Research

Planning Irrigated Farming Systems in Israel

by George Irvin*

(This article summarises the results of a recently concluded three month research trip to Israel by the author, and is part of a research project he is working on under the auspices of ODM)

The object of the work described below is to test the application of mathematical programming tools to the design of irrigated farming systems, and to the formulation of policy recommendations for irrigation planning in practice. The project has two components:

(i) the application of a linear programming model to the planning of a kibbutz farm, and in particular, the determination of optimal water storage capacity, pumping capacity, and irrigation scheduling.

(ii) building up a representative model of a group of irrigated farms (a moshav settlement) to investigate the effects of alternative policy recommendations for dealing with problems of unco-ordinated water demands at certain times of the year.

I. The Kibbutz Study

The first part of the study was carried out on Kibbutz En Chemer, located in the coastal plain 50 km. north of Tel Aviv. En Shemer is a 1,250 acre farm based mainly on dairy, citrus, and industrial crops. Intensive fodder production occupies about 10% of cultivable land, orchards about 25%, and the remainder is given over to a variety of crops of which cotton is by far the most important with respect to land use. Virtually all crops are grown under irrigation, and the small margin of land under dry farming will almost certainly disappear should more water become available. Water is supplied mainly from a deep well on the kibbutz itself, though additional water supplies are available from the national water company, Mekoroth (on a two part tariff arrangement) and from the tapping of a nearby stream of industrial waste water.

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In addition, there is a small storage reservoir in which water available at times of slack demand can be stored to meet demand peaks. As only a small part of the stream flow is presently tapped, the main scope for increasing the supply of water in the peak period lies in expanding reservoir capacity.

The problem is to estimate how far it will pay to increase water storage capacity under a variety of assumptions about the nature of the demand profile for water, the latter being determined by: (a) the planned irrigated cropping pattern, and (b) the planned time profile of water use (water regime) for each crop. Given the variety of choices underlying the derivation of a farm's demand profile for water, and the existence of multiple factor constraints, this problem is best approached using a linear maximising model.

The solution to the problem is treated in two parts. Firstly, a linear programming model of the farm as a whole has been formulated, and is used to investigate efficient patterns of resource allocation under a variety of different assumptions about the length of the planning horizon and types of choices open to the kibbutz. Different assumptions about the nature of the choice set include such factors as the relative importance of grown and purchased fodder inputs for the dairy herd, the rate at which orchards can be expanded or contracted, the availability of markets for crops not previously grown, etc. The model includes sets of water buying activities (corresponding to the different sources from which water can be bought at different prices) defined in monthly terms. In the first stage, a set of optimal cropping plans are derived corresponding to permuted sets of assumptions noted above. Because, however, the model is defined in monthly terms, the profile of water demand implied by each optimal plan is crude in relation to the nature of the information needed to estimate optimal reservoir capacity and the optimal irrigation regime for each crop. Therefore, a second model has been set out in which the use of water for all irrigated crops is defined in six day periods. Choice variables in the second model are restricted to the timing of water applications to each crop and the choice of reservoir size, acreages of all crops (with the exception of cotton) having been derived from the first model and "forced into" the second at the indicated optimal levels. Optimal cotton acreage is, however, a choice variable in the second model, and 22 alternative water regime vectors have been defined for cotton giving the planner a wide choice timing of water application, amount of water applied per irrigation, and corresponding yield level. As the two models differ with respect to precision of definition of the production possibility surface, divergences in results from the second model are used to amend the first, and thus the overall problem is solved iteratively.

II. The Moshav Study

The moshav, or co-operative farming village, is made up of a number of individually operated small farming units, and is thus more directly comparable to the system of family farming found in many less developed areas of the world than is the kibbutz. Though levels of income on this particular moshav compare favourably with those achieved in Western Europe, the moshav raises problems of sample definition, data collection, etc. associated with studies of conventional farming communities. The moshav chosen for this study, Lakhish, consists of 40 full time farming families working an average of eight acres each; Lakhish is situated in a low rainfall area of Israel where water supply is a principal factor limiting the growth of farm incomes. The seasonal demand for water on this moshav is highly peaked resulting in severe pressure fluctuations in the supply system; in addition, there is uncertainty with respect to future levels of water supply for irrigation, as well as variation in yearly irrigation water use arising from the need for supplementary irrigation in years where total winter rainfall is either too little or poorly distributed. The object of this study is to recommend optimal irrigated cropping patterns consistent with (a) alleviating the water peaking/ pressure fluctuation problem; (b) alternative assumptions about future water supply, (c) assumptions about the incidence of drought years and the need for supplementary winter irrigation, and (d) assumptions about the degree of risk which farmers are willing to bear.

As the moshav exhibits a wide variety of individual farming systems, it was decided at the outset not to attempt to build up different models of representative farming systems; instead, the sample is designed to define representative vectors of all the most important farming activities, treating the moshav as a single decision making unit. This aggregative approach limits the study in one basic sense--the model is in no sense predictive; it cannot be used to indicate what farmers will do. It merely serves as a guide to what farmers might rationally do under certain assumptions about coincidence of farmers' objectives, mobility of moshav resources, etc. Nevertheless, as the moshav is subject to an important degree of centralised control, the question: "What is the most efficient pattern of resource use for the moshav as a whole?" is of clear policy relevance.

Some thirty basic cropping and livestock rearing activities are used in the model. As variations between farmers in methods of carrying out particular activities were found to be important in the sample, each basic crop is represented in the matrix by a number of "processes" representing a cross-section of moshav practice. The model can be run to select the most efficient" vector for a particular crop, or alternatively constrained so that only "average experience"vectors enter the final solution. Secondly, there is considerable variation in the degree of risk associated with the range of farming activities under consideration, and interviews suggested that farmers differed widely in their willingness to bear risk. The survey was designed to assess not only the average expected return (gross margin) from a particular activity, but also the minimum expected return; the model incorporates a minimum income constraint which can be parametrised to generate an array of optimal policies, each corresponding to a different degree of riskiness. More important, the model is solved repeatedly with respect to a number of alternative estimates of future water supplies; and corresponding to any particular assumption about water supply, a subset of solutions is derived with respect to different assumed supplementary irrigation needs in the winter period. Since the probability distributions of dated rainfall variables are known, an approximate probability can be assigned to the levels of income associated with each of the farm plans so generated. In general, the model has been designed to be as flexible as possible in exploring the implications for policy making of a variety of permuted assumptions.

III. Conclusions

As the work so far described is still in the computational stage, it is too early to hazard any predictions about what issues will emerge as crucial in the two contexts described. Some general points about the usefulness of the tools, and how they might be extended, are worth making however. Firstly, the treatment of the kibbutz study underlines the importance of articulating decisions about water regimes for particular crops to the full farm decision making environment. The notion of fixed water norms in determining irrigation needs has been abandoned entirely; instead, the model starts from an approximate definition of the crop water production function for a particular crop, and can be used to indicate on which part of the production surface (the region of the constrained maximum) the definition needs to be improved. Again, the choice of investment (optimal size of reservoir) is shown to be clearly connected with the water regime problem. The method of solution used, breaking the problem into two and solving iteratively, raises some interesting possibilities with respect to getting around some of the diseconomies of scale associated with building very lar models.

The Moshav study raises a rather different set of problems, particularly those associated with the treatment of risk. In the model described above, risk is treated in a relatively crude fashion. Equally important, because the model described is static, no allowance is made for questions about how farmers readjust beginning of year plans to deal with unforseen circumstances arising during the growing season (such as rain failure). "Dynamising" the present model is seen as one of the next important steps in the development of this research. However, the model as it stands does go some way towards meeting some of the familiar objections about crude determinism which are normally made with respect to such uses of linear programming, particularly where the emphasis is clearly set upon sensitivity analysis and exploration of different versions of the model.

In general, the work described should provide a useful illustration of new uses of programming methods in planning irrigated farming systems. It is hoped that a final version of the work, encompasing both the case study material described above and a more general section of the theory and application of programming tools to irrigation planning, will be published upon completion of the project at the end of the present year.