plants. In contrast, Zandstra has said that many of the small-scale rice farmers in Southeast Asia are anxious to experiment. This readiness perhaps helps explain the rapid acceptance of improved rice varieties in that region.

Economic conditions

Economic factors may be divided into those that are *endogenous* (under the farmers' control) and those that are *exogenous* (not under the farmers' control) Gilbert *et al.*, 1980).

Exogenous factors likely to influence farmers' actions include land availability and rental rates, share cropping arrangements when established by custom, land pressures, size of holdings and fields, input

supplies and markets for farmers' output, price stability, availability of services such as credit and transportation, seasonal labor for hire, supplies of consumer goods, and so on. Differences in these exogeneous factors can be a basis for stratification when they persistently influence farmers' decisions.

Endogenous factors to consider include family customs and preferences and how these relate to decisions concerning cropping and livestock patterns, timing of farming activities, allocation of family resources among its farming enterprises and between on-farm and off-farm activities, acceptance or rejection of available credit, consumption or sale of its output, and so on. Customs and preferences that are relatively fixed serve as a basis for stratification, whereas those that are relatively flexible do not.

Farmer decisions over these endogenous factors may in large part be set by the family's income, assets, and general standard of living. The closer the family is to bare subsistence, the less flexible it is in allocating its resources. The KSU team used this distinction as one of the bases for stratifying farmers in Botswana (Bussing *et al.*, 1981). Hildebrand (1978) says that in 'commercial agriculture, the tractor and a strong capital base are effective homogenizers of what is otherwise a complex milieu'. In other words, the greater the farmers' resources, the less need for stratifying on economic grounds.

Socio-cultural conditions

Some of the economic factors shade into the socio-cultural setting, so that the division between these two categories may seem arbitrary—e.g. land rental and share cropping arrangements might be classified as either economic or socio-cultural. Regardless of the classification, knowing whether to stratify farmers depends on a reasonably accurate appraisal of farmers' practices. For this, an understanding is needed of the farm family and its socio-cultural environment.

Concerning the farmer, Beal and Sibley (1967) studied Guatemalan farmers' potential for change based on statistical analyses of farmers' characteristics (e.g. age and sex), knowledge (e.g. information about alternative management practices), beliefs (e.g. emotions and sentiments), behavior (e.g. marketing practices), and goals (e.g. family desires).

Knowing farmers' attitudes and behavior when confronted with risk or opportunities for leisure can influence both the timing of introduced

change and the nature of that change. According to this Beal and Sibley study, farmers' education, age, and frequency of visits to metropolitan areas are some of the variables that correlate with the adoption of new technologies. Where the distinction among groups of farmers is strong enough, stratification into separate groups could be recommended. Family preference for red or black beans could be important enough in varietal selection during research design that stratification on these grounds is necessary.

Institutional factors also help shape farmers' acceptance of change and, hence, deserve consideration. Land tenure and share cropping arrangements, cooperation during times of social or economic stress, organizations for regulating irrigation water, and religious laws and customs are some of the social factors that may distinguish farmer groups. Livestock herders compared with sedentary crop farmers is a rather obvious basis for stratification. Differences in religion, on the other hand, may not be important. Henderson (1980) points out the flexibility that religion often provides its followers.

Concluding remarks

Systematically considering all possible combinations of the foregoing bases for stratification would be both difficult and time consuming. In practice, researchers have been able to identify certain key factors that separate farmers and farmers' conditions according to possibilities for technological change. Moreover, not all possible combinations need to be considered. Logically, some factors are subsumed by others, such as bean diseases and frost damage according to elevation. Approaches to stratification practiced by four organizations are described next.

Strategies for stratification

A strategy for stratification is simply an educated, possibly intuitive, approach for identifying those factors important in grouping farmers who will benefit from specific improvements in technology. Strategies followed by the Agricultural Science and Technology Institute (ICTA), CIMMYT, The International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), and IRRI cover a variety of approaches.

The ICTA strategy

ICTA's approach to stratification makes use of reconnaissance teams criss-crossing an area in search of commonality among farmers

(Hildebrand, 1978). This commonality centers on cropping patterns (e.g. maize intercropped with beans), production methods (e.g. variety selection and time of planting), and farmers' resources (e.g. access to income from off-farm employment). The approach is relatively simple to implement, since distinguishing characteristics are generally observable and of the type farmers readily recall and are willing to reveal. Research on farmers' fields, with farmer participation, coupled with production records and farmers' reactions serves to confirm the stratification or provides the basis for modification.

An advantage of this approach rests with the assertion that the output of a farming system integrates a complexity of environmental and farmer-related factors. For example, the variety, time of planting, cropping pattern and rotations, and yields reflect soil and climatic conditions, farmers' preferences, market conditions, and so on. By focusing on what the system produces, researchers are relieved of expensive and sometimes complex data collection and analysis.

Major drawbacks to the approach center on two limitations. First, without having detailed data on the environment (e.g. soils and climatic characteristics), farmers' reasons for accepting or rejecting changes may be inadequately understood. Secondly, commonalities in farm output may hide basic differences in farmers' conditions and management. For instance, differing soils or microclimates could be offset by differing inputs of labor and materials to yield essentially the same results. Some of these differences will become apparent from the on-farm trials and records; but more thorough knowledge of the physical, biological, and socio-economic environments would help in designing experiments and understanding the results.

The CIMMYT strategy

Much of CIMMYT's FSR&D efforts center on farming systems in which maize is the farmers' dominant crop. Partly as a result of its mandate, the focus on maize (and sometimes wheat) is both a restriction and a part of its strategy for selecting recommendation domains. Once maize farmers are identified, CIMMYT researchers search for major distinguishing factors. As in the earlier examples, stratification can be according to elevation, with the accompanying influence on disease and frost conditions. In other cases, the practice of intercropping maize and beans and the availability of seasonal labor may serve as the basis for stratification. For example, 'different disease incidences for beans...

cause farmers in one part of the agro-climatic environment to plant beans early, therefore delaying maize plantings [so that in] this case recommendation domains may result from natural circumstances (i.e. diseases) affecting bean production and an economic circumstance (i.e. labor scarcity) translating this effort onto maize practices' (Byerlee *et al.*, 1980*a*). Other factors noted in this same reference include distinctions according to water source (irrigated or rainfed), main planting dates, vegetative cycle, and the nature and extent of maize sales.

The ICRISAT strategy

ICRISAT is 'concerned with the development of farming systems which would help to increase and stabilize agricultural production through the better use of the natural and human resources in the seasonally dry, semi-arid tropics...' (Krantz, 1982). Fundamental to its farming systems research has been the identification of two distinctive soil orders: Alfisols and Vertisols. Because of differences in clay content, these two soils impose substantially different cropping, management, and risk factors on the region's farmers. Moisture retention is 'considerably higher in the Vertisols in spite 'of their lower saturated hydraulic conductivity, [because surface cracks allow] higher initial intake rates and less runoff in the early rainy season than do Alfisols' (Krantz, 1982). The result of this difference in moisture availability is a growing season of 17 weeks for Alfisols and 26 weeks for Vertisols. These differences show up in the choices of crops, planting times, decisions on water storage, risk of loss, and related factors.

The IRRI strategy

Fundamental to IRRI's approach is its efforts to intensify rice-based farming. Because of this focus, areas conducive to rice production are sought out. Accordingly, physical conditions related to soil texture, dependability of rainfall, terrain, and type of water system are evaluated for their suitability for alternative types of farming. As examples, soils are categorized according to their water retention capacity; rainfall in excess of 200 mm and less than 100 mm; terrain is distinguished according to land types such as terrace, bottomland, plateau, and sideslopes; and water supply is divided according to irrigated and rainfed systems and to the likelihood of flooding (Zandstra *et al.*, 1981). Referring to these factors, Zandstra (1982) says that 'double cropping rainfed lowland rice

in regions with more than 200 mm rain for six months may be possible in heavy textured soils but not in light textured soils'.

The logic of concentrating on these particular factors becomes apparent when one understands IRRI's strategy of intensifying rice-based farming. In contrast, temperatures are not a major factor because of the generally uniform climate throughout the region. Also, less attention is directed to socio-economic factors because, in IRRI's experience, rice farmers are generally willing to experiment—more so than many of the tradition-bound farmers in parts of Central and South America.

By focusing on the physical environment, IRRI researchers have developed considerable information on the region's rainfall, land types, and related characteristics. Such information forms a base for identifying areas with common physical characteristics where new rice varieties and other technological improvements can be introduced. Such information also aids in explaining experimental successes and failures.

CONCLUSIONS

As the foregoing sections indicate, those concerned with FSR&D have developed a number of approaches and procedures in stratifying farmers and farmers' conditions to produce recommendation domains. But given the importance of stratification and the limited experience with the FSR&D approach, considerably more remains to be accomplished. Opportunities exist across a broad front, related to agroclimatic zones, soil classifications, farm households, societal conditions, and modeling. Following are some examples of ongoing work and some thoughts about ways to improve the state-of-the-art.

Some time ago Chang (1968) brought attention to the need for relating the fundamentals of climatology to the specific requirements of individual crops. He stressed then, and more recently (Chang, 1980), the critical influence on plant performance of photoperiod, night-time temperatures, moisture's effects on plant diseases, and wind stress. Lawson of IITA expressed interest in more carefully defining relevant climatic characteristics for individual crops and in planning experiments to test crop responses across gradients in West Africa. The International Center for Agricultural Research in The Dry Areas (ICARDA) plans to collect data that will allow it to identify agroclimatic zones in the drier areas of Western Asia and Northern Africa. This 'characterization requires the assessment and recording of critical agrometeorological parameters in

conjunction with other relevant details of crop phenology, soil moisture supply, soil nutritional status and agronomic management' (ICARDA, 1981). Hargreaves' moisture availability index (1977) is being applied by IITA and CIAT to help identify irrigation and drainage needs and to help select crops according to moisture regimes. Virmani *et al.* (1978) of ICRISAT have gathered data and developed procedures for the semi-arid tropics that use conditional probabilities to aid in reaching decisions on crop selection, planting times, water storage, and similar matters.

The Soils Benchmark Project of the Universities of Hawaii and Puerto Rico is 'designed to test the hypothesis that agro-production technology can be transferred to other areas with similar agro-ecological conditions. To test this hypothesis, a network of experimental sites was established in the Philippines, Indonesia, Cameroon, Brazil, Puerto Rico and Hawaii . . .' (Brady, 1982). Burgos and Meneses (1979) of the Tropical Agricultural Research and Training Center (CATIE) are studying how soil characteristics, such as soil texture, pH and fertility change with terrain. Such characterization fits in with Plucknett's suggestion of using transects to infer changing soil conditions from the differences in vegetation encountered across agroclimatic zones' (National Research Council, 1977).

Study of the household offers considerable opportunity for improvements to the stratification process. Communal versus individual effort, livestock ownership (as a means of traction, store of wealth, and family nutrition), and women as heads of households appear to be fruitful areas of study. Hart's (1982*b*) experiments in applying ecological systems analysis to household activities (energy, nutrient, and cash flows) offer another avenue for study.

Eventually, mathematical modeling could add sophistication to the study of the complexities of farming systems (Wymore, 1976; Valdes and Franklin, 1979). Simulation of alternative farming systems could build on approaches such as that of Hart, thereby providing knowledge of how farming systems might change under alternative conditions. Such mathematical modeling provides the opportunity for testing the effects of changes to the farming system through sensitivity analysis. Such analysis would point to the more relevant factors affecting the system, which thereby become appropriate topics for research.

In time, these and other approaches to stratification can be expected to add precision to the definition of recommendation domains and in doing so add to FSR&D's cost-effectiveness.

REFERENCES

Beal, G. M. & Sibley, D. N. (1967). *Adoption of agricultural technology by the Indians of Guatemala*. Rur. Soc. Rep. No. 62, Dep. of Soc. and Anthro., Iowa State Univ., Ames, Iowa.

Brady, N. C. (1982). AID's soil management activities. *Soil Taxonomy News* No. 3, 3-4.

Burgos, C. F. & Meneses, R. (1979). Performance of cropping patterns across a soil texture gradient in Costa Rica. Paper presented at the 71st Ann. Meeting of the A. Soc. of Agron., Ft. Collins, Colorado, 5-10 Aug. 1979.

Bussing, C., Converse, J., Koch, B., Van Withee, L., Nkwe, T. & Modiakgotla, E. (1981). *Recommendation domains for districts in Central and Francistown regions of Botswana: final report*. Farming Systems Research Team, Kansas State Univ., Manhattan, Kansas.

Byerlee, D., Collinson, M. P., Perrin, R. K., Winkelmann, D. L., Biggs, S., Moscardi, E. R., Martinez, J. C., Harrington, L. & Benjamin, A. (1980*a*). *Planning technologies appropriate to farmers: concepts and procedures*. CIMMYT, El Batan, Mexico.

Byerlee, D., Harrington, L. & Marko, P. (1980*b*). *Farmers' practices, production problems and research opportunities in barley production in the Calpulalpan/Apan Valley, Mexico: working paper*. CIMMYT, El Batan, Mexico.

Chang, J. (1968). *Climate and agriculture*. Aldine Publishers, Hawthorne, New York.

Chang, J. (1980). A climatic consideration of the transference of agricultural technology. Paper prepared for the Farming Systems Research and Development Methodologies project. Consortium for International Development, Tucson, Arizona.

CIMMYT (1981). *CIMMYT today*. No. 13, April. CIMMYT, El Batan, Mexico.

Cochrane, T. T., Porras, J. A., Azevedo, L., Jones, P. G. & Sanchez, L. F. (1979). *Explanatory manual for CIAT's computerized land resource study of tropical America*. CIAT, Cali, Colombia.

FAO (1976). *A framework for land evaluation*. Soils Bull. 32. FAO, Rome.

FAO (1978). *Report on the agro-ecological zones project, Vol. 1: methodology and results for Africa*. World Soil Res. Rep. 48, FAO, Rome.

Gilbert, E. H., Norman, D. W. & Winch, F. E. (1980). *Farming systems research: a critical appraisal*. MSU Rural Dev. Paper No. 6, Dep. of Agric. Econ., Mich. State Univ., East Lansing, Michigan.

Hargreaves, H. (1977). *Water requirements manual for irrigated crops and rainfed agriculture*. Utah State Univ., Logan, Utah.

Harrington, L. (1980). Methodological issues facing social scientists in on-farm/farming systems research. Paper presented at a CIMMYT workshop on Method. Iss. Facing Soc. Sci. in On-Farm/Farm. Sys. Res., 1-3 April 1980. CIMMYT, El Batan, Mexico.

Hart, R. D. (1979). *Agroecosistemas: conceptos basicos*. CATIE, Turrialba, Costa Rica.

Hart, R. D. (1982*a*). An ecological systems conceptual framework for agricultural research and development. In: *Readings in farming systems research and development*. (Shaner, W. W., Philipp, P. F. & Schmehl, W. R. (Eds)), Westview Press, Boulder, Colorado, pp. 44–58.

Hart, R. D. (1982*b*). One farm system in Honduras: a case study in farm systems research. In: *Readings in farming systems research and development*. (Shaner, W. W., Philipp, P. F. & Schmehl, W. R. (Eds)), Westview Press, Boulder, Colorado, pp. 59–73.

Harwood, R. R. (1979). *Small farm development: understanding and improving farming systems in the humid tropics*. Westview Press, Boulder, Colorado.

Harwood, R. R. (1982). Farming systems development in a resource-limiting environment. In: *Readings in farming systems research and development*. (Shaner, W. W., Philipp, P. F. & Schmehl, W. R. (Eds)), Westview Press, Boulder, Colorado, pp. 1–16.

Henderson, H. (1980). Anthropological and sociological principles of farming systems research and development. Paper prepared for the Farming Systems Research and Development Methodology project. Consortium for International Development, Tucson, Arizona.

Hildebrand, P. E. (1978). Motivating small farmers to accept change. Paper presented at the Rockefeller Foundation Conference Center, 18–23 October 1978. Bellagio, Italy.

Hildebrand, P. E. (1979). Summary of the *sondeo* methodology used by IITA. Proceedings, conference on Rapid Rural Appraisal. 4–7 December, 1979, IDS, University of Sussex, Brighton.

ICARDA (1981). *Farming systems program*. ICARDA, Aleppo, Syria.

IITA (1977). *Annual report*. IITA, Ibadan, Nigeria.

Jones, P. G. (1979). *Agroclimatology study*. CIAT manuscript, CIAT, Cali, Colombia.

Krantz, B. A. (1982). Farming systems research at ICRISAT. In: *Readings in farming systems research and development*. (Shaner, W. W., Philipp, P. F. & Schmehl, W. R. (Eds)), Westview Press, Boulder, Colorado, pp. 135–56.

National Research Council (1977). Resources for agriculture. In: *Supporting papers: world food and nutrition study*, Vol. II. National Academy of Sciences, Washington, DC.

Norman, D. W. & Gilbert, E. (1982). A general overview of farming systems research. In: *Readings in farming systems research and development*. (Shaner, W. W., Philipp, P. F. & Schmehl, W. R. (Eds)), Westview Press, Boulder, Colorado, pp. 17–30.

Odum, E. P. (1971). *Fundamentals of ecology*. Saunders, Washington, DC.

Palmer, B. C., Shaner, W. W., Gichohi, C., Hash, C. T. & Mbatha, B. M. (1978). *Kenya marginal/semi-arid lands pre-investment inventory, report No. 1: analysis and project identification*. Consortium for International Development, Tucson, Arizona.

Ruthenberg, H. (1971). *Farming systems in the tropics*. Clarendon Press, Oxford.

Shaner, W. W., Philipp, P. F. & Schmehl, W. R. (1982). *Farming systems research and development: guidelines for developing countries*. Westview Press, Boulder, Colorado

Valdes, A. & Franklin, D. L (1979). Evaluation of design parameters for cattle production in the Colombian Llanos pp. 83 101. In: *Economics and the design of small-farmer technology*. (Valdes, A., Scobie, G. M. & Dillon, J. L. (Eds)), Iowa State Univ. Press, Ames, Iowa.

Van Wambeke, A (1982). *Calculated soil moisture and temperature regimes of Africa*. SSMS technical monograph No. 3. Soil Conservation Service, USDA, Washington, DC.

Virmani, S. M., Siva Kumar, M. V. K. & Reddy, S. J. (1978). *Rainfall probabilities for selected locations of semi-arid India: research report No. 1*. ICRISAT, Hyderabad, India.

Winkelmann, D. & Moscardi, E. (1982). Aiming agricultural research at the needs of farmers. In: *Readings in farming systems research and development*. (Shaner, W. W., Philipp, P. F. & Schmehl, W. R. (Eds)), Westview Press, Boulder, Colorado, pp. 31 43.

Wymore, A. W. (1976). *Systems engineering methodology for interdisciplinary teams*. John Wiley & Sons, New York.

Zandstra, H. G (1982). A cropping systems research methodology for agricultural development projects. In: *Readings in farming systems research and development*. (Shaner, W. W., Philipp, P. F. & Schmehl, W. R. (Eds)), Westview Press, Boulder, Colorado, pp. 74 99.

Zandstra, H. G., Price, E. C., Litsinger, J. A. & Morris, R. A. (1981). *A methodology for on-farm cropping systems research*. IRRI, Los Banos, Philippines.