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New Technologies for Rainfed Rice-Based Farming Systems in the Philippines and Sri Lanka

Report of a workshop held at Iloilo, Philippines, 20–24 July 1987

Contents

Foreword

In 1983 ACIAR approved two complementary projects: one to study the environmental constraints to increased productivity of rainfed rice-based farming systems in lowland and upland regions of Sri Lanka and the Philippines, and the other to focus on the socioeconomic factors responsible for the difference between potential productivity and actual farm performance. These projects linked scientists from the following institutions:

CSIRO Division of Water and Land Resources
Department of Economics, Research School of Pacific Studies, Australian National University
Sri Lanka Department of Agriculture
Philippine Department of Agriculture
College of Agriculture, University of the Philippines at Los Baños
Department of Economics and Statistics, National University of Singapore
International Rice Research Institute

Because environmental constraints may affect the choice and productivity of cropping patterns, the results of socioeconomic and agronomic studies may apply only to the seasons in which the data were collected. To overcome this problem, the first project used base data analysis and a simulation model of existing farming systems and of improved technology options to define the environmental factors. On-farm experiments were used to help validate the models. The model was then run on a long sequence of weather data to determine the long-term stability of possible new cropping patterns. The second project measured relative technical and economic efficiency of a sample of farmers in major farm and off-farm activities, compared the range of crop performance with that found in on-farm and research-station experiments, and quantified agronomic and socioeconomic factors which explained gaps in performance, with a view to drawing policy inferences for research and technology transfer.

In mid 1987 the project leaders and other scientists and extension workers attended a five-day workshop in Iloilo to review the results of the projects, and to prepare recommendations concerning the adequacy of current extension practices and to define future research needs in this area. The recommendations are contained in the last section of this report. Abstracts of the papers presented to the workshop are also included. Copies of the complete papers are available directly from the authors.

Opening addresses were given by the Under Secretary of the Philippine Department of Agriculture, Roberto Ansaldo, and by the Governor of Antique Province, Enrique Zaldivar. Their strong expressions of interest and support were welcomed by the participants.

The workshop was made possible through the generous financial support of the Australian International Development Assistance Bureau (AIDAB). We are grateful to AIDAB for their assistance. The major papers presented at the workshop are now being reviewed for possible publication as an ACIAR Monograph.

J.G. Ryan
Deputy Director
ACIAR

Background to Workshop Discussions

J.V. Remenyi*

The great improvements experienced in cereal production and food self-sufficiency in Asia since the 1950s have relied heavily on irrigated farming systems. These systems are well placed to exploit the genetic potential of modern high-yielding cereal varieties, a primary characteristic of which is their capacity to exploit 'added inputs' of fertilizer, water, herbicides, etc., delivered in measured quantities. While it is difficult to delineate the relative importance of these inputs, irrigation has given farmers an unprecedented degree of environmental control; control that is absent in rainfall-dependent agriculture systems. There is, therefore, a close association between the expansion in irrigated area, the spread of modern varieties, and the increase in agricultural output in the tropics.

Considerable potential for further increases in output still exists in irrigated cereal production. However, in large part the best land and least expensive areas for irrigation development have already been taken up. In most of Asia there exists now a chronic shortage of land and water systems readily suited to irrigation development. Consequently, if current levels of output per head of population are to be maintained, future increases in total output and yield per hectare will rely on developments in rainfed cereal production (Barker and Herdt 1979).

This publication and the two projects to which the abstracts that follow refer, focus on rice and rice-based rainfed farming systems as critical components of the Asian food system. Rice dominates Asian food systems and Asian agriculture. Moreover, given the high and increasing cost of expanding the irrigated cereals area in Asia, the importance of rainfed lowland and upland rice must increase if future total rice output per head of population and current levels of regional self-sufficiency are to be maintained. Some of the pressure for improved performance of rice-based rainfed farming in Asia will be alleviated by foreign trade, but political imperatives are unlikely to change so radically as to see a significant shift from contemporary commitments to national food self-sufficiency goals and away from imports. Consequently, it behoves all concerned with improving agricultural performance in Asia to devote more attention to rainfed rice-based farming systems than has been the case heretofor.

Half the gross area planted to rice in the world is solely dependent on the rain for moisture (Barker and Herdt 1979). Of this area, around three-quarters is in lowlands dependent on flooding following monsoonal rains, and the balance is in upland areas where rice is grown using dryland farming techniques, similar to those usually associated with wheat, maize or barley. Almost two-thirds of the rainfed rice area is classified as 'drought-prone.'

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Critical Keys to Improved Performance

On the physical side there are three strategies available: (1) increase the farm area; (2) improve the crop yield per unit of land; (3) increase the number of crops harvested from the existing farmland.

In the irrigated zone, expansion of the gross area planted by moving to two and possibly three crop-seasons per year has been an important element of growth in output. Though the potential of multiple crop seasons per year is not as great in rainfed systems, it is an option that appears underutilised in much of rainfed Asian agriculture (Zandstra 1977).

The second strategy—improved yield from the area sown — relies not only on improving the available technology, but also on loosening the constraints to the adoption of new technology. In some cases, these constraints may be institutional (i.e. poor infrastructure for delivery of inputs, credit, etc.), while in others they are environmental or technical (e.g. drought, or cereal varieties poorly adapted to soil types), but often they will be policy-related (i.e. constrained pricing and marketing systems that disguise true profits and costs).

The Research Agenda

In contrast to irrigated rice-based farming systems, very little research has been done on how to raise the productivity of rainfed rice-based systems. Consequently, very little documented data exists on the yield potential or yield gap in rainfed agriculture. Similarly, our knowledge of constraints on double and triple cropping strategies is scant compared to that for irrigated farming.

The two research projects described in the abstracts presented below were complementary efforts to address these lacunae. In one project, this was attempted by exploring ways of defining areas where multiple-cropping is feasible in an agronomic sense, given water availability. In the other project yield performance was examined in an effort to explain the yield gap between actual on-farm performance of farmers. These data were also examined with a view to identifying constraints influencing farm-level productivity, and as a means of assessing the adequacy of current extension practices and recommendations. As an interactive component between the two projects, an attempt was made to compare the performance of research-managed trials with on-farm performances and to seek explanations for the gaps encountered.

In the process of pursuing these aims, both projects have sought to explore appropriate methods of analysis and field-level research; and have done so with some success. We learn, for instance, that while frontier-analysis of the yield-gap problem requires much data to yield reliable farm-level production functions, the project has shown that such data can be collected in the field, and this new analytical approach, with careful farm-level survey work, can yield rich new insights into factors influencing variations in farmer performance. On the other hand, the great variety of input-responses across farms and plots in rainfed agriculture makes it essential that economists work with agronomists if meaningful assessments of farm data are to be conducted. The agronomy project also gives us heart in that the initial attempts to utilise agronomic water-balance crop-modelling techniques, together with meteorological time-series data to describe the risks of successfully growing second or third crops (each of which identifies the probability that multiple-cropping will succeed), have proved promising. If such risks can be described with confidence, the analysis can form the basis of far more realistic programs of agricultural development using multiple cropping than has been possible before. Moreover, such data can also be used to specify levels of 'potential profitability' associated with any new technology (e.g. new seed variety, rotation, management practice, etc.). This provides a standard against which existing and potential extension recommendations can be evaluated.

There is a great deal of research that is needed if the productivity of rainfed agriculture in the tropics is to be increased fast enough to meet future needs. A great deal of this research will involve replications of experiments and analysis to accommodate the situation-specific requirements of farming in the tropical rainfed zone. These replications are properly the preserve of local researchers imbued with essential specific knowledge, language, and social-cultural familiarity. International collaboration fits into this system insofar as there is a need to: assist in developing methods of analysis and field work that are practicable; provide peer reviews of data interpretation and experimental design; and join in collegial exploration of options available in research methodology which will generate meaningful insights, to the farmer, and to policymakers.

Some Important Results

Although the research reported here focused on the Philippines and Sri Lanka, there are substantive implications of the results discovered that have a broad relevance for rainfed rice production generally, and in particular, for research on this agricultural system.

Reexamination of Extension Systems

A critical consequence of the environmental control available to farmers in irrigated farming was the ability of researchers to define a 'package' of technologies that extension officers could 'recommend' to farmers. Typically, this package incorporated a modern variety plus inputs of irrigation, fertilizer, herbicide and insecticide. There were few variations on the package and the technology was presumed relevant to the entire irrigated zone. In rainfed agriculture this 'package' approach to the spread of improved farming methods is less appropriate. Field scale variability of input response and a current inability to predict performance reduces the relevance of the fixed package, necessitating the development of a more flexible system. Central to the success of such an alternative will be the ability to rapidly identify soil types, soil variability, soil deficiencies, and rainfall patterns across farms and regions. This task is so massive and daunting, it is difficult to see how any extension system can meet it without farmers themselves being part of the testing and extension system. What is now suggested are simple input-response trials which farmers can implement and interpret in conjunction with extension advisers. In such a system the role of the extension agent will be much different from that under the current 'blanket-recommendation' system.

Expansion of Multiple-Cropping

The potential for successful and profitable exploitation of double-cropping in the rainfed tropical areas such as those represented in these research projects in the Philippines and Sri Lanka is substantial. However, before this potential can be realised we need more information on the key constraints to its spread. In the Philippines early establishment of the first crop seems to be a critical factor. Early establishment is influenced especially by the turn-around time between crops. This is susceptible to manipulation by altering key cultural practices to those that favour transplanting, more efficient use of draught animals, quicker land preparation, better harvesting techniques, and improved postharvest practices.

Profitability to the Farmer

The new technologies and cultural practices noted above are not riskless options to the farmer. The farmer wants to — needs to — know whether each or several will alter the profitability of his/her whole enterprise. For example, it is often the case that early establishment of the first crop results in a lower yield for that crop. What is not clear is whether total profitability across the whole year suffers.

Profitability cannot be divorced from the risks associated with the pursuit of profit. It is little use mounting a program to encourage double-cropping unless we have the data to demonstrate that the risk of failure is acceptable. Farmer-managed field trials, targeted at farms in areas where the probability of success is good, can prove to be essential in this process. The end result will be a more farm-oriented and integrated rural research and extension system.

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Overview of the Agronomic Studies

J.F. Angus*

In areas in which rainfed rice is grown, such as the parts of the Philippines and Sri Lanka where these studies were conducted, it is possible that more than one crop can be grown on a parcel of land in a year, so that annual crop production is made up of the yield per crop and the number of crops grown each year. This project is concerned with both components of production. Each is studied from both agronomic and socioeconomic aspects, as reported in the papers presented at this workshop. The principal research methods used in studying the constraints to higher productivity were: in the agronomic study, field trials and simulations for yield per crop and number of crops respectively; and in the socioeconomic study: surveys and frontiers, and discriminant functions.

Agronomic Studies

Yield Per Crop

The agronomic study of yield per crop was based on conventional field trials located on farmers' fields. These trials indicated the yields obtainable with recommended technology, and the yield responses to changes in the levels of the major inputs of fertilizers, herbicides and pesticides. The trials highlighted gaps between yields with farmer-technology versus researcher-technology, and the reasons for such gaps. Associated with the field trials was a program of crop-cuts on farmer-managed rice crops growing on land which was as close as possible to that used for the field trials. The agronomic project in the Philippines, called Pharlap, has been described in detail (Tasic et al. 1987). The field trials were concerned not only with rice but also with upland crops, and where possible mungbean and cowpea were grown as a second or in some cases a third crop.

Cropping Patterns

In regions which are marginal for multiple cropping, the number of crops which it is possible to grow per year cannot reliably be determined from field trials conducted over a few seasons. Successful multiple cropping under rainfed conditions largely depends on seasonal conditions. Trials conducted over a series of atypical seasons will give a misleading indication of the potential for multiple cropping. The key to promoting an increased number of crops grown in a season lies in better understanding how crops

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respond to the environment, particularly the water balance. Research experience over a number of seasons is needed to provide a confident recommendation on feasible cropping patterns.

A computer model based on water balance concepts during a season was used to estimate the potential number of crops growing at specified landscape positions during long sequences of seasons. The yields measured in the agronomic trials were used to calibrate the simulation model to particular landscapes and seasons.

This simulation model is a development of an earlier version produced at IRRI (Angus and Zandstra 1979). During model development, it became clear that a simplified version, suitable for use on microcomputers, was needed both in analysing the results of particular experiments as well as for studying the adaptation of new cropping patterns in different environments. An interactive and user-friendly version, called Polycrop, has now been released for use in the Philippines Department of Agriculture and is available for interested users.

Interaction

The agronomic and socioeconomic studies are linked through their estimation of actual and potential productivity and through the estimated yield responses to inputs. The two disciplines utilise different methods of estimating productivity, with the socioeconomic methods being based on interviews with hundreds of farmers. It was not feasible to conduct field trials in such numbers, but generally there were sufficient numbers of trials to reliably sample productivity of the same environments where farmers were surveyed by social scientists.

Since the major emphasis of the socioeconomic study was to explain the variation in farmer economic performance, an attempt was made to measure the yield-variability of those crops when supplied with recommended inputs, and the variability of responses to the important inputs. This is an important departure from typical agronomic studies in which the emphasis is on mean productivity and responses. Some of the variation in production between farms is due to natural variability of soil and landscape and some is due to farmers' management and inputs. One aspect of interaction between the agronomic and socioeconomic studies was to examine the estimates, made by different methods, of the variation of crop yield.

A brief mention about topics not addressed in the biophysical project is also appropriate. There was no specific study of varietal yield differences. In the Philippine study areas, virtually all farms grew the modern short-duration variety IR36 at the commencement of the project, but gradually replaced it, during the 2 years of the study, with the varieties IR60 and IR64 which have better pest resistance but are otherwise similar to IR36. In Sri Lanka, varieties possessing a range of maturity types (from 3-4.5 months) within a modern genetic background have been widely available, and different varieties are selected by farmers depending on the duration of the expected growing season. It was felt that in both countries varieties are not major limitations to current production.

Pest control was not intensively studied in the Philippine project. In the Antique study areas there was little serious pest damage to the first rice crops of each season, and limited damage to second crops. This was partly due to the insect resistance in the varieties grown, and partly to low pest populations in the absence of irrigation schemes nearby. In Sri Lanka pest control was studied in the last three seasons of the study.

Environments of the Study Areas

The key environmental differences between the study areas are the relatively low rainfall, short growing season and relatively coarse-textured soils in the Sri Lankan areas compared with those in the Philippines. The recommended fertilizer levels in Sri Lanka, however, are higher than those in the Philippines, and although the amounts of fertilizer applied do not reach the recommendation in either country, the data compiled by Stangel and Harris (1987) indicate that more fertilizer (in kg/ha) is actually applied in Sri Lanka:

	N	P_2O_5	K_2O
Philippines	20	5	5
Sri Lanka	37	14	20

Philippines

The study areas selected in Antique Province on Panay Island have a weather pattern consisting of a more or less continuous rainy season which commences in April–June and finishes in October–January. During this time, at least two crops can be grown over most of the province, and since the mid 1970s when short-duration rice varieties such as IR36 were introduced, many farms in rainfed areas have been double-cropped with rice.

In Antique all rice crops studied in the Pharlap project were fully rainfed and there were no significant irrigation systems nearby. In this important respect the study areas differ from other rainfed areas where cropping systems have been studied previously by IRRI in Iloilo, Pangasinan and the Cagayan Valley. All of these areas are close to irrigation land. One consequence of the isolation of Antique rainfed rice from intensive irrigated agriculture was that inputs such as fertilizer and pesticides, and services such as credit and extension advice, were poorly supplied. Another consequence was that there was no consistent supply of seedlings for transplanting of second crops although transplanted rice has a shorter growth duration, which is recognised as an advantage in rainfed areas. Nor was there an active market in renting hand-tractors from farmers on irrigated areas or good access to spare parts or repair services. On the positive side, the pests and diseases which can persist from season to season under irrigation and spread into rainfed areas during the rainy season are largely eliminated during the reliably dry season.

Rice yields in Antique during the 1980s have averaged 2.5 t/ha which is relatively high by national standards. However in recent years Antique yields have been static while national yields have continued to rise.

Sri Lanka

In Sri Lanka the study areas were in the Kurunegala and Anuradhapura districts, both of which experience a bimodal pattern of rainfall. Most rain falls in the major (or Maha) season which extends from October to February, and less falls in the Yala season which extends from April to June. Rice is grown on rainfed land as well as on land irrigated from major and minor tanks. The former are nationally managed irrigation systems which command large contiguous rice-growing areas. Minor tanks are managed by local communities, and command irrigated rice areas ranging up to about 50 ha. In the undulating landscapes of the study areas in Sri Lanka, the land irrigated from major tanks was typically located at low landscape positions, while that irrigated from minor tanks is at a generally higher elevation but normally not distant from the major schemes.

In the three systems of rice culture, it is normal for farmers to grow rice on lowland areas while growing upland crops on nearby upland areas. In seasons which are wetter than average, rice yields are likely to be high but there is a risk of waterlogging damage to upland crops. In seasons which are drier than average, rice yields are likely to be more severely affected than upland-crop yields. One of the problems for farmers in such a system is that both rice and upland crops need to be established at the commencement of the Maha season so that there may be competition for labour among competing farm activities.

Because farmers have access to both lowland and upland areas, they do not necessarily grow rice when the season is relatively dry. In minor-tank areas particularly, rice may not be grown if there is inadequate or marginal water storage for the commanded land area. Therefore, a reduction in crop area rather than in yield per hectare may be a consequence of drought.

In Kurunegala, three forms of rice culture – major irrigation, minor irrigation and rainfed – were initially included in the experimental program. However, the later experimental series focused on minor tanks and some rainfed land. Rainfed rice in the Kurunegala district is mostly located along the floors of linear valleys which receive run-on from upland areas on the neighbouring ridges.

In Anuradhapura, the rainfall pattern is generally inadequate for rainfed rice, and only riceland in major and minor irrigation areas was used for the experiments.

The national rice yields in Sri Lanka (3–4 t/ha) are relatively high despite the low and unreliable rainfall. This reflects the importance of irrigation and large applications of fertilizer. It also reflects the flexibility of minor-tank systems in which crops are grown only if sufficient water is available to ensure a successful crop.

Objectives

The overall objectives of the agronomic studies on rainfed crops were to measure productivity per crop based on recommended management and inputs, and to measure yield responses to changes in the level of those inputs. The measurements of productivity were to calibrate a simulation model of growth of rainfed crops growing in sequence, and to use this model to help specify the most appropriate cropping patterns for various climatic environments. The measurements were also used for linkage with the socioeconomic studies.

The field trials also had the objective of specifying the most efficient set of inputs for rainfed rice growing in the study areas.

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Overview of the Socioeconomic Studies

R.T. Shand*

In the Philippines, the research sites chosen were the rainfed lowlands of Antique Province in the Western Visayas. Little researched, Antique provides a wide spectrum of agroenvironmental conditions, which we believe will be relevant to, and perhaps characteristic of, many other rainfed lowlands in the Philippines. In Sri Lanka, there is a wide variety of agroecological zones available for research. It was decided to choose two: one in the Dry Zone in the north (Anuradhapura district) and one in the Intermediate Zone (Kurunegala district). Within each of these two districts there is much variation, and bearing in mind our objective of studying less-favoured eotironments, it was decided to draw samples from major irrigation (for the sake of comparison), minor tanks (restricted irrigation), rainfed and mixed conditions (irrigated/rainfed), in Kurunegala district. Anuradhapura had virtually no rainfed areas, so the samples had to be drawn only from areas under major irrigation and minor tanks.

Objectives

The broad objectives were to: (1) Determine the performance of farmers and crops within complex farming systems located in less favourable areas of production, including individual crops within the system, and for the whole farm system (including both farm and off-farm activities). (2) Compare farmers' crop performance with that achievable under field trial and experiment station conditions. (3) Determine and quantify factors contributing to gaps in performance between farmers, field trials and experiment stations (including agronomic, involving location-specific adaptation of technologies; socioeconomic (farm and community level factors) and their interactions with farmers' attributes; and risk parameters associated with different farming systems and cropping patterns). (4) Evaluate the efficiency of the technology transfer mechanism and draw implications for the research/extension interface; to derive policy recommendations for improving farm productivity; to assess implications for developing country research systems and priorities, and for their research collaboration with developed country research institutions (e.g. ACIAR) and aid agencies (e.g. AIDAB); and to interact with the agronomic studies project in analysing the yield gaps between researchers and farmers at field level.

In an attempt to meet the objectives of this study, the methodology development was critical and was focused in two main directions: (1) Technology adoption and its impact were analysed within a farming systems context and within a multidisciplinary framework in order to give a more holistic analysis of farm performance. On the socioeconomic side, a series of farm level surveys were undertaken in each location over

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a number of crop seasons and years which took account of all crop, other farm and non-farm activities from 1983 to 1986. These surveys were paralleled in the agronomic study by complementary field trials which were designed to help to test and 'fine tune' technology under varying conditions. (2) To quantify and explain the range in farm performances under different agroenvironmental and socioeconomic settings. The methodological basis for this is a *frontier production function* framework, a cornerstone of the analysis. Broadly, this approach gives us the 'farm frontier' or best practice performance amongst farmers for any given set of input levels. The performance of farmers below the frontier, i.e. who are less technically efficient, can be quantified. Other techniques are then applied to determine why farmers fail to reach their frontiers. In other words, farmers are individually ranked according to their technical performance, and attempts are made to identify the factors that determine the rankings, from which policy implications can be drawn. This approach also permits measurement of farm-specific allocative efficiency. These two efficiencies together determine farm performance, but can be separately analysed using the frontier function framework.

Preliminary results of the frontier production function analyses were presented at the workshop and are available in project working papers.

Abstracts

Background to Lowland Rainfed Cropping Systems in Antique Province, Philippines

D.S. Magbanua*

A brief survey is presented of the recent origins of lowland cropping systems. The replacement of the traditional tall long-duration varieties began in the late 1940s and was complete by the mid 1950s with the release of several improved varieties which were shorter in stature and growth duration than traditional varieties. At about this time the first fertilizer, ammonium sulfate, and the first pesticides, were used on lowland rice in Antique Province. In the mid 1960s, the first IRRI rice varieties were released and were widely adopted. The duration of these varieties was sufficiently brief that it was possible, for the first time, to grow two rice crops on rainfed land, and a small proportion of the rainfed lowlands in Antique Province was double-cropped with rice. Several years after release, the first IRRI varieties became susceptible to disease, and were replaced by a series of IR-numbered varieties, the most successful of which was the short duration IR36 which was first grown in 1977 and is still not completely replaced by the latest varieties, IR60–66. The availability of effective pre- and post-emergence herbicides in the mid 1970s, combined with the adoption of IR36, enabled large-scale direct seeding and hence early crop establishment and the widespread adoption of double rice cropping.

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Agronomic Studies in the Pharlap Project

R.C. Tasic*, A.B. Delima*, D.A. Marquez*, G.T. Estomata* and J.F. Angus**

Field experiments were conducted on rainfed lowland farms in the three municipalities of Antique Province in the Philippines to compare yields from farmers' fields with those from adjacent fields managed by researchers in accordance with recommended practices. Part of each researcher-managed field was used to establish replicated field trials designed to assess the contribution of the recommended practices singly and in combination. A total of 148 experiments were conducted with rice and 41 with the upland crops, mungbean and cowpea. All experiments were within the normal farming system which consisted of one or two rice crops, with a possibility of an upland crop growing after rice.

The mean yield gap between rice crops managed by farmers and by researchers using recommended technology was 0.55 t/ha, and farmer-managed crops yielded 98% of researcher-managed crops. The yield gap was made up mostly of responses to phosphorus and potassium, neither of which were widely used by farmers. Nitrogen and herbicide did not contribute much to the yield gap because they were applied by most farmers. An additional yield of approximately 0.3 t/ha above the yield with recommended inputs could be obtained by applying Zn, while a small additional response could be obtained by applying S.

The most striking result from the project was the large between-field variability in rice-yield response to P, K, Zn and S, some of which were very large, indicating severe but patchy deficiencies. None of these nutrients were widely used by farmers in the project areas. There was no clear association between the yield responses to nutrients and either soil tests, fertilizer history or soil water status. A blanket recommendation of fertilizer containing P, K, Zn and S is unlikely to be justified because of the variability of yield responses. To identify responsive fields it is suggested that agronomists and farmers conduct large numbers of strip-trials to test fields for suspected deficiencies.

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Agronomic Aspects of the Rice Yield Gap Between Farmer and Researcher in the North Central Dry Zone of Sri Lanka

B.M.K. Perera*, M.P. Dhanapala*, D.B. Wickremasinghe*, C.A. Fazekas de St. Groth and R. Wetselaar****

In the dry and intermediate-dry zones of Sri Lanka, there was a need to identify and quantify the factors responsible for the grain 'yield gap' in lowland rice between farmers and researchers when using modern rice technologies. Two series of on-farm experiments were conducted, each over three seasons, in the Kurunegala and Anuradhapura districts between 1983 and 1986. In the first series, the yield gap was quantified by comparing researcher (R) and local farmer (F) management in approximately 15 experiments per season. In the second series, recommended herbicide, N fertilizer and pesticide were compared with farmers' usual practices in 12–19 modified factorial experiments per season.

Taken over both series, the yield gap (R–F), with an average of 1.23t/ha per crop, decreased significantly in time over the six seasons (3 years) considered. Since the gap was location- and season-dependent, a longer series would be needed to draw a confident conclusion that the farmers' yields are improving. Any decrease in yield gap with time was not associated with an increase in N fertilizer input by farmers, as this remained approximately constant over the 3-year period, suggesting an improvement in N fertilizer management by the farmers. The correlation between soil N availability measurements and plant N uptake at anthesis was exceedingly weak and therefore prediction of fertilizer requirements using soil N measurements was impossible. Comparison of fertilizer N efficiency between F and R shows that there is scope for improved fertilizer N efficiency. In addition, this efficiency might be further increased through provision of location-specific probabilities of water availability combined with postponement of some of the N fertilizer application.

The major and most consistent factor contributing to the yield gap was lack of effective insect pest control. On average, this accounted for 0.5 t/ha of grain per crop. Recommended weed control was not significantly better than the farmers' usual weed control practices.

Where water availability was generally not regarded as a problem by the farmer, there was no significant yield increase with recommended N fertilizer because farmers applied approximately the recommended rate. However, in areas where water stress was common, farmers were reluctant to apply much fertilizer N and in a good season the recommended N treatment produced a significant yield increase.

The general conclusions are that: (1) more intensive extension related to insect pest recognition and control and N fertilizer management is warranted; and (2) the possibility of controlling insect pests on a regional scale should be investigated.

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Socioeconomic Surveys in the Philippines

M.C. Mangabat*

Farm surveys were conducted in the three project municipalities during the 1984–85, 1985–86 and 1986–87 crop years. A total of 603 farms were randomly selected from lists of primarily rainfed farms in each municipality. The sample was distributed across municipalities according to their populations and represented 42% of the total.

Two surveys were conducted for each crop season. Interviewers who spoke the local dialect were hired and trained prior to the surveys. Farm visits were made immediately after crop establishment and harvest. Precoded questionnaires were used; these, however, were designed to record unexpected data.

Three sets of questionnaires were used in each season: (i) the household data recorded socioeconomic and demographic details of all household members including incomes and sources, assets, access to inputs and credit. It also recorded less detailed input-output data on non-rice crops. (ii) This questionnaire recorded very detailed input-output data on each lowland rice plot. A farm map was used to identify each plot over the various seasons. (iii) Crop disposal/income recorded data on production of all crops on all land parcels of the whole farm, their disposition (consumption, sale, etc.) and incomes from other farm activities (e.g. livestock).

To obtain more accurate data and to eliminate problems caused by farmers' subjective assessments of physical descriptions of plots (soil texture, fertility, etc.), an intensive 'close monitoring survey' of a subsample of 150 farmers was conducted in the first season of 1986-87. Farms were visited fortnightly and an agronomist visited each plot and provided data on physical characteristics.

A number of problems noted in the earlier surveys were eliminated in subsequent surveys. However, typhoons and civil disturbances sometimes created problems.

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Scope and Effectiveness of Socioeconomic Surveys of Rice-Based Farming Systems in Sri Lanka

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Analysis of past trends in paddy production indicated that farmers were not obtaining the field potential of the rice technology. It was hypothesised that possible factors were biophysical and socioeconomic, and could vary according to the agroclimatic zones and method of cultivation.

Socioeconomic surveys were initiated in Anuradhapura district of the dry zone and Kurunegala district of the intermediate zone under major irrigation, minor irrigation, and mixed rainfed conditions of cultivation to investigate the causes of the technology gap. Data were used to estimate production functions, technical efficiency, economic efficiency and factors that contribute to efficiency. Analysis of the effectiveness of the survey indicated that the scope of the survey was sufficient to analyse the above indicators and many key factors were identified to explain the inefficiency based on the outcome of the analysis. Nevertheless there were gaps in exploratory farms using large-scale surveys. Therefore a close monitoring survey was introduced midstream. Farmers were visited six times during a season and a field inspection was made with agronomic researchers to obtain values for management variables introduced with the new survey weather data. Data relevant to the research plot were also recorded to replace regional weather data. This method improved the quality of data, eliminated cleaning of data at analysis stage, and improved the explanatory power of variables affecting the technical and economic efficiency of paddy cultivation.

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Measurement of Farm-Specific and Location-Specific Technical Allocative and Economic Efficiencies

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In recent years, the green revolution (or new technology) has been recognised by policymakers as an important tool to increase agricultural productivity. Thus, the primary objective of agricultural policies is to examine and to eliminate the constraints on the adoption of new technology. This is based on the assumption that productivity will be increased once there is adoption of new technology by farmers.

Productivity increases do not depend on adoption rate alone. What is also needed is the effective use of available new technology. In agriculture, productivity per hectare can be improved in the following ways: (1) Technology Development – by introducing and changing input combinations through advances in the technology itself; and (2) Technique Improvement – by improving the techniques of production, given the technology, but without changing input combinations, (i.e. through improvement in the components of a given technology). The literature focuses extensively on the first method but much less attention has been paid to the latter approach. This latter approach is important and deserves more consideration because, with the existing resource structure, it is possible to raise agricultural production without incurring any significant additional expenditure by using the component technology approach.

Basically this latter approach relates to the development of location-specific technology in the sense that the fine tuning that is necessary is in the components of a given new technology. The main objective of this study was to demonstrate and measure the contribution of the 'technique improvement' approach in agricultural production.

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Performance of New Rice Technology in Sri Lanka

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Farm performance in the socioeconomic project was measured in terms of technical and allocative efficiency, using recently developed methodology extended to meet the objectives of this study. In Sri Lanka it was applied by sample surveys in two areas (Kurunegala and Anuradhapura districts), and in different environments in each area: major irrigation, minor tanks, rainfed and mixed locations.

The analysis of seasonal data sets was incomplete at the time of the workshop, which precludes drawing any broad conclusions. Nevertheless, the findings suggest the following:

First, variations in farm performance cannot be fully explained by technical and allocative efficiencies, and the extent to which they vary by location and by season. We believe that much of the unexplained variance in performance is due to plot location and season-specific environmental factors which are extremely difficult to measure at field level. Nevertheless, in most surveys much of the variation in performance could be explained by efficiency levels and by the factors that influenced these.

It appears that technical efficiency consistently has the greatest impact on farm performance. Factors that affect technical efficiency can be divided into two groups: direct managerial decisions made in advance of and during the cropping season, and farm/farmer attributes which can be regarded as proxy variables, many of which embody human capital. In the former category, probably the most important is the critical harvest date or period which affects yield levels,which depends on factors such as rainfall distribution. Other such factors include incidence of pests and diseases, time of planting, establishment methods, use of fertilizer (number of dosages, types and dosage levels), control measures for pests, diseases and weeds. The latter category includes age, schooling, and farming experience of the household head and size of family, but analysis to date has shown inconsistencies in the direction and significance of these variables.

To date our analysis has indicated a second important set of relationships broadly described as a dependency of allocative upon technical efficiency, suggesting an important and fundamental hypothesis for dynamic agriculture in developing countries. Under conditions where a location-specific new technology fine-tuned to the environment is available, farmers will be aware of the technical parameters of their production function and of best practices. Where the outcome is reasonably well assured (under irrigation), they will also be able to judge with fair accuracy the correct mix and levels of inputs to be applied to achieve allocative efficiency and maximise net returns.

It is where uncertainty exists as to the best practices for particular environments, i.e. where location-specific technology has not been identified, that problems of farm performance become manifest. Farmers who are unsure of the best practices will vary in their management decisions about which practices to apply, and consequently, technical efficiency will also vary. This carries the added consequence that they will be uncertain about the correct levels and combinations of inputs to apply.

Hence the relationship between the two components of economic efficiency (technical and allocative) will depend upon the characteristics of the environment, the degree of adaptation of the new technology to the particular environment, and the time which farmers have had to adapt to the new technology. Two contrasting examples may be offered. First, the location-specific

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technology has been defined but is not as yet known universally. Under these circumstances the relation may be positive. Second, location-specific technology has not been defined so that farmers have a range of new practices from which to choose. Risk takers may be optimistic and prefer potentially high-yielding practices which may give them high technical efficiency if events are favourable, but they may make allocative errors for lack of information. Alternatively, risk-averse farmers may prefer a more conservative set of practices for which the input mix and combination are familiar. Under these conditions the relationship may be negative, i.e. lower technical efficiency but high allocative efficiency.

Even in the light of these preliminary observations, we would argue strongly for the need for accurate specification of technologies for particular environments, and against blanket recommendations generated for a particular set of conditions (e.g. for favourable, well-irrigated environments). Management decisions determine technical performance which in turn gives the lead for greater allocative efficiency and, of course, the combination of these determines overall economic performance. Thus we should stress the vital importance of the role of research and extension in widening our knowledge of best practice technology over the range of environments in which rice is grown. It would appear that the 'frontier' methodology affords us new insights into progress being made in this direction.

Production Function Analysis of Rice Production and Farm-Level Efficiency in the Philippines

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Data obtained from sample surveys of farm households in the three Panay Island municipalities (Pandan, Patnongon and Dao, Tobias Fornier) for five crop seasons were analysed using the stochastic frontier production function framework to quantify the various 'yield gaps' in rice cultivation. These functions were then utilised to obtain farm-specific technical and allocative efficiency measures. The determinants of inter-farm variations in these efficiency levels were explored with the aid of multiple regression models and, in some cases, discriminant function analysis. The hypothesised determinants included variables which could be diversely manipulated by policy (e.g. access to credit and extension services) as well as other farm-specific attributes (e.g. farmer's age and responses to fertilizers and other inputs that are highly location-specific).

The influence of micro environmental factors on output levels in rainfed rice is much greater than in the relatively homogeneous conditions of irrigated rice. The results clearly indicated that: (a) there is little scope for raising productivity (with available technology) purely by manipulating conventional policy variables; (b) however, if a practical and cost effective approach can be developed to enable farmers to experiment and tailor the broad technology package to their individual farm conditions, then there is the possibility for substantial increases in productivity.

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Infiltration, Percolation, Seepage and the Water Balance of Rice Fields in Sri Lanka

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The water status and crop yield of lowland fields on farms in the Anuradhapura and Kurunegala districts were studied using a simulation model of the daily water balance. Examples of both rainfed fields and those irrigated from minor tanks were included in the study. The inputs to the model were daily rainfall and pan evaporation, and estimates of the rates of percolation, seepage and lateral percolation for each field, measured with concentric ring infiltrometers.

Percolation rates were 1–3 mm/day, which are similar to reports in the literature. The combined seepage and lateral percolation beneath the bunds of flooded fields varied from 6 mm/day in the Maha season to 21 mm/day in the Yala season in Anuradhapura, and constituted a major part of the water balance and a major cause of variation in water status between fields.

Rice yields were related (r=0.75) to evapotranspiration accumulated over the life of the crops, as estimated from the water-balance model. The highest yields found were in irrigated fields in Anuradhapura and were associated with high rates of evapotranspiration.

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An Interactive Water-Balance Model for Interpretation of Field Experiments for Planning Cropping Patterns in Rainfed Areas

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An interactive simulation model of the water balance of rainfed fields (Polycrop) is described. The model contains a conventional water budget which simulates daily water balance in relation to daily rainfall, estimated mean weekly evapotranspiration, infiltration and runoff. Options for upland and lowland water balance are provided. The input is driven by a user-specified cropping sequence, a menu of crop parameters such as rooting depth and water-use efficiency, and a menu of soil parameters such as field capacity, wilting point and infiltration rate. The system also contains options for user-specified parameters. Water use is estimated for each crop in the sequence and is the basis for estimating yield, based on water-use efficiency.

The model can be operated with long-term daily rainfall data which are available for 103 locations in the Philippines. Using such data the model can provide an indication of the long-term adaptation of specified cropping patterns to a location. It can also be used with weather data for an experimental site so as to compare actual yield with an estimate of water-limited yield for model-tuning or to provide insight into the severity of water deficits.

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Simulation Models of Water Balance and the Growth of Rainfed Rice Crops Growing in Sequence

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Models of water balance and crop growth were used to characterise the environments of rainfed cropping systems in the Philippines and Sri Lanka. In both countries the models were used in conjunction with long-term daily rainfall data and estimates of mean evapotranspiration. In the Philippines, rainfall data for 103 locations over a mean period of 35 years were available; and in Sri Lanka, for 51 stations, for periods averaging 25 years.

A water balance model similar to those used in the previous two studies was used in conjunction with the Sri Lanka weather data in order to characterise the rainfed environments in terms of the duration and reliability of the Maha and Yala growing seasons. It was found that describing the seasons independently was unsatisfactory, but that a prior classification into season failures, continuous seasons and independent seasons gave a more satisfactory description.

In the simulation studies in the Philippines, a model of the growth and development of lowland rice was combined with the water balance model and used to estimate the yield of lowland rainfed rice crops, including crops growing in sequence. This model, a more comprehensive version of the one described in the previous abstract, was adjusted on one set of data and tested on an extensive and independent set of data from the Pharlap project. The yield estimates were found to fit observations of the highest yields found in the Pharlap trials, but to overestimate yields of many fields. It is likely that the widespread nutrient deficiencies found in Antique led to the low observed yields. The model therefore simulates potential yield of rainfed crops.

Based on this model running with a set of parameters describing a typical lowland field, the productivity of different cropping systems was simulated for the locations of the Philippine weather stations. The simulations suggest that one wet-seeded rice crop can be grown in virtually every year, but that a second crop is likely to be successful in a smaller proportion of seasons, varying from 30% in northern Luzon, to 80% in parts of Mindanao. There appears to be little advantage in hastening crop turnaround in the relatively short growing season of northern Luzon nor in the long growing seasons of Mindanao, but in the intermediate-duration growing seasons of the Visayas the model simulated greater productivity from a reduced turnaround period.

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Factors Affecting Cropping Intensity in Antique: Interaction Between Agronomic and Socioeconomic Factors

J.F. Angus* and S.K. Jayasuriya**

The intensity of crop production – the number of crops grown on the land in a year – was studied in the municipalities to compare the actual and potential performance of multiple cropping and to identify factors constraining intensification. Throughout the study areas, rice was virtually the only crop grown on lowland areas, so this part of the study focused on double cropping of rice, with an emphasis on hastening the operations of land preparation and crop establishment which would enable two crops to be grown within the available growing seasons.

Surveys of farmers' cropping systems conducted over 2 years indicated differences in the incidence of double rice cropping between the three study areas, with 100% double cropping in Pandan, 40% in Patnongon and 33% in Tobiàs Fornier. These percentages are consistent with the durations of the growing seasons in the three municipalities.

For the latter two study areas, canonical discriminant analysis indicated that the factors associated with double cropping were early establishment of a first rice crop, irrespective of the method of crop establishment, and the possession of two or more carabao.

Calculations from the survey data also indicated marked differences between municipalities in the rates in which land was prepared for crop establishment, with the most rapid land preparation in Pandan, followed by Patnongon and Tobias Fornier. The presumed reason for the rapid land preparation in Pandan is that, because of the long growing season, farmers were confident of establishing two rice crops, and so were prepared to invest considerable resources in ensuring that two crops were grown on all land.

Simulations of yields of rice crops growing in sequence, using long runs of weather data, confirmed that double rice cropping was virtually assured in long-growing-season environments like Pandan, provided that the rate of crop establishment was no slower than is practiced at present. For short-growing-season environments such as Tobias Fornier, the simulations confirmed the risks of double rice cropping. However for environments of intermediate growing-season duration, the simulations indicated a relatively high chance of success provided crop establishment was rapid, and suggest opportunities for rice intensification.

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Linkage Between the Agronomic and Economic Studies

C.A. Fazekas de St. Groth*, J.F. Angus**, R. Wetselaar*, T. Law***, R.T. Shand*** and S.K. Jayasuriya***

The field experiments and economic surveys conducted on farms in the same regions enable comparisons to be made of rice yields obtainable with recommended practices and those obtained by the most efficient farmers. The latter yields were estimated for farms at the production frontier, assuming the use of recommended inputs.

In the Philippine study areas, the comparison for the dry environments of Tobias Fornier and for the second crop at Patnongon showed little difference between yields in experiments and those of farmers at the technical frontier, suggesting that there is no gap between the available technology and that employed by the most efficient farmers. For the wet environment of Pandan, there was a large gap between experimental yields and those at the farmers' frontier; it was largely due to the lack of fertilizers other than nitrogen in an environment with multiple nutrient deficiencies. For the first crop at Patnongon it was difficult to draw clear conclusions because of the highly variable yields associated with the heterogeneous landscape and the difficulty of specifying the most profitable inputs for a particular field. It may be that the heterogeneity of the landscape itself is a major constraint to increased productivity in this environment.

In Sri Lanka, all comparisons of researcher and frontier yields showed a gap. The conclusion from both agronomic and economic studies was that pest control was the major management practice contributing to the gap in rainfed conditions and in major and minor tank areas. The generality of the pest-control problem suggests that the problem would be more effectively addressed on a regional scale rather than on the scale of individual farms.

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Implications of the Results of the Philippine Agronomic Studies for Development Policy, Extension and Further Research

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The field experiments and simulation studies are discussed in relation to their implications for the specific problems in Antique Province, and for other regions of the Philippines. The implications of the more novel results are highlighted. The results of the field trials showed large and relatively reliable rice-yield responses to potassium in Pandan and to zinc in the three locations studied, and showed some very large but not widespread responses to potassium in the other two locations, and to phosphorus and sulfur in all locations. For the more reliable results the implication is a need to strengthen the extension effort to promote use of appropriate fertilizers. For the less reliable inputs it is suggested that a program of numerous strip-trials be included in extension programs to test for suspected deficiencies on farmers' fields.

The unexpectedly large yield responses to nutrients found in Antique lead to the possibility that there may be other Philippine locations with previously undiagnosed deficiencies. Strip-trials may also be the most cost-effective means of identifying such locations, and for gaining insight into factors leading to such deficiencies.

The simulation studies point to a possibility for increasing the cropping intensity in central parts of Antique. The use of simulation models may also have application in identifying scope for different cropping systems in other regions of the Philippines.

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Workshop Recommendations

- Rainfed farming systems are not well described or documented. The degree of edaphic variability is greater than has been presumed. There is a need, therefore, to analyse data available so as to identify essential gaps that must be filled. This is a task best suited to national research groups, including local Department of Agriculture and university personnel. The results of the data analysis ought to be subject to peer review at a workshop called for this purpose.
- Crop modelling is a promising method of examining the impact of new technology or policy on farm output. Further development of models to incorporate policy variables may lead to improved farm-level profitability.
- There is a need for researchers to expand their investigation beyond the rice-rice rotation. In rainfed cereal zones, the second crop that produces optimal results may not be another rice variety. The role of upland crops and livestock as profitable alternatives needs to be considered.
- The gap between yields achieved by farmers, and that achieved by researchers under rainfed conditions, needs to be more precisely and reliably measured. Both the agronomic and economic studies reported here confirm that farmers are, on average, rational in the choice of techniques and the pursuit of the highest net return for their endeavours.
- Further attention is needed to continue to refine the models underlying empirical results bearing on important policies, practices and interrelations between crop responses and environmental variables. In particular, research is needed to increase our capacity to extrapolate beyond the situation-specific nature of current research and models, into new and different environments.
- The pest management of rainfed agriculture needs special attention in environments where pests can migrate from irrigated areas. This problem may be best understood from a regional rather than farm-specific perspective.

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