MODELING FARMERS' DECISIONS TO CHANGE: USING COGNITIVE SCIENCE IN THE DESIGN OF AGRICULTURAL TECHNOLOGY

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INTRODUCTION

The new technologies developed by the IARCs generally require that farmers change their farming practices and strategies, some of which have been used for generations. Often these strategies are "survival" strategies (i.e., widely-diffused plans) which farmers have developed to survive in often hostile agroclimatic and socioeconomic conditions (Barlett 1980, Bennett 1969, Gladwin 1983, Gladwin and Butler 1984). Farmers are loath to change these, and often for good reasons. The trick to the design of appropriate agricultural technologies is thus to determine *a priori* which farming practices will be adopted (or adapted) by local farmers, and which will not. This entails the researchers knowing a priori which of farmers' traditional practices can be changed, and which cannot because they are an integral part of farmers' "survival strategies."

Several new approaches which put the farmer at the center of the research extension project offer some hope of doing just that. These include the "farming systems" approach (CIMMYT Economics Program 1980, Collinson 1982, Hildehrand 1986) the "farmer-hack-to-farmer" approach (Rhoades 1984, 1986), and "On Farm Client-Oriented Research" (OFCOR) developed by ISNAR. The farming systems research and extension (FSR/E) approach uses multidisciplinary teams of physical and social scientists to generate new adoptable technologies via a carefully designed sequence of diagnoses, experimentation (including researcher- and farmer-managed on-farm trials), evaluation, and extension. Although the farmer is clearly at the center of the FSR/E program and makes the final decision about what to adopt or not to adopt, a persistent problem faced by even this new approach (and old philosophy) is how to get the farmers to participate more fully in the technology-generation sequence. Although philosophically the FSR/E approach starts with the farm family's constraints *us given,* and tries to work around them to generate recommendations to improve the family's standard of living, getting enough feedback about farmers' constraints and survival strategies during the design stage is still an elusive goal.

In my judgement, the crucial role of the social scientists in a NARC or an **IARC,** is to provide this feedback from the farmer or, more correctly, the farm family. Feedback from all family members is essential because most Third World families

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have farmers of more than one gender and more than one generation who do not necessarily have identical constraints and roles within the family farm operations (Moock 1986). Feedback of this sort has usually been through formal surveys or informal *sandoes* (Hildebrand 1981), and recent articles debate the value of one kind of survey instrument over the other (McIntire 1984, Franzel 1986).

Such debates miss the point. Rather than collect good *quantitative* data about family size, income on and off the farm, size of land holdings, and quantity of fertilizer applied, the social scientist should be trying to understand the farmers' way of life from their point of view. To "grasp the native's point of view, his relation to life, to realize his vision of his world" is the goal of ethnography (Malinowski 1922).

The ethnographer's goals in an agricultural institute and contributions to a research/extension team are twofold. The first is to understand the farm family's perfectly rational reasons for farming the way they do; and the second is to describe to biological scientists the "indigenous knowledge systems" and logic (Brokenshaw, Warren, and Werner 1980) that make some farming practices unchangeable and others changeable. The ethnographer's aim is not only to understand the meaning of native expressions that farmers use to describe their soils, their seeds, their fertilizers, or their irrigation practices, although this knowledge can be very useful (Brush, Carney, and Huaman 1981, Johnson 1974). The purpose is also to elicit the decision rules and traditional strategies that farmers use—and refuse to change—in order to survive in an increasingly bureaucratic world of government and donor agencies which wants them to *change.*

The remainder of this paper provides examples of farmers' decision rules and strategies that I, as ethnographer-cum-agricultural economist, have elicited in Third World settings. My goal is to show the usefulness of these methods, drawn from cognitive anthropology and agricultural economics, to an agricultural institute that focuses on the farmer in the design stage, and works **for** the farmer in the extension stage.

WHY WON'T THE FARMERS ADOPT?

In 1973-1974, a study was conducted of farmers' adoption or nonadoption of the agronomic recommendations of the Puehla Project, which aimed to increase yields of rain-fed maize in Puehla, Mexico. The project, started by CIMMYT focused on one or two recommendations ahout fertilizer use and timing, and plant population for the local variety of maize. The aim of the study was to view the "Plan Puehla" through the eyes of the proposed adopters of the new technology— farmers in one representative village — and explain why *so* few (less than 20 percent of) farmers were adopting the Plan Puehla technologies.

The methodology **used** was the development of "decision-tree models" for each of the farmers' four decisions: to get credit for fertilizer, to increase plant population, to increase the number of fertilizer applications, and to use a recommended level of fertilizer per hectare (ha). Previous studies of the Puebla Project had lumped together all these decisions to describe why the farmers did not adopt the "package" of recommendations (Benito 1976, Moscardi 1979, Moscardi and de Janvry 1977, Villa Issa 1976). This study, however, assumed farmers could decide to adopt one agronomic recommendation without adopting the others. The decision models were developed after intensive interviews with 20 or more farmers in the village to discover their reasoning and elicit their ***perceived*** alternative and decision criteria. They were then tested in interviews with another, a separate set of 34 decision makers. The method can he understood via the following example.

The Decision to Fertilize Twice Instead of Once

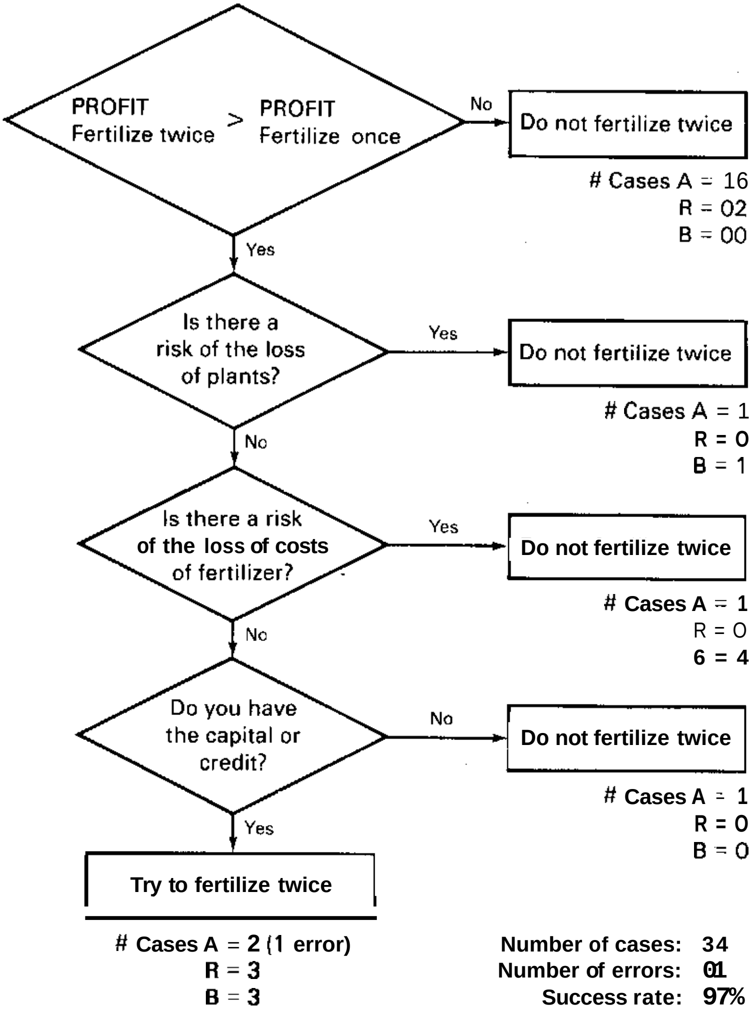
Traditionally, farmers in Puehla fertilized once, at the first weeding, which occurs when the plants are 10 to 20 centimeters (cm) high, or about **20** days after planting. The Plan Puebla, however, recommends fertilizing twice, at planting and at the second weeding, which occurs when the plants are 50 cm high or about 40 days after planting. Nevertheless, from 1973-1974, no farmer fertilized at planting in all of his fields, and few farmers fertilized at planting in one field.

The decision-tree model in Figure I was put together after interviews with 20 farmers. It is read from top to bottom, and asks each decision maker a set of questions in the diamonds about the alternative he or she has to choose in order to reach an outcome at the end of a branch. The models are hierarchical rather than linear additive as in a multiple regression analysis because it is assumed that people compare alternatives on a piecemeal basis (i.e., one dimension at a time, when making decisions).

The model in Figure I states that farmers will try to fertilize twice, at planting and at the second weeding, if they think fertilizing at planting is profitable, and they can pass constraints including the risk of losses of plants and input costs, **as** well as a capital or credit constraint. The model is a bit more complicated than shown, because the profitability criterion is itself a set of criteria of logical statements of the form: **if** you do X in a field of type **Y,** then fertilizing of planting is profitable.

These profitability criteria are different for the various types of fields in the village: type R, fields with irrigation; type **A,** fields without irrigation but with volcanic ash in the soil, which gives them enough moisture if plowed correctly after the preceding harvest so that the farmer can plant early in April; and type B. fields with sodic soils and without irrigation or moisture in April ***so*** that the farmer must wait for the first "regular" rain to plant, which may occur in April or May, but often as late as June.

Figure 1. The decision to fertilize twice: at planting and at the second weeding.



The profitability criteria for type A soils state that it is not profitable to fertilize at planting, if a farmer plants early in April "in dryness" (*en seco*) — as he should — and does the first weeding before the first regular rains come. In that case, the soil is too dry at planting to let the fertilizer (applied by hand above the ground) dissolve, so that it just sits there until the first regular rains come, and does nothing. There is no head start for the plants with fertilizer at planting for a good farmer with type A soils. (Yet most demonstrations of the Plan Puebla were in April, necessarily on type A soils; they used fertilizer at planting and lost credibility with village farmers.)

The opposite is true for type **R** and B fields, however. It is profitable to fertilize at planting in fields that are moist at planting (from irrigation or rain) because the fertilizer will dissolve at planting and give the plants a head start. Plants in type B soils, because of later planting, can use a fast start if they are to withstand the heavy rains (*los aguacerros*) that come in the middle to end of June.

Thus, the main fact limiting adoption of this recommendation was nonprofitability on type **A** soils: 16 out of 21 farmers with type **A** soils did not think it was worth while to fertilize at planting. On type R soils, three out of five farmers tried fertilizer at planting. On type B soils, the factor limiting adoption was risk of **loss** of plants or input costs. The model successfully predicts 97 percent of village farmers' decisions about fertilizing at planting.

The results of developing similar but separate decision models for the other recommendations of the Plan Puebla showed that village farmers did not use the plan's recommended level of fertilizer because it was too low, but 53 percent were on plan-sponsored credit lists. Only seven percent adopted the plant population recommendation because they did not know what the real population recommendation was, and ***no one*** adopted fertilizer at planting for two years in a row. Unfortunately, data at the regional level could not be used to test this model in the Puebla region.

WHY WON'T THE FARMERS CHANGE THEIR CROPS?

The same methodology had been used, however, in another study to help regional policy planners understand their clientele and address issues of ***regional*** importance, such **as:** farmers in the Highlands of Guatemala grow too much corn when there's too little rain for corn, and the growing season is too long. The price of corn is too low. How can we encourage them to grow and sell higher-valued cash crops and buy corn in the marketplace?

The answer to this question was the subject of a study done with the Guatemalan farming systems research and extension program at the ICTA in 1978-1979 (Gladwin 1982, 1983). The goal was to build one decision model of farmers' cropping patterns which would be generalizable to all the different agroclimatic, socioeconomic subregions or "zones" in the Highlands.

The model of the farmers' cropping decision was developed via interviews with 20 farmers in I subregion **or** zone with homogeneous agroclimatic, socioeconomic conditions. It was then tested and revised, based on interviews with another 60 farmers in the 6 different agroclimatic and socioeconomic zones. These include: 1) Totonicapan, which is the geographical and ***indigenous*** commercial center of the Highlands (Smith 1978); 2) Tecpan in Chimaltenango, the department nearest the capital city; 3) San Carlos Sija, a high-altitude region of large-scale farmers with strong Ladino (i.e., Spanish) heritage; 4) the Xela Valley near Auezaltenango, the Ladino commercial center of the Highlands (Smith 1976); 5) Almolonga, an irrigated valley in Quezaltenango; and 6) Llanos de Pinal, an area of rain-fed vegetables, also in Quezaltenango. Some of the features which distinguish the zones from one another include, altitude, average cultivated farm size, crop mix, type of off-farm labor available, socioeconomic features of inhabitants, and percent of the population which is rural, indigenous, and engaged in agriculture.

The study tested the hypothesis that *some* decision rules are ***shared*** by farmers in a geographical region, *so* that one decision model can be built for the region. If crop decisions of farmers in different agroclimatic, socioeconomic zones differ (within the region, sets of crops), the diversity is due to differences in initial agroclimatic, socioeconomic conditions, rather than differences in farmers' decision rules. In short, farmers in a region may "think" the same, but end up growing different sets of crops in different locations in the region because the agroclimatic, socioeconomic conditions within the region are location-specific.

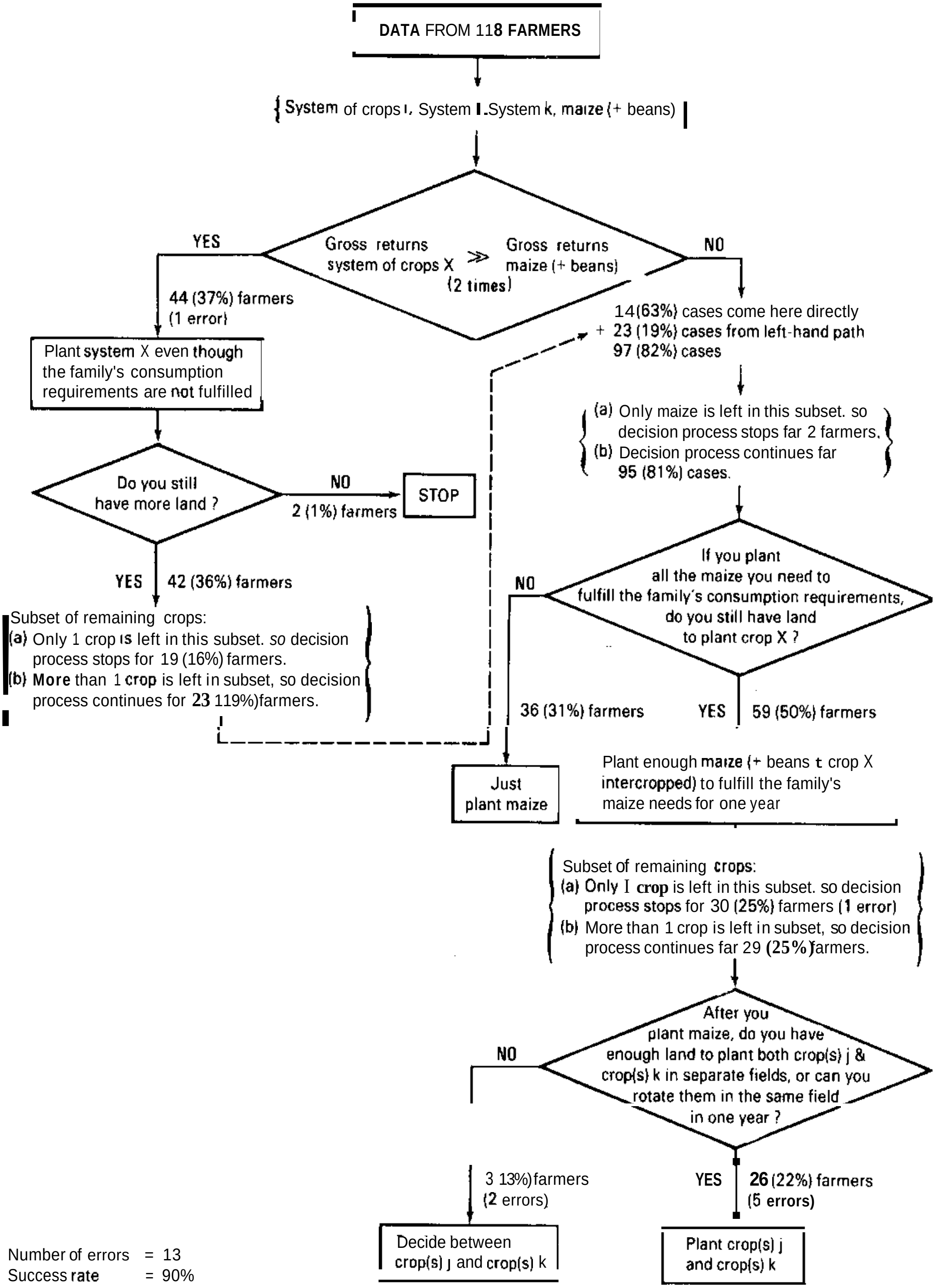
The main subroutine of the cropping decision model, described in more detail elsewhere (Gladwin 1980, 1983), is shown in Figure 2 along with the results of testing it on cropping-choice data gathered from 118 farmers in the 6 zones, As in the previous example, the model tests or processes data from each farmer independently.

The farmer's cropping decision is a two-stage choice process. In Stage 1 he or she first narrows down the complete set of possible crops to a feasible subset that satisfies minimal conditions. For example, given 8 to 10 different crops, a farmer may rapidly, often unconsciously, eliminate vegetables because of a lack of irrigation. He or she might not consider planting potatoes due to lack of planting knowledge or understanding of how to apply pesticides. Alternatively, the farmer might not think of growing coffee, because the land is at too high an altitude. In addition to constraints of altitude, water, and knowledge, Stage 1 criteria also include time, capital, and market demand constraints. With the smaller subset of ***feasible*** crops that emerges from this "elimination-by-aspects"stage (Tversky 1972), the farmer proceeds to Stage 2, the hard-core part of the decision process.

Stage 2 allocates the farmer's available land to the crops in the feasible subset at the top of the tree pictured in Figure 2 that pass Stage 1 constraints. If the farmer has a lot of land, Stage 2 is a simple decision process; all the crops that pass Stage 1 will he planted. If, however, the farmer does not own or operate much land, the crops that pass Stage 1 constraints compete for the little land there is, and the decision process becomes more complicated.

Criterion 1 proposes that farmers give priority to crops or systems of crops that are at least *two* times as profitable as maize, the main consumption crop. Each alternative cropping system is compared with maize because, as the farmers testify, "maize is first." Usually, maize is intercropped with beans (*frijole* and *haba*), so is written

Figure 2. Stage-2 results in six zones of the Altiplano



maize (+ beans), for brevity hereafter referred to as maize. A crop system is also defined here as crops harvested on the same field in one year (e.g., a first harvest of wheat and a second harvest of peas, or two harvests per year of potatoes, or three harvests per year of vegetables).

Very profitable crops, which may be up to five times as profitable as maize, are then "sent down" the left hand branch of the tree. Of the I18 test farmers, only **44** (37 percent) have a crop i (or system of crops i) that is twice as profitable as maize. Data from these farmers pass to the outcome "plant that crop even though you may not fulfil the family's consumption needs for maize." Farmers, thus, consider only a handful of cash crops ***so*** profitable that they will be planted before maize. These cash crops require irrigation, which exists in Almolonga, or special soil/climate conditions marked by sandy **soils,** and an afternoon cloud cover, such as occurs in Llanos de Pinal. The results show that one crop per year of rain-fed vegetables, potatoes, or wheat is not profitable enough to be planted first, before maize; they are therefore sent down the right-hand path to criterion 3.

If the farmer still operates more land after planting the very profitable crop i (criterion **2),** the model sends him or her to the consumption criterion 3 on the right-hand branch of the tree. Here the farmer is asked if he or she has enough land to plant the not-so-profitable cash crop(s) ***after*** enough maize has been planted to meet the family's consumption requirements. If there is enough land, the outcome below criterion 3 predicts maize will be planted first, before the decision of how many cash crops will be planted. (In the Highlands, people do not feel comfortable sleeping without at least ***a*** six-month supply of maize stored above their heads on rafters.)

Ninety-seven farmers proceed to the decision process on the right-hand branch 74 go directly to criterion ***3*** because they do not have a crop that passes Stage-I constraints and is twice as profitable as maize. Twenty-three cases come from the left-hand path because they have more land left after planting the twice-as-profitable-as-maize crop, and have two or more crops left in their feasible subset from Stage I. At this point the decision process stops for two farmers, because maize is the *only* crop left in the feasible subset.

Of the 95 remaining farmers, 59 (50 percent) pass the consumption constraint. They have the land to plant enough maize to fulfil their family's consumption requirements and one or more cash crops. After planting enough maize to satisfy their consumption needs between harvests, these farmers allocate their remaining fields to the cash crops that remain in their feasible subsets. Only one cash crop is left, for 30 of the 59 farmers, in the feasible subset at this point. The remaining farmers have two or more cash crops still in the feasible subset, ***so*** their decision process continues on to diversification criterion **4.**

The latter diversification decision between two or more cash crops is simple if the fanner has enough land to plant both crops. If there is not enough land and the farmer cannot rotate the crops within the year, then he or she may decide between them by trading off the profitability and risk of the cash crops. This model is presented elsewhere (Gladwin 1980). Results show that 26 of the 29 farmers with 2 feasible cash crops manage to grow both crops; or the climate and altitude are such that they can rotate the 2 crops on the same field within the year, **as** occurs in Llanos de Pinal and Tecpan.

Thirty-six of the 95 farmers on the right-hand branch of the tree fail the consumption criterion: they do not have enough land to be self-sufficient in maize and plant a cash crop. Their data are therefore sent to another subroutine presented elsewhere (Gladwin 1983), which tells them to plant only maize ***unless,*** . . ., and then lists the relevant conditions: if cash crops can he interplanted or multicropped with maize, if land can be rented for the cash crop, if special agroclimatic conditions limit production of maize on all fanners' fields, and if the farmer needs cash badly. In those cases, the farmer will plant the cash crop even though he or she will then not be self-sufficient in maize. Exceptional circumstances include high risk dependency on the marketplace to purchase maize, lack of capital to buy maize when it's needed, or low profitability of cash crops. Three-quarters of these test cases end **up** planting a cash crop, even though it means sacrificing self-sufficiency in maize.

The decision model in Figure 2 has a 90 percent success rate (i.e., the model successfully predicts what crops, 105 of 118 farmers in the test sample plant, across the region as a whole). The results in each of the six zones show success rates ranging from 69 to 95 percent in the different zones (i.e., the model predicts ***every*** crop in the crop mix for 69 percent of the farmers in Tecpan, and for 95 percent of the farmers in Totonicpan and Llanos de Pinal). **A** Chi-square test shows that these differences are not significant, so that the assumption of ***one*** decision model for the region is not rejected.

IMPLICATIONS

Because the results consist of data collected over a region rather than only a village, they have policy implications for the highlands and can answer the question posed earlier by revolutionaries and conservative politicians alike. The counterargument to the claim that "maize is not the right crop for the highlands" is, of course, that farmers are the real experts at deciding what they should do. They know all the reasons why they should plant maize. In the subregions sampled, 60 percent of the farmers plant a cash crop only if they can first meet their consumption needs for maize, because dependence on the marketplace for a subsistence crop is risky, especially because maize is eaten **3** times a day, with no complementary foods.

Because farmers are the real experts in making cropping decisions, their "**expert** systems" (which is another name for decision trees in the field of artificial intelligence) can be used **by** policy planners to help them diversify their cropping strategies. Such diversification strategies will become more crucial in the future. As population increases and farm size decreases further, farmers in more zones will not have enough land to plant their maize consumption requirement first and a cash crop second. Because a majority of farmers will plant maize first, one diversification strategy is to increase maize yields so that more cash crops can be planted. This should prove to be the most effective diversification strategy of **all,** capable of reaching the ***majority*** of highland farmers, and obviously acceptable to the maize program at ICTA. (Some success has already been achieved in this direction, with the widespread adoption of an improved open-pollinated ICTA variety, ***San Marceno.)*** Another strategy is to introduce irrigation in more subregions, so that more twice-as-profitable-as-maize cropping systems can be planted. Results show these systems include two crops of potatoes or vegetables per year, a rotation of wheat and potatoes (or vegetables), coffee, and a monocrop of fruit trees. Few fanners perceive ***one*** crop of rain-fed vegetables **or** potatoes or wheat to be twice **as** profitable as maize; these crops are incapable of replacing maize as the "number one" crop. Another diversification strategy for farmers with very small land holdings (five ***cuerdas*** or **less)** is intercropping or multiple cropping with maize: unfortunately, knowledge of "relay crops" of "double rows" (Hildebrand **1976)** has not yet diffused widely in the highlands. But in the future, **as** population increases and farm size decreases, this strategy may be the only way farmers can diversify and, thus, raise their farm incomes.

WHEN **WILL THE** FARMERS CHANGE?

By now the reader must be wondering under what conditions will farmers change, because examples have focused on cases when farmers will *not* change their traditional farming practices. Fortunately, work with ICTA also allowed me to observe farmers who ***were*** changing their cropping strategy. This occurred when irrigation, terraces, and vegetable technology were introduced into the region of San Ramon and Santa Rita in the State of San Marcos. When these new complementary technologies were introduced, policy planners and technicians wondered whether farmers would switch to higher-valued vegetables and potatoes. If they did, would they then take land out of maize, the lower-valued subsistence crop, or wheat, also a lower-valued crop? If they did take land out of maize, the subsistence crop, what would happen to their family's consumption requirements **for** maize?

To answer these questions, the decision model described in Figure **2** above was tested on another set of **20** farmers in the San Ramon-Santa Rita region who had invested in irrigation on some of their land (with the ***mini-reigo*** project) and had also built terraces. Their cropping patterns were elicited before (in **1978)** and after (in **1979)** irrigation, terraces, and vegetable technology were introduced. Their responses to the questions in the decision model were also analyzed to predict their cropping pattern before and after irrigation.

The results show that before irrigation, the farmers on average cultivated **0.83** ha in all. On average, farmers had 0.66 ha in maize, 0.14 ha in wheat, and only 0.04 ha and 0.16 ha in potatoes and vegetables respectively. After irrigation, terraces, and vegetable technologies were introduced, farmer cultivation averaged 1.04 ha in all. On average, farmers had 0.59 ha in maize, and 0.14 ha in wheat. But **as** a **result,** they also planted 0.25 ha in vegetables, and 0.04 ha in potatoes. Clearly, in order to double- or triple-crop higher-valued vegetables on irrigated terraces, farmers took some land out of maize, the consumption crop. The overall effect of this change was that total land under cultivation increased rather than decreased.

What effect did this change have on the family's consumption requirements for maize? Of the 20 farmers sampled, half reported that they planted ***less*** maize after the change, while 40 percent reported that they planted the same .amount of subsistence maize. Was this a drastic change? Sixty-five percent of the farmers reported that the family's consumption needs were met in the year before the change, and *70* percent reported that they were also met in the year after the change to irrigated vegetables. Although farmers took some land out of subsistence maize, they did not take out enough to **risk** their family's consumption requirements for maize. In my judgement, any change to higher-valued irrigated crops must proceed in a cautious way, always mindful of the family's consumption requirements for the subsistence crop, be it maize, rice, potatoes, or cassava.

Testing the decision model in Figure 2 on this new sample of farmers resulted in a 95 percent success rate for the "hefore" decisions, and a 90 percent success rate for the "after" decisions. In the case of large-scale farmers, (av-1.3 ha) the tendency **is** to switch from wheat and maize to wheat, vegetables, potatoes, and maize; while in the case of small-scale farmers the pattern **is** to switch from maize intercropped with fruit trees to maize, vegetables, and potatoes. In both cases, farmers benefit from the introduction of irrigation and change of cropping pattern.

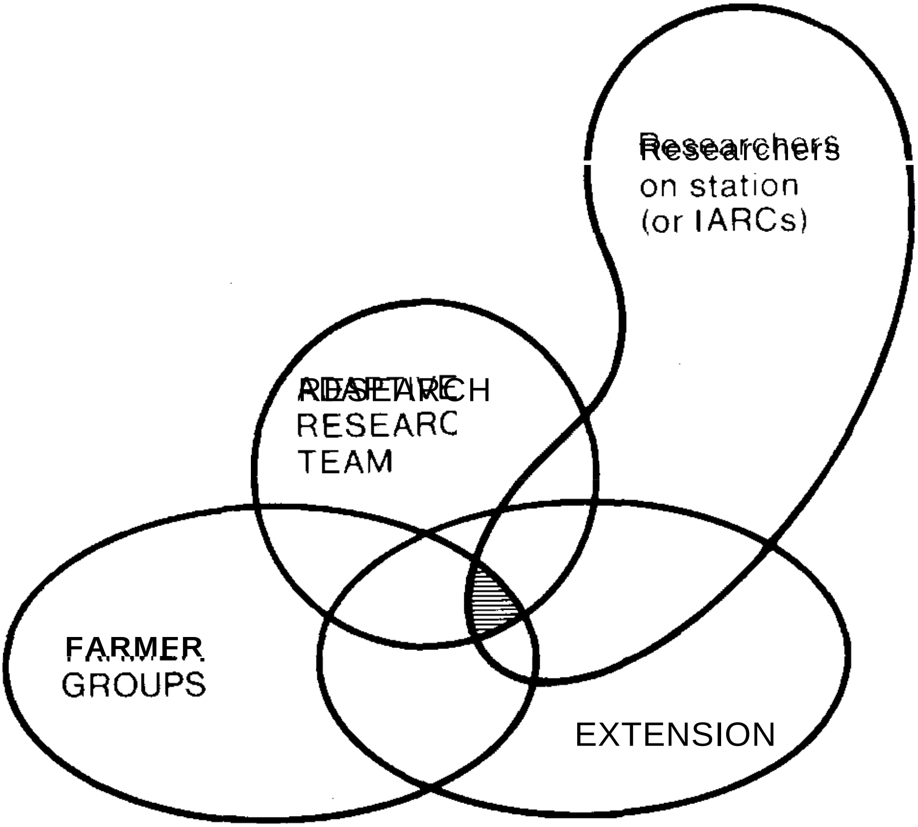
FUTURE DIRECTIONS WHY DON'T THE INSTITUTIONS CHANGE?

A big problem facing IARCs, whose clientele are agencies rather than farmers, and NARCs, which can employ the more direct FSR/E approach, is how to institutionalize a new approach, like the new FSR/E adaptive research team, into a Third World country with a set of separate research and extension institutions already in place. How can this be done while minimizing intra- and interinstitutional conflict (University of Florida: **FSSP** 1985)?

The change of cropping pattern in the region of San Ramon-Santa Rita in the State of San Marcos is an example of how institutions or agencies can work together for the farmer's benefit. The unusual cooperation of four agencies or institutions with farmer groups in San T/Ramon in **1979** was rare. The institutions included: ICTA, which provided the adaptive research team and vegetable technicians; DIGESA (the extension service), which provided the extension manpower and also housed the USAID donor agency research team who were experts in terraces and mini-riego (little irrigation) systems; and *Educación Extra-Escolar* (the adult education monitors) who worked with the farmer groups to make the terraces and plant the vegetables. Incredibly, all these teams worked together to bring a twice-as-profitable-as-maize cropping system to farmers in this region.

Figure 3 shows why cooperation is rare among institutions each of which tries to put the farmer at the center of its work: the common core of interest among all four sets of activities representing all the work of all the institutions is a very small set indeed. Yet workers in the four institutions are all doing their work energetically. The moral of this story is that institutions, like farmers, do not change because they have pressures imposed on them from the outside. Like farmers, they have developed "survival strategies" to allow them to survive in an often-hostile environment. Research on institutional decision-making processes and strategies is needed to identify the conditions under which institutional change is possible.

Figure 3. Cooperation among researchers, adaptive research teams, farmer groups, and extension agents.



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