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Integrating Biological and Economic Considerations in Building Production Intensive Systems

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FOR the purposes of this paper, a production intensive system is considered to be one in which production per unit of input, or set of inputs, per unit of time is intentionally increased from a previously existing state. Production intensive systems may be regarded as forming a continuum ranging from those that exhibit increases in productivity that are just measurable to those that exhibit increases of several hundred per cent over a previously existing state. While emphasis will be given to the considerations involved in attaining the upper end of the continuum of production intensity, it is not intended to limit the scope of discussion unduly.

Overview

Production intensive agricultural systems, in the sense defined above, are by no means new; in fact it can be argued quite reasonably that most agricultural research and development has been devoted to the construction of the component parts of production intensive systems. The building of economically viable production intensive systems, or any other economically viable production system, depends upon achieving favorable relationships among the prices of factors of production and products. Obviously economics has an important role to play here; given a set of production relationships and prices, applied economics should be able to specify expansion paths and determine profit maximizing output and resource levels for production intensive systems in a manner similar to that used for others which are less intensive. In the process the economist would have to give special attention to issues such as ways of dealing with changing profiles of risk and uncertainty, capital or labor intensiveness, suitability for developing or developed countries, the relevance of objective functions as well as those relating to the timing of production activities when production sequences, as in the case of multiple cropping overlap; or follow each other more closely than is usual as, for example, when land is used to produce more than one crop in a year.* Economists or perhaps farm management specialists also have a special role in the development of methodologies for developing 'whole farm' production systems that include a production intensive system as a significant component. When working with biological and physical scientists the economist should be able to make a significant contribution to the building of production intensive systems in terms of aiding in the establishment of research priorities. This may be achieved by model construction or sectoral analysis which can indicate areas of larger payoff.

Interaction between economics and biology may be more clearly seen by considering in some detail the various sources of increased agricultural productivity which form the basis of production intensive systems and their relationships with biological, physical and economic sciences.

Sources of increased productivity and the role of economics vis-à-vis *the biological and physical scientists*

Increased understanding of growth and production requirements of plants and animals and of the ways by which growth and/or productivity may be modified and increased is fundamental to the development of any productive intensive system. There is no substitute for the biological and physical sciences in this area and economics has little to contribute here except perhaps in aiding in the determination of adequate levels and kinds of financial support for basic sciences.

The techniques of improvement of productive capacity of plants and animals by selection, breeding or a combination of both, rest firmly on basic biological sciences such as genetics, biochemistry, physiology, and pathology. Once again, economics has little to contribute directly in terms of ways or means by which such modifications are achieved. At the same time, however, economics can make a useful contribution to the determination of the kinds of changes in plants or animals that would be profitable. For example, the economist could reasonably be given the responsibility for evaluating the market acceptance of different kinds of high yielding maize or rice so that efforts in their development may be efficiently directed toward a saleable product. In addition, the economist may give the plant or animal breeder useful guidance on such matters as acceptable levels of production variability in relation to increases in yield or indications of the magnitude of yield changes requisite to result in the adoption of an improved variety.

Another source of increased productivity is that which may be best characterized under the general heading of improvements in production practices. A wide range of biological and other sciences at the applied level are required here. The economist if he is both competent and imaginative can well perform an important role acting as an integrator of the research efforts and results of the other scientists in the development of efficient production intensive systems and their integration one with

* See, for example, Winder, J. W. L. and G. I. Trant 1961 'Comments on determining the optimum replacement pattern', *Journal of Farm Economics*. XLIII 939–51.

another. To be really useful in this area of production practices the economist must be eclectic in his approach to the solution of practical problems. He must be willing to work with problems ranging from work simplification and the economic consequences of time saved by once-over tillage operations to the appropriate way of providing least cost veterinary services to a beef feedlot. When sequential production is practical as in the case of continuous cropping from the same land or the continuous production of livestock or livestock products in the same buildings, the economist may well make his most important contribution in identifying the relevant objective function to be maximized, where appropriate, so that efforts are directed toward it and not to another.

The improvement of existing inputs other than crops and livestock and the development of new ones has been an important feature in the recent development of production intensive systems. Although economic factors have to a large degree determined the adoption of these new or improved inputs, the applied biological and physical scientists have made the major contributions in this area.

Changes in factor proportions have been an important feature in the development of production intensive systems. The formal tools of economic analysis appear to have an increasingly significant role to play relative to the biological sciences. Production economics has as one of its main objectives the establishment of the conditions for obtaining least cost or expansion path conditions of production. At the same time, techniques ranging from those of budgeting to linear programming and its modifications, simulation, and econometrics have permitted the economist to play a role of increased practical significance in the development of agricultural production systems whether intensive or not. These and related techniques also permit the economist to demonstrate the consequences of combining production intensive systems with others in a competitive, supplementary or complementary way. While the role of the biological scientist in these areas is obviously important in terms of the specification and modification of physical relationships, the economist has an important role in determining feasible factor and product combinations. It is perhaps worth noting in passing that in many instances the production scientists have done a good deal of economic analysis on their own. Unfortunately it has been too frequently dedicated to the maximization of output to a single factor.

Concomitant with the development of production intensive systems has been the increase in the producers' ability to control physical resources coupled with an increasingly sophisticated managerial requirement. The biological and physical sciences and their attendant technology have obviously made and will continue to make major contributions to the ways in which physical control can be established over productive resources such as land, water, machinery, chemicals and buildings. However, economics is of vital importance in establishing an adequate financial environment in which managerial control over productive assets can be maintained.

Intensive crop systems

The most appropriate way to examine the integration of economic and biological considerations in the construction of production intensive systems is to consider a range of systems that exhibit differing degrees of production intensity. High yielding crop varieties form the basis of some of the better known and least complex of the newer production intensive systems. The high yielding varieties of rice and wheat of the 'green revolution' are examples. These improved varieties produce very large crops relative to 'unimproved' varieties when grown under conditions of adequate water, relatively high levels of fertilizer and close attention to excellent crop production practices. When they are grown under non-irrigated conditions, their production intensity tends to be confined to one crop per year. However, even this level of intensity requires an increased dependence on off-farm produced inputs such as seed, fertilizer and other chemicals as well as a knowledge of new frequently different production practices. In general, the producer particularly in developing countries, has to bear new costs and increased risks as he enters the market-place for new inputs and the credit required to purchase them. The economist acting as a planner must give special attention to such factors before deciding that production intensive systems are appropriate and if such a decision is reached, care must be taken to handle such factors adequately.

The next step in increasing production intensity using the new high yielding varieties to produce more than one crop per year on the same land requires further control of water supplies. Usually this means the construction of some type of artificial irrigation system whose complexity and cost will vary widely according to location specific conditions. While increased control of productive resources reduce the probability of a crop failure, increased dependence on the market-place for credit and off-farm produced inputs introduce other risks. Where two crops are produced per year, increased attention has to be given to the timing of field operations and new problems of crop storage and transport emerge. When additional crops are introduced into the production sequence the complexity of the operation increases further. If a large investment has been associated with the irrigation system, increasingly intensive production per acre becomes a necessity for the producer to meet his financial obligations. While only rice and wheat have been mentioned so far in intensive crop production, somewhat similar developments in intensity are taking place in maize, coffee, and orchard production. In the case of the latter two, it has taken the form of higher rates of planting of dwarf varieties to increase yield per acre and reduce labor costs.

Possibly the most intensive types of crop production are those associated with highly controlled environments such as greenhouses and growth chambers. In these types of production, virtually all resources used are supplied from non-agricultural sectors of the economy including not only water, seed and chemicals but heat and light as well. These types of intensive production systems are largely confined to temperate regions and designed to exploit an economic opportunity that arises from a relatively short growing season. Commercial production has largely been confined to greenhouses although there is a considerable increase of interest in growth chambers both in Europe and North America as something more than a laboratory tool. They are both at a rather interesting technological and economic crossroads, however, because of their relatively large labor and energy requirements and the fact that increasingly sophisticated technological changes in field production of fruits and vegetables as well as transport put their competitive position in some question. The result is that their continued survival in most areas will have to depend on some combination of increased efficiency and tariff protection.

Intensive livestock systems

The range of degree of intensity of livestock production is in many ways similar to that exhibited by crop production. Possibly large-scale beef feeder operations may be regarded as being at the lower end of the production intensive distribution for livestock. These operations tend to be located conveniently to feed suppliers and appear to depend on economies of size, rapid turnover achieved through high levels of feeding intensity of well balanced rations and low labor requirements to make them efficient producers of table quality beef. While increasing attention is being given to breeding programs that improve rates of gain per unit of time and also feeding efficiency, the relatively long reproductive cycle of cattle has inhibited progress in these respects relative to hogs and poultry. Cattle feedlots can be found in many parts of the world, both developed and developing; nevertheless they appear to be most frequently encountered as commercial enterprises in North America where relatively abundant feed supplies at comparatively favorable prices relative to those of fed beef coupled with relatively high labor costs have encouraged this type of development.

Intensive hog production systems are basically similar to those that have been developed for beef with the exception that buildings, at least in temperate climates, tend to provide more control of temperature and humidity. Mechanical feeding, watering and waste disposal are common to both. Again, it should be noted that favorable conditions of feed supply prices relative to pork prices together with relatively high wage rates tend to be the conditions which favor this type of production intensive system. Disease control problems do appear to have limited the size of these operations to a greater extent than for beef or poultry.

Possibly the best known and certainly the most widely distributed of all production intensive systems are those available for poultry meat or egg production. Here there has been developed a comprehensive production intensive system based on the development of improved breeds and advanced nutrition work that permit high levels of feeding efficiency. At the same time a good deal of work has gone into the development of labor-saving production technology including housing which can be used with these production systems but is not essential in its totality. Disease control which was initially a problem appears to have been solved. Production intensive poultry systems appear to exhibit slightly increasing returns to scale and are readily adapted to vertical integration on both the input and product sides. Unlike intensive beef or hog production systems they can more nearly compete, because of high levels of feeding efficiency, with people for feed supplies. Difficulties which have arisen with the use of production intensive systems of poultry and egg production have largely been related to the very large volume of production of which they are capable and which has resulted in rapid and spectacular price declines. As a result, producers have frequently sought assistance for market control.

With the above comments in mind, it is appropriate to consider in a more specific manner the ways in which economic considerations need to

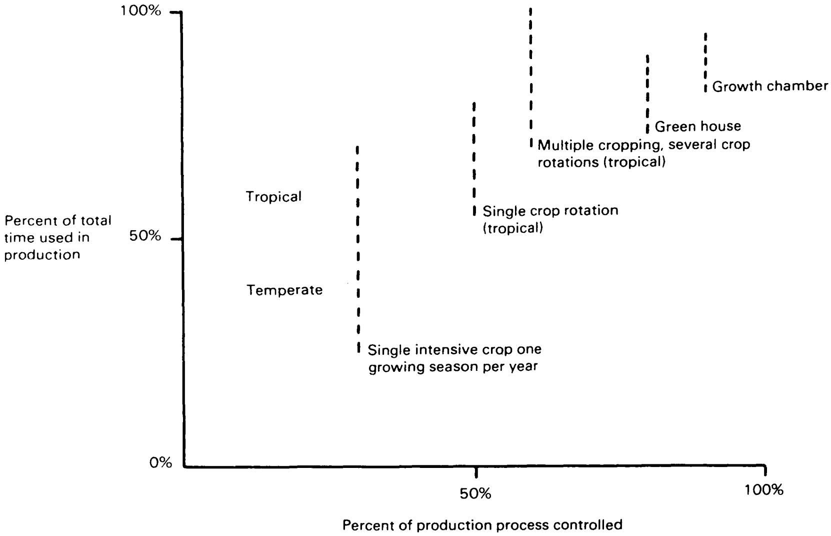

FIG. 1. Probable relationship between degree of control of productive resources under different crop production systems and proportion of time out of total available that can be used for productive purposes.

be integrated with biological ones in building production intensive systems in agriculture.

Implications of production intensive systems for risk, managerial capacity, control, and related matters

In Figures 1 and 1(a) apparent relationships between different kinds and degrees of production intensive systems are related to degree of production control required and proportion of time that can be used for productive purposes.* It may be observed, for example, that these range from rather low levels for single intensive crops grown in temperate regions to high levels for intensive multiple cropping under tropical

* In the figures used in this article, all relationships shown are hypothetical but are based on observation.

conditions and greenhouse and growth chamber production. A less marked difference among different levels of intensity of livestock is shown. This occurs because most livestock can be produced year round under a wide range of temperature conditions and the primary gains in increased use of productive time appear to come from situations in which cattle are fed on an intensive all year basis rather than permitted to be maintained only, or lose weight under unfavorable seasonal conditions.

There is a special role for economists in working on optimum production sequences of production intensive systems and in establishing in a fairly clear-cut manner the nature of the tradeoffs between differing degrees of production intensity in meaningful terms of economic

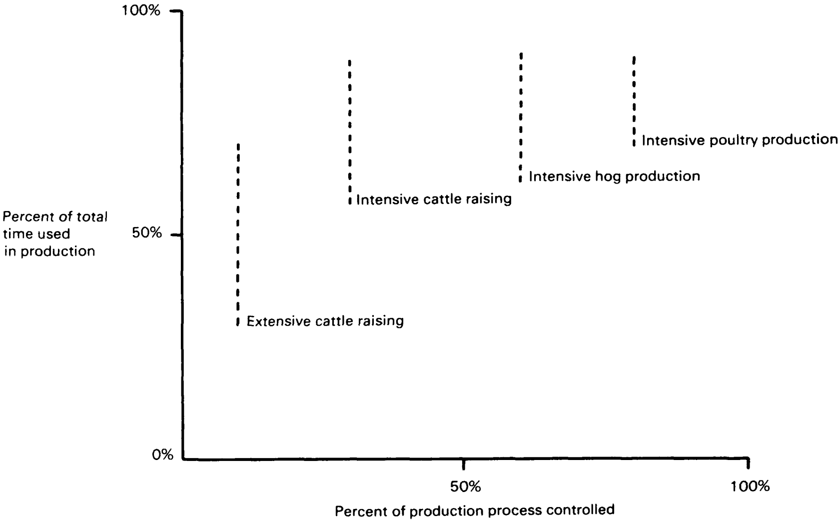

FIG. 1A. Probable relationship between degree of control of productive resources under different crop production systems and proportion of time.

efficiency. Specific questions that come to mind include: At what stage should one crop be harvested to permit it to be replaced by another? With what crop should the first one be replaced? How can time be saved in the replacement of one crop with another? What are the additional costs of this saving in time?

At what time should one lot of broilers be replaced by another in view of the fact that feeding efficiency declines with time on any given lot of birds?

Similar questions can be posed for other types of production.

Initially, increased control of production processes gives both increased intensity of production as well as a reduced probability of loss in the production process itself. However, as higher levels of production control are achieved these are usually obtained from increased use of off-farm produced inputs. This immediately introduces the possibility of two sources of increased risk. On the one hand, the market system may not always be able to deliver the right kind of input at the right time and place and in the form required. On the other, the producer may well have to rely increasingly on borrowed capital to finance his operation. It would seem most appropriate for the economist to discover whether the risk-production-control curve postulated in Figure 2 is as postulated or whether it takes varying forms for different types of production. This matter will be discussed in more detail in describing possible implications of other relationships later on.

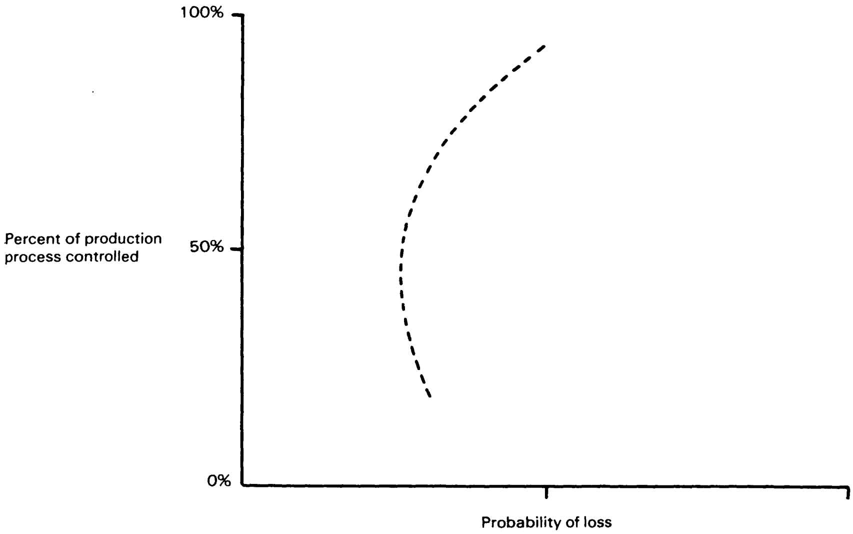

FIG. 2. Probable relationship between degree of control of productive factors and probability of loss.

In Figure 3 it is suggested that increasing levels of managerial capacity are required if higher levels of production process control are to be realized. This stems not only from the changing risk situations mentioned above in connection with the previous figure but also relates to the achievement of purely technical types of managerial control requisite to obtain high levels of production control in increasingly intensive systems. Economics as a powerful, useful tool of analysis can surely be used in the training of managers so that they make better economic decisions.

As production becomes more intensive and hence requires increased control of productive resources, the degree of production specialization tends to increase, with the result that many of the inputs are so highly specialized, e.g. cages for laying hens, that they cannot be used for any other type of production. This in effect locks the producer in to one particular type of production, eggs or broilers, for example, so that he lacks the risk reducing effects of diversification. The economist's role in this type of problem situation would appear to be to investigate and suggest institutional means whereby the producer may be protected or perhaps examine ways and means of achieving some sort of least cost diversification. This type of problem stemming from specialization presents very special problems when there are increasing returns to scale, as there would appear to be in both egg and poultry meat production, with the result that producers are encouraged to increase production in the face of inelastic demand and hence encounter unusually volatile prices for their products. Under these types of circumstances involving not only increasing returns to size but also specialization, producers have variously

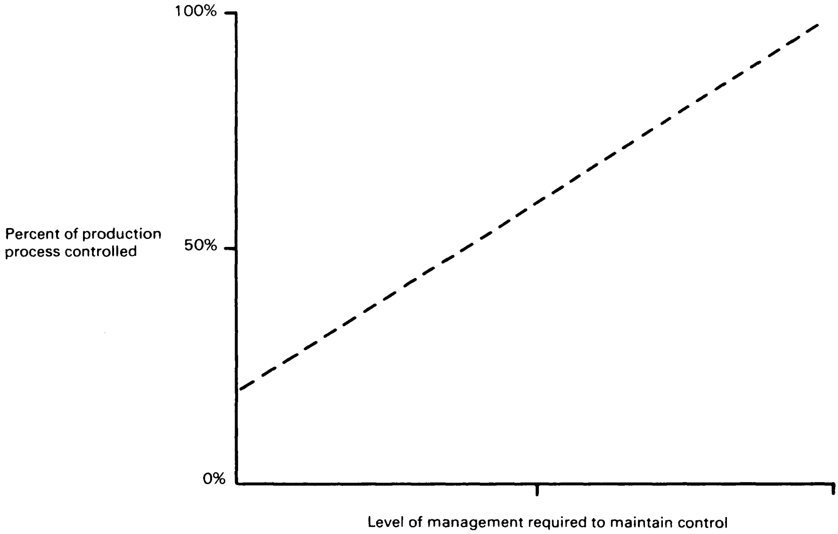

FIG. 3. Apparent relationship between managerial requirements and attainment of control of production process.

turned to vertical integration at the factor market and product market side to find someone with whom to share their risks. This obviously raises some rather interesting questions as to the type of agricultural policy with respect to the control of agriculture that a nation may find to be desirable.

Figure 4 suggests that there is basically a negative relationship between the proportion of the production process that can be controlled and the degree to which it is location specific, which in turn suggests that those who develop the most highly developed production intensive system may not be its final beneficiaries.

Many questions remain unanswered

The foregoing was intended to suggest ways in which both biological and economic considerations may be combined in the building of production intensive systems. Obviously the presentation was not complete nor was it intended to be. Only a few of the issues have been examined and these only in part. Before concluding, it would be advisable to indicate that many modifications could have been made in this presentation.

For example, attention needs to be given to the types of production intensive systems of agricultural production that involve objective functions that must be constrained in such a way that they provide at least minimum levels of living or food production for those who depend directly on them for their livelihood.

Political issues relating to the ownership of productive resources and control of production under intensive systems might have been examined.

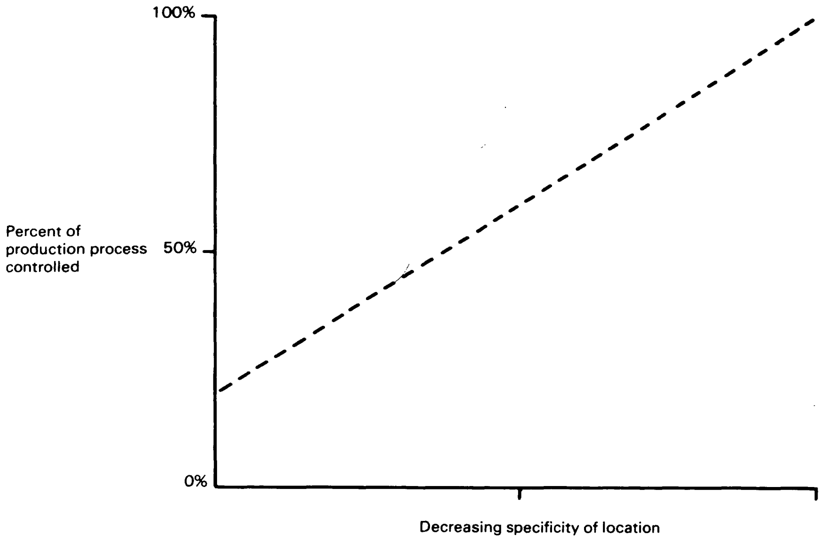

FIG. 4. Probable relationship between degree of locational specificity and degree of control over production process.

To the extent that production intensive systems are efficient producers of food but require little labor, they present an agonizing decision problem for developing nations with large supplies of labor and food shortages. Both modifications of production intensive systems and tradeoffs between them and labor use need to be looked at.

Highly intensive systems of production have been developing rapidly in recent years. To the extent that they appear to exhibit constant or increasing returns to size, their increased use has rather startling implications for the structure of world agriculture.

Finally, what in fact will be the role of production intensive systems in meeting world food needs?

SPECIAL GROUP L REPORT

The paper was summarized by the author. The discussion following the author's presentation focused on (1) the methodology of developing intensive production systems, (2) the objective function to be used in estimating the relative efficiency of these systems, (3) potential marketing problems reducing the efficiency of the systems and (4) the extent to which such systems could be transferred from developed to developing countries.

Two approaches to the development of improved systems were mentioned: (1) comparisons among existing systems and (2) development of systems using a model building approach. While the former is very limited in scope, the latter provides for a large number of possible systems, the list of which may be tested under real farming conditions. The need to understand existing systems in order to provide the basis for subsequent manipulation was emphasized. A considerable interest was expressed in the issue of determining a relevant set of farmer goals within the improved systems. The possibility of conflict between maximizing net returns from one crop or lot of animals and maximizing net returns to the farm over time was discussed. The need to use optimum replacement models to estimate net returns over time was emphasized. Furthermore, goals other than maximum net returns might be relevant to determine the relative efficiency of the improved systems. Risk reduction was mentioned as being one such goal. It was argued that improved systems need not be capital-intensive and it was suggested that more attention be given to developing labour-intensive systems for regions with a large labour supply.

The importance of strong collaboration between biological scientists and economists in developing improved production systems was stressed. Some of the discussion participants felt that such collaboration had been lacking due to communications problems and lack of appreciation of the work done in other disciplines. The establishment of multidisciplinary teams was suggested as a means to overcome these problems.

The need for efficient factor and product marketing systems to support the intensive production was discussed. Frequently, the marketing systems do not respond to the requirements of the intensive production system, hence the potential of the latter may not be realized. Unavailability of inputs at the time needed and lack of facilities to handle an expanded production were found to be the most severe marketing constraints.

The transfer of intensive production systems from developed to developing countries was not considered to very promising due to differences in the physical as well as socio-economic and institutional environment. However, some systems, such as intensive broiler production, seem to be readily transferable.

Finally, it should be mentioned that a number of discussion participants considered systems analysis to be a very useful tool in developing improved production systems.

Among the participants in the discussion were: José Rodriquez Alcaide, *Spain*; Barry Dent, *U.K.*; Bhupendra Desai, *India*; John Dillon, *Australia*; Ron Duncan, *Australia*; J. B. Hardaker, *Australia*; J. Hildreth, *U.S.A.*; José Alceu Infeld, *Brazil*; Truman Phillips, *Canada.*