THE PHYSICAL FARM BUDGET: AN INDIGENOUS OPTIMIZING MANAGERIAL ALGORITHM

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Abstract:

In the debate on peasant rationality, no one has asked whether peasants have the kinds of relatively complex formal models that rational calculation requires, and, if so, whether the use them and whether they produce the results they seem to predict. The answer is "yes" in all cases, and the models can be elicited and displayed as a computer spread-sheet. This paper provides and demonstrates such models from two farms in one area in eastern Maharashtra state, India, that readers can download and examine on their own.

INTRODUCTION

In the long debate on peasant rationality, no one has asked whether peasants have the kinds of formal models that rational calculation requires, and, if so, whether they use them and whether the models are in fact accurate. I do not mean just decision models that provide rules for binary choices or other such simple decisions (Barlett 1980), or even whether one can apply something like a game theory model to their behavior (Barth 1959). Both these points are well established, but do not get to the heart of the matter. I mean whether we can find an actual optimizing algorithm, present as a conscious item of culture in its own right. The answers are that there are such algorithms, they are used, and they are accurate, in the sense that they lead to precise and replicable results. Given the same input, they yield the same outputs, exactly.

In South Asian peasant agriculture for certain, and probably in all peasant agriculture, there is not one such model but a system of them. The most central of these can be elicited and displayed in a spreadsheet[1] and looks a great deal like a linear programming model. Moreover, although it is not a linear programming model in the way one arrives at its solution mathematically,[2] it works the same way functionally. It permits conceptual iterations that

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[1] I prefer the term model to alternative usages, such as schema, for two main reasons. One is that it conforms to current usage in farm management and related areas, in which one speaks of planning models more than planning schemas. The second is that I think what people have in mind actually is a mental construct, an image of their actual farm, that they use to plan for that actual farm much as ancient architects, boat builders, and engineers used physical models.

[2] Mathematically, the simplex model is a system of simultaneous equations, each representing the inputs and

progressively close in on an optimal solution. Since the models are moderately complex I will confine myself to demonstrating just two, but it should be obvious that it will be like demonstrating the existence of a new species of plant from one specimen. In the nature of the case, because of the way such things must reproduce themselves, where there is one there must be more, as well as the context that sustains them.

That peasants think rationally follows from the presence of such models. There is no reason for the existence of the models except as a tool for such thought, for discussing and making the kinds of decisions the model formalizes. Their presence testifies to their use just as the presence of yardsticks would testify to the practice of measuring linear distance and sextants the practice of measuring latitude. Of course it is not evidence that they think rationally all the time and for all purposes, any more than the presence of similar models in our society is evidence that we do. No one has ever claimed that peasants are more rational than we are, only that they are no less rational. The argument for peasant irrationality was mainly advanced with respect to thought that ought to have been rational from our own point of view, which is to say thought that *prima facie* was or ought to be instrumental, aimed at solving practical problems. And since peasants are preeminently farmers this thought should have to be preeminently the thought that goes into their farming activity. This is what the evidence of the model addresses with the greatest possible directness.

Before giving the models themselves, I will very briefly indicate just what kind of thing they are and how they were elicited.

MODELS AND CULTURAL SYSTEMS

The best way to describe what these models represent is as the farm family's physical farm budget. Every productive enterprise must balance its books, but how it sets up those books must vary depending on what it produces and what it uses. These models are the books for peasant farms, which is to say for subsistence farms in which a large part of the energy and

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desired output (objective function) for one productive activity. For farm planning, to make the relation between input and output linear the output (objective function) is usually money and one of the inputs is land by unit area. The system is solved step-wise, according to criteria that amount to assigning the most possible resources to the activity that makes the largest apparent initial contribution to the overall objective function, then adding further activities to make the best use of resources still unused. Although linear programming layouts for agricultural planning resemble the present model in form, using one line to represent one output with its contributing inputs, it seems to me impossible to write the present model as such a computable system for at least four major reasons. First, linear programming is too narrowly constrained to represent all the internal checks on consistency that this model has. Second, the farm budget has a large number of internal transfers in which one input leads to many outputs. Linear programming computer routines have a very limited capacity to deal with such transfer functions. Third, this model allows for adjustment over time and linear programming models require a fixed time period. Fourth, computational procedures for linear programming generally are limited to two objective functions. This works well enough in commercial farming when the aim is usually simply to optimize profit. For these farms, whose aim is to provide shelter, cash income, and a balanced diet, each activity provides more than one output (such as cash plus food of a certain type plus fodder of a certain type), so that I cannot see how the total number of objective functions could be less than about twelve (four major types of fodder, six major categories of food, plus cash).

resources used are produced on the farm itself. I have elicited them literally from north to south in India and from Gujarat to Bangladesh[3], and am quite sure from conversations with farmers that very similar models exist as far afield as Japan to the east and Italy to the West. They are analogous to kind of books that might be kept in a commercial firm, but they are not homologous. The reasons lie at two levels, one pertaining the idea of the firm as a pure theoretical construct, the other to the idea as a practical ethnographic reality, used by actual commercial enterprises.

As a pure theoretical construct, the main problem with the idea of the firm is its theoretical presumption that the only constraint on changing the scale of operations is available funds: that you can obtain more land, labor, or whatever other resources are needed if you pay the price. This is in fact very often not the case even for firms, and almost never for peasant farms.

As a practical ethnographic reality, a cultural construct in its own right, the problem with the idea of a firm is that by evolved convention it is considered appropriate in such an enterprise to conceptualize all resource flows in terms of money, to measure performance by profit and loss, and to do this by considering costs for the time of labor and management as expenses to be taken out of income before the final balance is struck, thus externalizing the costs for maintaining the workers' households, educating their children, providing for their health, helping them with searches for employment, and the like. Peasant farms cannot be accurately conceptualized this way for two main reasons. First, in a family farm like these maintenance of the farm family is as much income as it is cost. It makes no sense to assign a charge to the farm account for the value of food given to family members to eat without crediting the farm account with the same amount as farm income, since the family members who get it are at least as much the equivalent of plant capital as they are the equivalent of hired workers. Second, many of the important resources are simply never paid for and most likely are never going to be sold. They are produced internally and consumed internally. They do not need to be accounted for monetarily, and very often it is needlessly confusing to try to do. But they do need to be accounted for physically. The farmhouse is very often built out of local materials and by the farm family, the people themselves are born and raised, not bought to hired, and the same is often true of the animals.[4] What peasant

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[3] In India, I personally elicited a total of 46 budgets from families in four states: Maharashtra, Gujarat, Rajasthan, and Punjab, in addition the generalized model for a "typical" farm in all these same states plus Tamil Nadu. In Bangladesh, I subsequently incorporated the questions necessary to fill in the model in a survey I designed to assess people's priorities in responding to floods, and field interviewers returned consistent results for all the households in the survey, totaling 2,264.

[4] This may be what Chayanoff was trying to capture when he portrayed the peasant farm (in Russia) as entirely self-contained. Perhaps it was in Russia at that time, but if so this would be a largely unaccountable exception to the historical and archaeological general rule, which is that mathematics, agriculture, and agricultural trade have developed together. Moreover, there are strong reasons for such an association in the nature of agricultural production. Bluntly, no set of cultigens can so closely match the farm consumption needs as to yield a set of products and by-products that are all of equal marginal utility on the farm, and of greater utility than what might be available from off the farm. If grain is sufficient, straw will be in excess. If milk is abundant, there will be more calves that family may be able to keep, and so on. The consequence is that any subsistence-oriented system in which individual farm families neglected the opportunities for trade would in the nature of the case be less efficient that did not.

farmers, with limited financial resources and committed to farming as a lifetime venture, have to be interested in is the growth or contraction of their *physical* establishment. Concepts of profit on operations exists and are important, but as a contributing factor in this growth or decline and not a surrogate for it. In economic or commercial terms, what the physical farm budget does is conceptualize the animals, people, land and buildings as fixed or sunk costs that do not need to be calculated, but that have certain maintenance requirements. The purpose of the budget is to consolidate those requirements and plan how to meet them. If they are met in any given year, the farm breaks even. If they are not it is a loss year, and if they are exceeded it is a good year, comparable to a profitable year, in which the enterprise may grow.

The farm budget model is a cultural model. It is not my invention but theirs. It is, moreover, part of a system of logically interrelated cultural models that constitute a cultural system, one of several. This particular cultural system can be described as the system of management—the cultural system that provides the algorithms for bringing resources together in workable and mutually acceptable and enforceable combinations.

No society has culture as a Tylorian whole, either as a monolithic pattern "of and for" behavior as Tylor originally meant it or in what appears to be Geertz's sense of a unitary interpretive schema. What is observable ethnographically and what we learn and reproduce as cultural participants are discrete cultural systems. Each has its own distinctive content and its own logic and type of logical closure. And for the more elaborately organized ones, each also has its own formal learning and teaching conventions, self-reproducing bodies of experts who serve as custodians, sanctions, and established genres of symbolic mnemonics. In 1964-66, when I first tried to elicit such systems in a village in Punjab state with a view to seeing precisely how many there were, how they were delineated from one another, and how they maintained their integrity, the answer was that there were six in substantially universal consensus in the village and a large number of others held by only a few people as specialized lore. The systems in substantially universal consensus were kinship, the Sikh religious tradition, parties or factions, the division of labor (the ideas by which people bring themselves together as occupational units), economics (system of prices and market conventions), and ecology (knowledge of the village as a biological community) (Leaf 1972, 1984). Others were sets of ideas for religious traditions other than Sikhism, extra-village organizations like the government courts, and the lores of specialized occupations. .

In Punjabi and other North Indian languages, the general term for what I have described under the heading of the division of labor would be *parbandi*, literally binding together. In my first village studies, although I elicited the ideas by which this was done and spoken of generally, I did not then elicit the budget model as such. The reason was not that it was not there. The reason was that I did not realize there might be anything quite so sophisticated and therefore did not follow up the clues that suggested its existence. I had assumed households had budgets and had asked about various components that might be economized individually in some way or another, but it did not occur to me that they might be brought together in a way that was so specific and so well formed—that there would be, in effect, a formal cultural hyper-model. I did, however, come away with substantially all the information it incorporates, some of which comes from elsewhere in the division of labor, some from the ecology and some from the economy. These included the specific knowledge of how to grow each crop and process it, very well-formed conventional ways to calculate costs and gains on specific crops, rules and techniques for knowing what one has in storage and how fast it is being consumed, rules of thumb for diet planning, standard menus and recipes with understandings of how much of each crop product yields how much final food product, systems for recycling, the division of household tasks, and elaborate conventions for obtaining services in exchange for commodities in such a way as to include a provision for maintenance in all labor arrangements for labor hiring.

I first recognized that such ideas must come together in something like the farm budget model in a subsequent project, concerned with the operational efficiency of India's irrigation projects. Although in this case I was acting as a development consultant and not a pure ethnographer, the issue was the same: rationality. The aim of the project was to improve irrigation productivity by improving the cooperation between farmers and the irrigation administration. Pursuant to this, the project had designated five sites in the five main cooperating states for "action research," were we would attempt to design and implement improved practices. Although the phrase was taken from Sol Tax, by the time it circulated through the development community for more than a decade and then filtered down through several layers of USAID and Indian government bureaucracy, with important informal input from the World Bank, the idea was something rather different. The emphasis had very largely shifted away research and onto action, understood as obtaining quantitative changes that could be reported back up the chain of command as improvements.

In Tamil Nadu, the predominant opinion in the irrigation and agriculture departments that were associated with the project was that the way to improve productivity was to change the farmers. My view was that it was more likely to be to change the departments. Their view was that they had to promote more "scientific" farming: greater use of fertilizers, improved seeds and pesticides and, as a concomitant, more rigorous water control. They saw their job as telling farmers what this involved. They recognized that farmers were resistant to their suggestions and attributed this resistance to irrationality.

The alternative view was that it was the recommendations themselves that were irrational. Specifically, that they did not in fact justify the additional expense and effort they required. Although there were many good reasons to suspect that this was the case, abstract argument with officials in such situations is generally useless. What works, if anything, is concrete demonstration, and the way to conduct such a demonstration is to give the farmers an opportunity to speak for themselves in a convincing way when the officials are present and listening. Accordingly, early in my term of consultancy, when I was first introduced to a group of about twenty five senior farmers from the two villages in the action research area in a formal public meeting, instead of lecturing them on the importance of good practices (which I think had been expected), I took the opportunity to do some ethnographic interviewing instead.

The meeting was in a clearing along a canal minor toward the tail-reaches of the Cauvery delta in the fall of 1987. The farmers were seated on rows of benches, the officials standing around, and two officials and I were seated on chairs before them. After I was introduced, rose, and briefly stated my purpose and my concerns, my question was whether they followed the recommended practices. One older man in the center of the group raised his hand, I recognized him, and with absolutely no hesitation he said they did not. Everyone else indicated agreement. My next question was why. The same person said they did not have the money and the others again agreed. I asked what the costs were, and the entire group immediately went down the items of expense for a typical rice crop and compared it with the gains. The result was a net return of 14% over costs. Further, since cooperative interest rates are about 12% and the penalty for late payment is an additional 6%, borrowing made no sense. They would therefore have had to put up the money out of savings, which they did not have. With cheaper inputs (which meant not following the recommended practices), they could come out "a little ahead" in most years. The others were absolutely firm in their agreement. There was no dissent.

I was not surprised that the farmers could support their claim in a way that could not possibly considered to be contrived for the occasion (since neither they nor the officials had any reason to expect these questions). It was precisely the sort of detail I had expected on the basis of my work in Punjab. But I was immediately struck by the level of consensus in the group as a whole and the narrowness of the spread between what was an acceptable margin of gain and what was not, the precision of their idea of "a little ahead." What it implied was that these cost figures themselves were not all that was well established in consensus, but that there must also be an equally well established consensus on some larger picture that they fit into, and if I was to head off the predictable objection that the farmer's costs were somehow not "real" costs or were offset by gains elsewhere, the obvious next step was to see what it was.

Accordingly, my next question was whether there was a "typical" farm and, if so, what was it and what would it grow? The answer was relatively quickly given in terms of number of people in the farm household, its animals, land, and crops, and their respective consumption and production, and it was clearly no less well established than the statement for the single crop. The question after that was whether the numbers added up. Were the elements of the description of the "typical" farm capable of being set down as a system that could logically balance? I had not brought my laptop with me, but set up the first spreadsheet when got back to Delhi. It was indeed internally consistent, and I developed it further in subsequent visits with the same group in Tamil Nadu, and in other states with comparable groups. Depending somewhat on the crop, it turned out that the estimates of the model were consistently within about 2 to 5 percent of what farmers said was their actual surplus or loss on each item they produced, and overall.

In short, while the books do not balance "to the penny" they balance a great deal more precisely than one might expect for a running farm, and give a good deal more precise account than the conventional farm budget analyses that treat farms as firms (Leaf 1998:44ff,; Neale 1990).

ELICITATION METHOD

After the first few exploratory interviews, the elicitation procedure I settled on involved three major steps. First, walking around the area and usually in the presence of what I was asking about, I would ask for the constituent information used by the model but separate from it: inputs, products and by-products for all the crops with their uses, prices, rotations and growing seasons, menus for the year, recipes (if I did not already know them), ecological constraints, and broadly all other major features of the area that were likely to affect crop planning, such as whether farmers had confidence in the quality of fertilizers they bought from government sources, or whether credit might be available for some crops as not others. Second, I would discuss the model as I had developed it up to that point with a group of farmers in general terms, to be sure the variables were real to them and to get general estimates to use in the internal computations of consumption, production, and surplus or deficits. These would include how much of each food-stuff was normally allowed for a man, woman, and child, what a child was considered to be, what consumption allowances were made for fodder, what things were used for fodder, and in general everything that would not vary, or not vary much, from farm to farm. On this basis, I set the general formulas for totaling food consumption and fodder consumption in each row in a way that would reflect the local system[5]. This gave me a prototype model for the area. Then, finally, with the help of people from the local action research team, I visited specific farm families on their farms or groups of farmers in a village area and filled in this prototype model for each specific farm, modifying it as the progress of the interviews showed to be necessary and spot-checking a few specific conceptualizations in each interview to be sure that practices that I judged to be uniform were uniform in fact.

The reason for interviewing in groups was that if a person wandered off into unreality it would be very likely to be detectable from the reaction of others around him. Also, as is often the case for knowledge that is in fact held and used collectively rather than merely personally, individuals with different responsibilities in the family division of labor did not always know all the values for all crops or crop products with equal assurance, and it was often helpful to have the views of several people before arriving at a final conclusion — just as it would be in an actual planning discussion.

Since the spreadsheet was built up on the computer during the interview, some internal cross checks were automatic, but others were not. The spreadsheet could not tell me, for example, whether all the areas reported as farmed at each point in the year added up to no more than the total land available. Accordingly, I would have to go through them afterwards to be sure they made agronomic and physical sense as well as mathematical sense. When this revealed difficulties, I would generally come back to the households on a return visit. But some uncertainties, particularly pertaining to fodder usage, simply were inherent in the nature of the material. Some fodder is usually in the form of a material that can be stored and allocated in measurable quantities, but much is in a form that is cut daily and immediately consumed. In this case, its weight and bulk are not only not relevant but actually very variable. In such cases, mutually understanding the problem of producing a good representation, we simply worked with the farmers to make the best estimates possible.

The interviews were generally conducted with the help of a local official from the irrigation department I was working with in each state, most often their agronomist[6]. They

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[5] This is not to say that there was just one precise local system of measurement and that it was adhered to rigidly by everyone. In fact, each family used a hodge-podge of units and techniques. For example, fodder was consistently measured in volume, but foodstuffs were sometimes measured in volume and sometime by weight, and in both cases farmers usually had no trouble at all moving back and forth between metric, English, and several different local systems of units. Rather that I would get agreement on common units that the spread-sheet could accept and that every person could translate their household units into.

[6] The agronomists' own local knowledge was further assurance of empirical accuracy. Of course it may be asked whether they were rendering what they were told accurately, and the answer is that they were. While I do not

usually knew the people and the area personally, and uniformly took a substantial interest in the process. Those with agricultural backgrounds had as a rule always been uncomfortable with the "blame the farmer" mentality implicit in their agencies' claims of farmer irrationality and were happy to find the support in the kind of undeniable evidence the spread sheets provided[7]. Those without such backgrounds were usually engineers, and still thought of themselves as empiricists, understood evidence, and as a rule quickly came to see what they had been missing. No one, to my knowledge, in the end claimed that the models were only my invention or anything other than real things really described.

THE CASES

Both models presented here are from a group of seventeen elicited from farmers in four villages in the Pus irrigation command in Eastern Maharashtra, India, in March, 1988, in a sequence of visits extending over about eighteen months. I have presented both these tables elsewhere in print, in the context of a fuller discussion of the agricultural practices they represent (Leaf 1998: 108). Here, I want to take advantage of the ability to include live spreadsheets to concentrate more on their inner logical structure and, on that basis, their epistemological character. In both cases, the table presented in the running text is a static "snapshot" from the spreadsheet, since the spreadsheet itself cannot be incorporated in the adobe format, but the full spreadsheet can be downloaded as a Microsoft Excel file by clicking on the title.

The first model is from one of the simplest farms, the second the most complex. The simple model is from the poorest farm in the smallest and most remote village, and the farmer was engaging in almost all the practices that those who see farmer as irrational have at one time or another blamed for the persistent failure of irrigation projects to yield the returns their planners had expected. In the second case, the farmer was from a much better-off village and was among the most "progressive" in the region.

The geographical characteristics of the Pus area are very well suited to an irrigation project of this type. It is a broad valley flanked by low mountain ridges, that receives relatively heavy summer rains but very light and irregular winter rains. In theory, therefore, a storage reservoir that could fill in the summer and support a winter crop should greatly increase the marginal return to fixed farm assets, as well as general security. The problem, from the point of view of the irrigation authorities, was that this was not happening, in two respects. First, farmers were not changing from their traditional crops to the recommended commercial crops that would, in the official view, be more remunerative to the farmer, more valuable to the country, and

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speak Tamil at all, many of the farmers in Tamil Nadu spoke English. In Gujarat, my situation was similar. In Maharashtra, Marathi is close enough to Hindi and Punjabi that I could generally follow the interviews although I could not conduct them, and since it is written in the same script as Hindi I could read the farmers' own records, crop records of the action research team, and the like.

[7] Each state institute had a teaching center with a computer facility. After the spread sheets were made up, I would place them on these computers and train one or two people to access and use them, generally including whoever had been with me for the interviews. My hope was that these would then find their way into the teaching program.

provide more tax revenue to defray the costs of the irrigation system. Second, farmers were not irrigating nearly as much land as had been projected. The command was designed for an intensity of 114%, meaning that it could provide irrigation for the entire area for one season and 14% of the area for a second season. The actual intensity was 42%. The two points were related, in that the design intensity was predicated on the recommended crop mixture. Farmers were in fact using all the water, but applying it to different crops that occupied less area than had been projected. Mainly, they were keeping much more land than recommended under rainfall crops in the summer monsoon season and concentrating the irrigation on cane which grows for twelve to fourteen months and on wheat and groundnut that grow only in the winter season. Groundnut had not been in the official plan. For other crops, the areas grown were never even close to the areas recommended—differing not by percentages but by large multiples (Leaf 1998: 61). As in Tamil-Nadu, from the official perspective what needed to be done was to change the farmers and my task was to help them do so. From my perspective it was first of all to find out why they were growing what they where.

1987-88 was not a good year. The rains in the previous rainy season (summer, 1987) had been light and the winter rains had failed completely. Since the irrigation reservoir had filled to only 35% of capacity, each user was allowed 35% of the normal water and usage was more tightly restricted near the tail ends of the system (to minimize losses from seepage). There had also been heavy white-fly infestations in cotton and other crops. Cotton yields were no better than a third of normal, often nothing. In the portion of the command area represented by the first table, irrigation was only being allowed for sunflower, which the irrigation department was attempting to promote as a water-saving cash crop in place of groundnut. This farmer received a permit for one acre[8]. There were few good wells in this village, and this farmer did not have one. Table 1 gives his actual cropping pattern for the two seasons beginning mid-April 1987.

The model represents the disposition of resources, most explicitly land, required to provide the family with a relatively fixed customary menu of food and fodder, and for the monetary and non-monetary means to maintain their house and equipment throughout the year. Each row represents one of the required food, fodder, or cash crops or crop components. The columns represent what the farmer considers in order to know how much of it to produce and what a failure to do so will imply.

For the food section, the columns represent the amount consumed by an adult male at each meal, the actual numbers of people of each type, the yields the farmer can expect if he produces the material on the farm, the price of the item in the market, and the number of meals per year in which the item is consumed. In this region, families prepare meals twice a day, and meals generally consist in either rice or a bread made of wheat or millet with a side dish of curried pulse[9] or vegetable. If pulse, it is from the previous crop season. If a vegetable, it must

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[8] Maharashtra uses a system of allocating canal water only against applications. The department advertises the crops and areas that farmers may apply to water. Others will not be sanctioned. For this season at this part of the command, sunflower was the only crop allowed. The application system is described in Part III.

[9] A pulse is any bean or pea.

be picked fresh. The meals are taken in the late morning and evening; breakfast is tea and something left from the previous evening.

TABLE 1: POOR FARM, REMOTE VILLAGE, PUS 1987-88

FOOD	Gm/ Meal	No. Men	No. Wom	No. Child	Yld. Q/acre	Price/ Kg.	Meals/ Yr	Acres Req.	Acres Sown	Rs. +/-
Sorghum	275	3	2	0	4.5	1.25	650	1.99	2	7.81
Wheat	200	3	2	0	8.67	2.8	80	0.09	0	-224.00
Rice	50	3	2	0	15	4.75	0	0.00	0	0.00
Tur w/C	55	3	2	0	0.625	7.5	365	1.61	2	184.69
Mung	55	3	2	0	3	4.5	365	0.33	1	898.31
Veg.	80	3	2	0	40	3	0	0.00	0	0.00
Oil	12.5	3	2	0	4.5	23	730	0.10	0	-1049.38
Sugar	27	3	2	0	12	5.7	730	0.08	0	-561.74
Chilis	3	3	2	0	10	30	730	0.01	0	-328.50
Total								4.21	5.00	-1072.80
FODDER Crop	Bun/day Pair	Ox	Buff.	Cow	Yield Bun/ha	Rs/ Bun.	Days/ Year			
Sorgh. Dry	8	2	0	0	500	0.75	125	2.00	2	0.00
Sorgh. Wet	6	2	0	0	500	0.75	0	0.00	0	0.00
Grndnut	2.5	2	0	0	300	1	0	0.00	0	0.00
Lucerne	1	0	0	0	1000	0	0	0.00	0	0.00
O/cake,kg	2	0	0	0	0	2.5	0			0.00
Total								2.00	2.00	0.00
COMMERCIAL CROPS						Yield	Area	Price	Cost	Net
Sesamum						0.75	0	1150	400	00.00
Cotton						2.00	2	700	150	2650.00
Safflower						3.00	1	1000	100	2900.00
Sunfower						2.40	1	681	100	1534.40
						Total	8		Gain	7084.40
						Commercial + Subsistence:				6011.60
						Total land farmed				5.00
All land on canal.							Value/ Acre:			1202.32
Lost .5 acre gram. Sorghum sown w/tur, + 1 acre gram.										
No sorghum was sold. Wheat was harvested in 1986.										

The model is divided into three sections, corresponding to three distinct components of the farm's subsistence requirements: food, fodder, and cash[10]. Each provides cross-checks. In all rows, at least six points of verification were elicited.

[10] Fuel is also an important requirement, but since the main sources are cow dung and agricultural waste, no land is specifically set aside for it, and it does not have to be explicitly allowed for.

The spread-sheet converts the number of people for each type in adult-male equivalents for projecting the total required. The conversion factor is locally elicited. This is multiplied by the allowance for that foodstuff per meal and the number of meals per year with that ingredient and divided by yield to return the area required to provide it for the year. The area actually planted is the farmer's direct report. The rightmost column, "Rs. +/-," is the surplus or deficit for the year. It is calculated by the spread-sheet by comparing the required area with the area actually planted, multiplying the resultant surplus or deficit area by the yield expected, and multiplying that in turn by the local market value.

Going quickly down the rows, the first consumption item is the grain of sorghum millet. Sorghum is the quintessential "traditional" crop that irrigation experts decry. It does not need irrigation and is not reputed to be particularly responsive to it, yet it is persistently grown in irrigated command areas such as this one. It is grown in the summer monsoon season, planted as the rains begin and harvested about October. Although not a prestige grain like wheat or rice and of much less interest to government planners and politicians, in this area it is a reliable grain producer. Equally importantly, its stalks and leaves are by far the most important fodder—a fact that official feasibility studies for irrigation projects consistently ignore. In this case, the consumption allowance is 275 grams per meal per adult man, there are three men and two women in the family and they all ate it for 650 meals out of the 730 for the year. The yield is 4.5 quintals (450 kilograms) per acre, the price Rs. $1.25 per kg., and at the stated rates of consumption and yield they need 1.99 acres. They planted 2.00 acres, so they should have a surplus for the year worth Rs 7.81, 6.73 kgs. Actually, according to the farmer, there was neither deficit to surplus. Since this is well within any reasonable rounding error, it is close enough to be taken as consistent.

The next row, for pearl millet, is in the table because other farmers in the area grow it. This farmer, however, chose not to. His reason was that it is not a good fodder.

Wheat complements sorghum, growing in the winter season. Since winter rains here are usually insufficient, it must be irrigated. The farmer had not planted it this time because of the drought, but had harvested two acres the previous March and still had some left. This had provided the 80 meals left by the shortfall in sorghum grain, and some still remained. Wheat has twice or more the storage life of millet, but is riskier. The main reason is that it requires chilling to stimulate good grain development and in this areas winters are sometimes not cold enough. It is considered to taste better, but the straw is not considered real fodder. Nevertheless, it is kept and will be used if there is a shortfall sorghum stalks. If not needed as fodder is commonly used as fuel.

The rows for *tur* (pigeon pea, *Cajanus cajan* (L.)) and mung bean (*Phaseolus mungo*) are complementary. The farmer refused to state a number for meals for each. One or the other will be eaten for one meal each day. Both provide essential proteins and the stems and leaves of both are a good fodder supplement. In addition, the long flexible stems of *tur* are an essential material for heavy basketry, wall partitions, and the like. It is usually grown interplanted with cotton — another practice irrigation planners deplore as irrational (although farmers consider it "free" and recognize that it adds useful nitrogen that increases cotton yields). Pulses are an essential component of the diet, and both these crops are reliable. The strategy in planting both was to assure that there would sufficient quantity to exceed the family's minimal requirements. As a matter of taste, *tur* is usually preferred, but is also more profitable than mung. If the family needed money, they could eat the mung and sell the *tur*. If they were not so pressed for cash, they could sell the mung. The choice can be made according to circumstance, and this evidently was his plan.

The remaining diet items, consumed but not grown, are purchased.

The fodder analysis is constructed exactly as for food. Note that the sorghum acreage required, on the basis of the fodder allowances, is exactly what was grown. There was no surplus or deficit. This was exactly what the farmer said, and it underlines the importance of the fodder constraint on farming. The reason is that while fodder commands a much lower unit price than grain, it is much more difficult to find in the market, more laborious to transport (the buyer provides the haulage). There is also a very large difference between the cost of purchase and the cost of production. “Sorgh dry” is sorghum millet cut, stored, and fed as a dry fodder. “Sorgh wet” is sorghum millet that is cut while growing and fed green. In this area, this is seldom done because it involves forgoing the grain and also because at the time the sorghum would have to be cut, which is late in the rainy season, there is usually ample browse that can be had free of cost in the areas surrounding the villages and many farmers have groundnut leaves and stems in storage. In the winter, however, other forms of fodder become scarce. Toward the end of the dry period the price may rice from Rs. 0.75 a bundle noted in the table to Rs. 2.00 or Rs.3.00 per bundle.

Finally, there are the strict cash crops. This farmer managed a total of four acres: two of cotton (mixed with *tur*), one of sunflower planted after sorghum, and irrigated, and one of safflower planted after mung. Mung is harvested early enough so that there is still enough lingering rain and/or residual soil moisture for the safflower. Sorghum finishes later, so that the sunflower has to be irrigated. The cotton and safflower yields are estimates. Neither safflower nor sunflower had been harvested at the time of the interview, but the safflower was further along. The yield was predictable because its main water requirements had been met. The outcome for sunflower would depend on the canal, the farmer said pointedly. With one more watering, the yield would be about 3 quintals per acre. Without it, the yield would be about 20% less. Since the irrigation engineer who was translating for me had been in the forefront of urging the adoption of sunflower as a water saving crop, saying this was a not-too-subtle way for the farmer to urge him to assure that the additional irrigation would be provided. It was.

Cotton and *tur* together are a ten-month crop, planted in the rainy season and continuing to the subsequent winter. In a good year the yield would have been 10 quintals per acre (lint and seed are sold together). Safflower, as noted, was planted following the mung. Sunflower followed sorghum, as did an acre of gram (chickpea, *Cicer arietinum*) that was lost.

The deficit/surplus (Rs.+/-) column shows a net deficit in the food portion of his budget balanced by the surplus in the commercial portion. Thus although it is a subsistence farm, commercial calculations are integral to his strategy for meeting his subsistence needs.

Apart from having the farmer provide or verify the input values and evaluate the calculated surpluses and deficits, a further check on internal consistency is whether the total land used is consistent with the available. In this case, the total area of the summer array was 5 acres and of the winter array 4.5 counting the failed gram (the two acres of cotton plus tur carries over both seasons). Since the area available was 5 acres in each season, this was consistent.

The main question for judging rationality is whether this array is optimal—by which I do not mean "satisficing" or any other such vagueness, but straightforwardly the best that can be done within the limits of the situation. What a simplex linear programming solution does, essentially, is to close in on an optimal solution by seeing that all possible alternatives are sub-optimal. We can use this spreadsheet the same way.

Since the farmer is growing one ten-month crop and two summer crops, each of which latter can followed by one of five winter crops, there are a total of eleven possible rotations. But if we assume safflower will always follow mung this reduces to six: cotton, mung-safflower, and sorghum followed by gram, sunflower, groundnut, or wheat in some combination. But since in this case the only crop after sorghum that could survive was sunflower, because of the irrigation restriction, the model was reset for just four alternative possibilities: 1) four acres of cotton with *tur* and one of mung (eliminating sorghum), 2) four acres of sorghum with one of cotton and *tur* (eliminating mung), 3) four acres of cotton with *tur* along with one of sorghum (eliminating mung), and 4) five acres of cotton and tur (eliminating sorghum and mung). In the accompanying spreadsheets, yellow background highlights indicate the areas as reported. Blue background highlights indicate values that I have increased for purposes of estimation, red indicates values that were decreased. Only input values have been changed, not formulas. The changing totals in the surplus deficit column were calculated by the spreadsheet.

Case 1. If the farmer grew four acres of cotton with *tur*, the most profitable second rotation would be mung and safflower, eliminating sorghum and sunflower. With this pattern, the net value generated for all operations is Rs. 6239.70, or about Rs.228 more than he actually produced. In exchange, however, he would have much more work in marketing the cotton and buying the sorghum and, especially, the fodder. (The convention is that the buyer provides the transport.) If the fodder price went up to Rs. 2 per bundle, as expected, the gain would be obliterated. Cotton also fails more often than sorghum.

Case 2. If the farmer grew four acres of cotton and *tur*, eliminated mung and safflower, and grew one acre of sorghum followed by sunflower, his fodder position would be better (deficit of Rs. 375 at a minimum), but his total return would drop to Rs.4,462.

Case 3. With four acres of sorghum and one of mung followed by safflower, he would still have been able to plant only one following acre of sunflower, since that is all he was allowed irrigation water for. The net value of his production would be Rs. 4149.10.

Case 4. Five acres of cotton and *tur*, again losing the mung followed by safflower along with sorghum, would have reduced his earnings to Rs.3758.45, and his risk and transport effort would be still greater than in case 1. Since all other combinations would be between these extremes, no combination could be better than what the farmer chose.

Finally, I should note what may seem to be a fifth option on economic grounds that is not viable ecologically: five acres of mung followed by safflower. At the actual returns for this year, if the farmer had planted this on all his land it would have given, would return Rs. 3,202 an acre compared to Rs. 1,503 for the farmer's actual pattern if the yields had been normal. But there was no hint whatever in his remarks that he might have done so our would consider doing so, and no other farmer out of the seventeen interviewed grew any safflower at all. The reason is that it is essential for safflower that there be no rain after flowering, and since the crop takes four to five months to mature this is not likely in most years. Without the safflower, the return would be Rs.

202 per acre. Evidently, the rotation was in the nature of drought insurance that made sense for this farmer precisely because his water supply was so precarious, and this year it paid off. In most years, with more rain, it would have been his chickpeas and cotton that did well instead.

The second farm, in Table 2 is in a much larger village on a metalled (paved) main road near the district town. The farmer is much wealthier, better educated, and younger. He also spoke good English and I was able to talk with him personally at greater length than other farmers in the area, over about five meetings. He is a leading innovator, is politically prominent, and had been the sarpanch (chairman) of the village panchayat.

As can be seen, he farms 14.5 acres, grows high-value commercial crops and relies on the market for most household requirements. His family eats wheat and rice from the market rather than sorghum. The sorghum grain they do produce is used for paying workers and local debts. To meet his stated needs would require 13.98 acres under food and fodder crops. He actually grew 11.23 --six of which was cotton and tur. The net value of his production per acre was Rs. 3,170, or 2.64 times that of the first farmer, but at the time of the interview he indicated far more concern for the future. He was in debt. He said his credit was exhausted, and he had no way to continue the level of investment this strategy required

The crops that are the same as for the first farmer are grown for the same reasons. The main additions are cane and groundnut. Since this part of the command was nearer the headworks, canal water was allowed for cane as well as sunflower. He grew the maximum permitted. The cane land was also covered by his well. This is the usual practice because of the unreliability of the canals. Maharashtra sugar mills provide full credit for inputs, often in kind (such as good quality cuttings for seed), and very good extension advice. This makes the crop reliable and profitable so long as a farmer is influential enough to be sure the mill cuts it on time. Because his best-watered land went to cane, the cotton was rainfed, although he fertilized it. Because of poor rains and whitefly, it failed almost completely and he suffered a substantial loss.

Whitefly damage was increased by problems with pesticides and lack of confidence in the government. Because of the Bhopal insecticide plant explosion two years before, the usual insecticide was unavailable. In its place, the agriculture department was recommending rotenone, which they provided. Rotenone, however, has to be used in precisely the right doses. Enough to kill the whiteflies might also kill the plants. The farmer must apply just enough to suppress the whiteflies but not so much as to do unnecessary damage to the crop. K. H. Pandey, senior agronomist on our consultancy team, was with me on the visit and had checked with the agricultural extension officers to see if they knew the dosages required. They did. I therefore asked the farmer if he had been told what the concentration should have been. He said yes and quoted the right figure. Then he added that had used twice that amount. I asked why. He said (as I had expected he would) that such insecticides are normally adulterated. He had just made the usual allowance. The greatest losses were consistently suffered by farmers like him, who fertilized their cotton most heavily and used the most insecticides.

TABLE 2: WEALTHIER FARM, CENTRAL VILLAGE, PUS 1987-88

FOOD	Gm/ meal/ man	No. Men	No. Wom.	No. Child	Yield	Price/ kg.	Meals / year	Acres Req.	Acres sown.	Rs. +/-
Sorghum	300	3	2	0	16	1.25	0	0.00	2	4000.00
Wheat	200	3	2	0	8.67	2.8	730	0.84	0	-2044.00
Rice	50	3	2	0	15	4.75	365	0.06	0	-433.44
Pulses	55	3	2	0	1	4.5	365	1.00	6	2248.31
Veg.	80	3	2	0	30	3	365	0.05	0	-438.00
Oil	12.5	3	2	0	4.5	23	730	0.10	0	-1049.38
Sugar	27	3	2	0	12	5.7	730	0.08	0	-561.74
Chilis	3	3	2	0	10	30	730	0.01	0	-328.50
Total								2.15	8.00	1393.27
FODDER	Bun/ day/pr.	Ox	Buff.	Cow	Yield Bu/ha	Rs/Bu	Days/ Year			
Sor. dry	8	2	2	0	500	0.75	180	7.20	2	-1950.00
Sor. wet	6	2	2	0	500	0.75	60	1.80	0	-675.00
Grndnut	2.5	2	2	0	300	1	120	2.50	1	-450.00
Lucerne	1	0	2	0	1000	0	220	0.33	0.33	0.00
O/cake,kg	2	0	1	0	0	2.5	270			-1012.50
Total								11.83	3.33	-1681.74
COMMERCIAL CROPS						Yield	Area	Price	Cost	Net
Cane						350	6	22.9	13000	35090.00
Cotton						0.33	6	700	2400	-1014.00
Groundnut						5	1	700	0	3500.00
Sunflower						2.4	1	681	300	8689.20
						Total	18.5		Gain	46265.20
Total area required:					4.48	Commercial + Subsistence				45976.73
Total Cultivated Area					27.83	Total land farmed				14.50
One Well, can serve 7-8 acres.						Value/acre				3170.81
Kharif pulse was tur with cotton.										

Groundnut competes for land only with winter wheat. Its fodder yield is about 40% that of sorghum by dry weight, about 12% more than wheat straw. It is higher in protein than either. The financial return for groundnut is about a third that of cane and about twice that of cotton. But it was not in the original irrigation plan and the irrigation department was trying hard to discourage farmers from growing it because if the rains were late it could require about twenty percent more water than sunflower to mature—so that it was, in their view, a major cause of the lack of *area* under irrigation. Since the irrigation department would not provide canal water for it, whatever was grown had to be irrigated from the farmer's own wells. Otherwise, this farmer would have grown more and reduced the cotton[11]. Had he done so, he would have been far better off.

The sunflower was sown reluctantly, following the failure of another experimental crop that the government had been recommending—mulberry for silk-worm culture—because it was the only crop he could get an irrigation permit for.

The farmer had watched my use of the computer during the interview and evidently felt it was showing his situation. After the relatively formal questioning broke up and we were chatting by ourselves, he asked what he could now do to make up the loss. I explained that the purpose of the computer was only to describe what he himself had said, loaded his spread-sheet back in, and quickly altered his cropping pattern to an array that would have met his household subsistence needs directly rather than through market exchange, expanding the "traditional" and "subsistence" crops and reducing the recommended cash crops. He apparently had no difficulty following what was happening on the screen[12]. What it showed was that to meet his needs for grain and fodder, he could have grown about seven acres of sorghum and reduced his cotton and tur to one acre. For that season, the value of the return calculated by the model was about 39% greater than the pattern he chose. (This was with an erroneous entry for the sunflower acreage, 5.5 acres instead of one acre. With the correct value, the model would have shown an increase of 46%). He agreed, but added that it would be "impossible" because of what he owed and the need to use the equipment he had invested in. Despite the risks, he had to seek a new high-profit market crop just to stay even. The problem was that there were none available.

The tallies for each season in the table match the total land. Surpluses and deficits all accord with what he described, as does the summary balance. Because of time pressure I did not ask for all the details given in the spreadsheet on the different fodder allocations for the plow oxen as against the milk animals (one buffalo and one Jersey) but this follows the general rules of thumb: about 120 to 180 days for the former, and five to seven months for the latter[13]. Meals fed total properly. Was this farmer, too, rational? Although he had done less well economically

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[11] In Maharashtra, farmers must request irrigation for specific fields growing specific crops, and cannot apply the water to a different field or a different crop on the same field. The crops determine the irrigation charges, although the irrigation department does not guarantee enough water to mature the crop. If a farmer receives one watering, his field is considered to have been irrigated for the season and he is charged this full rate. This is a major reason why farmers attempted to take irrigation on as little land as possible, which the lower level irrigation officers are well aware of but the higher level officials persist in ignoring.

[12] Even though this was a 1987 model NEC laptop with a monochrome liquid crystal display that was not easy to read.

[13] As it turned out, the way I had set up the cattle fodder section was not able to accurately capture the fact the same foodstuff might be fed to different animals for different lengths of time, and for subsequent elicitations I reorganized the framework to elicit both the numbers of each type and the days fed separately. It appears not to matter greatly in the present case because sorghum was limited and "some" fodder (presumably for the milk animals) was bought, but in other farms it was common to feed the main stored fodder to plow animals for three to four months a year, but to milk animals that were lactating for about seven months.

than the seemingly more "traditional" farmer this year, he was certainly regarded as such and did in fact make almost three times as much per acre.

It would make little sense to reset the spreadsheet for different combinations in the manner of the first farm, since he did not in fact have the option to grow very much other than what he did[14]. His crop acreages were largely dictated by the need for cash in interaction with his own water resources and the official permit restrictions. But if we reset both this spreadsheet and the first with more normal yields, we can see that while the return to the first farmer goes up only to about Rs. 1,500 per acre, the return for this farmer goes up to about Rs. 5,603 per acre. By contrast, the return to this farmer from the pattern of crops that places subsistence first, assuming normal yields, would be Rs. 5, 266. This totals Rs. 13,538 per year less, a substantial amount given his need for cash to repay loans. Hence there is no question that his pattern actually can and normally would yield a greater return to his fixed resources and time. It just happens that it did not work this time, mainly because the support organizations did not provide enough options and were not reliable. In short, to be rational is not to be rich, or poor. It is not to have the fates work in one's favor. It is simply to do the best one can in a constrained situation, and both farmers are clearly doing it.

EPISTEMOLOGICAL STATUS

Now if it is clear that the spreadsheets are capturing something real, the next question has to be: What is it? Clearly, where people have never seen a spreadsheet or a computer it makes no sense to say that they are actually going about with computer spreadsheets in their imaginations. The spreadsheets are traces of an elicitation process that is an ethnographic experiment, an attempt to capture a piece of nature, just in the way that decay tracks on a film negative are traces of a physical experiment. The tracks are real, of course, but also not precisely the phenomenon under investigation. They are rather an artifact of the way that phenomenon interacts with the experimental setup. What is really important is the explanation of what it is in nature that leads that particular experiment to produce that particular artifact. What is important in order to get to such an explanation is to set the experiment up in such a way that the effect of the experimental apparatus is limited, known, and conceptually isolable0.

Although the ethnographic reality cannot be a spreadsheet as such, it can be in the relationships that structure it. These are of two related sorts. First, and most obviously they are the mathematical formulas arranged as a matrix that interlinks the rows and columns: the formulas for computing the needed food of each type, the needed land for it, and the consequent surpluses or deficits on the basis of the relation between what is needed and what is deployed, and for summing these results. The spreadsheet is not an ethnographic reality but these computational relationships within it and the allocations that produce are, and the spreadsheet

[14] In response to his request for advice I had offered to try to construct a linear programming model when I got back to Delhi and send him the results. In the event, however, I found that I could not do so. There were two main reasons. The first was that the restraints on land use broke up the possibility of shifting land to alternative crops. The second was because such models cannot handle the kind of "if this fails I will plant that" contingency that the indigenous model recognizes.

itself is an almost ideally pre-adapted eliciting frame to get to them. The reason is that it permits us to represent the indigenous statements without any transposition into some supposed common denominator or comparative heuristic like the cost and return relations of the economic model of the firm or Chayanoff's "utility" versus "drudgery" (cf. Durrenberger and Tannenbaum, 1992). Once done, such transpositions cannot be undone and have the same effect as pulling an artifact out of the ground without noting the circumstances of its removal. They break the chain of evidence and reduce inference to speculation.

Second, beneath this, we have to recognize that these formulas are not free cultural inventions like beliefs in such things as goblins or demons might be, but reflect the character of the things they pertain to. The amount of land to be apportioned to the best uses over the year reflects the amount of land and water and time that actually exists. The grain eaten per meal times the number of meals per year adds up to the grain consumed per year because that is what grain in meals actually does. The total of the grain harvested minus grain consumed, grain sold, and storage losses equals grain still on hand because that is what grain in storage does in a very straightforward way (but not, for example, green cut fodder). Land given over to one crop for one period of time cannot be given over to another, so the total of fields over time must sum to the total amount of land over time, and so forth. What the farmers' family members actually seem to share as a mental image is knowledge of their total land and its division into working fields, and then for each field a set of calculations regarding people and animals represented by the rows in the table—a kind of image that would be very closely approximated if we could indicate the land area for each crop graphically instead of numerically, in such a way as to show both the relative areas and the times that crops were put in, taken out, and followed by others.

It is probably not a defect but a strength that we cannot set up a purely internal criterion for judging the logical consistency of the model but have to bring in information from the empirical situation, such as the sowing and harvest dates of crops. This is part of what binds the model to its "referent," the situation it helps to organize, and in turn binds the organized situation to the model.

My argument is not that mathematics is some sort of universal language that naturally, therefore, must apply to these specifics. The problem with this view is that this sort of mathematics (arithmetic set up this way), simple as it seems, does not work equally well as a formalization of a logic of internal relationships with just any other specifics in fact. The empirical situation is more probably a kind of parallel evolution of such conceptual devices for agricultural planning along with the material apparatus they help sustain and are sustained by—cultigens, tools, and animals in the old world, cultigens and tools only in the new. From a few initial points of origin, they have been in constant motion since, with multiple subsequent backward and forward borrowings and, consequently, continuous elaboration and refinement. Mathematics of this sort applies to these specifics because historically it was, apparently, precisely such specifics—the birth of settled agriculture with agricultural trade—that gave rise to mathematics of this sort to begin with, and it has spread through cultures and through time in precisely such associations. There are plenty of other sorts of cultural items whose inherent logic is quite different, and which would therefore require eliciting frames with quite different logics as well. Kinship terminologies are one, as Read has demonstrated (1984), and in the area of farm management itself the Balinese *tika* model for representing and managing irrigation cycles is another (Lansing 1991: 70). Even in India, the model does not work if farmers actually operate their farms as commercial firms, without relying on family and animals maintained within the framework of the farm budget, as was the case for one farmer I encountered in Maharashtra (Leaf 1998: 99).

In terms of the distinction between models that are "etic" and those that are "emic," the farm budget is not one or the other but both. It is a model that is both culturally meaningful *and* objective, because, precisely like comparable models in our own communities, that is what it has been designed to be.

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