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Recommendation Domains: A Framework for On-Farm Research

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PREFACE

In cooperation with researchers in many national agricultural research programs, CIMMYT has sought to develop procedures which help to focus agricultural research squarely on the needs of farmers. The process involves collaboration of biological scientists and economists to identify the groups of farmers for whom technologies are to be developed, determining their circumstances and problems, screening this information for research opportunities, and then implementing the resulting research program on experiment stations and on the fields of representative farmers.

CIMMYT's Economics Program has emphasized developing procedures for the first stage of this process, through to establishing experiments. The evolution of the procedures, now synthesized in a manual "Planning Technologies Appropriate to Farmers: Concepts and Procedures" has been strongly influenced by collaborative research with many national programs and with CIMMYT's wheat and maize training programs.

There is a need to synthesize the experiences of those working in on-farm research in order to provide more detailed guidelines on particular concepts and issues. One example is the present paper, which summarizes experience with the concept of the "recommendation domain" and provides guidelines for applying this concept to a research program. We believe it will be useful to anyone interested in on-farm research.

As with other working papers we will appreciate comment and criticism in order that we might improve the paper and the procedures. We would be especially grateful for comments and observations from those who have used the concept in orienting their own work.

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We wish to acknowledge the contribution of many colleagues in the development of this paper. The phrase "recommendation domain" was originally used in the first CIMMYT Economics Manual (Perrin et al, 1976). Don Winkelmann saw the need for a further elaboration of the concept of recommendation domain, and has guided this paper through several drafts. Earlier versions of the paper have also profited from comments and suggestions by Poniah Anandajayasekeram, Malik Ashraf, Kwasi Bruce, Derek Byerlee, Edward Clay, Mike Collinson, Greg Edmeades, Dan Galt, Edith Hesse, Alberic Hibon, Peter Hobbs, Roger Kirkby, Ron Knapp, Allan Low, Juan Carlos Martínez, A.F.E. Palmer, David Rohrbach, Gustavo Sain, Pat Wall, and Michael Yates. We are, of course, responsible for remaining errors or deficiencies. Maria Luisa Rodriguez cheerfully typed numerous drafts and this final version.

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1.0) Introduction

Many national agricultural research programs are moving toward the adoption of on-farm research techniques.[1/] This implies location-specific research for representative farmers. Among the challenges that scientists face in this type of research are the identification of priority themes for investigation, the selection of representative sites for on-farm experimentation, and, most important, the definition of the clientele for whom the recommendations are to be developed. The concept of the "recommendation domain" is a powerful tool for resolving these problems and for organizing an efficient on-farm research program.

The term "recommendation domain" was first introduced in the CIMMYT Economics manual on the use of partial budgets for economic analysis of agronomic data (Perrin, Winkelmann, Moscardi and Anderson, 1976). In this manual, the recommendation domain was described as follows:

> "It is impossible to conduct experiments on each farm to make recommendations tailored to each farm. Instead, you must define a target group of farmers, conduct experiments under conditions representative of their farms, and make recommendations which are applicable to the entire group. We shall call such a group of farmers a recommendation domain. Generally, a recommendation domain will consist of farmers within an agroclimatic zone whose farms are similar and who use similar practices..." (p.1).

Further discussion of the recommendation domain concept was presented in the second CIMMYT Economics manual, on assessing farmers' circumstances (Byerlee, Collinson, et al, 1980). In this manual, the recommendation domain was defined as "a group of roughly homogeneous farmers with similar circumstances for whom we can make more or less the same recommendation" (p.71).

The aim of this paper is to discuss in more detail the concepts and procedures associated with forming recommendation domains. First, the need for domains will be discussed, with emphasis on their operational

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1/ The term "on-farm research" will be taken to mean "research with a farming systems perspective, using on-farm research techniques". For a discussion of concepts and vocabulary associated with on-farm research, see Byerlee, Harrington and Winkelmann (1982).

role in OFR. Then the recommendation domain concept itself will be examined and techniques for forming domains will be presented, followed by a discussion of issues and complications involved in the practical use of domains in on-farm research.

2.0) Recommendation Domains in the CIMMYT On-Farm Research Strategy

Over the past several years, CIMMYT agronomists and economists have developed a set of procedures for multidisciplinary, on-farm research with a farming systems perspective.[2/] These procedures are designed to be used by biological scientists, social scientists and farmers, in order to derive appropriate recommendations. They include the following series of steps: the diagnosis of farmers' circumstances, the design and management of on-farm experiments, the analysis of experimental results, and the presentation of recommendations to farmers. The concept of the recommendation domain is vital to every one of these steps of on-farm research.

2.1) Diagnosis

The early stages of on-farm research are concerned with diagnosing farmers' practices and problems and identifying opportunities for on-farm experimentation. The diagnosis begins with a review of secondary data and talks with local officials, extension agents, etc. Then researchers carry out an informal exploratory survey of farmers. This may be followed by a formal survey with a short questionnaire. During this diagnosis researchers must propose at least tentative recommendation domains. The delineation of the domains helps address the following questions: What are the principal research opportunities in this area? What are the target crops that deserve first attention? Are target crops and opportunities the same throughout the area, or are there significant differences? And most importantly, on what themes should research concentrate in order to derive useful recommendations for farmers in the shortest time possible?

2/ See Byerlee, Collinson *et al.* (1980); Palmer, Violic and Kocher (1982); Perrin *et al.* (1976); and Violic, Kocher and Palmer (1981).

2.2) Design of experiments

Once an experimental program has been defined there are a number of issues with regard to actually setting up on-farm experiments that must be addressed through reference to recommendation domains.

What is a representative site and a representative farmer cooperator for an on-farm trial? No farmer or site is ever completely representative but many mistakes in selecting cooperators may be avoided by careful attention to the current characteristics and practices of farmers. Clearly, a site should be representative of the conditions of the recommendation domain that is being studied.

At what levels should non-experimental variables (fixed factors) be set? In any experiment, experimental variables are distinct from fixed factors; the former vary over treatments within an experiment but the latter do not. Nonetheless the (unvarying) level of each fixed factor must be chosen. CIMMYT OFR procedures (e.g. Palmer, Violic and Kocher, 1982, p. 12; Moscardi *et al*, 1982) advocate setting fixed factors at "representative" levels, so that on-farm experiments may measure the yields and profits that farmers can expect when they superimpose one or more of the treatments on top of their own current practice. Once again, "representativeness" can be defined with reference to a given recommendation domain: Fixed factors should be set at levels representative of those for the domain being studied.[3/]

2.3) Analysis

Researchers must analyze the experimental data in order to formulate farmer recommendations. Three kinds of analysis are usualy needed: (1) agronomic analysis (how may observed responses be explained in terms of biological and physical processes?) (2) statistical analysis (are observed responses real or due to random chance?) (3) economic analysis

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3/ This does not mean that fixed factors are necessarily uniform for experiments in one domain. Farmer practice will vary somewhat within a domain, and the experiments may want to sample this variation. For more discussion of issues related to site selection and the level of non-experimental variables, see Kirkby, *et al.* (1981) and Tripp (1982).

(which alternative technologies will be preferred by farmers?).[4/]

In doing these kind of analyses pooling the data is generally recommended. Data from trials within the same domain should be pooled but data from different domains should be analyzed separately.

2.4) Recommendations

The ultimate purpose of on-farm research is of course to derive recommendations for farmers. If the concept of the recommendation domain has been followed faithfully, then by the time recommendations are ready for farmers, extension agents know exactly who their targets are. Using recommendation domains helps avoid two equally unpalatable alternatives: (1) offering a different recommendation for each farmer (too expensive) (2) offering a single recommendation for the whole farmer population, despite differences among farmers (inappropriate for many farmers). Instead, recommendations are derived and offered with well-defined groups of farmer clientele in mind.

2.5) The policy context

At any point in the on-farm research process the use of recommendation domains allows researchers to be able to spell out for which groups of farmers they are working, approximately how many farmers are in each group, what are their principal practices and problems, and what types of recommendations are likely to be produced. This is a great help in developing good relations between researchers on the one hand, and institutional or national policy makers on the other. Not only does this kind of information help researchers in the allocation of their own research resources but it also gives them useful information to offer to those who set research policy.

4/ We have emphasized that farmers will prefer technologies that are compatible with their circumstances. An understanding of these circumstances, both socio-economic and biological, should be accomplished in the diagnostic, planning, and early experimental phases of on-farm research. Economic analysis will then be carried out on technologies otherwise acceptable to farmers. For a review of partial budgeting techniques for economic analysis of agronomic data, see Perrin et al. (1976) and Harrington (1982).

3.0) Definitions

Recommendation domain has already been defined as a group of farmers whose circumstances are similar enough so that they are all eligible for the same recommendation. It should be emphasized that the domain is a group of farmers, not a geographical area or land type. Domains are composed of farmers because farmers, not land types, take decisions on new elements of technology. Defining domains in terms of groups of farmers underlines the possible importance of socioeconomic criteria in domain identification. It also allows the possibility of domain distinctions that are not amenable to mapping (neighboring farmers can belong to different domains or, as well, a given farmer can belong to more than one domain).

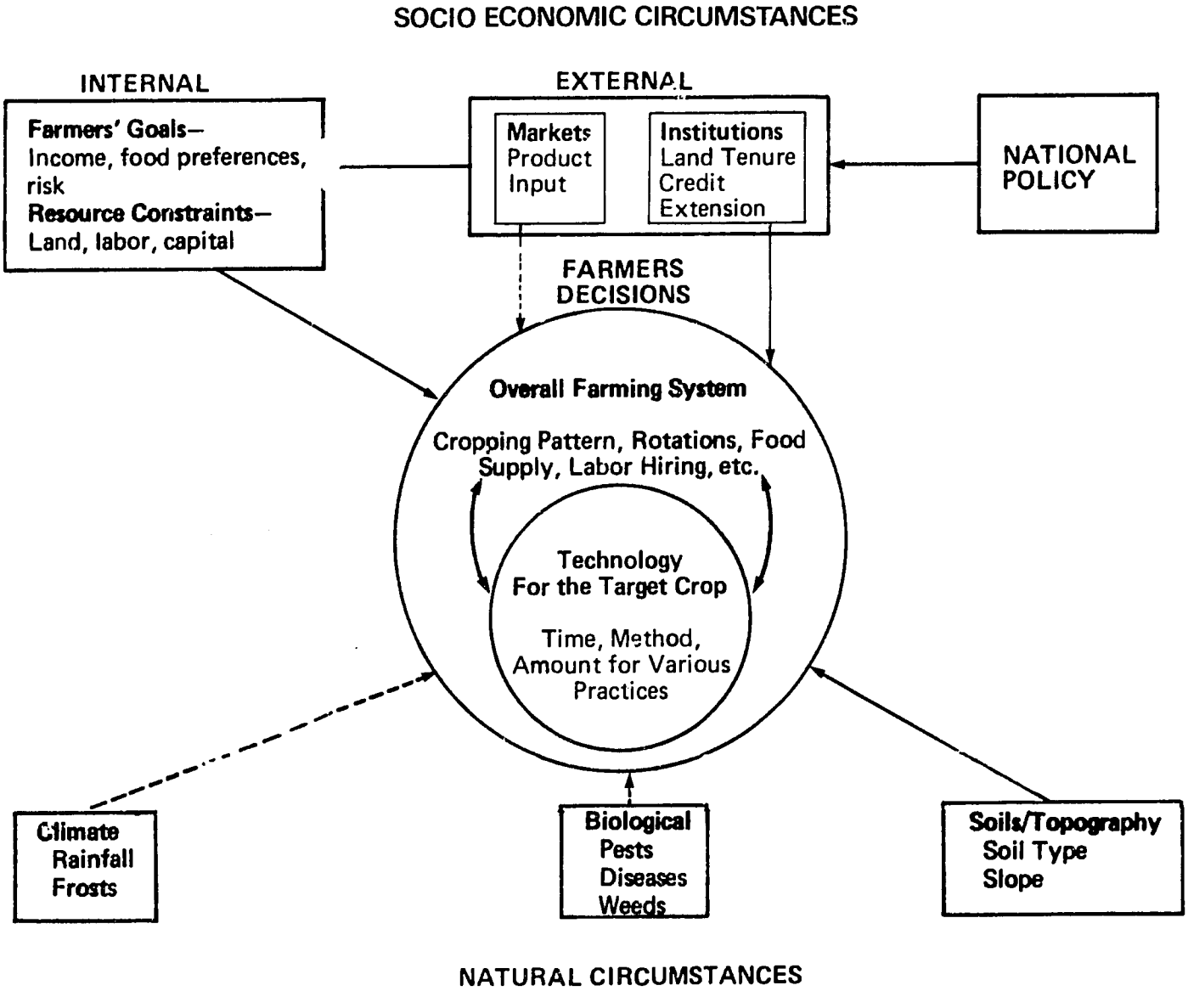
It usually happens that there are a number of research opportunities for a particular commodity, or even for several commodities, that a group of farmers have in common. These opportunities should of course be considered together, taking account of their interactions and relative importance as plans for a research program evolve. It is natural to think of the group of farmers that share these opportunities as a single recommendation domain. But because two groups of farmers may share some opportunities, but not others, it is well to remember that a recommendation domain is really specific to a particular enterprise and a particular research problem. That is, our interest is in defining the group of farmers for whom a specific recommendation is applicable.

Research area in this paper will simply mean the area in which investigation is to take place. This is usually defined by the research institution and may have administrative or agroclimatic boundaries. Although the concept of recommendation domain is often quite helpful in refining these boundaries, we will assume here that the research area is given. Our job is to take the mandated research area and decide how it should be divided into recommendation domains.

Farmers' circumstances are used in order to identify recommendation domains. They are defined as "all those factors which affect farmers' decisions with respect to use of a crop technology. They include natural

factors such as rainfall and soils, and socioeconomic factors such as markets, the farmers' goals and resource constraints" (Byerlee, Collinson, et al. (1980): 70). Figure 1 shows how circumstances may affect farmers' practices and their abilities to adopt new recommendations.

Figure 1 Farmers Circumstances
Source: Byerlee, Collinson, et al. (1980).



---→Circumstances which are often major sources of uncertainty for decision-making.

A recommendation is a description of a new element or elements in a production technology (an improved variety, a new chemical, a different practice, a change in the timing of an operation, etc.) which researchers believe farmers will find useful. In the case of the on-farm research paradigm described here it is derived from an understanding of farmers' problems and a thorough testing under farmers' conditions. Recommendations are sometimes made in groups or "packages", as when a new variety is recommended along with a certain planting density, insect control and fertilizer level. This is particularly important when there are strong interactions among several elements. The emphasis, however, should always be on recommendations that farmers can adopt in a step-wise fashion. There is now considerable evidence that farmers are more likely to adopt simple recommendations and make changes gradually, rather than make abrupt, large-scale changes in their practices (e.g. Byerlee and Hesse de Polanco (1982)). Thus on-farm research identifies and tests technologies with a limited number of new elements under farmers' conditions, to find out which recommendations can be accommodated by farmers.

4.0) Guidelines for Domain Formation

The process of domain formation is usually a gradual one, as researchers gain more experience in their area. Although there is no unique formula for determining domains there are a set of guidelines that can be used. These are discussed in the following sections.

4.1) Principles of recommendation domain formation

Recommendation domains are formed based on the researcher's understanding of farmers' circumstances and practices. Sometimes the identification of domains can be achieved in the early stages of diagnosis, after examination of secondary data and conversations with extension agents, for instance. At other times they are not really well defined until after a formal survey, and it is not unusual that the final delineation of recommendation domains must await the results of a year or more of experimentation. But from the very beginning of the process researchers should at least begin forming impressions about possible domains. These impressions are tested and refined as the on-farm

research progresses, until a final definition of the domains in the research area is established.

The concept of farmers' circumstances is used both for identifying opportunities for investigation and for forming recommendation domains. An understanding of farmers' circumstances allows the researcher to explain current farmer practices, identify key problems and propose improvements that can be tested on farmers' fields. It also provides the researcher with an idea of whether or not a particular improvement is appropriate for all farmers in the research area or only for some.

There is a sense in which the formation of recommendation domains is related to the statistical concept of stratification. The statistician stratifies a sample in order to eliminate certain types of variability and better concentrate on the particular factors under study. In forming recommendation domains we are grouping farmers who have roughly homogeneous circumstances and whose needs for technology are thought to be similar. Through that grouping we are able to develop technology more appropriate to those specific groups, at a considerable saving in research costs.

Recommendation domain formation can be thought of as a process of considering all the various circumstances that might affect farmer practices and deciding, for each one, if it is the basis of significant differences in practices and possibilities within the research area. One way of making this operational is to think of a checklist, such as that in Table 1, which lists major categories of circumstances that may be used to define recommendation domains. The list is by no means complete, and researchers working in different areas will surely add other factors to this list. It will also be appreciated that many of these factors are interrelated: altitude affects temperature and frost incidence, for instance, and rainfall affects weed population.

Several examples may make clear how the variables on this checklist can be used to define recommendation domains. Consider the case of soil differences, which are often important in determining farmer practices.

In one research area in southern Veracruz, Mexico, there were two basic soil types. Farmers in the river flood plain had alluvial soils and grew wet season vegetables and dry season maize. Neighboring farmers had sandy, acid soils and grew pineapple and maize, in the wet season only. The difference in soils is responsible for very different maize practices and problems with respect to such factors as moisture stress, disease and insect incidence, and fertility requirements. Recommendations about maize appropriate for one group would not likely be appropriate for the other. Thus we have two separate recommendation domains for maize, in this case determined by soil type.

Table 1 Variables Often Considered in Forming Recommendation Domains.

Natural Circumstances	Socioeconomic Circumstances
Climate	
Temperature	Farm size
Frost incidence	Land tenure
Rainfall pattern/quantity	Access to markets and inputs
Risk of drought	Access to family labor
Risk of flooding	Access to other labor
Altitude	Access to credit
Soils	Access to cash
Texture	Access to markets for selling crops
Drainage	Power source
Slope	Access to irrigation
Depth	Off-farm labor opportunities
Nutrient supply capacity	Food preferences and diet
pH	Community customs and obligations
Salinity	
Biology	
Disease incidence	
Pest incidence	
Weed complex	

There are often differences in soils within a research area. Does this mean they will always correspond to different recommendation domains? No, not at all. In another part of Mexico, in a highland barley area, soil type varied from clay loam to sandy loam, and researchers hypothesized that these might cause different domains. But a closer study of the area revealed no significant differences in farmers' practices or problems by soil type, and researchers realized that they were either dealing with a single domain, or that another circumstance on their checklist besides soil type might be used for distinguishing different domains.

Another natural circumstance that may lead to significant differences in practices and research opportunities is altitude. In part of the Callejon de Huaylas in Peru, maize researchers identified two recommendation domains, based on altitude. In the lower domain, from 2,600 to 3,000 meters, farmers could plant two crops a year and had serious problems with leaf fungus diseases. In the higher domain, above 3,000 meters, only one crop a year was possible and one of the principal problems that farmers faced was frost damage to their maize. Altitude here served to distinguish two domains, with different maize practices, problems, and opportunities for research. Again, altitude will not always serve to distinguish recommendation domains. If variation in altitude is not associated with significant differences in farmer practices or biological response then it can be crossed off the checklist.

The same holds true for other natural circumstances. In their study of farmers' practices and problems researchers will want to ask whether such things as rainfall pattern, slope, or pest incidence can be used to define different recommendation domains. Important factors are of course not limited to natural circumstances, and Table 1 presents a number of socioeconomic circumstances that may also be useful in identifying domains. An example or two may be helpful.

It is often the case that farmers who share the same natural circumstances nevertheless have different access to resources which affects their practices and their ability to adopt innovations. In one

area in Zimbabwe maize farmers prepared their plots with ox plows before planting. As only about half of the farmers owned oxen the rest had to rent them. The renters were delayed in their planting, which affected their production through drought risk, disease, and other factors specific to late planted maize. There are a series of research opportunities for animal renters which are not applicable to owners, and thus it is worth considering two recommendation domains, distinguished by animal ownership.

Another case will provide a counter-example. In a research area on the north coast of Honduras most farmers controlled weeds in the maize crop with herbicides, but only one-third of the farmers owned backpack sprayers. Researchers believed there might be a difference in weed control practices between sprayer renters and owners. But a survey showed no differences in weed control practices or timing between the two groups and revealed that the rental market for backpack sprayers was quite adequate. Thus access to a sprayer did not affect farmer practices and did not serve to distinguish recommendation domains.

Farmers can also often be distinguished by access to land. Differences in farm size may not only directly affect the type of practice that a farmer follows, but may also be correlated with many other differences, such as access to equipment, credit, or marketing facilities. At times these distinctions are quite clear and are responsible for the formation of different recommendation domains. In parts of the highlands of Ecuador small and large wheat farmers occupied the same natural environment, but their socioeconomic circumstances were quite different. The former relied on animal traction and had no access to credit, while the latter used tractors and credit facilities (which lowered their costs for obtaining fertilizer.) This led to quite different practices (e.g. different rotations and fertilizer treatments) and these in turn indicated different research opportunities. The result was two recommendation domains in a biologically homogeneous area - one of small wheat farmers (under 5 ha) and the other of large wheat farmers.

It is of course not always the case that farm size is a determining

factor for domain formation. Researchers want to ask if two farmers in a given region with different sized farms use essentially the same technology for a particular enterprise and if they have access to the same type of resources and markets. Do they use the same variety, the same seeding techniques, the same seeding dates, the same fertilizers, etc.? If there are differences, then there may be two domains. If there are no significant differences, then farm size will not be used in defining domains. In this case researchers will go on and ask the same questions about other natural and socioeconomic circumstances on their checklist (Table 1). If farm size is not important, does altitude or soil type or land tenure serve to distinguish farmers' practices and problems? If not one or more of these factors, what else on the checklist might define different domains? As researchers gain more experience in domain formation they will probably rely less on a formal checklist.[5/] But the process is always the same, considering how a series of circumstances affect how a farmer undertakes a particular enterprise.

In the examples considered so far a single factor (e.g. altitude or farm size) has been used to divide a research area into recommendation domains. But it is not always the case that only one factor influences farmer practices and research opportunities. Researchers must exhaust the possibilities on their checklist in the search for relevant circumstances for defining domains. An example of maize research in Peru was discussed earlier, in which researchers identified two domains, based on altitude. In fact, the actual situation was more complicated, as there were other important differences in farmers' circumstances in the research area. In the lower zone there were two principal farm types - small farms averaging less than 2 hectares and large farms averaging 40 has. These two farm types had quite different patterns of rotation, input use, varietal requirements and maize sales. In the higher zone there were not such marked differences in farm size, but some farmers had

5/ Researchers will have their own preferences on how to think about these factors during diagnosis. Collinson (1979), for instance, suggests first considering agroecological factors and then moving to "hierarchical" divisions due to socioeconomic differences.

access to irrigation while others did not (all farmers in the lower zone had irrigation). This was responsible for significant differences in rotations and input use. Thus there were actually four different recommendation domains in the research area, based on altitude, farm size and access to irrigation.

In order to form recommendation domains researchers must study the circumstances and practices of farmers in their area. Using a checklist of circumstances they can consider in turn various possibilities for defining recommendation domains. It may be that the area is homogeneous enough to constitute a single recommendation domain. If not, there are usually one or at most a few key circumstances that can be used to define domains. This is not to say that the differences between the domains are necessarily simple, but only that there should be a relatively straightforward way of identifying and describing them.

In the case of the two domains formed by differences in altitude, researchers are not so much interested in altitude per se but rather in the way altitude is responsible for determining two quite different, complex patterns of disease and pest incidence, cropping cycle and varietal preferences. It is these factors that determine the practices that farmers follow and the innovations that they are likely to adopt. It is these factors that dictate two separate sets of on-farm experiments for researchers. Delimiting the two domains in terms of altitude is simply a convenient way of identifying the domains and helping researchers to plan their work. It may be that the distinction between altitude zones is even correlated with other factors such as human population density, with lower densities at the higher elevations. This would lead to differences in rotation patterns and soil fertility between the two domains, even though there is no a priori relationship between altitude and rotation. Again, the denomination of the high elevation and the low elevation domains is a convenient way of describing a whole series of different circumstances among two groups of farmers.

It is often asked if this process of domain formation is adequate for covering all farmers in a research area. Will there not be a few

farmers in the high elevation domain, for instance, whose practices are different from the rest? Or might there not be some farmers whose circumstances are in between the two altitude zones? There may well be, but are there enough such farmers to make it worthwhile to form separate recommendation domains? Recall that domains are formed so that researchers can effectively deal with the majority of farmers in a particular area. The selection of good criteria for domain formation will result in a few large domains, each roughly homogeneous with respect to major research opportunities and current production practices, with distinct differences between domains. There may be some farmers who are not covered by the definitions, but forming special domains for them might not be a wise use of research resources.

4.2) Policy variables in recommendation domain formation

The question of which farmers should be addressed by an experimental program is not only related to research efficiency, but also to policy. If several domains have been identified it is often necessary to decide which ones will receive attention. Very often national policy will contribute to making these decisions, as priority may be given to certain types of farmers (small farmers, commercially-oriented farmers, etc.) or to certain types of crops (basic grains, cash crops, etc.). As research policy is usually concerned with obtaining high benefits from a given research investment, this also often implies concentration on domains that contain the largest numbers of farmers and present the most promising opportunities for improving productivity.

The relationship between policy and on-farm research is not one-way, however. There are substantial opportunities for feedback from on-farm research to policy makers. In the case of recommendation domains there is the opportunity for providing policy makers a much clearer idea of the nature of the farming population. Very often policy mandates are stated in terms of "target groups" whose definition (e.g. "the small farmers of region X") masks considerable variation in circumstances and potential. Dividing the research area into recommendation domains can contribute to much more precise targeting.

4.3) Acquiring data for domain formation

There is an apparent paradox in the definition of a recommendation domain. If it is defined as a group of farmers whose circumstances are similar enough to make them elegible for the same recommendation, how can we be sure of the constitution of the domain before the recommendation has been made? The answer is that we often cannot be completely certain, but as the process of on-farm research passes from diagnosis through experimentation to recommendations researchers become more and more confident of the boundaries of their domains. From the beginning of the research process hypotheses are formed about possible domains. These hypotheses are tested during surveys and the conclusions are used in the design of an on-farm experimental program. At times it is only after a year or more of experiments that researchers are able to make the final adjustments in their domains.

In order to acquire information useful for domain formation adequate data collection methods are required. The initial diagnosis must be done rapidly and efficiently, so that on-farm experiments can be planted as quickly as possible. Thus elaborate studies which collect great amounts of detailed information are not appropriate. The idea is to identify research opportunities and likely recommendation domains and use this information to begin experiments. Procedures for assessing farmers' circumstances are described in Byerlee, Collinson et al. (1980). These procedures include a review of secondary data, an exploratory survey and, often, a short, well-focused formal survey.

Initial hypotheses on variables for dividing farmers into domains may be developed during a review of secondary data for the research area. Keeping in mind the checklist (Table 1) of circumstances which may affect domain formation, the researchers can examine the secondary data with an eye towards identifying possible key factors. Soils maps, census reports or other data may suggest possible sources of variation in farmers' practices. Conversations with local extension staff can also be quite valuable. With the initiation of the exploratory survey the evaluation of these hypotheses may commence. For example, if census data indicated three major land tenure classes in the research area the exploratory

survey could be used to ascertain whether these tenure classes had any important effect on farmers' practices or problems. The exploratory survey is the time when the checklist is most fully utilized. By talking to farmers and observing their fields researchers have the opportunity to decide which circumstances on the list are likely determinants of differences in farmers' practices.

During the exploratory survey, development of hypotheses on recommendation domains and hypotheses on research opportunities proceed together. Researchers strive to understand how different circumstances lead to different practices and problems, and whether or not these differences are relevant to the research opportunities that have been identified. For example, if the important research opportunities in a maize area appear to be insect control and disease-resistant varieties, then soil differences may not define recommendation domains. If, in the same area, the principal research opportunities turn out to be fertilization and moisture conservation then the difference between maize farms on sandy soils and those on heavier soils is probably enough to determine two separate recommendation domains.

There need not be any difference in current farmer practice in order for a particular research opportunity to divide an area into different domains. In one area in Honduras both land owners and renters had similar maize practices, using a maize-fallow rotation which allowed several years between crops of maize on one piece of land. Research opportunities for weed control and variety were the same for both groups. But in thinking about the possibility of intensifying the system by introducing a cover crop of velvet beans which would allow several years of continuous maize plantings, the difference between owners (who had assured access to their plots over time) and renters (who did not) became important, and defined two different domains with respect to this opportunity. The interaction between research opportunities and domain boundaries is therefore quite important.

At the end of the exploratory survey the checklist has been significantly reduced so that researchers generally have only a few

possible candidates for defining recommendation domains. The exploratory survey is often followed by a formal survey in which random sampling and a short, well-focused questionnaire are employed. Samples for the survey should be drawn so that each tentative recommendation domain is represented by at least 25-30 farmers. During the survey, information should be collected on the "short list" of variables that are proposed for defining recommendation domains as well as on variables that measure key aspects of farmer practice (i.e., practices related to important research opportunities). Cross-tabulation of "short list" variables by farmer practice variables will indicate which criteria most strongly and consistently influence the farmer practice.

The survey analysis should seek to identify a small number of domains, each as homogeneous as possible, which allow efficient research on the highest priority themes. The survey may, for instance, define two recommendation domains with very distinct research opportunities, as in the example of domains defined by altitude in Peru. In that case, research on maize varieties (one of several opportunities) was oriented by farmer responses to a question on principal problems. Those at the lower altitude indicated a problem with leaf fungus disease, while those at the higher altitude expressed interest in maize of a shorter cycle because of frost damage.

In other cases, two domains may share at least some research opportunities, but require experimentation under different conditions. Domains that are defined by access to irrigation, for instance, may share chemical weed control in maize as a research opportunity, but different products, levels and application methods may be indicated for each domain. The survey is used in this case to define the circumstances that are representative of irrigated and non-irrigated domains, in order to choose the levels of non-experimental variables for each domain.

Particular care must be taken when proposed criteria for domain formation are proxies for actual practices and conditions. Analysis of the survey should lead to major, as opposed to merely statistically significant, differences between domains. For example, in one survey in a

barley producing area tractor ownership was proposed as a criterion for distinguishing recommendation domains. Analysis of the survey showed several differences in land preparation between tractor owners and renters. In the case of early harrowing before ploughing, for instance, 54% of the owners, but only 41% of the renters, did a pre-plough harrowing. The difference was statistically significant (at 5%) and showed, not surprisingly, a tendency for tractor owners to do a more thorough job of preparing their fields than tractor renters. Differences of this magnitude were observed for several other land preparation methods. They were not, however, sufficient to define recommendation domains. Whether or not the farmer did an early harrowing was affected by competing labor demands, previous crops, soil conditions, and several other factors besides machinery ownership. Thus more effort should be made to specify the complex of circumstances that conditions land preparation methods. The single factor of tractor ownership identified in the survey, although responsible for statistically significant differences in practices, is not sufficient to divide the research area into two clearly distinguishable domains. In the meantime, if research opportunities are identified which interact with land preparation (seeding methods and timing, for instance), then research should be carried out for the major categories of land preparation, using land preparation itself as a defining characteristic of the domains, rather than tractor ownership, which is only a weak proxy.[6/]

4.4) Using domains as a framework for on-farm research

Once recommendation domains are identified they are used as the basis for the on-farm experimental program. Experiments are designed for specific recommendation domains; the exact number of a certain experiment to be planted in one domain depends largely on the type of experiment. If it is an experiment of an exploratory nature then it may be repeated only a few times, while if it is a verification experiment (the stage just before demonstration) then it will be very widely distributed within

6/ This example assumes that land preparation itself is not an opportunity for investigation, which of course may not be the case.

the recommendation domain.[7/]

It should be noted that the number of experiments required for a given domain does not depend on the size of the domain. It was pointed out earlier that one can think of domains as statistical strata, and on-farm experimentation can be considered an exercise in sampling. Each experiment measures the effect of new elements of technology on crop yields, income and risk for the respective cooperating farmer. The benefits of a particular element may be estimated for the target farmer population by averaging the results of several trials. When strata are internally homogeneous (as recommendation domains should be), a small sample from each is sufficient to obtain a precise estimate of the stratum mean. This is because the sample size needed to achieve a desired level of precision at a certain level of probability does not depend on the population size, but rather on its variability.

The experiments are of course planted under conditions representative of the recommendation domain. If the domain is defined as all farmers who have less than 10 hectares, have fields between 2,600 and 3,000 meters above sea level, and do not have access to irrigation, then the experiments for this domain must be planted under these circumstances. Beyond this, the survey will have specified what the representative farmer practices are for the particular domain. Non-experimental variables are usually set at the farmer's level, unless there is the expectation that farmers will soon adopt a new practice which warrants being included as a non-experimental variable.

Although recommendation domains can usually be identified before planting the first year's experiments it occasionally happens that the results of the experiments themselves are useful in refining domain definitions. If a domain is a group of farmers who face similar circumstances, follow similar practices and share similar opportunities, then one would expect similar results from experiments planted with

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7/ For more on the stages of on-farm experimentation, see Violic, Kocher and Palmer (1981).

different members of the same domain. In terms of analysis of variance, "site by treatment interaction" should not be consistently significant. When this interaction term is significant (at an appropriate level) researchers should see if this is merely random variation (e.g. because of rainfall differences), or if there is a constant factor (e.g. a previously unidentified difference in soil types) which is responsible. In the latter case, this may lead to a division of what was formerly one domain into two or more. Similarly, when experimental results are consistently uniform across two domains, researchers may consider combining them into one.

Once domain boundaries are firmly identified, the agronomic, economic and statistical analysis of experiments proceeds by pooling the data within each domain. The results are then used to form recommendations for the domain.

4.5) Preliminary zoning [8/]

At times research programs wish to use a set of tentative domains to organize OFR in a large area. Senior research planners may feel, for example, that one domain may occur in numerous small defined areas (each handled by a different OFR field team). To reduce duplication of effort in on-farm trials, these senior researchers may wish to make a first "rough cut" at domain formation, assigning each OFR field team to work with one or two of them.

In these cases, "zoning" procedures can be used. Specifically, formation of numerous tentative domains in a large area can be initiated by means of a very brief formal survey with local extension personnel that provides data for grouping together farmers with similar farming systems. As OFR teams are assigned to initiate fieldwork, they can accept or adjust the tentative domains identified in the zoning process.

8/ This section draws heavily on the experience of M. Collinson (1979) and S. Franzel (1981) in East Africa.

5.0) Issues and Complications

As researchers deal with domain formation in their study areas several issues and complications tend to arise. These include questions of domain size, domain permanence and others. The purpose of this section is to discuss these questions and show how they may be addressed.

5.1) Domain size

What is the appropriate size of a recommendation domain? There is no set answer to this question, but obviously the larger the domains the more cost-effective will be the research program.

Domain size is influenced by the heterogeneity of the area. In places where there are many different microclimates and great variations in the socioeconomic circumstances of farmers a relatively large number of domains are likely to be identified. In other places, vast areas may be subject to similar circumstances and farmer practices, and a few domains will suffice.

Domain size is also determined by the availability of research resources. More resources allow the exploration of more research opportunities and thus the delineation and management of more and smaller domains. At times these factors may have contradictory influences on domain size, as when work is carried out in a very complex, heterogeneous target area with very few resources available for implementing OFR. In these cases a decision is often taken to carry out research in only a few high-priority domains, selected according to research opportunities, farmer characteristics or national policy.

Domain size is thus bounded on the small side by expected returns to research expenditures. Domains should not be so small that benefits from new technology for that domain are less than corresponding research costs (or better, less than the expected returns from alternative uses of research resources). Domain size need not be bounded on the large side. In fact, domains should be as large as possible, with the condition that farmers in the domain can still be expected to adopt recommendations arising from work on major research opportunities. Large domains allow

the fixed costs of on-farm trials to be spread over a wider number of users.

In practice, domain sizes demonstrate considerable variation. They have ranged from a few thousand farmers to several tens of thousands, or more. There is clearly no "best" size for a recommendation domain.

5.2) The permanence of domains

We have already seen that the definition of domains may be refined during the process of on-farm research. As workers become better acquainted with the area, their perspective of research opportunities and agronomic responses will change, leading at times to redefinition of domains.

Similarly, we have seen that domain definitions are linked to research opportunities, and as research themes tend to shift over time these shifts often require adjustments in domain boundaries. In one research area in Ecuador, for example, where maize was the principal crop, farmers with and without complementary irrigation constituted a single domain for maize research, as no significant differences in practices could be detected between these two groups of farmers. But as research progressed, and especially as an early-maturing maize was released for farmers which allowed new rotation patterns, the difference in access to irrigation became important. Rotation possibilities that included crops grown in the dry season were much different between these two groups of farmers, and where previously there had been a single domain two were formed as research advanced.

It must be kept in mind that the simplified, shorthand definitions of domains really serve to summarize researchers' perceptions of how a complex of farmer practices and circumstances influence the identification and development of research opportunities. As these opportunities change and evolve so do domain definitions. Domains may be joined, split or otherwise redefined, and researchers should do so when research efficiency may be improved.

5.3) Correspondence between domains and on-farm experiments

Recommendation domains are formed in order to help researchers define different experimental programs. At times the difference between domains in a given research area may be extreme, including different target crops and completely different research opportunities. In this case the on-farm experiments planted in the two domains would bear no relationship to each other. Even when the target crops are the same, research opportunities sometimes differ so greatly that the maize experiments (for example) in one domain are totally different from those in another.

Because recommendation domains are partially determined by research opportunities, it sometimes happens that two domains (with respect to one opportunity) are included in, and share the experiments of, another larger domain. As an example, in one wheat area two domains were based on soil type. The soil type determined land preparation and crop rotation possibilities and hence strongly influenced the nature of the weed population. Thus separate sets of weed control experiments were planted in the two domains. Soil type had no influence on varietal requirements however, so the area constituted only one domain with respect to variety, and the number of variety trials planted (across the two soil types) was appropriate for a single domain. If there were reasons to suspect an interaction between varietal performance and soil type (or the practices determined by soil type), however, two sets of variety trials would be indicated.

In certain cases, the experimental program may be exactly the same between domains. In the example of the two domains distinguished by soil type it may be that similar fertilizer trials should be planted in both domains in the initial stages of experimentation although the agronomic responses and final recommendations will likely be different. Or in the case of domains distinguished not by soil type but rather by land tenure, the same fertilizer trials may give the same agronomic response, but lower net benefits to sharecroppers than to owners will mean somewhat different fertilizer recommendations for the two domains. In this latter case, a single set of experiments may suffice for deriving the two

different recommendations.

6.0) Summary

As national agricultural research programs move toward on-farm research, the need grows for a way to specify the clientele for that research. The recommendation domain concept can fill this need.

Conceptually, a domain is a group of farmers with similar circumstances who are eligible for the same recommendation. Operationally, domains are formed around farmers with similar practices for a given enterprise and for whom researchers see similar opportunities for the improvement of these practices. Such farmers can be grouped together in terms of biological and/or socioeconomic variables.

Recommendation domains are useful as a framework for on-farm research. As researchers strive to select the few most important experimental variables and then study them under representative conditions, domains provide the necessary context for defining "important" and "representative". Recommendation domains also provide a criterion for pooling the data obtained from on-farm trials, thus resolving the classic problem of extrapolating research results beyond the farms on which trials are conducted.

Domains are formed by considering farmers' circumstances. As researchers begin their work, they are interested in how these circumstances affect farmers' practices and how they condition research opportunities. As ideas for research opportunities emerge so do clear definitions of recommendation domains. Beginning with a comprehensive list of farmers' circumstances researchers conduct an informal survey which helps to eliminate many of these as potential criteria for defining domains. A reduced number of possibilities may be tested through a formal survey to see if they are in fact useful for dividing farmers into roughly homogeneous groups who could benefit from the same recommendation. This information is utilized in the design and planting of on-farm experiments. It may be that the final domain boundaries are not decided upon until the experimental results are analyzed. In any

case, by the time recommendations are ready, they are already targeted to well-defined groups of farmers.

In providing a framework for on-farm research, recommendation domains are a useful tool. Like all tools, however, they are most helpful when used with imagination and care.

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