INCLUDING DIETARY CONCERNS IN ON-FARM RESEARCH: AN EXAMPLE FROM IMBABURA, ECUADOR*

Robert Tripp**

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ECONOMICS PROGRAM

CIMMYT

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* The views expressed in this paper are not necessarily those of CIMMYT

** CIMMYT Economics Program

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 research opportunities. 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. Our efforts with national programs began in 1974 with Zaire's national maize program, then moved to work in Tunisia, Pakistan, and Egypt. The pace of work accelerated notably in 1976 with assignment of regional economists stimulating similar work in Kenya, Tanzania, Zambia, Ecuador, Peru, Bolivia, Panama, El Salvador, and India. Cooperation with still other national programs is now underway. We believe that the resulting procedures offer cost effective and robust guidelines to national programs.

We are now preparing reports that illustrate the implementation of these procedures in various national programs. While not all such work can be reported, we take this opportunity to thank all of those who have collaborated with us.

This report describes work undertaken with the Production Research Program of INIAP, Ecuador's national agricultural research institute. It concerns the use of dietary data in helping define farmers' circumstances and plan agricultural experimentation. We believe that it illustrates the utility of our on-farm research procedures for generating technologies relevant to the needs of farmers.

Donald L. Winkelmann
Director, Economics Program

CONTENTS

I. NUTRITION AND AGRICULTURAL RESEARCH

This paper describes the way in which dietary and nutritional concerns are included in an on-farm research program in Ecuador. The on-farm research program seeks to improve the production and welfare of small farmers, and the analysis of dietary and nutritional information is important to this effort for two reasons. First, most small farmers use at least part of their production for home consumption. An understanding of farm families' dietary preferences and patterns is thus valuable if a new agricultural technology is to have a good chance of acceptance. Second, nutritional improvement among rural populations is often not achieved in the course of economic development, so that technological change must be more carefully directed if it is to solve nutritional problems.

On-farm research is an agricultural research approach which has many variations, but it is characterized by a strategy which selects target groups of farmers; diagnoses the way in which they manage their crops, animals and off-farm enterprises; identifies elements of agricultural technology which might improve this farming system; tests those elements with representative farmers; and analyzes the results in order to provide recommendations to farmers and feedback to agricultural scientists and policy makers. It is thus based on a careful understanding of the dynamics and variations of small farm management, working towards technological improvement based on farmers' circumstances.1/

In this sense it shares a good deal with current thinking on nutrition planning, which "must be seen as an activity that begins and has its dynamic at the grass roots level rather than at the level of central government. It should, in fact, engage the attention of people of the highest professional caliber at the lowest level of disaggregation of the

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1/ See for instance, Byerlee, D., M. Collinson, et.al., "Planning Technologies Appropriate to Farmers - Concepts and Procedures". CIMMYT Mexico, 1980.

population."[1] The type of information available to such "grass roots" nutrition planning and the data developed by on-farm research are in fact complimentary. Any effort to use agricultural change as a vehicle for nutritional improvement must take account of farmers' production interests and the technical and economic realities of small farm management. Agricultural change programs, on the other hand, must assure that they are consistent with farmers' consumption preferences and offer real opportunities to improve farm families' welfare.

Thus both for predicting nutritional consequences and for helping gauge the acceptability of technnologies to be tested, some dietary information is often necessary to help guide on-farm research. What follows is a description of a few simple methods for developing that kind of information and examples of how the results are utilized in an on-farm research program in Imbabura Province, Ecuador.

II. ON-FARM RESEARCH IN ECUADOR

With assistance from the CIMMYT Economics Program, an effort at on-farm research was established in Ecuador by the National Agricultural Research Institute (INIAP) in 1977. Called the Production Research Program, it goes about its work by assigning technicians to various provincial centers with responsibility for carrying out on-farm research on the principal crop or crop association of those areas. The work described here is part of the Production Research Program in Imbabura Province, where maize, associated with climbing beans, is the principal crop. Research work was begun in Imbabura in 1977 when a farmer survey was carried out to assess current maize practices and identify priorities for maize research. INIAP technicians assigned to the area then began the process of selecting representative farmers with whom to plant trials and managing, harvesting and analyzing these on-farm experiments. Trial work focused on lines of maize and beans of both normal and rapid maturity, experimenting with fertilizer levels and investigating insect and weed control technologies. Work was

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1/ Payne, P.R., "Improving Patterns of Consumption" in N.S. Scrimshaw and M. Béhar (eds.) Nutrition and Agricultural Development, New York, Plenum, 1976, p. 403.

also done on simple methods of maize storage. By the 1980-81 season the program was in its fourth year of on-farm trials and was beginning to generate recommendations for farmers.

The activities of the INIAP technicians are quite varied. The primary concern is the management of the trials themselves, but beyond this the technicians are responsible for: spending considerable time with farmers who collaborate in trials, and their neighbors, in order to further their understanding of the farming system; following up on adoption of technologies by former collaborators; and obtaining market data on crops and inputs. At times this informal data gathering in conjunction with the trials is complemented by short formal studies.

The data that form the basis for this paper come from four different sources:

- In 1980 a series of simple qualitative 24-hour dietary recall surveys were carried out in three communities in the research area. The surveys concentrated on foods consumed, methods of preparation and source of each food item. The study was carried out by a person trained in dietary survey methods.

- In 1981 a farmers' survey of ten households in each of nine communities was carried out to help set research priorities for the following cycles. Three of the communities were the same as those included in the dietary recall survey. A few questions on diet were included in this questionnaire, which was administered by technicians of the Production Research Program.

- Information was derived from contacts developed by program technicians in the course of trial management. Their observations and conversations with collaborators on subjects such as the utilization of new varieties offer valuable insights that more formal methods cannot provide.

- Finally, secondary data were also analyzed, in the form of a few published quantitative dietary surveys from the research area, or similar areas in Ecuador.

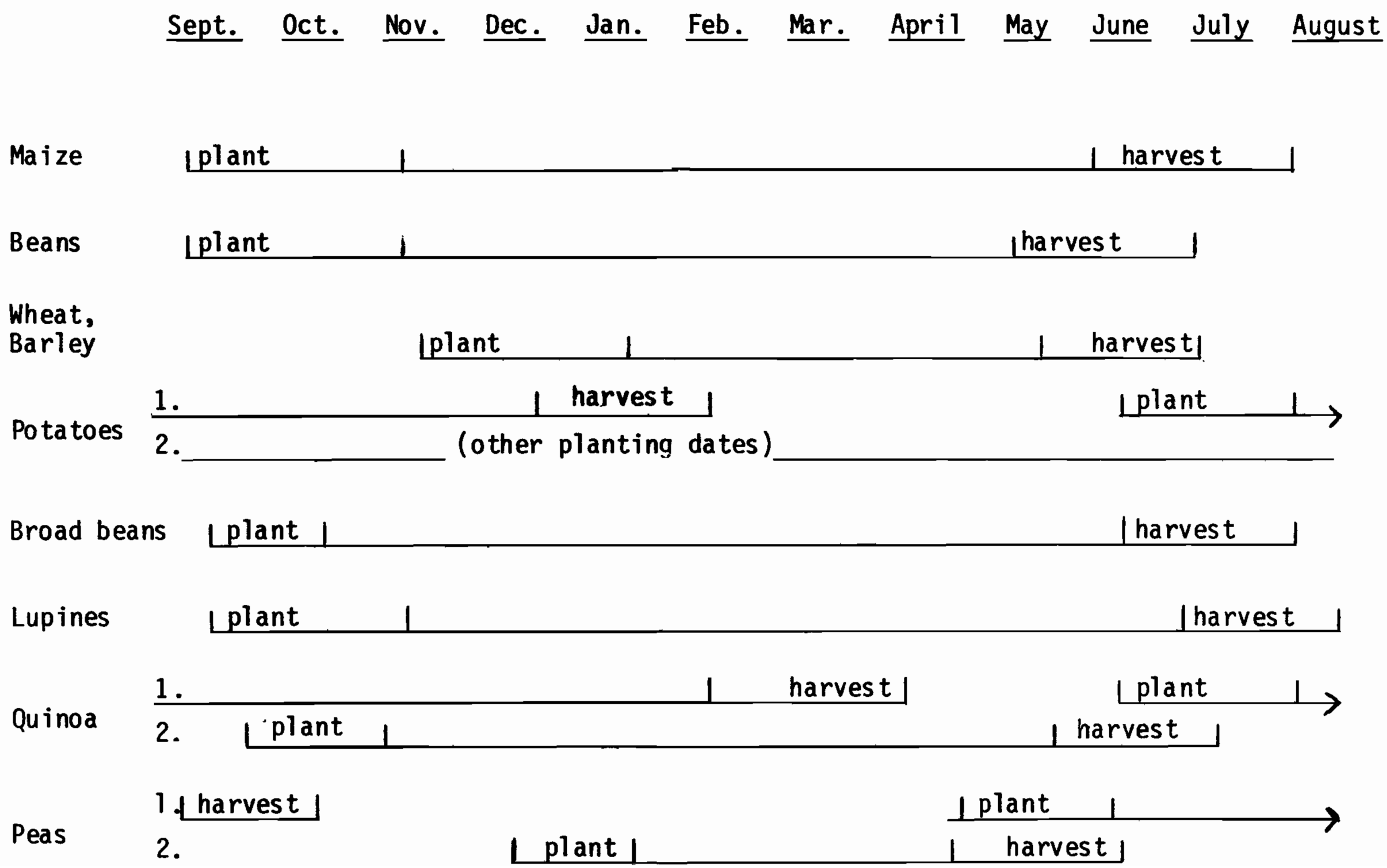
III. THE RESEARCH AREA

The Production Research Program in Imbabura Province works in an area of approximately 1,000 square kilometers of highlands, between 2,300 and 3,200 meters above sea level. There are about 12,000 small farm households in this region, almost all of which depend upon maize as their principal food crop. The data discussed in this paper are from the southern half of the research area, including the cantons of Otavalo and Cotacachi, a densely settled zone of small communities of farmers, the majority of whom speak Quechua as their first language. Most farmers work less than two hectares of land.

Maize is planted in September through November and harvested nine to ten months later. Besides maize, a wide variety of other crops are raised in the area; some of the more important are illustrated in Figure 1. Climbing beans are almost always planted with the maize. Broad beans and lupines (*Lupinus sp.*) may be sown with the maize or separately. Barley, wheat and potatoes are also important crops in the area. Quinoa (*Chenopodium quinoa*), an Andean crop producing a very tiny grain of high nutritional value is planted by most farmers. Other crops of some importance are: peas, various types of squash (Cucurbita pepo, C. Ficifolia), the Andean tubers *melloco* (Ullucus tuverosus) and *oca* (Oxalis tuberosa), lentils, and cabbage and other vegetables, usually in very small quantities. Farmers also utilize a number of "weeds" as greens for cooking purposes, including wild turnip, wild radish and *Amaranthus sp*.

Many farmers sell small amounts of their crops, but almost all must depend on other activities to provide cash income. Most farmers keep animals; guinea pigs and chickens occasionally provide meat for the diet, but are more often raised either for sale or for use on festive occasions. Pigs and goats are also raised for market, as well as sheep, which are also

Figure 1. Common Cropping Patterns, Imbabura



a source of wool for sale or home weaving. Cattle too are raised both for sale and for milk and traction. Beyond this, the majority of the farmers work at least occasionally at off-farm activities, often as laborers in nearby haciendas or in the larger towns. Commerce and handicrafts are also important sources of income for some families.

Table 1 provides some data comparing the three communities in which the dietary survey was carried out. Only Morlan has irrigation water for agriculture; farmers have rights to use about two hours every two weeks. The other two communities must depend on rainfall, and the soils of Morochos are quite sandy and retain little moisture. Agricultural practices are fairly similar among the three communities, with maize the principal crop in all cases, but some differences are outlined in Table 1 for wheat, barley, quinoa and peas.

IV. MAIZE USE AND THE ACCEPTANCE OF NEW VARIETIES

As maize is the target crop of the research program and the most important item in the diet, it would be well to briefly describe the types of maize that are grown and how they are utilized. The predominant maize type in the highlands of Imbabura is known as floury maize, common to the Andes and almost unknown elsewhere. It is generally large grained and, as the name implies, its endosperm when dry is floury or chalky in texture. Another type of maize common to the area (but planted to a much lesser extent than the floury) is known as morocho, with a white, large grain which is hard on the surface and floury within. Finally, and to a very minor extent, one can find some flint maizes and various other types such as the local sweet corn (chulpi) and a type of popcorn (canguil).

Maize can be consumed either green or dry. There are a variety of preparations for dry maize, but three are predominant. The most common use of floury maize is tostado; the maize is simply placed on a griddle, sometimes with a bit of cooking fat or oil, and toasted for 10 to 15 minutes. It can then be eaten, carried to the field, or stored for several days. Another common use is in colada, a gruel prepared by adding maize flour to

Table 1. Characteristics of the Three Communities in the Dietary Survey

	CASCO	MORLAN	MOROCHOS
No. of households	78	87	88
Altitude (meters)	2,800-3,200	2,600-2,900	2,700-2,900
Canton	Otavalo	Cotacachi	Cotacachi
Nearest town	San Pablo	Imantag	Quiroga
Walking distance to nearest town	30 min.	30 min.	50 min.
Irrigation	No	Yes	No
Potable Water System	No	Yes	Yes*
Soil quality	Fair (sandy loam)	Fair (sandy loam)	Poor (sandy)
% of farmers that plant maize	100%	100%	100%
% of farmers that plant barley, wheat	90+ %	90+ %	30%
Quinoa planting date	July, with potatoes	July, with potatoes	October, with maize
Peas planting date	November, interplanted with barley	May-June, alone	April-May, alone

* potable water system not functioning in Morochos at the time of the dietary survey.

boiling water and cooking for a short time; other items may be added, including legume flour, potatoes, vegetables, or meat (coladas de sal) or milk, sugar or fruit (coladas de dulce). A third use is mote, where the whole grain maize is boiled with ashes or lime and then scrubbed with large quantities of water to remove the hull; it is then returned to boil for another hour or more.

Maize can also be used to make griddle cakes or other preparations. It is also used to produce corn beer, chicha. The semi-hard maize called morocho is ground to small pieces and boiled in a soup of the same name. If floury maize is harvested before it is dry it can be parboiled, dried, cracked and cooked to give chuchuka.

The above is by no means an exhaustive list of the types of maize preparation, but gives a general idea of the day-to-day uses to which maize is put. The relative frequencies of use are illustrated in Table 2, which describes all instances of dry maize use recorded in the three communities in the dietary surveys. It can be seen that the great majority of cases are toasted maize and gruel (colada). It should be emphasized that this is not meant to represent the exact quantity of maize consumed in each type of preparation, but merely its frequency. In response to a question in the farmers' survey administered in nine communities on how most maize was utilized, tostado and colada were always mentioned as the most important; two-thirds of the farmers said that they used most maize in coladas. Where time, firewood, and occasionally water are in short supply, it is not surprising that the most rapid methods of preparing maize are the most common.

The preparation of tostado requires but a few minutes and utilizes no water. Maize gruels also require little cooking; the majority of the time is taken up in preparing the flour. In all three communities most of the maize flour was prepared by a grinding mill in the nearest town. Some flour is also prepared at home, either on a stone or with a hand mill which can reduce the soft Andean maize to flour if it is milled several times. The

Table 2

Proportion of Meals in Which Various Dry Maize Preparations Were Reported During Dietary Survey

	CASCO	MORLAN	MOROCHOS	TOTAL
No. of observations	32	59	40	131
Tostado (Toasted maize)	38%	36%	50%	40%
Colada (Maize gruel)	31%	29%	30%	30%
Mote (Boiled maize)	3%	20%	3%	11%
Morocho	9%	7%	15%	10%
Chuchuka	6%	7%	0%	5%
Other	13%	2%	3%	5%
Total	100%	101%	101%	101%

cost of grinding is low, but poorer families sometimes prepare flour in their homes rather than spend the money at the mill. Maize at times may be toasted before it is ground.

The other popular maize dish, mote, is prepared much less frequently. It requires not only a great deal of time to prepare, but also alot of water, as the maize must be thoroughly washed after it has been boiled with the ashes before being cooked again. In Table 2 it can be seen that only in Morlan was it at all common, and this was the only community that had access to household water at the time of the survey. But in any case, it is not very commonly prepared in any of the farming households surveyed. It is more likely to be found where it has been prepared in large quantities, either to feed communal work parties, or for sale in markets and towns.

Not all maize is consumed in its mature, dry state however. When the maize is ripening in the fields people utilize ears to boil, roast, or for other preparations utilizing green maize. In Casco in early August, for example, 60% of the instances of maize use were of green maize.[1/] As different fields are planted at different times in any given community, and maize matures at different rates at different altitudes and due to variations within each farmer's maize, there is a period of three months or more during which some green maize is available, either from one's own field or in exchange or as gifts from neighbors. Farmers whose maize supply is precarious from year to year may consume as much as 25% of their maize before it has dried for harvest.

A word should also be said about maize color. Floury maizes of both white and yellow pericarp are grown (the endosperm is always white), but yellow is by far the more common. There is a general preference for using

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1/ In a quantitative survey conducted in two villages near Otavalo in May-June 1953, 73% of maize consumed (by dry weight) was green. (Instituto Nacional de la Nutrición, "La Realidad Alimentaria Ecuatoriana: Un Estudio de Cinco Encuestas Alimentarias", Quito, 1956).

yellow maize in tostado and colada, and white maize in mote, but among poor farmers they are used interchangeably. Urban consumers are willing to pay a premium for white floury maize (for preparing mote) and when sold it may get as much as a 30% higher price. Farmers claim that their white maizes do not yield as well as the yellows, and relatively few small farmers in the area grow white maize to sell.

This type of information on maize uses was employed in analyzing the possibilities of introducing two types of maize. In one case breeders had expressed interest in the possibility of working with harder endosperm maizes for the Ecuadorian highlands. This type of maize would offer greater disease resistance in the field and insect resistance in both field and storage. It would also offer access to a wider range of genetic material that could be used to improve the local varieties. As many farmers grow a bit of hard endosperm maize they have some experience with its possible uses. It was relatively easy therefore to ascertain the potential of harder endosperm materials under local preparation techniques. This type of maize is totally unacceptable for tostado and requires much longer to prepare as mote, yielding a product of low quality. harder maizes can be boiled or roasted green, but again the product is not preferred. Harder maize can be ground to flour for colada, but not at home, and the local mills charge a bit more to grind harder maize. Further evidence of the low acceptance of harder maizes comes from market data which show a considerable difference in price between hard and soft maize, the latter selling for 30% or more than the former. Finally, in 131 instances of dry maize use recorded in the dietary survey (Table 2) only 1 was hard maize, ground to flour. Thus it became obvious that unless harder endosperm maizes offered very large yield or storage advantages over local floury maizes it was not advisable to initiate this line of research.

The second case in which knowledge of maize use proved helpful was in the monitoring of a new variety of maize, INIAP 101, which had been tested with considerable success in on-farm experiments in Imbabura Province. Farmers were particularly interested in the variety because it matured as much as two months earlier than their own maizes. Although INIAP 101 has a white, floury grain type which has high acceptance among farmers, it was thought worthwhile to investigate farmers' opinions on the qualities of the new maize. This is in fact normal practice in the course of on-farm research, where the technicians continually monitor the experiences of collaborators with new varieties, not only in the fields but also in cooking and marketing. After two years of research there were enough farmers who had some of the new seed that their experiences could be compared. This was done informally, through visits with farmers. It was found that they particularly enjoyed the new variety as green corn, roasted or boiled. There were also some who had prepared coladas with it and pronounced them satisfactory. When used in tostado, the new maize was also acceptable (although some found it a bit harder than average), but it did present a slight problem in that a part of the cob adhered to the tip of the grain on shelling and stayed attached throughout the toasting process. This problem was more serious in mote preparation, where a number of farmers complained about this hard tip on the cooked grain. Women who cooked mote for sale said that it would be acceptable in the home, but not in the market.

At the same time, some evidence began to appear that farmers who sold a bit of this maize were receiving a lower price than for the local white maize (but higher than for local yellow) both because of the shelling problem and because the grain is a bit smaller than some of the local white maizes.

The conclusion reached after this initial experience was that farmer interest in this new variety's agronomic characteristics, combined with its acceptability in the majority of common maize preparations, meant that on-farm experimentation should be expanded with INIAP 101 and that in all probability a very wide adoption of the variety could be expected, assuming continued favorable performance in farmers' fields. In the meantime, however, experiment station breeders were alerted to the problem and began to include shelling characteristics in their selection procedures for further improving this early-maturing variety. In addition, they expanded their work on yellow floury early-maturing materials, and initial tests indicated that these did not suffer the same shelling problems. As on-farm experimentation with these new varieties is expanding, more experience with farmers' observations can be expected, and these will be fed back to station scientists to help assure the development of new maizes of high aceptability.

V. DIETARY DATA

Data on diets discussed here come from two sources. One is the qualitative 24-hour dietary recall survey, done twice in Casco and Morlan and once in Morochos. The results are reported by meals; people tend to think in terms of three meals a day, although they do not always eat them. A meal here is any instance in which food is eaten during the day, and so may be anything from a complete meal to some tostado eaten while working in the field. This method seems adequate for obtaining information on the frequency and manner of use of principal crops, but shares with other recall methods a tendency to under-report foods eaten outside the home, such as fruits and other snacks. The proportion of meals that contain each of the principal crops is reported in Table 3.

The other source of dietary information are the few questions on diet included in the survey on farming patterns administered to ten randomly selected households in each of nine communities in the province. Some results from the three communities that were included in the dietary survey are reported in Tables 4-6. Table 4 gives the responses to a question as to whether the food had been consumed in the past week. Table 5 reports the way several of the crops are most commonly prepared, and Table 6 summarizes purchasing patterns. With only ten households surveyed in each community, the results reported in Tables 4-6 are obviously of limited significance, but combined with the data from the dietary survey and other observations they provide insights into food use and point to differences among communities in the research area.

Table 3

Percent of Total Meals in one 24-hour Period
Containing each Food

	CASCO		MORLAN		MOROCHOS	TOTAL
Month of survey	Aug.	Feb.	Aug.	Feb.	Jan.	
No. of households	17	15	19	18	20	89
No. of meals	43	37	51	38	50	219
FOOD						
Maize	51%	54%	64%	63%	78%	63%
Barley	26%	24%	10%	16%	4%	15%
Wheat	7%	14%	4%	8%	0%	6%
Quinoa	2%	3%	6%	11%	2%	5%
Potatoes	35%	62%	38%	47%	48%	45%
Oca, melloco, etc.	7%	0%	14%	5%	10%	5%
Beans	21%	5%	18%	21%	2%	13%
Peas	0%	0%	12%	3%	4%	4%
Broad beans	0%	0%	0%	8%	4%	4%
Lupines	2%	0%	2%	0%	0%	1%
Other legumes	0%	0%	6%	0%	0%	1%
Cabbage	7%	11%	14%	11%	6%	10%
Cucurbitae	2%	11%	8%	5%	14%	8%
" seed	0%	0%	0%	0%	6%	1%
Pot herbs	9%	8%	2%	0%	24%	9%
Meat	0%	0%	4%	3%	2%	2%
Milk	5%	3%	0%	5%	2%	3%
Eggs	0%	3%	0%	0%	0%	<1%

Table 4

"Have you eaten this food in the last week?"

(No. positive responses out of 10)

	CASCO	MORLAN	MOROCHOS
Beans	3	1	6
Peas	1	1	2
Broad beans	0	1	3
Barley	7	7	2
Wheat	3	5	2
Quinoa	3	6	9
Lupine	2	1	1

Table 5

"How is this food most commonly eaten in your home?"

	CASCO	MORLAN	MOROCHOS
Beans			
Green	3	1	5
Dried, or dried and green equally	7	9	5
Peas			
Green	4	2	6
Dried, or dried and green equally	5	8	0
Never use	1	0	4
Broad Beans			
Green	2	2	6
Dried, or dried and green equally	6	7	3
Never use	2	1	1
Barley			
Cracked (arroz)	10	10	7
Never use	0	0	3
Wheat			
Flour	3	10	4
Cracked or cracked and flour equally	6	0	1
Never use	1	0	5

Table 6

"Do you purchase this food?"
(No. positive responses out of 10)

	CASCO	MORLAN	MOROCHOS
Beans	0	0	2
Peas	0	2	1
Broad Beans	1	1	3
Barley	4	2	3
Wheat	1	3	2
Quinoa	0	1	3
Lupine	5	4	5
Potatoes	9	8	9
Maize	6	4	5

The results in these two data sets can be used to analyze the diets of the farmers of the research area:

Maize:

It can be seen from Table 3 that maize is the most common item in the diet, appearing in 63% of the meals reported. Two or more maize preparations are sometimes included in one meal. The data from Casco and Morlan indicate that maize maintains its importance in the diet throughout the year, although in neither case was the survey done at the time of greatest shortage. This occurs a month or two before maize is available to be harvested green. Conversations with poorer farmers indicate that often very little maize is available in the house at this time and they must either buy maize or eat other foods. Table 6 indicates that half the farmers are used to buying some maize for household consumption.

Barley and Wheat:

Table 3 shows that barley, and to a lesser extent wheat, form a somewhat more important part of the diet in Casco than in Morlan, and that in Morochos they are rarely consumed. Table 4 confirms this difference. This reflects planting patterns, where Casco plants more of these crops than Morlan because of their access to higher fields. In Morochos, only a minority of farmers ever plant these crops, due mostly to different soil conditions. It can be seen from Table 5 that although barley is usually consumed as arroz, cracked and boiled as a kind of soup, wheat is prepared in different ways. In Casco it tends to be cracked on a stone or hand mill, much like barley, whereas at Morlan it is usually ground at the mill in town and used as flour in making tortillas and other preparations. (The dietary survey showed 7 of the 8 instances of wheat consumption at Casco as cracked wheat, while all 3 of the examples of wheat use at Morlan were as flour). Whether this can be explained by economic differences between the two communities (Casco is poorer) or is simply due to a difference in taste is uncertain.

Potatoes:

After maize, potatoes are the most important item in the diet, appearing in 45% of the meals recorded. They are usually prepared by boiling, with or without skins, and at times they are also roasted. Table 3 shows a bit more seasonal differences in consumption. In both Casco and Morlan potato use is higher in February, after harvest. The source of potatoes is shown in Table 7. The fact that fewer potatoes are purchased in Casco than in Morlan, even before harvest, probably reflects the more difficult economic circumstances of Casco, the fact that they grow more potatoes than Morlan (they have developed communal land for this purpose), and that at the higher altitude they are able to store potatoes for a somewhat longer time. Table 6 shows that the vast majority of farmers in these communities often purchase potatoes, and Table 7 indicates that about one-third of the potatoes consumed are purchased. A large proportion of the potatoes purchased come from the province of Carchi, to the north of Imbabura, where farmers grow potatoes as a cash crop. Potatoes are a valued item in the diet, and although prices vary widely by variety and size, it is possible to purchase as much energy and protein per dollar with low to medium quality potatoes as with maize or other grains. (See Table 8).

Beans:

Table 3 shows differences in bean consumption both seasonally and between communities. There would seem to be a higher and more stable consumption of beans in Morlan than in the other two communities. This is reflected in Table 5, where about half the farmers of Morochos and a third of the farmers in Casco report that they eat the majority of their beans in the green state; that is, less than half of their production is harvested and stored as dry beans. Table 4 shows low bean consumption over a week's time, except in Morochos, where at the time of the farmers' survey people were beginning to harvest young beans from their fields. The differences in consumption patterns indicate that bean production is probably highest in Morlan. In any case, overall bean consumption in this area is obviously quite low, reflecting the low yields of this crop which are often obtained under traditional management practices. Few beans are ever purchased (Table 6), even though prices are relatively low (Table 8).

Table 7

Origin of Potatoes in Diet Survey

	CASCO		MORLAN		MOROCHOS	
Month	Aug.	Feb.	Aug.	Feb.	Jan.	TOTAL
ORIGIN						
Farm	60%	100%	16%	56%	50%	58%
Purchase	33%	0%	84%	44%	21%	34%
Gift	7%	0%	0%	0%	28%	8%
No. of observations	(15)	(23)	(19)	(18)	(24)	(99)

Table 8

Prices of Selected Foodstuffs
Otavalo Market - Oct. 25, 1980

	Cost/100 g. (Sucres)	Grams protein**/100 g.	Calories/**100 g.	Grams protein/Sucre	Calories/Sucre
Barley	1.36	9.2	344	6.8	253
Beans	2.22	20.5	335	9.2	151
Broad beans	2.22	25.1	337	11.3	152
Lentils	6.67	21.9	332	3.3	50
Lupine	1.78	41.2***	419	23.1	235
Maize	1.33	7.9	335	5.9	252
Peas	2.67	23.2	334	8.7	125
Potatoes****	0.33	2.0	80	6.0	242
Quinoa	1.47	14.2	353	9.7	240
Rice	1.56	9.7	359	6.2	230

* 25 Sucres = U.S.$ 1.00

** Values From "Tabla de Composición de los Alimentos Ecuatorianos", Instituto Nacional de Nutrición Quito, 1965

*** Other food tables given lower protein content for lupines (30-35%)

**** Medium quality potatoes

Peas:

Consumption of peas is very low in all communities. Table 5 shows that in Morochos all farmers who plant peas consume the majority of the production green, while in Casco use is more evenly divided between young and dried peas. (This may reflect the fact that peas planted with barley are often harvested dry). Only in Morlan is production sufficient to have a supply of dried peas in the house for at least part of the year. Of the 7 instances of pea consumption recorded in Morlan in the diet survey, 6 were of dried peas ground to flour with maize and prepared as colada. This is a popular method of using dried peas, but production is so low that it is not encountered very often. As with beans, few farmers purchase peas (Table 6).

Broad beans:

Broad bean consumption is also very low, but Table 5 shows more of a tendency towards use of dried rather than young broad beans. Of the 5 instances of broad bean use recorded in the diet survey, 4 were as flour as part of a maize colada. As with other legumes, few broad beans are ever purchased.

Lupine:

Both Table 3 and 4 show that lupines are infrequently consumed. Their preparation requires that they be boiled, then washed for two days in running water. Many farmers thus sell their harvest and buy prepared lupines from time to time in the market place. More lupine is planted in Morochos than in the other communities because it does well on the poor sandy soils, and it serves as a minor cash crop. Even in Casco, where lupines are usually only planted in a few rows around the borders of the maize fields, more than half of the farmers reported selling what they harvested because of lack of access to water for their preparation.

Quinoa:

Quinoa is also little utilized, appearing as a component of only 5% of the meals in the diet survey. Table 4, however, shows a higher use of quinoa over a week's time. It may be possible to explain this anomaly by proposing that quinoa is utilized sparingly but fairly evenly over the course of the year. It is most often used as a soup ingredient.

Other foods:

Gourds and squash are planted between July and November and are often eaten young although they can be stored for several months. Their seeds are toasted and ground and used as a condiment. Wild greens are boiled in soups and gruels. Cabbages and onions are found as soup ingredients; the majority are purchased rather than home grown. Noodles are also purchased for soups, and occasionally bread is brought from the market. Table 3 illustrates the very low consumption of products of animal origin.

VI. DIETARY ANALYSIS

The type of qualitative data collected in these small surveys obviously imposes rather strict limits on the depth or precision of any analysis, but it is nevertheless possible to use this information, in conjunction with other data sources, to obtain a general idea of the dietary situation in the research area.

Energy:

In the first place it is obvious that the diet, although drawing on a fairly wide range of foods, places major dependence on a few staples, which are the principal sources of energy. Chief among these are maize and potatoes, and to a lesser extent wheat and barley. The supplies of these basic crops are generally low. Of those farmers who produce maize, 50% also report buying maize for household use; the corresponding figures for producers of potatoes, barley and wheat are 86%, 32% and 23%, respectively. Surpluses are rare; only 20% of maize producers report selling any of their production, while 11% of those producing wheat and none of those producing potatoes or barley report ever selling their crop.

Another indication of the character of the diet is the low number of meals consumed during the day - an average of 2.46 - and the fact that many of these meals consist of a single item. A series of dietary studies done in various highland Ecuadorian communities have consistently demonstrated inadequate calorie intakes.[1/]

Children's diets are not analyzed separately here because it was found that they generally ate what and when the adults did (with certain restrictions, discussed below) and that nothing special was prepared for them. That children's diets are insufficient can be inferred from growth rate data. A survey done in the Ecuadorian highlands showed growth rates for both height and weight well below normal.[2/] Similarly, a study done in the province of Cotopaxi showed depressed growth rates for children and adolescents.[3/]

Protein:

The situation for protein is a bit more difficult to analyze. Although there are a number of good sources of protein available, especially legumes and quinoa, they are underutilized in the daily diet.[4/] Beyond this, legumes prepared for adults are sometimes not given to children because they are said to cause stomach problems. This is especially true for lupines, and to a lesser extent beans and broad beans when prepared as whole grains. When

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1/ Instituto Nacional de la Nutrición, 1956, op.cit.; Vallejo, L., "Encuesta Nutricional de la Parroquia La Esperanza, Canton Pedro Moncayo", INNE, Quito, 1967; Instituto Nacional de Nutrición, "Encuestas Alimentarias en el Ecuador: Estudio de Nueve Poblaciones Rurales de la Provincia de Pichincha", Quito, 1960; Varea Terán, M. & Varea Terán, J. (eds.), Nutrición y Desarrollo en los Andes Ecuatorianos, Investigaciones Médico-Sociales del Ecuador, Quito, 1974.

2/ ICNND (Interdepartamental Committee on Nutrition for National Defense), Ecuador Nutrition Survey, Washington, 1960

3/ Varea Terán, M. & Varea Terán, J., 1974, op.cit.

4/ For Ecuador in general, there seems to be a lower consumption of legumes than in most other Latin American countries; see, Office of Nutrition, Bureau for Technical Assistance, USAID, "Planning National Nutrition Programs: A Suggested Approach", Vol. 2, Washington, 1973, p. 71.

broad bean or pea flour is part of a colada, however, it is given to children. On the other hand, if one looks at the protein: energy ratio of the mixture of dietary staples it would seem reasonably adequate; a higher intake of the normal diet may well cover any current deficiencies. There are few clinical studies, but the little evidence available shows no specific protein deficiency apart from the general protein-energy undernutrition brought on by low food intakes.

Other dietary studies in the Ecuadorian highlands are equivocal with respect to protein. One in Otavalo[1/] and another in Cotopaxi [2/] show diets to be adequate in protein, while a series in the province of Pichincha[3/] show protein intakes below those recommended[4/].

The data available also permit only a first approximation at assessing the quality of the dietary protein. The most outstanding feature is the almost total dependence on vegetable sources; meat, milk and eggs are rarely consumed. On the other hand, the protein comes from a wide variety of sources, so its quality is not dependent upon that of the principal staple. Although maize is the predominant item in the diet, it is complemented by a number of other protein sources. Table 9 shows the proportion of meals in the diet survey in which maize is eaten with other foods. In 29% of the cases maize is eaten alone, or with foods that are very low in protein. But in most of the rest of the cases it is eaten with foods whose protein contains a considerably higher proportion of lysine and tryptophan (see Table 10).[5/] In 11% of the cases recorded, maize was the only significant source of protein during the entire day. But even though maize is the sole source of

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1/ Instituto Nacional de la Nutrición, 1956, op.cit.

2/ Varea Terân, M. & Varea Terân, J., 1974, op.cit.

3/ Vallejo, L., 1967, op.cit.; Instituto Nacional de Nutrición, 1960, op.cit.

4/ But these are based on protein recommendations of the U.S. National Research Council, 1948, which are about twice as high as current recommendations (World Health Organization, Technical Report Series No. 522, 1973).

5/ Lysine and tryptophan are the limiting amino acids in maize.

Table 9

Maize Consumed with Other Protein Sources

Food eaten with maize	CASCO	MORLAN	MOROCHOS	TOTAL
Only maize, or foods low in protein	33%	30%	25%	29%
Barley, wheat	12%	4%	0%	5%
Potatoes, or potatoes + grains	35%	26%	36%	32%
Beans	10%	19%	3%	12%
Other legumes	0%	19%	5%	9%
Green leaves	0%	0%	23%	6%
Quinoa, lupine, etc.	2%	2%	3%	2%
Milk or meat	6%	0%	5%	4%
No. of observations	(42)	(57)	(40)	(139)

Table 10

Lysine and Tryptophan Content of Foods*

Food	Percent moisture	Percent protein	Percent protein/calorie	mg/g total nitrogen** Lysine	Tryptophan
Maize	12.0	9.5	7.3	182	38
Barley	12.0	11.0	11.8	246	96
Potatoes	78.0	2.0	6.9	351	103
Beans	11.0	22.0	22.5	471	63
Broad beans	11.0	23.0	23.7	416	54
Quinoa	12.0	12.0	12.6	409	66

*Source = Amino Acid Content of Foods and Biological Data on Proteins, FAO, Rome 1970

**by microbiological method

protein in a certain proportion of meals or even during an entire day, the diet of even the poorest families varies such that other sources of protein, with different amino acid patterns, are utilized in succeeding meals or days. A survey done at Otavalo[1/] calculated that 35% of dietary protein was derived from maize, thus it would seem unlikely that lysine would be as seriously limiting in this diet as it is in more heavily maize-based diets. A tentative conclusion may be offered that although protein intake is perhaps borderline in terms of quantity, its quality is probably not a reasonable target for improvement.

Other nutrients:

The very low intake of green and yellow vegetables recorded in the survey would lead one to suspect that riboflavin and vitamin A are in short supply, and quantitative dietary surveys done in the Ecuadorian highlands consistently report deficiencies of these two vitamins. A third nutrient whose intake is always reported as low is calcium, due primarily to the minimal use of milk products. How serious any of these deficiencies might be is not known. One study[2/] showed no biochemical evidence of riboflavin deficiency, but did find some low and borderline serum vitamin A levels. It also showed a significant incidence of low hemoglobin levels, but does not speculate as to whether this might be caused by low bioavailability of dietary iron or by other factors.

VII. RECOMMENDATIONS

The information discussed in previous sections must be interpreted in light of farming practices and technological possibilities in order to see how the work of the Production Research Program might respond to dietary and nutritional concerns.

1/ Instituto Nacional de la Nutrición, 1956, op.cit.

2/ ICNND, 1960, op.cit.

Maize:

It must be borne in mind that the Production Research Program focuses on maize in Imbabura because of its central place in the agriculture and in the diet. Research over the past four years has concentrated on this crop and will continue to do so for at least several years more, as much progress has already been achieved and more advances are likely to be made.

Maize is an important source of both energy and protein for the farmers of the region. Any increase in production would be welcome. Part of it would go to meeting the seasonal maize deficits in the diet which occur for many farmers while the rest would go either directly to market or to feed animals destined for sale. In either case increased production of maize would add to farmers' cash incomes, but what the dietary effect would be is hard to say. There is little likelihood that any modest increase in maize production destined for animals would contribute to an increase in meat consumption. Pigs, for instance, are, and will certainly continue to be, fattened almost exclusively for market. (Maize, mostly damaged or rotten, constitutes a relatively minor part of their diet.) Domestic sources of animal protein, principally chickens and guinea pigs, currently consume little and no maize, respectively, and any significant increase in the production of these animals would depend more on improved management practices.

What, then, are the possibilities for expanding maize production in the zone? In its first four years of work, the Production Research Program has learned several things. First, farmers' preferences restrict research, for the most part, to varieties of floury texture; progress in finding higher yielding varieties will therefore be slower than elsewhere because of the relatively limited genetic base breeders have to work with. Results to date have not shown any varieties that yield significantly better than the local ones, although research will continue with new lines, especially combined with improved management practices, in an attempt to increase maize productivity.

Research and inquiry have uncovered a way of increasing maize availability, however. More than 90% of farmers surveyed mentioned losses of maize in storage to rats or insects, in most cases both. Simple storage trials have indicated economical methods for better preserving maize, and experiments will continue in conjunction with INIAP's engineers and entomologists in order to design and test various storage containers and insect control methods.

The most exciting development from the on-farm research in Imbabura is the experience with early-maturing maizes. Chapter IV reported on INIAP 101, a white floury material that has found high acceptability with farmers. Its yields are close to those of local maize and it can be harvested up to two months earlier than the locals. This opens up a number of possibilities for improving production by planting two crops a year. In some instances it may be possible to get two crops of maize, if one is harvested green, but the more important opportunities involve rotations and associations with other crops.

Crop rotations with early-maturing maize:

One interesting possibility from both a production and a nutritional standpoint is a rotation of early-maturing maize with peas. Many farmers currently attempt such a rotation, harvesting a small section of their maize when it is green and planting peas. With INIAP 101, the maize could be harvested dry and there would still be time for a crop of peas. People enjoy peas both green and dried and an increased production would certainly have a dietary impact.

On-farm experiments have begun testing this rotation, utilizing both local pea varieties and improved varieties which mature more rapidly, under several different planting practices. There is every indication that it will prove to be a viable and productive rotation pattern, but farmers' responses to survey questions about peas indicate that a number of management problems such as diseases may still have to be investigated.

As the planting of early-maturing maize expands, especially as new yellow varieties are introduced, it is likely that a considerable proportion of maize land will be planted to these new types. It is therefore important to consider other rotations. One possibility would seem to be with potatoes. Most farmers plant potatoes and they are an important part of the diet. Their low production means that they represent an important part of household food expenses, using money earned principally through off-farm labor or sale of animals. It would be particularly valuable to give farmers the possibility of harvesting potatoes at several different times of the year. It is impossible now to get a crop of maize and a crop of potatoes out of the same field in one year, but with early-maturing maizes it may be feasible. Farmers use more inputs on their potatoes than on any other crop, so a maize-potato rotation would offer the possibility of experimenting with a number of management practices. Fertility and disease problems are serious limitations to potato production in the area, and these can be dealt with through better management. Many farmers say they would plant more potatoes if they had more land, and the early-maturing maize will, in effect, give them this opportunity.

Intercropping with early-maturing maize:

It is important to remember that virtually all maize is intercropped with beans. An early maturing-maize requires an early-maturing bean, and the short slender stalk of INIAP 101 cannot tolerate beans that are as aggressive climbers as most of the local ones. Thus it is of the greatest importance to develop bean varieties that can be introduced with the new maizes. Trials have been planted with a number of different bean varieties, and some promising lines have been identified, but work must be accelerated here, for if short season maizes are not grown with beans much of what they offer in terms of new rotations will be cancelled by the loss of this important source of protein. Work with beans is made considerably easier by farmers' preference patterns. Farmers plant a wide variety of beans, and although certain types are better for the market there are no strong preferences as to color, size or shape for home consumption.

Broad beans are also planted in maize fields, either in separate rows or, more commonly, in between maize plants. The early-maturing maizes offer opportunities to continue and even expand this practice, for the smaller plant of the new maize types, with fewer leaves, offers more room and sunlight for associated crops. Broad beans are also planted separately, but this practice seems to be dying out, as diseases have become a serious threat in the past few years. Most farmers report that they do not plant more broad beans because of low yields due to disease. It seems fairly obvious that this important source of protein is disappearing. People often complain that they no longer have broad bean flour to add to their maize gruels. The dietary survey done near Otavalo in the early 1950's[1/] reported a consumption of broad beans equivalent to about 15% of total protein intake; the dietary studies reported here show broad beans included in merely 2% of meals consumed. Some preliminary work should thus be done on looking for new lines of broad beans or developing other methods to solve the disease problem.

Other crops:

The above suggestions represent short-term recommendations for on-farm research work which take account of dietary considerations. The goals presented here are few in number because it has been found that on-farm research is much more effective when it works with well-defined priorities, rather than trying to treat a wide range of problems. On-farm research attempts to take account of the complexities of the local farming system, but seeks key points of entry where rapid progress can be achieved. Most of these nutritional goals represent areas where the experience of the Production Research Program has indicated that progress is eminently feasible over the short term.

Barley and wheat are quite important to at least a part of the research area, but the Production Research Program has assigned technicians to work on these crops in the neighboring area of northern Pichincha Province, and it would not seem worthwhile to duplicate that work in Imbabura at this time.

1/ Instituto Nacional de la Nutrición, 1956, op.cit.

Quinoa is often cited as an underutilized crop of high nutritional value, but data do not indicate that it should receive priority at this time. Dietary surveys from the Ecuadorian highlands show consistently low intakes of this crop, typically 5-10 grams per person per day. It appears in only 5% of meals examined in the current study. No one in the study was heard to complain of shortages of quinoa, and only 4 out of 30 farmers reported ever buying quinoa, even though it sells for just a little more than other local grains (Table 8). Farmers plant some quinoa, usually associated with maize or potatoes, but report a wide variety of reasons for not planting more. Chief among these is lack of space. Quinoa takes so long to mature that there would not appear to be too many rotation possibilities with the new maizes. If higher yielding varieties are developed, particularly "sweet" ones without the saponin which makes preparation of quinoa so difficult, then there would certainly be reason to experiment with them, especially in higher zones, where quinoa is one of the few crops that will grow. But for most the research area it must be kept in mind that although quinoa is a crop of excellent nutritional quality it is only one of a number of options. Supposing, for example, that current quinoa production is 10% that of barley (certainly an overestimate), the extra protein that would be produced by doubling quinoa yields could be achieved by a mere 15% increase in barley production. Similarly, broad beans are comparable to quinoa in calcium and riboflavin content (the micronutrients for which quinoa is most often promoted) and seem to be more in demand.

Lupines are an excellent source of protein (with a content of 35% or higher) but survey data show their consumption is low even among farmers who plant a considerable amount. The principal drawback seems to be the difficulties in preparation, and it is likely that any increase in production of this crop would not find its way into the diet of these farm families. A further problem, as we have seen, is the fact that lupines are often withheld from children.

As current sources of riboflavin and vitamin A, the pot herbs that grow wild in the maize fields are undoubtedly important, and probably under-reported. Although it may be possible in the long run to introduce better sources of these nutrients, the nutritional importance of these "weeds" should be borne in mind in considering the feasibility of herbicide trials, although other factors preclude the likelihood of producing any kind of economical herbicide recommendation for this area for some time to come.

VIII. SUMMARY AND CONCLUSIONS

The purpose of this paper has been to illustrate some methods for deriving dietary information which are consistent with the resource constraints and philosophy of an on-farm research program. The emphasis has been on simple methodologies which can develop information that is quickly available and comprehensible to those who will use it. Some of the conclusions drawn from the Ecuador experience are:

- It is possible to include questions on diet in the types of formal surveys carried out by on-farm researchers. Questions can be asked about varietal preferences, common preparations, marketing habits, and household food supply[1/]. These questions, like others in formal surveys, are best designed after informal, exploratory survey work.

- For more dietary information, a qualitative 24-hour recall gives a good idea of the frequencies of consumption of various foods and can be used to disaggregate household consumption patterns as well. Although it is outside the capabilities of most on-farm research programs, its qualitative emphasis makes it easy to apply and analyze for people who have had a minimum of training in dietary surveys[2/].

1/ See also "Demonstrations of an Interdisciplinary Approach to Planning Adaptive Agricultural Research Programmes: Part of Serenje District, Central Province, Zambia", CIMMYT East Africa Economics Program, 1978, for another example of farmer surveys which include questions on preferences of staples, seasonality of diet and uses of secondary crops.

2/ Qualitative survey methods are now being used with increasing frequency. See for instance, Sierra Leone: National Nutrition Survey and United Republic of Cameroon: National Nutrition Survey, Office of Nutrition, Development Support Bureau, Agency for International Development, Washington, 1978.

- In a qualitative dietary recall which will be of use to on-farm research, it is advisable to ask other questions which will help in analyzing the food system:

    - How each food is prepared

    - The type or variety of each crop that is being used

    - The source of each food, whether from the farm, market, in exchange or as a gift.

- Informal questioning and casual observation provide excellent opportunities for studying matters that are complicated (e.g. food beliefs), sensitive (e.g. marketing) or long term (e.g. seasonality). On-farm research technicians are in constant contact with farmers during the management of trials and can use their conversations with farmers and their families to learn more about these issues.

- In short, there is a variety of methods that can be used to efficiently deliver practical information on diet to on-farm researchers. The choice of method will depend on research resources and the nature of the problems being studied.

Although qualitative methods provide much information for understanding dietary patterns and preferences, they obviously will not always be sufficient. There are certainly cases where quantitative dietary surveys and other specialized nutritional studies would be called for. Judgements on the adequacy of the diet in Imbabura in this study are based on qualitative recall data, information on food supply and secondary sources, and more careful examination of certain questions would probably be helpful. But quantitative investigations are much more efficient if they are focused on questions that have been identified through simpler methods.

This paper has argued that dietary and nutritional information is often necessary to on-farm research, both for ensuring that technological change contributes to improving the welfare of the rural poor and for helping identify technological alternatives that are compatible with consumption preferences. In the case of Imbabura, there is substantial congruence between nutritional and production goals. Both point to a strategy which concentrates on the floury maize-bean association and which seeks to increase total productivity by looking at possibilities of rotations with an early maturing maize. Both can capitalize on farmer interest in such crops as broad beans as well, where production increases would make a real contribution to the diet.

But there are other areas where production specialists and nutritionists might disagree. There is, for instance, interest among breeders in maize grain types particularly suited for mote (boiled maize). But this is more commonly consumed by the wealthier, urban part of the population and breeding efforts there would draw attention away from the types of maize which poor farm families consume, toasted or in gruels. There is considerable interest at the national level in developing quinoa production as well, because of the crop's nutritional quality, but data on diets and cropping patterns show that increased quinoa production would have little nutritional impact. A similar argument can be made against lupines, in which there is also interest. In another area, nutritionists would urge caution in using chemical methods of weed control with farmers where pot herbs contribute heavily to the diet.

On the other hand, nutritionists will advocate certain strategies in which production specialists may have little initial interest. One example might be certain types of rotation experiments with short-season maize. These should be done with potatoes, which contribute heavily to the population's calorie supply, as well as with more marketable but lower yielding crops such as peas. Another is the possibility for improving maize supply, especially among the poorest farmers, by developing better storage facilities.

In these cases, nutrition advocates and production specialists will debate, and they may have to call upon more detailed information on production possibilities, marketing behavior of households and specific nutritional problems in order to choose acceptable strategies. More serious conflicts may occur in agricultural production programs which significantly change cropping patterns, alter labor or land use, or ignore or jeopardize the poorest, most nutritionally vulnerable families. These sorts of problems can only be resolved within a well articulated national or regional policy for rural development which has the active participation of nutritionists.

In many instances, a more integrated approach to nutrition is undeniably helpful. Such an approach might include other institutions carrying out programs to improve water supplies, provide better health care, design nutrition education programs, alleviate women's work loads, and ensure wide access to productive resources and employment opportunities. A program of on-farm research such as that described in this paper would stand ready to coordinate its work with this type of effort. But this approach requires that the various institutions design their programs so that they build on field experience with their clientele, rather than emerge full-blown from a planner's office.

LIST OF AVAILABLE CIMMYT ECONOMICS WORKING PAPERS

No.

81/1 Kwasi Bruce, Derek Byerlee and G. E. Edmeades, "Maize in the Mampong Sekodumasi Area of Ghana; Results of an Exploratory Survey".

81/2 Derek Byerlee and Donald L. Winkelmann, "Accelerating Wheat Production in Semi-Arid Developing Regions: Economic and Policy Issues".

*81/3 Edith Hesse de Polanco and Peter Walker, "A Users Guide to FASAP- A Fortran Program for the Analysis of Farm Survey Data".

*81/4 Alan Benjamin, "An Agro-Economic Evaluation of Maize Production in Three Valleys of the Peruvian Andes".

*81/5 Derek Byerlee, Larry Harrington and Paul Marko, "Farmers' Practices, Production Problems and Research Opportunities in Barley Production in the Calpulalpan/Apan Valley, Mexico".

81/6 Larry Harrington, "Methodological Issues Facing Social Scientists in On-Farm/Farming Systems Research".

*82/1 Larry Harrington, et al., "Maize in North Veracruz State, Mexico--Farmer Practice and Research Opportunities".

*82/2 Larry Harrington, "Exercises in the Economic Analysis of Agronomic Data".

**82/3 J. C. Martínez, "Desarrollando Tecnología Apropiada a las Circunstancias del productor: El Enfoque Restringido de Sistemas de Producción".

82/4 Robert Tripp, "Data Collection, Site Selection and Farmer Participation in On-Farm Experimentation".

82/5 Robert Tripp, "Including Dietary Concerns in On-Farm Research: An Example from Imbabura, Ecuador".

82/6 Derek Byerlee and Edith Hesse de Polanco, "The Rate and Sequence of Adoption of Improved Cereal Technologies: The Case of Rainfed Barley in the Mexican Altiplano".

* Available in English and Spanish
** Available in Spanish only