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ABSTRACT

This book is intended to give animal scientists elementary tools to perform on-farm livestock analysis and to provide crop-oriented farming systems researchers with methods for conducting animal research. Chapter 1 describes farming systems research as a systems approach to on-farm animal research. Chapter 2 outlines some important animal-production concepts for nonscientists. Chapter 3 covers the economic concepts that are essential for technology evaluation and analysis. Chapter 4 briefly reviews the basic statistical concepts necessary for the design and analysis of on-farm animal research. Chapter 5 presents a model for screening animal technologies at the research station before on-farm testing is conducted. Chapter 6 provides guidelines for conducting on-farm research. Chapter 7 presents the tools needed to carry out simple economic analysis. Chapter 8 covers basic marketing concepts that are relevant to on-farm research, explaining the reasons that small farmers may be hesitant to test new practices and describing the marketing aspects that should be kept in mind when choosing a technology for on-farm testing. Chapter 9 deals with the risk and uncertainty inherent in new technologies. Chapter 10 covers such topics as obtaining support for on-farm research and the roles of different levels of management in supporting research. The book concludes with a glossary of some 700 terms, a 118-item bibliography, and exercises relevant to each chapter. (CML)

CONDUCTING ON-FARM ANIMAL RESEARCH: PROCEDURES & ECONOMIC ANALYSIS

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AND
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WINROCK INTERNATIONAL INSTITUTE FOR AGRICULTURAL DEVELOPMENT AND
INTERNATIONAL DEVELOPMENT RESEARCH CENTRE

The mission of Winrock International Institute for Agricultural Development is to reduce poverty and hunger in the world through sustainable agricultural and rural development. Winrock International helps people of developing areas — in Asia, Africa and the Middle East, Latin America and the Caribbean, and the United States — to strengthen their agricultural institutions, develop their human resources, design sustainable agricultural systems and strategies, and improve policies for agricultural and rural development. As an autonomous, nonprofit organization, Winrock International provides services independently as well as in partnership with other public and private organizations. The institute is recognized as a private voluntary organization.

The International Development Research Centre is a public corporation created by the Parliament of Canada in 1970 to support research designed to adapt science and technology to the needs of developing countries. The Centre's activity is concentrated in five sectors: agriculture, food and nutrition sciences; health sciences; information sciences; social sciences; and communications. IDRC is financed solely by the Parliament of Canada; its policies, however, are set by an international Board of Governors. The Centre's headquarters are in Ottawa, Canada. Regional offices are located in Africa, Asia, Latin America, and the Middle East.

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FOREWORD

There is increased awareness of the important role of livestock in Asian economics. Different livestock species are used to cultivate land, transport goods and people in rural areas, provide manure for fuel and crop production, utilize marginal lands and crop residues, and provide a form of insurance for the farm household. Thus it is that livestock makes many important contributions to the welfare of the people beyond the production of meat, milk, eggs, skins, and hides.

More research needs to be done on livestock, as animal scientists have lagged behind crop scientists in using farming systems research tools. Farming systems research makes modern production techniques applicable to the complex but poorly endowed mixed farms that are predominant in the developing world. The approach involves farmers in the research process — to define researchable problems, to develop and test possible solutions, and to disseminate the appropriate new technologies. The goal is to generate improved technology that is acceptable to farmers of a defined region, farm type, and production environment. The technologies are not confined to a single input; for example, irrigation research considers the balance among food crops, tree crops, animals, fish ponds, land use, and other enterprises.

There are many interactions between crops and farm animals. At times, livestock may be the only way farmers can benefit from community resources, such as grazing lands or forests. Livestock provides an alternative market for crops by use of low-quality roughages and poor-quality grains. In addition, livestock ownership provides a safe investment that can be stored and which produces increased returns through reproduction and gain in body weight. This flexibility in marketing and savings adds to the sustainability of farm enterprises and protects against natural calamities.

However, livestock does compete with food crops for land and labor. Forages may occupy land or can be intercropped with food crops, planted in hedgerows, or confined to land types that are difficult to manage. Livestock definitely competes for farm labor needed to feed and care for the animals and process the resulting products.

Because of the small number of animals on farms, high cost, and close emotional ties between the farm family and its animals, on-farm experimentation with animals becomes more difficult than with crops. Failure of a treatment, or even animals' adjustment to new feed sources, may lead to a drop in milk production, loss in weight, or listlessness. Disease effects can have more serious repercussions for livestock researchers than will reduced grain yield in a farm field.

For these reasons, the emphasis on ex-ante analysis of the biological and economic feasibility of new production methods should be greater in animal production than in cropping systems research. Modifying the animal production system — involving multiple products and a complex of difficult-to-cost crop by-products, labor, and agricultural inputs — can make analysis difficult.

Because of such complexities, animal scientists have been slow to adopt on-farm research strategies. This has prevented crop scientists, such as production-oriented agronomists, and economists from incorporating a livestock component in their analysis.

It is to address these problems and overcome such deficiencies that Amir and Knipscheer have prepared this publication. Its objectives are to give animal scientists elementary tools to do on-farm livestock analysis and to provide methods for use by crop oriented farming systems researchers to conduct or participate in animal research.

Winrock and IDRC have had a history of collaboration in this field, beginning with the workshop, "Livestock in Asia: Issues and Policies," held in 1982 in Singapore, and continuing with a workshop, "On-farm Animal Research and Its Economic Analysis," held at SEARCA, Los Baños, Philippines, January 18–23, 1987. Much of the material presented in this book was reviewed during the latter workshop.

We are grateful to the Office of International Cooperation and Development of the U.S. Department of Agriculture, the Economics Planning and Program Division of the Bureau of Science and Technology of the U.S. Agency for International Development, and the Small Ruminant Collaborative Research Support Program for their financial assistance in preparation of this volume.

Experience in on-farm animal production experiments is needed and is expected to increase rapidly. We believe this book will contribute to better understanding and communication among scientists, and thus be an important stimulus to further development of methods.

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In the earlier stages Dr. John De Boer of Winrock International provided leadership in the project design and was instrumental in developing the necessary contacts. At that time Dr. De Boer was Principal Investigator for the Small Ruminant Collaborative Research Support Program as well as Deputy Director of Winrock International with special responsibilities in Asia. We have greatly benefited from his insights and expertise. Similarly, Dr. Philip E. Church, Chief of the Economics Program and Planning Division of the Bureau of Science and Technology, USAID, Washington D.C., has taken deep interest in the development of this training manual. We are grateful to both these individuals without whom this book could not have been developed.

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The Southeast Asian Regional Center for Graduate Study and Research in Agriculture (SEARCA) and the International Rice Research Institute (IRRI) in the Philippines, provided the necessary field support to accomplish the project. In particular, Dr. F. Bernardo, Director General of SEARCA, and Dr. Ces Jeseana, Deputy Director General, were extremely helpful during the implementation stage. Dr. M. S. Swaminathan of IRRI generously offered the use of their facilities. Both the Multiple Cropping Systems and the Agricultural Economics Department played an active role in the preparation of this manual. The support given by Dr. John C. Flinn and Mr. V. C. Carangal is deeply appreciated. In addition, Mrs. Annie Frio and Dr. Marlin Van Der Veen, in charge of farming systems training at IRRI, shared their experience without reservation.

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Malaysia greatly supported our efforts. Participants from these countries gave a critical assessment of the training manual during a workshop. This improved the content and sharpened the focus in order to meet the needs of national programs.

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We also express our sincere thanks to Dr. C. Devendra, Mr. Christopher MacCormac, and Mr. Chin Saik Yoon, from the International Development Research Centre in Singapore, for their continued support. Dr. Devendra deserves special mention for helping us organize the material and improve the quality of the manuscript in many ways. Mr. Chin also made many useful suggestions regarding the design of the publication. Similarly, Dr. Gordon Banta of the IDRC head office helped review the chapters on economic analysis and Mr. Bill Carman made an editorial review and contributed many useful suggestions. Ms. Susan Stockwell represented IDRC in the production phase of the work. Without their encouragement this project would undoubtedly have been incomplete in many respects.

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While every effort has been made to produce an error-free document, any oversights remain our sole responsibility.

INTRODUCTION

There is widespread interest in and a large amount of published literature on the topic of Farming Systems Research (FSR). Much of FSR has been conducted in both national and international research centers with past efforts concentrating on improving the crop component of a variety of farming systems. Recently, the recognition has emerged that the animal component of the mixed-farming system has been neglected. This observation is reflected in the present state of Asian mixed-farming systems: while yields of rice and wheat have increased dramatically, animal productivity has remained unchanged.

Among the reasons presented for the neglect of animal research directed toward small farms are the high cost of on-farm research, the marketing constraints on increased production, and the popular belief that only commercial animal production is profitable. Presently, it is clearly recognized that new technologies must be found for the small farm, which comprises the majority of the agricultural sector in most developing countries. In order to be feasible, profitable, and acceptable, on-farm research is an essential step in the development of new technologies. Any realistic strategy for improving conditions on the small farm must be directed toward increasing the productivity of the crop and animal components simultaneously. The obvious need for materials on conducting On-farm Animal Research (OFAR) and evaluating innovative animal production technologies resulted in the preparation of this training manual.

The goal of this manual is to give the reader skills in designing, testing, and evaluating livestock technologies that can be used by small farm owners. The minimum of a B.S. degree (or the equivalent) is required to handle the material in this training manual. The subject matter is thus aimed at the junior- and middle-level researchers and extension workers who are involved in the planning, conducting, and evaluation of OFAR. It also should be helpful to graduate students taking a course in animal husbandry that focuses on animal production systems research and to those with a technical background who may wish to familiarize themselves with this relatively new field of study.

Some specific objectives are:

- To explain the framework of OFAR with special emphasis on its economic evaluation.
- To describe the economic, statistical, and animal-production concepts that apply to conducting OFAR.

- To provide case studies and analytical tools that will help researchers and extension workers improve animal productivity at the farm level.
- To provide training materials that can be used in FSR, animal husbandry, farm management, and extension.

Because of the many disciplines that OFAR encompasses, including economics, animal husbandry, and statistical analysis, the subject matter of this manual is very broad in scope. The authors have chosen to give each topic sufficient development to enable the practical application of the concepts presented and to ensure that the above objectives of the manual can be met. Sources of further information, including an extensive glossary and bibliography, will hopefully help to clarify the more difficult concepts that have been included. This book is not intended to make a contribution to the theoretical aspects of OFAR, but rather, to serve as a general guide and reference for those involved in the many stages of OFAR.

The material has been arranged in 10 chapters as listed below. Each chapter begins with a statement of purpose and list of objectives and ends with a summary of the chapter material. A description of each chapter is as follows:

- Chapter 1: Describes FSR as one approach to OFAR.
- Chapter 2: Outlines some important animal-production concepts for nonscientists. It is intended only as an overview. In a formal course, this chapter should be taught by an animal scientist and supplemented with additional readings.
- Chapter 3: Covers the economic concepts that are essential for technology evaluation and analysis. It is a prerequisite for later chapters and is recommended for noneconomists.
- Chapter 4: Briefly reviews the basic statistical concepts necessary for the design and statistical analysis of OFAR.
- Chapter 5: Presents a model for screening animal technologies at the research station before on-farm testing is conducted. The model illustrates the links between on-station and on-farm research.
- Chapter 6: Provides general guidelines for conducting on-farm research while identifying some common shortcuts and pitfalls.
- Chapter 7: Presents the tools needed to carry out simple economic analysis. Careful attention should be paid to this chapter, and, where possible, the concepts presented here should be applied to actual data.

- Chapter 8: Covers basic marketing concepts that are relevant to on-farm research. It explains the reasons that small farmers may be hesitant to test new practices and the marketing aspects that should be kept in mind while choosing a technology for on-farm testing.
- Chapter 9: Deals with the risk and uncertainty inherently related to a new technology.
- Chapter 10: Covers topics such as obtaining support for on-farm research, the roles of different levels of management in supporting research, and the incentives needed to promote on-farm animal development. It also identifies sources of further information. Although this chapter is directed to the manager interested in initiating on-farm research, it is also meant to give the OFAR practitioners an insight into the institutional constraints which their directors face.

Many of the examples presented in this manual can be duplicated and modified to meet specific situations. The words "animal" and "livestock" are used interchangeably throughout the manual and denote all domesticated animals. Therefore, the concepts presented here are equally applicable to ruminants, swine, chickens, ducks, and rabbits, as well as to draft animals, such as donkeys and camels.

In addition to the many concepts presented in the text, many other agricultural and economic terms are defined in the glossary. The glossary can thus be used as a tool for further clarification and explanation of important terms and concepts. A complete bibliography will also be found at the end of the training manual. This should be utilized as a source of further reading material as well as a reference list for the citations given in the text. At the end of the book a section has been added which contains a limited number of exercises arranged according to chapter. These will help to clarify and reinforce the concepts given in each chapter. In addition, they can be used as examples or as testing material.

For further information the reader is welcome to contact either of the authors at the Winrock International Institute for Agricultural Development, Petit Jean Mountain, Route 3, Morrilton, Arkansas 72110-9537, U.S.A.

CHAPTER 1

ANIMAL RESEARCH WITHIN FARMING SYSTEMS RESEARCH

PURPOSE

To improve technology that is pertinent to animal production on small farms requires a systematic analysis of farm problems, household goals and aspirations, existing crop-livestock enterprises, market potential, and government policy. Although several approaches are available to carry out this analysis, including the traditional farm management approach and agricultural extension methods, Farming Systems Research (FSR) has recently gained acceptance for the design of new technology. FSR is currently being used to describe, diagnose, design, and test new technologies at the farm level. This chapter introduces the basic concepts of FSR with emphasis on animal research at the farm level.

OBJECTIVES

After completing this chapter, the reader should be able to:

- Define FSR.
- Explain the activities of on-farm research in FSR.
- Describe the important characteristics of animal production systems in FSR.
- Define the goals of On-farm Animal Research (OFAR).
- Explain the strengths and weaknesses of FSR in improving the animal component.

FARMING SYSTEMS RESEARCH

A system is a conceptual artifice that includes a collection of interdependent and interactive elements that act together to accomplish a given task. The interactions with, and influence upon, elements outside the system may be either weakly or strongly connected to any intrinsic feedback mechanism of the system. A farming system is a unique and reasonably stable arrangement of farming enterprises that a household manages according to well-defined practices in response to physical, biological, and socioeconomic factors and in accordance with household goals, preferences, and resources (Van Der Veen, 1986). All of the above factors influence the production methods used by the household and the output that is achieved.

Within the farming system are the household, crop, animal, soil, weed, insect, and other subsystems. The household, crop, and animal subsystems are integrated and interdependent (see figure 1.1). The household provides labor and management, crops provide feed, and the animals generate power, manure, meat, milk, and capital. The farming system is part of a larger agrosystem composed of nonagricultural systems, market and credit systems, and other farming systems (see figure 1.2). While the importance of components such as crops, orchards, fish ponds, and off-farm employment are recognized, they are not addressed directly in this analysis. Instead of holistically studying the mixed farm, the focus of this manual will be on the animal component of a farming system, and changes in animal productivity will only be evaluated on noncommercial farms.

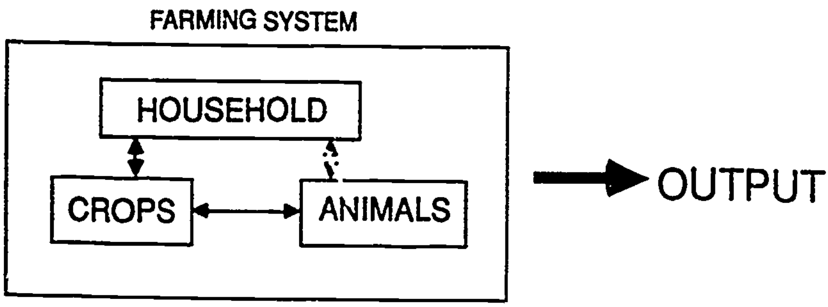

Figure 1.1. The interdependent elements of a farming system.

FSR is an approach to agricultural research and development that 1) views the whole farm as a system, 2) focuses on the interdependencies of the components under the control of members of the farm household and on the interaction of these components with physical, biological, and socioeconomic factors not under the household's control, and 3) aims at enhancing the efficiency of farming systems by improving the focus of agricultural research in order to generate and test better technology (Shaner et al., 1982; Van Der Veen, 1986).

On-farm research in FSR involves five basic activities (see figure 1.3). These are 1) the selection of target areas and farmers, 2) identification of problems and opportunities and development of a research base, 3) the design of an on-farm research plan, 4) execution of on-farm research and analysis, and 5) evaluation, implementation, and extension of the results. Activities carried out under on-farm research rely on the collaboration of the farmer with the extension worker and the research scientist. Opportunities for influencing public policy and improving support systems that affect the target farmers are also considered during the FSR process, but FSR does not explicitly address these issues.

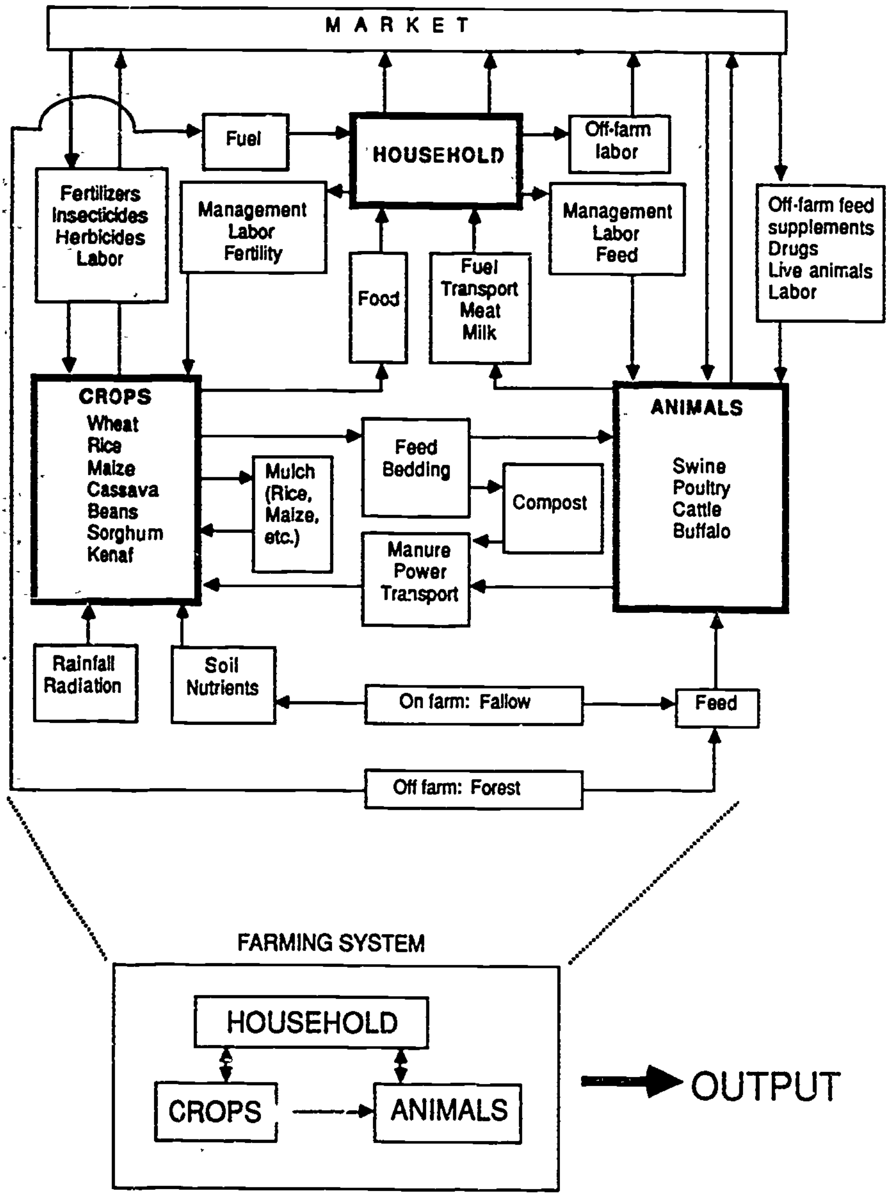

Figure 1.2. The interdependent elements of a farming system and their connection with other elements within the agrosystem.

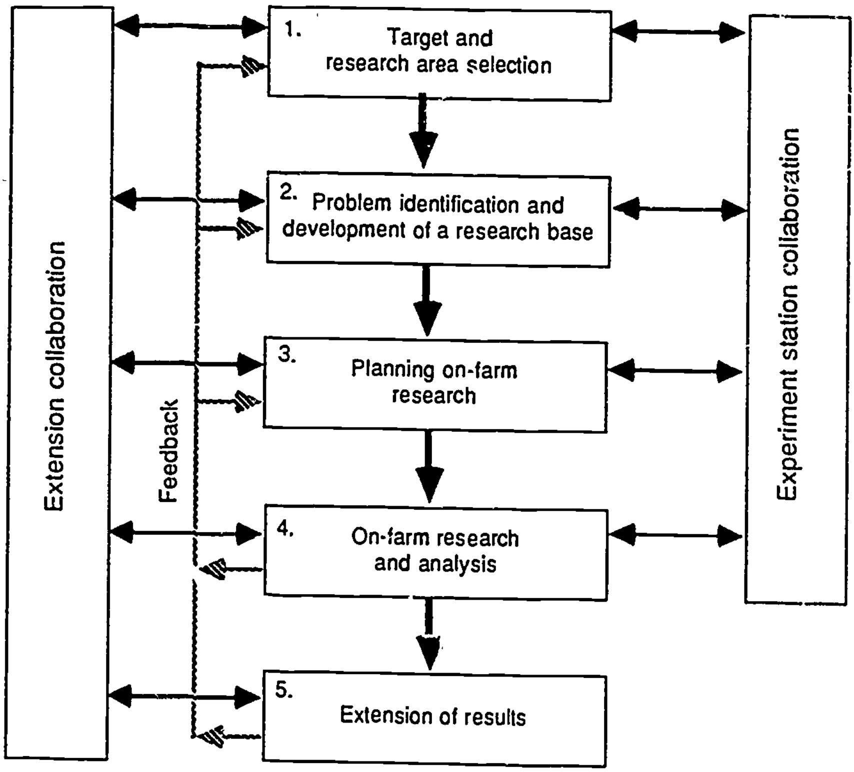

Figure 1.3. The five basic activities of on-farm research in farming systems research. (Source: Shaner et al., 1982).

Some of the key characteristics of FSR are:

- It views the production unit (farm) and the consumption unit (household) comprehensively. For small farms, these units are often synonymous.
- Priorities for research reflect the holistic perspective of the whole farm/household and the natural and human environments.
- Research on a subsystem is considered part of the FSR process if the connections with other subsystems are recognized and accounted for.
- FSR evaluates both individual subsystems, such as horticultural crops, and the overall farming system.

In practice, FSR often concerns a particular commodity and certain factors affecting its production, such as the dominant cropping pattern affected by water availability, fertilization, and fallow periods. These limits are used to focus the research.

The principal elements that distinguish FSR from traditional agricultural research are 1) FSR aims to understand the farm, farmer, and farm environment holistically — that is, as a complex system of interdependent parts, 2) priorities for FSR are determined by analyzing farming systems that represent target groups since the purpose of FSR is to use technology to solve farming system problems, and 3) the FSR process, including the analysis of the farming system, technology development and testing, and verification of test results, is carried out by interdisciplinary teams of social and biological scientists with the cooperation of local farmers.

There are both upstream FSR programs and downstream FSR programs. These two levels of FSR are differentiated by the type of research and implementation that is involved. Upstream FSR programs generate prototype solutions. Since these solutions lead to major shifts in the potential productivity of farming systems in general, upstream programs involve several years of research on and off stations and are particularly the concern of the international agricultural research centers and some regional research programs. Downstream FSR programs identify and test possible innovations that can be easily integrated into existing farming systems by focusing on close interaction with farmers via on-farm trials. (For this reason they are also known as site-specific FSR programs.) Downstream programs draw selectively upon results from commodity, discipline-oriented research or upstream programs and are commonly carried out within the context of a national agricultural development project or research institute.

Three categories of FSR can be identified: 1) farming systems research which attempts to simply understand the system (FSR *sensu stricto*), 2) on-farm research with a farming systems perspective, and 3) new farming systems development (Simmonds, 1985).

FSR sensu stricto is the study of farming systems as they exist. The analysis is usually technically and socioeconomically in-depth, and the orientation is academic or scholarly rather than practical.

On-farm research with a farming systems perspective is a practical extension to agricultural research based on the assumption that only the farmer's experience can reveal to the researcher what farmers really need. This approach, which has been adopted by the International Maize and Wheat Improvement Center (CIMMYT), has been followed in this manual. This category of FSR isolates a subsystem of the whole farm, studies it with just sufficient depth (no more) to gain the necessary perspective, and proceeds as quickly as possible to on-farm experimentation with the farmer's collaboration. It assumes that stepwise changes in an economically favorable direction are possible and worth seeking. In OFAR with a farming systems perspective, emphasis is placed on designing and testing new animal technologies at the farm level and on facilitating dialogue between researchers, extension workers, and farmers that can lead to improvements in productivity of animals.

New farming systems development starts with the view that many tropical farming systems are so unproductive that radical restructuring rather than stepwise change is necessary; therefore, the objective of this research is to invent, test, and exploit new systems. Introducing a new species of animal in an area along with a new forage crop would be considered a new farming systems development. In contrast to on-farm research with a farming systems perspective, which seeks to adapt technology to the farmer's economics, new farming systems development usually implies government intervention and the adaptation of economics to technology.

STAGES IN FARMING SYSTEMS RESEARCH FOR THE DESIGN OF NEW TECHNOLOGY

Commonly recognized stages in FSR for the development of new technologies are (Rohrbach, 1981):

Description	Examination of the characteristics of a series of representative farming systems. Most often, analysis of the farming system targeted for assistance requires an initial review of existing secondary information, such as baseline surveys on resources and climate, and then involves formal or informal farm surveys. During this stage, production systems can be studied and classified for the purpose of introducing appropriate modifications that lead to higher productivity. De Boer (1977) and Fitzhugh (1978) provide useful insight into the classification of production systems.
Design	Evaluation of the specific technological needs of the farming system and identification of technologies that might be developed or adapted to increase farm system productivity.
Testing	Trials of the chosen technologies on farmers' fields.
Verification	Final evaluation of whether the technology is acceptable to the farmer and provision of information about the technology to the extension service for dissemination.

ANIMAL-PRODUCTION SYSTEMS

Roles of Animals in Small Farms

Livestock make a significant contribution to Asian agricultural production. The various types of livestock existing throughout Asia and other developing countries provide farm families with food, draft power, fuel, and fertilizer (see table 1.1). These animals also provide regular income and employment, particularly for small farmers and landless laborers.

Table 1.1. Livestock contributions to people.

Food:	Meat, milk, eggs
Fiber and skins:	Wool, hair, hides, and pelts
Traction:	Power for crop production, irrigation pumping, threshing, and transport
Animal wastes:	Fertilizer, heating fuel, methane gas production, feed, construction material
Storage:	Storage of food supply or capital and seasonal excess of feeds
Weed control:	Biological control of brush, plants, and weeds along roadsides and waterways
Cultural:	Security and self-esteem — revered symbols
Sports/recreation:	Competition, exhibition, hunting, and companion animals

Although the contribution of livestock to household welfare is clearly recognized, improvements in livestock production are needed. The relatively inefficient animal production systems in most developing countries require continued innovation to make larger contributions to household income and to improve national nutrition levels. The demand for meat, dairy products, and eggs rises faster than the demand for crops; therefore, livestock production needs to increase at a relatively faster rate than crop production. Furthermore, livestock production effectively transfers income from high-income consumers to animal producers.

Some of the major roles that animals play in small-farm enterprises are as follows. More complete listings are given in McDowell (1977) and Sprague (1976).

- Animals provide food and nonfood products. Nearly all developing countries have shortages of protein foods that could be partially alleviated by including animals in farming systems.

- Animals provide manure for fertilizer and fuel. As an input into crop-cultivation systems, manure continues to be an important link between crop and animal production throughout developing countries. Manure (or dung) is an important source of fuel as well. It is estimated that 8% to 12% of the world's population depends on manure for heating and cooking.
- Animals provide power. Despite the increasing use of tractors, nearly 85% of total draft power used in Asian agriculture is still provided by animals. Twenty percent of the world's population depends partly or entirely on animals for transporting essential goods.
- Animals are a source of income. Income from the sale of animal products and by-products can be used to meet farm and household expenses. Timeliness of the cash flow is of utmost importance, and animals are usually sold in response to the needs of the household rather than in response to market prices. Animals can also provide an income distribution role within the household. Ownership is not limited to the head of the household (generally male), but is often shared or held completely by women and children.
- Animals provide jobs. Individuals can expend labor by processing primary animal products into marketable secondary products (for example, milk is processed into butter, cheese, and yogurt).
- Animals are a means of storing wealth. Animals can represent a household's savings, investments, and insurance, and their value tends to increase over time. Buying cattle is a preferred method of investment in rural areas where few other investment alternatives exist. Ownership of animals is a hedge against the risks of low crop yields.
- Animals provide a way to meet social obligations. The utility of animals may stem from their sacrificial value or ritual worth or the prestige they bestow upon their owners.

Characteristics of Animal Production

Some characteristics of animal production systems have special implications for designing, testing, and evaluating technology (Bernsten et al., 1983). These characteristics are listed below and in table 1.2.

- Mobility. Unlike crops, animals are mobile, so environment-animal interactions are difficult to describe and measure, and factors that are not included in trial treatments are difficult to control.
- Life cycle duration. The period of observation required for animal experiments is longer than that for crop experiments due to the extended life cycle duration of animals. Therefore, the cost is higher for experiments using animals than for those using plants, and the animals may die or be sold before the research is completed.

Table 1.2. Comparison of characteristics of crops and animals and implications for using animals for on-farm testing.

Characteristic	Crops	Animals	Implications for Using Animals
Mobility	Stationary	Mobile	Difficult to measure and control nonexperimental factors
Life cycle duration	Generally less than 4 months	Generally over 1 yr	Increased costs, likelihood of losing experimental units
Life cycle synchronization	All units synchronized	Units seldom synchronized	Difficult to find comparable units
Multiple outputs	Only grain/ tuber and residue	Multiple outputs: meat, hides, milk, manure, power	Difficult to measure value, treatment effect
Nonmarket inputs and outputs	Few	Many	Difficult to value inputs and outputs
Size of experimental unit	Small, divisible	Large, indivisible	Increased cost, risk to cooperator
Producer attitudes	Impersonal	Personal taboos	Difficult to cull, castrate
Management variability	Low	High	Difficult to isolate treatment effect
Number of observation units	Many	Few	Large statistical variability
Variability of observations	Low	High	Large statistical variability

Source: Bernsten, R., H. A. Fitzhugh, and H. Knipscheer, 1983.

- Life cycle synchronization. Farmers generally plant and harvest a given crop at a specific time. Therefore, at any time the crop is measured, all of the plants are the same age. Animal production, however, is not synchronized. It is often difficult to find enough animals in the same age category and the same production phase.

- Multiple outputs. Crops generally produce a primary output such as grain or tubers and a seco[illegible] output of crop residue. In contrast, animals may have several outputs of economic value such as manure, meat, hair, hide, milk, and draft power. These multiple outputs make it difficult to describe the production system, measure the impact of treatments, and evaluate the overall economic impact of experimental intervention.

- Nonmarket inputs and outputs. Crop-production systems typically use inputs and produce outputs for which there is a market and a price. Animal-production systems usually depend on inputs such as child labor and crop residue and produce outputs like manure for which there may be no ready markets. Other outputs, such as risk management, capital accumulation, and ceremonial functions, which are common for animals, are extremely difficult to quantify.

- Size of experimental unit. Plants are small and can be easily manipulated in field trials that affect only a small proportion of the producer's field. Because animals are large and a small farm usually has only a few, controlled trials and experimental interventions on a producer's animal may seem too risky for the producer.

- Producer attitudes. While producers do not usually develop emotional relationships with crops, they often become attached to their animals. Also, religious taboos and customs may make it difficult to cull, castrate, and earmark animals.

- Management variability. Crop-management practices are a major source of variability in on-farm crop research. Management practices are an even greater problem when conducting animal research because animal life cycles are longer and a greater number of critical management decisions must be made during this period. It is difficult, therefore, to observe the effects of an experimental treatment.

- Number of observation units. Crop research results are measured in yield (for example, production per hectare). No matter how small the plot used, the yield averages the production of many individual plants. Animal performance, especially in a small-farm setting, is measured as production per animal. Consequently, statistical variability of treatments between animal groups tends to be greater than between, for example, fertilizer treatments.

- Variability of observations. The following characteristics of animals may contribute to variability of observations in on-farm research:
  - Animals are of two sexes and exhibit sex differences (for example, variable weight gains because of pregnancy among female animals).
  - Animals have fast digestion processes, and, therefore, timing of the feeding has an impact on body weight.
  - Animals are mobile, so they must be restrained or confined
  - Animals establish social stratification when kept in groups.
  - Animals respond psychologically as well as physically and physiologically to various stimulants.

ON-FARM ANIMAL RESEARCH

Goals

The testing of new technologies or already well-established animal practices at the farm level has one general goal: to improve the productivity of the animal component of the farming system. The improvement in productivity may be accomplished by demonstrating new technologies or by refining existing practices. Better economic analysis of the production system will help to determine which technologies will increase productivity the most. Broadly speaking, the goals of OFAR include:

- Description of the animal component at the farm level. This should include a hierarchical classification of types of production systems that exist in a particular area. For instance, it is not sufficient to say that an area has a mixed system consisting of crops and livestock. Preliminary analysis should document the types of animals being kept, the roles and importance of animals in the farming system, the animals' economic significance, their present levels of productivity, the constraints to higher productivity, and so forth.
- Systematic screening of on-station technologies that can help alleviate production constraints at the farm level. These technologies should be analyzed at the research level to verify their superiority over farmers' current practices.
- Testing of the screened technologies at the farm level for their partial and whole-farm implications. The technologies that are absolutely superior to farmers' practices should be recommended to the farmers. This on-farm testing phase should guide researchers in conducting future research.
- Support of the implications of crop interventions. This may include the introduction of new varieties, changes in cropping pattern and agronomic practices, as well as testing of new forages and fodders at the farm.

Approaches to On-farm Animal Research

There are both traditional and innovative approaches to OFAR. The traditional approach to OFAR is a methodological approach which hinges on conventional analysis, such as replicate trials on farmers' fields, data gathering, and evaluation. Although the traditional approach has been utilized successfully in the past, it is becoming increasingly important to involve farmers more directly in the research process and the assessment of research results. Farmer participation is the key to the innovative approach to OFAR, which is based on the underlying belief that farmers should be full partners in the process of technology development.

Traditional Approach

Steps in the traditional approach are described by Devendra (1987) as follows:

Farm Surveys. Farm surveys are used to examine the nature of the system and prevailing patterns of management, for example, the role of buffalo in rice farms (Lai et al., 1973) or feed resources in the milk-collection centers in Malaysia (Hassan and Devendra, 1982). The survey results, while providing a firm understanding of the prevailing situation, enable specific interventions to be introduced. With OFAR, the survey is more restricted to examining farmers' receptivity, suitability to project objectives, nearness to a government experiment station or a university farm, ease of transportation, and costs in relation to scale of the operations.

On-station Research. A prerequisite to OFAR is research at the government experiment station or the university farm. First, a problem is identified which poses a major constraint to animal productivity. Under controlled conditions, the problem is examined from all angles bringing to bear the facilities available at the station or university. When a solution is found that is beneficial and has great potential value, including economic benefits, then wider application of the advantages through OFAR can be considered.

Implementation. After research at the station has been completed, on-farm research is implemented with the participation of animals, the farmer, and the farmer's resources. The research team identifies a farmer who is willing to participate, has resources (animals, land, family labor, and some capital), and has the potential to be successful. Only part of the farmer's land is used for the project.

There are two types of implementation. With the first type researchers conduct the research on the farm with the farmer's consent. The farmer is an on-looker, benefiting only from the rental of the land and other fringe advantages such as fodder production and animal production (meat and milk). With the second type of implementation, the farmer participates directly in the project. He will assist with animal treatments, day-to-day management, measurement of the animals' response (for example, milk production), and discussions about the project. When the research involves large ruminants, usually the adults of the household participate. When the subjects are smaller animals such as goats, sheep, chickens, and ducks, children also care for them.

According to Devendra (1987), the advantages with the latter approach are:

- The farmer learns the new technology first hand.
- Since more fodder is available, the farmer tends to buy more animals, and the animals tend to grow faster.
- The farmer is encouraged to consider expanding the enterprise.
- The farmer is motivated to conserve feeds for use during periods of scarcity.
- More dung is available for fertilizer and fuel.
- The farmer experiences pride in participating in a project with the government or a university.
- Neighboring farmers learn of the progress and become eager to participate and improve their economic situation.
- Well-planned and successfully executed programs stimulate rural progress and socioeconomic development.

The success of the implementation phase depends largely on the methods that are used as well as on the level of control, the sophistication of record-keeping, the seriousness of problems that arise and the ability to overcome those problems, the cooperation of the project team, and the commitment to the effort.

Extension. Whereas implementation involves performing successful on-station research at the farm, extension utilizes the results of on-farm implementation by introducing and demonstrating new technologies to the farming community. Very often, the implementation phase is consciously or unconsciously identified with extension. The validity of this approach is debatable since implementation is work in progress and the outcome remains to be assessed. As long as the research results are not discussed prematurely, and as long as expected benefits do not lead to inappropriate application, then extension demonstrations are useful to promote the importance of science and technology. Extension allows for a sense of partnership to be created between the researcher, who pursues knowledge, and the farmer, who is the beneficiary. This partnership has the common objective of increasing food production and improving the quality of life.

Interpretation of Results. Interpreting the results is generally easy if the implementation was thorough and efficient. The data are analyzed to determine the responses of the animals and possible economic benefits of the project. If results are difficult to interpret or are of doubtful validity, the effort and scarce resources of the researchers and farmers have been wasted.

Innovative Approach

The innovative approach is based on the belief that farmer participation is critical in OFAR. Farmer involvement increases the willingness of the farmer to submit animals for testing. Since most of a farmer's savings is in his livestock, he may be reluctant to submit his animal to any perceived risk. Therefore, on-farm livestock experiments should be very carefully screened and thoroughly debated. Scientists and farmers need to discuss the new technology, and an insurance provision can guarantee compensation for any losses incurred during the experiments.

Perhaps the most important aspect of the innovative approach to OFAR is the need for the farmer's assessment of the results of field experiments. Lack of sufficient replications and large variability in farm management, animal performance, and environmental conditions lead to a wide range of statistical variability (see table 1.2). Thus, many trials could show differences between treatments that are not statistically significant. Individual farmers, however, usually do not evaluate interventions by comparing results between farms or treatments; rather, they relate to production experience built up over their farming careers. This enhanced perspective must be utilized by acquiring the farmer's cooperation when assessing new technical interventions.

Many of the innovative approaches to OFAR are complementary to the traditional ones and have the following general objectives in common:

- Enhanced dialogue between farmers, researchers, and extension workers. Discussions should include specific situations, problems, and technologies in breeding, reproduction, feeding, health, management, and marketing of animals. A lack of understanding by participants results in a lack of motivation.
- Development of field recommendations for farmers. These include general recommendations on breeding, feeding, and farm management which may increase the probability of "new discoveries" at the farm level.
- Contribution to knowledge. This may involve contributions to the farmer's knowledge of different animal husbandry practices or to the researcher's understanding of animal production problems and constraints in the village.

The following are examples of innovative approaches to OFAR which address the need for increased farmer participation (Chambers, 1987).

Increased informal contact. Informal contact between researchers and farmers can be fostered and supported by encouraging and eliciting farmers' experiments, developing experimental and accounting methods for farmers, holding innovator workshops to discuss problem definition and trial design and execution, and developing networks of farmer experimenters.

Farmer-researcher activities. Joint activities which can be held among farmers and researchers utilize the organization of farmer groups; adapt trials based on farmers' experiments and systems experiments; utilize farmers' identification of problem areas and research priorities; involve farmers in breed and seed selection; and use adaptive trials with monitoring by farms.

Better understanding. An approach to better understanding can be achieved through in-depth interviews of farmers, ethnohistories of animal species in different locations, and analysis of farmers' adaptations of technology transferred through extension. In addition, rapid appraisals, selective surveys, field agronomic mapping, utilization of farmers' taxonomies, simulation modeling, chain interviews, and systems diagramming can be utilized for better understanding of the farm situation.

An in-depth description of the above examples is beyond the scope of this manual, but it is important to be aware of the research activities which can be utilized in an innovative approach to OFAR.

ON-FARM ANIMAL RESEARCH WITH A FARMING SYSTEMS PERSPECTIVE

In recent years, the FSR approach to animal production improvement has gained considerable attention from researchers. This approach seeks to understand the animal component as it interacts with and relates to other parts of the farm system and is often studied through analytical models. These models, such as that shown in figure 1.2, consider the whole farm perspective and generally require use of modern computers to analyze new technology options at the farm level. Although most research conducted thus far has been oriented to academic study and is difficult to apply directly to the problems of small farms, animal technologies are currently being tested under the umbrella of FSR in several Asian countries.

Because FSR developed from cropping systems research, it has traditionally emphasized crops rather than animals. Therefore, most FSR approaches to animal production improvement have a cropping system bias; that is, the research examines the effects of a crop intervention (such as a new rice) on the animal component. The goal is often to design a new cropping pattern or analyze new agronomic practices, but some animal trials are included as part of the testing program. Research projects supported by international agricultural research centers and research agencies tend to use this approach, which has several advantages:

- The long-term effects of any crop changes on animals can easily be studied because, in the presence of a cropping system bias, the crop component is often more important than the animal component.
- Lack of funds, a key constraint in animal research, is relieved since conducting OFAR under a cropping systems umbrella allows for cost sharing.
- The effects of the new technology on livestock can be viewed holistically; therefore, the effects on by-product use, on-farm employment, and labor, especially the labor of women, can also be studied.
- The farm operates as a system and the farmer considers all of the farm's enterprises simultaneously. This interactive decision-making process is available for study when all important components of the farming system are studied together.

Some disadvantages of OFAR with a farming systems perspective are:

- The inclusion of animals in crop-animal farming systems is relatively recent. (Initial work began through the Asian Rice Farming Systems Network (ARFSN) based in the International Rice Research Institute (IRRI).)
- Most animal husbandry requirements (except nutrition) are ignored due to the crop bias which usually exists in on-farm research.
- It is difficult to assemble a large interdisciplinary team for FSR that can adequately address the animal component.
- Animals must be monitored once or twice a month, but crops usually can be checked less often; therefore, the research team may have problems in scheduling visits.
- Evaluation of animal performance requires a longer period than crop performance evaluation; therefore, conflicts may arise within the team about meeting evaluation schedules.

SUMMARY

FSR has proven to be an effective methodology for describing and diagnosing farm problems and screening appropriate technologies for on-farm testing and evaluation. It is important to note that as the FSR approach becomes increasingly important in many countries' research efforts, more attention must be directed to improving the animal component on small, resource-poor farms. A collaborative arrangement between farmers, extension workers, and research scientists can effectively direct OFAR in order to implement innovative technologies which have been successful at the farm level.

CHAPTER 2

ANIMAL PRODUCTION CONCEPTS

PURPOSE

Principles of animal production must be understood before improvements can be made and new animal-production technologies can be introduced. Attempts to introduce new livestock enterprises or to change existing ones have to be within the resources available to the farmer and the climatic conditions affecting production. This chapter introduces key concepts of animal husbandry while suggesting methods for improving animal performance. In addition, the terminology introduced in this chapter will aid in discussions with animal scientists.

OBJECTIVES

After completing this chapter, the reader should be able to:

- Discuss basic concepts of animal growth, reproduction, lactation, nutrition, and health.
- Compute animal feed rations and prepare a concentrate mixture.
- Describe ways in which animal performance can be improved.

THE ROLE OF LIVESTOCK IN THE FARMING SYSTEM

Animals are an important component of many farming systems. In addition to providing society with quality foods, animals also provide numerous other goods and services (see table 1.1, Chapter 1). In fact, the monetary value of non-food products likely equals or even exceeds the value of food goods (McDowell, 1977). Not only is it necessary to recognize all the products and services provided by animals, it is also important to be aware of all the purposes for which a farmer keeps animals. This is because the reason for keeping livestock affects the management practices used by a producer.

An example of this can be seen in cattle production. In the United States, cattle are raised for a specialized purpose, either meat or milk production, while in parts of Africa, cattle are raised for both the production of milk as well as meat. Another example is in Haiti where pigs are kept mainly as a "walking bank account". In times of family difficulty, a pig can be sold to generate necessary cash, and, therefore, a minimum of capital is invested for keeping pigs.

However, in countries where grain is available for feed, pig farming is an intensive production system.

Since animals have evolved according to the ecology of a region, an animal in a particular climate or culture may occupy a unique ecological niche, or satisfy some specific function. For example, reindeer can be raised in a cold and harsh climate, as in some Nordic countries, while camels are raised by nomadic cultures in an arid climate. Although there are many different domesticated animals throughout the globe, some animals, particularly cattle, buffalo, sheep, goats, swine, and poultry, are commonly kept across many different climates and cultures. Therefore, this chapter will focus on these six species. A list of terms that apply to these farm animals is presented in table 2.1.

Table 2.1. Common terms applied to farm animals.

	Cattle	Buffalo	Sheep	Goats	Swine	Poultry
Species	Bovine	Bovine Butaline	Ovine	Caprine	Swine Sus	Gallus
Group of animals	Herd	Herd	Flock	Flock Band	Drove Stock Herd	Flock
Adult male	Bull	Bull	Ram Tup	Buck	Boar	Rooster Cock
Adult female	Cow	Cow	Ewe	Doe	Sow	Hen
Young male	Bull calf	Bull calf	Ram lamb Tup lamb	Buckling	Boarling	Cockerel
Young female	Heifer calf	Heifer calf	Ewe lamb	Goatling	Gilt	Pullet
Newborn	Calf	Calf	Lamb	Kid	Piglet Pigling	Chick
Castrated male	Bullock	Bullock	Wether Wedder	Wether Wedder	Hog Stag Barrow	Capon
Offspring with mother	Calf at foot	Calf at foot	Suckling	Suckling	Suckling	Clutch Brood
Act of birth	Calving	Calving	Lambing	Kidding	Farrowing	Hatching
Act of mating	Serving	Serving	Tupping	Serving	Coupling	

Source: Sastry and Thomas, 1976.

GROWTH OF FARM ANIMALS

Determining the Ages of Animals

Each farm animal has an age at which its performance peaks. Cattle and buffalo live up to 28 years; however, their productivity declines with advancing years. Cows and buffalo reach peak milk production at around seven years of age (corresponding to second lactation in late-maturing buffalo and third lactation in cows). Sows' litters reach maximum when the sows are 3 to 4 years old. The age of animals, therefore, is of practical importance to the breeder, the seller, and the buyer and being able to determine the age of an animal is important in animal husbandry.

The approximate age of an animal can be determined by examining its teeth. Teeth erupt at about the same rate in all animals of a species. By noting the time of appearance and the degree of wear of the temporary and permanent teeth, the age of the animal can be ascertained with a fair degree of accuracy. The temporary teeth are readily distinguished from the permanent ones by their smaller size and whiter color. In addition, broken or worn teeth can have an adverse effect on the nutritional condition of the animal and can be used to determine an animal's overall health status.

Cattle and Buffalo

These species have a total of 20 temporary teeth and 32 permanent teeth. Estimating the exact age of cattle is particularly difficult. In zebu cattle, for example, differences in age of as much as 16 months have been found in animals whose teeth were at the same stage of development. Differences of such magnitude are rather rare, but variations of up to 6 months are usual. Cattle and buffalo beyond eight years of age are generally called aged and no effort is made to determine their exact age. Aged animals that have lost one or more teeth are called broken mouthed; those that have lost all of their teeth are known as gummers.

Sheep and Goats

Mature sheep and goats have 32 teeth: 24 cheek teeth, and 8 incisors on the lower jaw only. The temporary and permanent dentition formulae are the same as for cattle. Small animals are categorized as aged after 5 years.

Pigs

Adult pigs have 44 teeth. Of these, 12 are incisors, 4 are tusks, 4 are premolars, and 24 are molars (with half of each type of teeth on each jaw). The tusks or canine teeth are more prominent in males than in females. The canine teeth in piglets (usually called needle teeth) are often removed in modern operations.

The Growth Curve

While animal species differ vastly in size, shape, and weight, their pattern of growth is much the same. As shown in figure 2.1, when weight is plotted over time, the resulting curve is S-shaped and is a result of the rate at which an animal grows. This S-shaped growth curve is the same for a mouse as it is for a whale, or even for a man. An animal increases its body mass slowly at first, then enters a period of accelerated growth when body mass increases rapidly, then reaches a stage when growth slows markedly. Eventually an animal stops

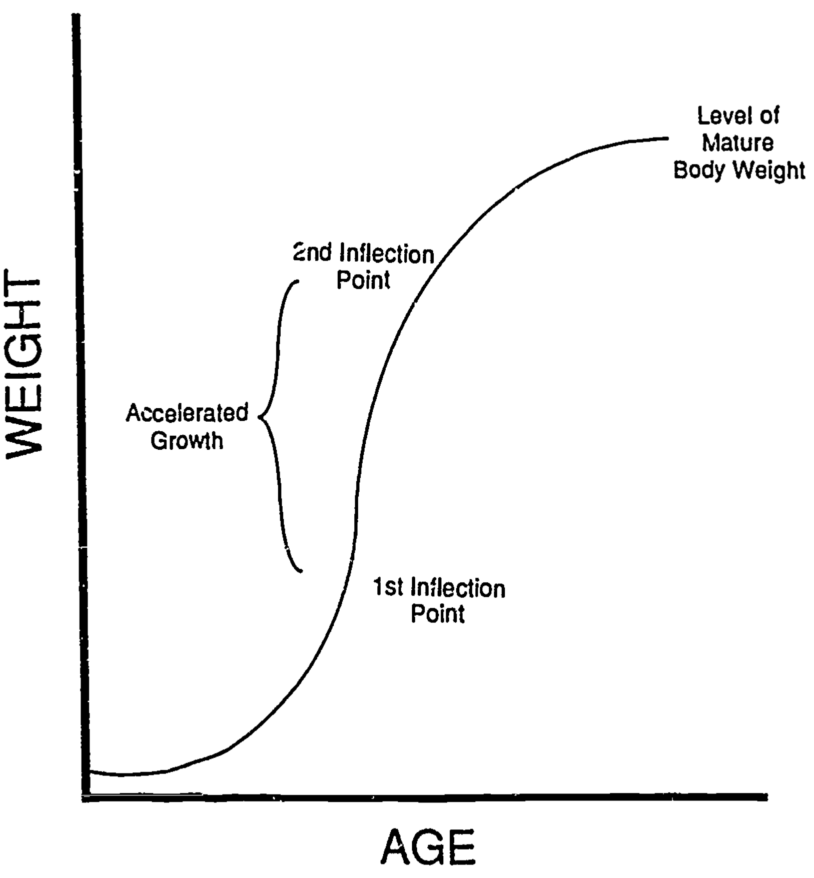

Figure 2.1. The S-shaped growth curve represents the growth of mammals from conception to maturity.

growing and body mass levels out at the animal's mature body weight. The point where the growth rate changes is unique for each species and is dependent on an animal's age.

Food Intake and Growth

Animals with a higher intake of feed will grow better, produce more, and work longer and harder. The maximum amount of dry matter (DM) consumed by an animal is based on its metabolic body size, and intake falls exponentially as fattening progresses (Preston and Willis, 1974). The quality of the feed is one factor influencing the amount of consumption by the animal. Animals of all species, after being restricted in their feed intake, will experience a faster growth rate for a short period of time than if on an unrestricted feeding program. This type of growth behavior is called compensatory growth.

Phases of Growth

Growth can be split into prenatal growth and postnatal growth. These two phases of growth are discussed in the following sections.

Prenatal Growth

Prenatal growth takes place from the time of fertilization of the ovum (egg) until the birth of the animal. In mammals, prenatal growth occurs in utero, while in poultry this growth occurs inside the fertilized egg which has been laid by the mother hen.

In mammals, prenatal growth can be divided into the following three phases:

Phase 1: Period of the ovum. This period lasts from the time the ovum (egg) is fertilized until the fertilized egg attaches itself to the uterine wall.

Phase 2: Embryonic period. During this period, the fertilized egg grows rapidly, cell differentiation occurs, and tissues, organs, and major systems are formed.

Phase 3: Fetal period. This period is the last phase of prenatal growth and lasts from the time that major features of the animal are recognizable until the animal's birth.

The relative growth rate of a developing animal is most rapid during earlier stages of gestation and declines as gestation progresses. That is, body mass increases by the greatest percentage during the first phases of growth. However, absolute growth increases exponentially, so that the greatest amount of actual body mass is added late in gestation. For example, in cattle, the fetus more than doubles its weight during the last two months of gestation. During the first two phases of prenatal growth, the embryo derives nourishment from fluids contained in the uterine lining (the endometrium). During the fetal period, the fetus receives nutrients directly from maternal blood circulation via the placenta and umbilical cord.

The fetal growth and birth weight of a mammal are dependent on a number of environmental and genetic factors. The mother's age, parity, size, and nutritional status are all environmental factors as is any climatic stress on the mother during gestation. In animals that produce several offspring at one time, such as pigs, sheep, and goats, litter size will also influence birth weight. Genetic factors that affect the animal's birth weight are its sex and its inherent rate of cell division. While low birth weight can cause reduced viability of the young animal, poor prenatal growth has little effect on mature size if postnatal nutrition is adequate.

Postnatal Growth

Lactation, or the production of milk by the mammary glands, is a distinguishing characteristic of mammals. This characteristic has led to the distinction of two phases of postnatal growth in mammals. These two phases are the following:

Phase 1: Preweaning phase. During this phase the young mammal is nourished on milk from its mother. Even when they start to eat other feeds, young mammals may continue to nurse.

Phase 2: Postweaning phase. This is the period that occurs after the animal no longer relies on its mother's milk for nourishment, i.e., the animal has been weaned.

The length of time that young animals depend on milk is governed by their state of development at birth and on the particular farm management system in place. Some animals are born less developed than others and therefore require a longer period with the mother. In farming systems where milk is a desired product, young animals may be weaned early, may be given milk replacers or specially balanced feed, or may share the cow's milk with the family.

Partitioned Growth

The three major tissues of an animal that are affected by growth are bone, muscle and fat. Bone growth occurs first, followed by growth of muscle, and then fat (Berg and Butterfield, 1968). The depositing of fat does not generally occur until after the second inflection point in figure 2.1. Animals on a low plane of nutrition and only satisfying maintenance requirements will not be able to deposit fat. This condition is typical of animals raised under pastoral conditions in arid regions of the world.

Reproduction and Lactation

The fertility of an animal is dependent on its age and level of nutrition. Intake of poor quality feed delays development and the onset of sexual maturity. The period between conceptions for an animal will also depend on the quality of its feed. Under semi-arid and arid conditions, heifers may not become fertile until twenty-four months of age. A buffalo in China may not have its first calf until the age of four. Overfeeding can also have detrimental effects on fertility and may lead to difficulties in conceiving, giving birth (parturition), and reconception, as well as sterility.

The age of an animal and the nutritive value of its feed influence the animal's level of milk production. Milk production increases with subsequent parturition until the age of the animal causes a decline in production. In cattle, peak milk production occurs around the seventh or eighth year of a cow's life. Peak milk production for cattle during a lactation period occurs within the first 12 weeks. After this time milk production steadily declines.

An animal's disease state is another factor affecting reproduction and lactation. Venereal diseases in animals can result in sterility. Certain contagious diseases, like brucellosis, can result in abortion of the fetus or a still-born calf. Mastitis of the mammary glands can cause reduced milk production resulting in poor performance of the offspring.

ANIMAL FEEDS

Animal feed is an important factor affecting an animal's growth and nutritional status. Feedstuffs can generally be divided into roughage and concentrate (see figure 2.2).

Roughage

Feeds with high proportions of crude fiber (nondigestible material) are called **roughage**. Animals such as cattle, buffalo, sheep, goats, and horses can meet some of their nutritional requirements by grazing on the roughage in good pastures. Pigs and poultry also derive a certain proportion of their nutrients through grazing. Since pastures are an economical source of animal feed, this system of feeding should be encouraged whenever it is available.

Roughages may be classified as succulent or dry, depending on their moisture content. Succulent roughages are further classified into green fodder and **silage**, with green fodder including leguminous and nonleguminous fodder.

Leguminous fodder consists of the stems and leaves of legume plants. Legumes have a higher nitrogen content than nonlegumes and are a major source of

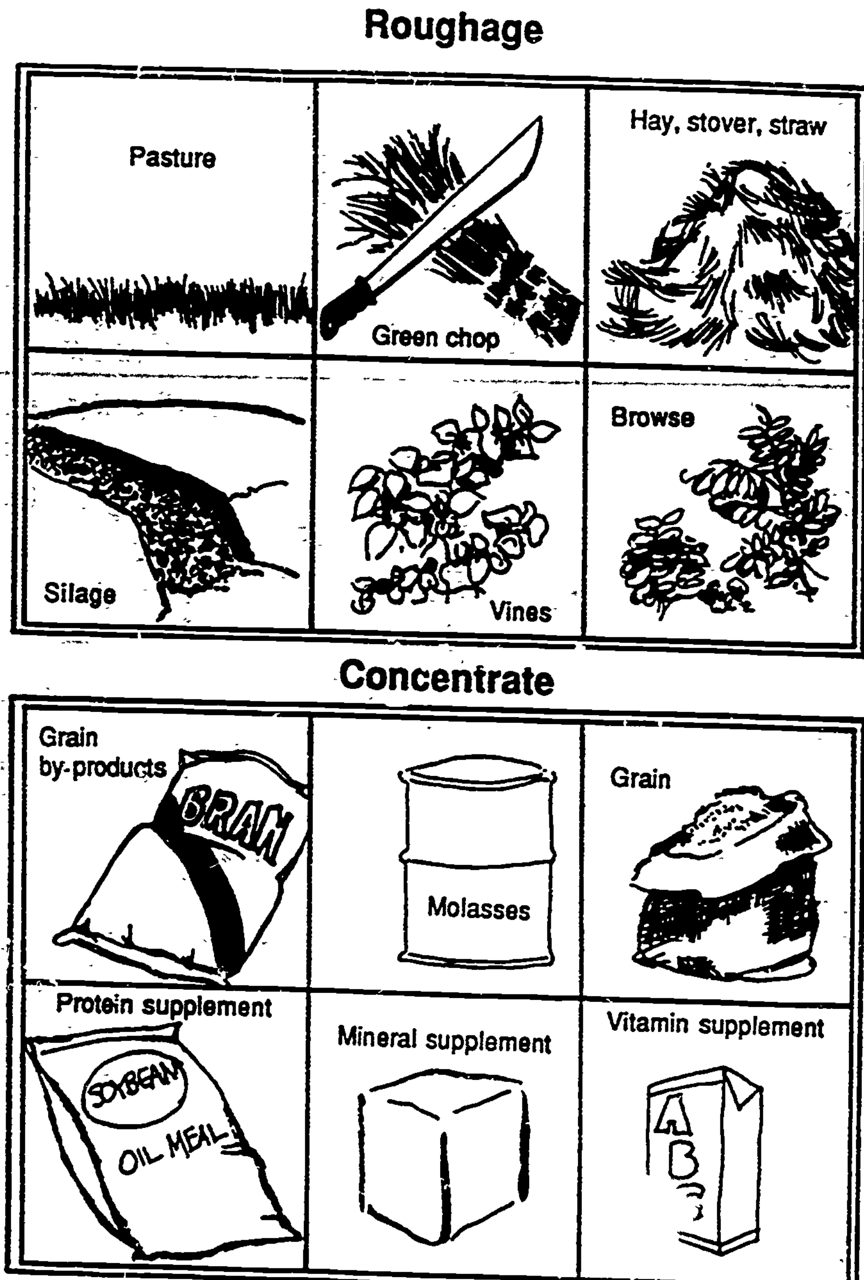

Figure 2.2. Classification of feedstuffs.

protein for farm animals. If cattle and buffalo are fed legumes liberally, they do not need additional protein. Legumes that are important crops include true clovers, medics, and *Crotalaria* species.

Some important true clovers that are useful as leguminous fodder are:

Berseem	*Trifolium alexandrium*
Shaftal	*Trifolium resupinatum*
White clover	*Trifolium repens*
Red clover	*Trifolium pratense*
Crimson clover	*Trifolium incarnatum*
Alsike clover	*Trifolium hybridum*
Subterranean clover	*Trifolium subterraneum*

Among medics, the following are used for leguminous fodder:

Lucerne (alfalfa)	*Medicago sativa*, the most popular fodder crop
Black medic	*Medicago lupulina*
Bur clover	*Medicago hispida*

The *Crotalaria* group also includes a number of species useful for leguminous fodder, such as the following:

Sunnhemp	*Crotalaria juncea*
Cowpea	*Vigna sinensis*
Kudzu	*Pueraris thunbergiana*

Certain other legumes, like soybeans (*Glycene soya*) are also important in animal feeding.

Nonleguminous fodder generally contains less nitrogen than leguminous fodder. Therefore, when an animal is fed nonleguminous fodder, protein-rich concentrates must be added to balance the animal's diet. Nonleguminous fodder may include many cereals, fodder crops, perennial cultivated grasses, some indigenous grasses, and introduced grasses.

Important cereal crops used as fodder are:

Maize	*Zea mays*
Sorghum	*Sorghum vulgare*
Oats	*Avena sativa*
Teosinte	*Euchlaena mexicana*

Important perennial crops cultivated for fodder are:

Paragrass	*Brachiaria mutica*
Guinea grass	*Panicum maximum*

Napier grass	*Pennisetum purpureum*
Hybrid (giant) napier grass	a cross between napier and bajra
Rhodes grass	*Chloris gayana*
Blue panic grass	*Panicum antidotale*
Sudan grass	*Sorghum vulgare var. sudarense*

Concentrates

Concentrates are feeds that have lower moisture and fiber contents but a higher digestible nutrient content than roughage. They can be classified into energy and protein concentrates, with the latter further classified into low protein and high protein concentrates.

Low protein concentrates (or basal concentrates) include all grains and some grain by-products. They are rich in carbohydrates and usually have low protein percentages. Maize, oats, sorghum, and barley are the most important grains. Wheat is rarely used as an animal feed in wheat-deficient countries. Only when it spoils in storage and is unfit for human consumption is it used as an animal feed.

High protein concentrates have a greater protein content than roughage. They may be of plant or animal origin. Pulses and grams like cowpeas, black gram, horse gram, and gram form an important group of protein-rich concentrates of plant origin. However, most are consumed by humans, and only their by-products are regularly used as animal feed. Such by-products include oil cakes of groundnut, linseed, coconut, cottonseed, rapeseed, and rice bran. Feeds produced from animal sources include by-products such as fish meal, meat meal, dried skim milk, and dried buttermilk. Monogastric animals must have certain proportions of animal proteins in their rations. Ruminants do not need animal protein.

Nutritive Value

The nutritive value of a feed is determined by the quantity of various nutrients it makes available to the animal for maintenance, growth, or production — that is, how well it provides energy, protein, minerals, and vitamins. Kearl's work is an excellent source of information about the common feeds and nutrient requirements of ruminants in developing countries (Kearl, 1982).

Energy Value

The first step in evaluating the energy value of a feed is to measure the absorbed (digestible) portion of its gross energy. Digestible energy (DE) equals gross energy (GE) minus the energy lost in feces (E_{fec}), or $DE = GE - E_{fec}$. The energy lost in feces is thus the portion of the gross energy that is not absorbed.

Energy is also lost as the combustible gases and urine that the animal expels. About 2% to 3% of gross energy is lost by the excretion in urine of incompletely oxidized nonprotein nitrogenous compounds like urea and uric acid. When gas and urine energy losses ($E_{gas,urine}$) are subtracted from digestible energy, the result is metabolic energy (ME), which is the proportion of total energy that can be metabolized in the body for maintenance, growth, production, and activity. And so, $ME = DE - E_{gas,urine}$.

The heat produced by fermentation and intermediary metabolism often exceeds the animal's need, depending on environmental temperature. Since this heat cannot be used for production, it is a loss of energy. This heat is subtracted from metabolic energy to derive net energy (NE), thus $NE = ME - heat$. Net energy has been formulated by Armsby as the maximum proportion of feed energy convertible to work, milk, eggs, meat, and maintenance. Thus, this is the part of energy that is available to the animal for maintenance, growth, and production.

Maintenance energy (E_{main}) is defined as the energy needed for basal metabolism. This is more or less constant for an animal. The remaining net energy, which can be transformed into products, is called the **net energy for production** (NE_p). Therefore, $NE_p = NE - E_{main}$. When the symbol NE is used to denote a specific energy of production, the product being produced is always indicated as a subscript, for example:

NE_{milk}	Net energy for producing milk
NE_{egg}	Net energy for producing eggs
NE_{gain}	Net energy for gaining weight
NE_{wool}	Net energy for producing wool
NE_{preg}	Net energy for sustaining pregnancy and growth of fetus
NE_{work}	Net energy for work

The efficiency of conversion of NE_p in a productive process is about 100%. Therefore, if the NE_p of feed is known precisely, this can be considered a fairly accurate estimate of its feeding value.

All digestible organic nutrients — carbohydrates, protein, and fats — are either used immediately for energy, stored as fat, or incorporated into body tissue. Because fat offers 2.25 times the energy of an equal amount of carbohydrates or protein, the energy value of a feed is its fat content multiplied by 2.25.

The starch-equivalent system developed by Kellner in Germany roughly represents net energy. The starch-equivalent value is the quantity of starch that will yield as much energy to the body above maintenance needs as would 100 pounds of the feed in question. It is calculated as:

$$\text{Starch equivalent} = [\text{Carbohydrate} + 0.94\ (\text{true protein}) + 2.4\ (\text{fat})] \times \text{a fiber correction}$$

Costs of Nutrients

The cost of each nutrient in feedstuffs used in animal experiments can be calculated using simple arithmetic. The following examples use feedstuffs common in the Philippines. Costs are based on the price index as of February 1977 and are expressed in pesos (Eusebio et al., 1977).

Limestone (calcium carbonate) is the mineral supplement most often used to supply calcium. It contains 33% calcium and costs ₱0.90 per kilogram. Thus, the cost per unit (one) percent of calcium in limestone is ₱0.90/0.33, or ₱0.03.

The cost per unit percent of calcium can then be applied in additional calculations. For instance, in the following example, the costs of phosphorus in bonemeal and in dicalcium phosphate are determined in order to decide which is a more economical source of phosphorus.

Bonemeal contains 28% calcium and 13% phosphorus, and it costs ₱1.28 per kilogram. Using the cost per unit percent of calcium (₱0.03), the cost per unit percent of phosphorus can be determined as:

$$₱1.28 = 28\ (₱0.03) + 13\ (X)$$
$$13X = ₱1.28 - ₱0.84$$
$$X = ₱0.44/13 = ₱0.034$$

Thus, the cost per unit percent of phosphorus in bonemeal is ₱0.03.

Dicalcium phosphate contains 24% calcium and 17% phosphorus, and it costs ₱5.50 per kilogram. If calcium costs ₱0.03 per unit percent, the cost per unit percent of phosphorus can be determined by the following:

$$₱5.50 = 24\ (₱0.03) + 17\ (X)$$

$$X = \frac{₱5.50 - ₱0.72}{17}$$

$$X = ₱4.78/17 = ₱0.281$$

Thus, the cost per unit percent of phosphorus in dicalcium phosphate is ₱0.28. The comparative costs of phosphorus from bonemeal and dicalcium phosphate are ₱0.03 and ₱0.28 per unit percent, respectively, and so bonemeal is the more economical source of phosphorus.

Similar calculations can be used to determine the most economical source of crude protein based on data concerning imported fish meal, local fish meal, and soybean meal.

A kilogram of imported fish meal costs ₱4.85. It contains 61% crude protein, 5.4% calcium, and 2.81% phosphorus. As calculated above, the cost per unit percent of calcium in limestone is ₱0.03, and the cost per unit percent of phosphorus in bonemeal is ₱0.03. Therefore, the cost of crude protein is:

₱4.85 = 61 (X) + 5.4 (₱0.03) + 2.81 (₱0.03)

61X = ₱4.85 − (₱0.162 + ₱0.084)

X = ₱4.60/61 = ₱0.075

Thus, the cost per unit percent of crude protein in imported fish meal is ₱0.075.

A kilogram of local fish meal has 48% crude protein, 6.55% calcium, and 3.97% phosphorus, and it costs ₱4.10 per kilogram. If the cost per unit percent of calcium and phosphorus is ₱0.03 each, then:

₱4.10 = 48 (X) + 6.55 (₱0.03) + 3.97 (₱0.03)

48X = ₱4.10 − (₱0.196 + ₱0.119)

X = ₱3.78/48 = ₱0.079

Thus, the cost per unit percent of crude protein in local fish meal is ₱0.08.

A kilogram of soybean meal has 40% crude protein, 0.26% calcium, and 0.52% phosphorus, and it costs ₱2.85 per kilogram. If the cost per unit percent of calcium and phosphorus is ₱0.03 each, then:

₱2.85 = 40 (X) + 0.26 (₱0.03) + 0.52 (₱0.03)

40X = ₱2.85 − (₱0.008 + ₱0.016)

X = ₱2.83/40 = ₱0.071

Thus, the cost per unit percent of crude protein in soybean meal is ₱0.07.

Based on this cost analysis of the nutrients in different feedstuffs, soybean meal appears to be the most economical protein source. However, imported fish meal or local fish meal, which have considerably higher amounts of calcium and phosphorus, might be preferred if the diet calls for these two nutrients.

Balancing the Diet

In computing rations for ruminants, the farmer must consider the nutritional contributions of dry matter (DM), total digestible nutrients (TDN), digestible energy (DE), metabolizable energy (ME), net energy (NE), crude protein (CP), minerals, and vitamin A. For nonruminants, in addition to the items listed above, the essential amino acids and B vitamins must also be considered. Rations are computed by first calculating the maintenance requirements for the animal and then adding the production requirements.

For example, in computing a ration for a cow weighing 400 kg and producing an average of 10 kg/day milk at 4.5% fat, the feeds available are green berseem, wheat bhusa, groundnut cake, wheat bran, barley, and maize. The cow has the following daily nutrition requirements (per Sen and Ray Standards kg):

	DM (kg)	CP (kg)	TDN (kg)
Maintenance		0.254	3.03
Milk production (10 kg/day at 4.5% fat)		0.480	3.39
Total	8.0 to 10.0	0.734	6.42

Out of a total dry matter requirement of 8 to 10 kg, two-thirds (about 6 kg) can be roughage and one-third (about 3 kg) can be concentrate. The dry matter from roughage may be divided equally between green fodder (such as berseem) and dry fodder (such as wheat straw); therefore, the roughage can be:

	Raw weight (kg)	DM (kg)	CP (kg)	TDN (kg)
Berseem	20.0	3.00	0.564	2.58
Wheat straw	3.5	3.15	—	1.52
Total	23.5	6.15	0.564	4.10

To complete its nutritional requirements, the animal needs an additional 0.17 kg CP (0.734 kg CP − 0.564 kg CP) and 2.32 kg TDN (6.42 kg TDN − 4.10 kg TDN); therefore, the animal needs about 3 kg of a concentrate that will supply 0.17 kg CP and 2.32 kg TDN. That means the concentrate should have a CP content of 6% to 7% (0.17 kg/3 kg × 100) and a TDN content of 77% to 78% (2.32 kg/3 kg × 100). Barley can be an ideally suited concentrate for this animal. The ration will therefore be:

	DM (kg)	CP (kg)	TDN (kg)	Cost (Rs)
Berseem (20 kg)	3.00	0.564	2.58	10.00 (@Rs 0.5/kg)
Wheat straw (3.5 kg)	3.15	—	1.52	3.15 (@Rs 0.9/kg)
Barley (grain ground) (3.0 kg)	2.70	0.197	2.33	2.40 (@Rs 0.8/kg)
Total	8.85	0.761	6.43	15.55

A mineral mixture may be added to this ration, and salt licks should be provided.

Preparing a Concentrate Mixture

Usually a suitable concentrate mixture with desired CP and TDN content, incorporating many concentrate feeds and minerals, is prepared for generalized use. An animal's CP and TDN intakes are controlled by the amount of the concentrate it is offered. For example, in preparing a concentrate mixture with 12% CP and 70% TDN from barley, oats, wheat bran, groundnut cake, cottonseed cake, and mineral mixture, the ingredients can be classified into two groups: those having less than 12% CP, and those having more than 12% CP. The preparations of the feedstuffs in the first group can then be adjusted so that the TDN of the mixture is less than 70%. Thus, the first mixture could be:

Feed		CP (kg)	TDN (kg)
Wheat bran	8 parts	0.8496	5.400
Barley	1 part	0.0807	0.780
Oats	1 part	0.0707	0.787
Total	10 parts	1.001	6.967
	percentage	10.01	69.67

The second mixture could be:

Feed		CP (kg)	TDN (kg)
Groundnut cake	1 part	0.4175	0.710
Cottonseed cake	1 part	0.1748	0.716
Total	2 parts	0.5923	1.426
	10 parts	2.9615	7.130
	percentage	29.62	71.30

The final mixture with 12% CP is calculated using the Pearson Square. The Pearson Square is a short-cut determination of algebraic calculations, yielding the proportions and percentages of the mixtures which are required. The Pearson Square starts out as the following:

Feed	CP	Parts	Percentage
Mixture 1	10.0		
Mixture 2	29.6		
	12.0		

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Portions of the square are gradually filled in, with the second column being filled in first. The value of the parts required for mixture 1 is determined by taking the difference between the desired CP% and the CP% in mixture 2 (29.6 − 12.0 = 17.6). Similarly, the value of the parts required for mixture 2 is determined by finding the difference between the desired CP% and the CP% in mixture 1 (12.0 − 10.0 = 2.0). And so the Pearson Square looks like the following:

Feed	CP	Parts	Percentage
Mixture 1	10.0	17.6	
Mixture 2	29.6	2.0	
	12.0	19.6	

The values in the third column are derived by expressing the parts of each mixture as a percentage of the total parts. The percentage of mixture 1 is 89.8% (17.6/19.6 × 100), and the percentage of mixture 2 is 10.2% (2.0/19.6 × 100). The Pearson Square can now be completed.

Feed	CP	Parts	Percentage
Mixture 1	10.0	17.6	89.8
Mixture 2	29.6	2.0	10.2
	12.0	19.6	100.0

The following algebraic formula would yield the same results:

$10.0(a) + 29.6(1 - a) = 12.0,$

where a is the percentage of mixture 1 required (the percentage of mixture 1 plus the percentage of mixture 2, expressed in decimal form, must total 1). Thus,

$10.0(a) + 29.6 - 29.6(a) = 12.0$
$17.6 = 19.6(a)$
$a = 0.898$ or 89.8%

Out of 19.6 parts, mixture 1 should be 89.8% and mixture 2 should be 10.2%.

Therefore, the ingredients of the concentrate mixture will be:

Feed	Parts (kg)	CP (kg)	TDN (kg)	Cost (Rs)
Barley	8.98	0.725	7.07	14.28 @ 159 Rs/q
Oats	8.98	0.634	7.06	13.47 @ 150 Rs/q
Wheat bran	71.84	7.629	48.49	28.74 @ 40 Rs/q
Groundnut cake	5.10	2.129	3.62	9.18 @ 180 Rs/q
Cottonseed cake	5.10	0.891	3.65	7.14 @ 140 Rs/q
Mineral mixture	2.0	—	—	2.80 @ 140 Rs/q
	102.0	12.008	69.89	75.61 @ 74.1 Rs/q

Nonruminants, such as pigs, must also be provided the essential amino acids and B vitamins. To be balanced, the diet must have at least one animal source of protein in addition to the proteins of plant origin. Because the ration is usually self-fed, the energy and protein contents are adjusted on a per kilogram basis.

MANAGEMENT SYSTEMS

Livestock management is important to economic viability of an operation. Since the availability of inputs and their costs are factors affecting the utilization of livestock, the limitations of key inputs — land, water, labor and capital — will influence the animal-production management style. Two common classifications of animal production are intensive production and extensive production. In intensive production labor is substituted for land, and livestock are raised in confinement facilities with high levels of input costs. An example of intensive production is feedlot finishing of cattle. In extensive production land is substituted for labor, and animals are maintained with lower levels of input costs. Pastoral grazing on range lands is an example of extensive production. Management practices under each of these production systems will vary for all species.

IMPROVING ANIMAL PERFORMANCE

Animal performance can be improved by 1) genetic improvement of the species through planned selection and breeding and 2) improved animal management (nutrition, health, reproduction). These are described below.

Genetic Improvement

Genetic improvement is slow. The rate of genetic gain is dependent on a number of factors, including the number of genetic traits for which one selects, the integrity of the animals selected to reproduce, and the generation interval. Selection of fewer traits increases the rate of genetic gain. When animals are kept for several purposes, selection is frequently based on an index in which economic weights are applied to the various products. Both the male and female selected for breeding should be of superior genetic stock. Ideally one would mate only the very best animals. However, to obtain enough replacement animals for the next generation, one must frequently reduce the selection integrity and allow less desirable animals to reproduce. Genetic improvements are not seen until the next generation since the offspring must be born and then mature. Even though genetic improvements are gradual, it is still an important part of animal husbandry. No matter how good animal management is, superior performance will not be attained if animals are of poor genetic stock.

Improved Animal Management

More rapid improvements can be made in animal performance through improved management practices. Good husbandry is necessary for the animal's welfare and to derive maximum benefit from the animal. Animal management is not only the allocation of resources to yield animal products and services useful to society. Good animal management also includes the general supervision, shelter, and care of animals and the maintenance of proper hygienic conditions. According to the Indian Council of Agricultural Research (1985), all animals need:

- readily accessible fresh water and nutritionally adequate food
- adequate ventilation and suitable environmental temperature
- adequate freedom of movement and ability to stretch the body
- sufficient light for satisfactory inspection of animals
- rapid diagnosis and treatment of injuries and diseases
- adequate backup in the event of breakdown of essential mechanical equipment
- flooring that does not cause harm or undue stress
- no unnecessary mutilation

Good husbandry is the key factor in the welfare of all animals.

Breeding Programs

Animal performance can be improved by controlling the mating of the breeding herd. Restricted access of males to females can prevent parturition during stress periods, resulting in fewer animals born during the periods when the climate is harsh or feed and water are limited. Technologies are available for the livestock manager to synchronize the estrus of the females so that parturition will occur in a prescribed range of time. This grouping process improves the manager's ability to control breeding and incorporate artificial insemination (AI) into a whole herd management plan.

Supplementation

Providing feed supplements and minerals to livestock is important for improved animal performance. Information on cost of feed is necessary to decide when, how much, and to what animals to give supplements. Feeding calves, kids, and lambs before and during the weaning period can reduce the stress and weight losses associated with this period. Feeding other animals for selective purposes can also be a beneficial management practice.

Weaning

Young stock can be weaned from their mothers at different ages. Weaning an animal too soon can result in stunting of the animal's growth or even death. Weaning too late interferes with the mother's ability to maintain its condition and conceive again.

Culling

This practice is important to remove unhealthy and unproductive animals from the herd or flock. Animals which are determined to be uneconomical or unsuited for a breeding program are removed for sale or slaughter. Females which have difficulty conceiving should also be removed.

Disease Prevention

Disease prevention is an important management practice for maintaining the health of the herd. Diseases affecting animals vary widely and some are more contagious than others. Inoculations for certain diseases, such as black leg, pleural pneumonia, and coccidiosis, can prevent the spread of a disease. In some tropical climates, animals need to be dipped on a regular basis to prevent scabies, flies, and lice, which can affect the performance of the animal.

Resources for Livestock Management

The implementation of improved management practices has inherent requirements. Feed and water are the most basic inputs for animal husbandry. Sources of water need to be clean and unpolluted. Water can be provided through lakes, rivers, impoundments, or tanks. Animals should be prevented from fouling the water with their urine and feces. Containers and bunks are used to hold feed for efficient utilization and should be designed to prevent animals from walking in them. A feed mixer can be used to prepare rations by grinding and mixing several feedstuffs for a balanced ration.

Livestock handling equipment is important for safe and proper handling of animals. Large animals will require more expensive and heavy-duty equipment. Improved breeding programs will need enclosures to separate males from females during certain times of the year. Holding facilities are needed for gathering animals for health inspection and treatment. A weigh scale is a necessary item for maintaining animal performance data to determine if animals are growing according to established standards. The weigh scale is also an important item for implementing a culling program for breeding stock.

MARKETS AND PRODUCTS

The purpose of keeping livestock is for the products and services they provide. The value of these products is determined by the demand of the final consumer. For example, in China, people are not accustomed to drinking goat milk so goats are not milked, but raised only for their meat and hair. In Mexico, goat milk is a valuable commodity and is made into cheeses and candies. The final value of an animal product depends on its quality. Animals which are bruised and stressed during marketing will receive a lower sale price. During transport animals will shrink in body weight because of loss of fluids. These fluids need to be replaced within a reasonable period to avoid health problems.

One means of expressing value of a slaughter animal is the dressing percentage (Higgs et. at., 1981), also referred to as the yield. The formula for determining the dressing percentage is:

$$\text{Dressing percentage} = \frac{\text{hot carcass weight}}{\text{live weight}} \times 100$$

For example, if an 82 kg hog yields a hot carcass weighing 63 kg, the dressing percentage is calculated as follows:

$$\text{Dressing percentage} = \frac{63\text{ kg}}{82\text{ kg}} \times 100 = 0.768 \times 100$$
$$= 77\%$$

If a 400 kg beef animal yields a hot carcass weighing 200 kg, its dressing percentage is:

$$\text{Dressing percentage} = \frac{200\text{ kg}}{400\text{ kg}} \times 100 = 0.5 \times 100$$
$$= 50\%$$

Table 2.2 gives the approximate dressing percentages of various classes and grades of animals. Most animals slaughtered in the tropics and subtropics have lower amounts of fat compared to animals from temperate areas. This affects their dressing percentages and tends to lead to lower dressing percentages.

SUMMARY

Although an in-depth discussion of the principles of animal production is beyond the scope of this book, this chapter has presented some fundamental concepts relevant to animal husbandry. The major aspects of animal production — growth, reproduction, and lactation — have been introduced in order to provide the background needed for designing and conducting On-farm Animal

Table 2.2. Dressing percentages of livestock.

Cattle	(%)	Sheep/Goats	(%)	Hogs	(%)
Steers & heifers		Lambs/Kids		Barrows & gilts	
Choice & prime	63	Choice	50	US No. 1	69
Standard & select	60	Good	50	US No. 2	70
Commercial	56	Fat ewes/does	51	US No. 3 & 4	72
		Thin ewes/does	46	US utility	67
Cows					
Utility, cutter,		Sows	70		
& canner	52				
Average	60	Average	50	Average	70

Source: Higgs et al., 1981.

Research (OFAR). It is thus necessary to understand the factors which affect animal production, namely, health, nutrition, and animal management, and the variety of methods which are available for improving animal performance. By recognizing the animal management practices being utilized by the small farmer and the inputs that are available on the small farm, new animal-production technologies can be introduced where they are most likely to have the best results.

CHAPTER 3

ECONOMIC CONCEPTS

PURPOSE

Basic concepts of economics must be understood to properly design and successfully analyze on-farm animal trials. Many of the tools that economists use to analyze the data produced by On-farm Animal Research (OFAR) can be learned by noneconomists. The concepts presented in this chapter are the building blocks for conducting simple economic analyses and can be applied to the real-life situations which occur on farms.

OBJECTIVES

After completing this chapter, the reader should be able to:

- Describe how agricultural economics can be utilized during the three stages of testing a new technology in OFAR.
- Explain how economics of production can be applied to farming decisions.

ECONOMICS AND ON-FARM ANIMAL RESEARCH

The key elements of economics are **human wants**, **scarce resources**, and **techniques of production**. OFAR deals with the human wants or goals of the farmer, the limited (scarce) resources of the farm, and the farmer's techniques of production, which can be used to combine resources in varying proportions to achieve the optimal output.

Agricultural economics is an applied discipline — it applies economic theory to problems of agriculture. Often the agricultural economist has a strong background in one or more technical aspects of agriculture. In analyzing OFAR, the economist helps scientists estimate the economic profitability of a new technology, such as feed supplements, animal-drawn equipment, vaccines and medicines, and husbandry practices.

The three stages of testing a new technology while conducting OFAR are screening, experimental design, and evaluation. Agricultural economics can be usefully applied at each of these stages.

Screening

Befo a new technology is chosen, the technologies that are available are matched with the needs of the farm community. This is called screening. The economist can conduct a simple analysis, such as a partial budget and a benefit-cost analysis, to help screen technologies for different groups of farmers. Similarly, the extension worker may wish to look at the technical data and estimate basic economic relationships to be verified by further experimentation on the farm.

Experimental Design

Conducting OFAR requires planning, analysis, and financial resources; therefore, the technology should be refined as much as possible at the research station before it is tested on the farm. Research on animals is more difficult to conduct than research on plants. A fertilizer, pesticide, or seed-placement trial may involve only an acre of land and a few other resources, and if the new technology does not have significantly better results than the current practice, the farmer will not lose much money by participating in the crop experiment. The potential for financial loss from animal research is much greater. Therefore, economic analysis can be used to develop cost-effective designs for on-farm experimentation as well as to determine the optimal experimental design based on the goals that are sought. If the objective is to verify the performance of the technology at the farm level, then the number of farms on which the technology is tested is less important than the types of farms and their representation of the general situation. The on-farm experiment should be designed within the framework of the whole farm situation, including the seasonal calendar and the farm plan, so that experiments will not conflict with other farm goals and are scheduled for times when the farmer is able to participate.

Evaluation

Once the new technology requirements have been analyzed and suitable technologies have been screened for on-farm testing, evaluation should be deferred until animal scientists have had maximum time to test the technology. The guiding principle here should be to observe and record "with and without" effects or "before and after" effects of interventions. The results of the tests can then be evaluated and analyzed to determine the economic value of the technology.

ECONOMICS AND FARMING DECISIONS

Since resources of farms are limited (scarce), the ability of a society to produce goods and services is also limited. Therefore, all societies face decisions about what to produce, how to produce, for whom to produce, how to ration commodities over time, and how to provide for the maintenance and growth of the system (Salvatore, 1974). Similarly, a farmer must decide what crops to raise, what type of animal system to have, what type of machinery or equipment to buy, what amounts of fertilizers and chemicals to use, how to use credit, when to market animals and crops, and so on. Day-to-day decisions must be made as well as long-term plans (see figure 3.1).

A small farmer faced with the problem of allocating resources (land, labor, and capital) to the production of crops and animals on the farm must ask four fundamental questions:

- What should the farm produce? To answer this question, the farmer takes into account the family's subsistence requirements, opportunities for marketing the surplus, the price situation, and availability of resources on the farm. Resources are the most critical factor because they determine what can realistically be produced. If labor is scarce, then crops or animals that require high labor input will not meet the farm's needs.
- How should it be produced? This question relates to choice of production technology. Should animals be stall-fed or grazed in the pasture? What variety of crops should be grown and how many times should the fields be tilled? What kind of fertilizer should be used, a commercial brand or farmyard manure? The mere existence of a new technology does not make it superior to the farmer's traditional practice. The farmer normally wants to produce at the least cost and with as little deviation from traditional practices as possible. Therefore, when conducting OFAR, it is important to understand the farmer's considerations in deciding on a production method.
- How much should be produced? This question concerns how land and labor are allocated to production, such as how many acres of corn to grow or how many sheep to keep.
- How should it be marketed? Small farmers, in particular, must consider what to do with the final product. Is there a demand for the product in the local market or is it possible to transport the product to more distant markets? Is the market price dependent on the quality of the product or when it is produced? The market price for crop products (grains) can fluctuate: the price is low after harvest because the supply is high, but price will increase with time as the supply decreases. Animal and poultry markets can also be seasonal; for example, during the dry season, the supply of milk may be low so the price of milk will be high, and in Muslim countries the demand for sheep and goats is very high during the festival of Idul Adha.

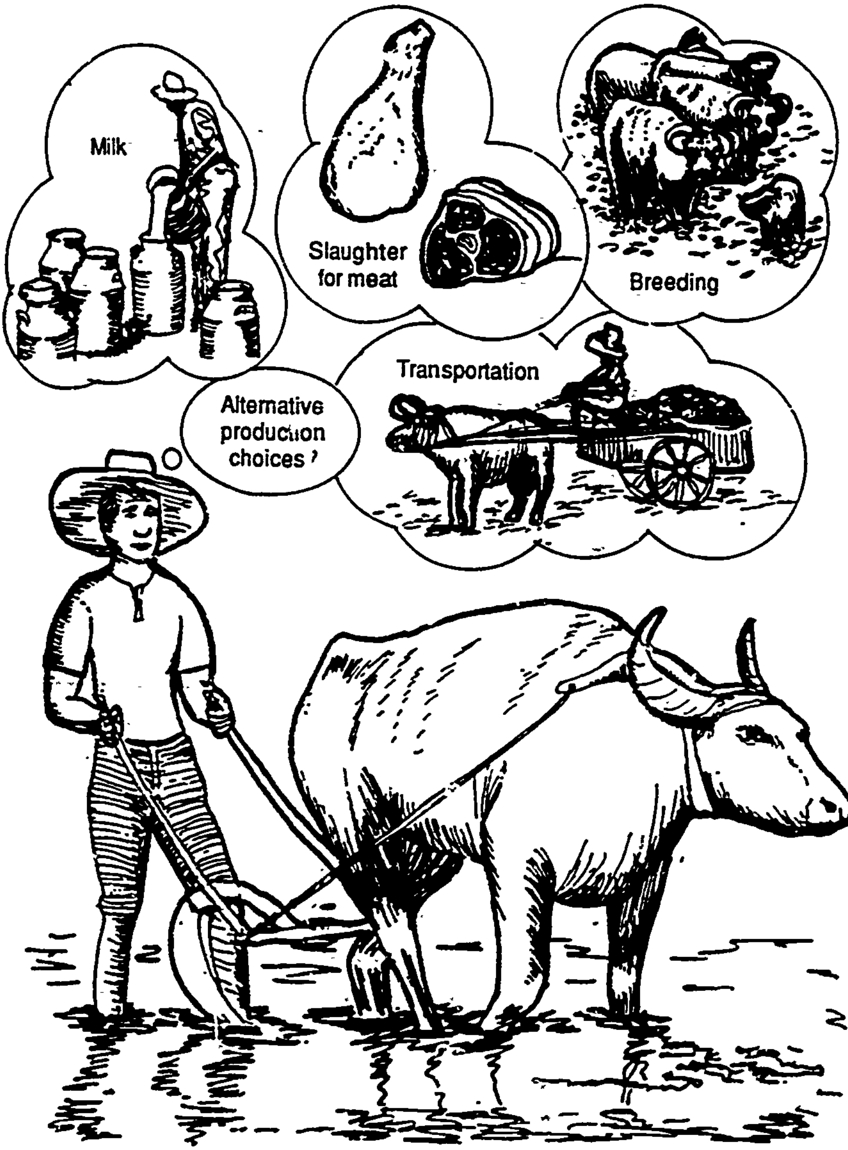


Figure 3.1. Farming decisions: Production choices for buffalo.

ECONOMICS OF PRODUCTION

There are physical and mathematical relationships between the level of inputs used and output received in a production process. Generally, given a level of fixed resources, higher levels of output can only be obtained by adding more variable resources. It is thus important to be able to identify the profitable levels of inputs to combine with a given level of fixed resources (Tan et al., 1980). This section describes the concepts necessary to identify the profitable use of variable input in a production process.

Production Relationships

In a production process, several inputs (factors of production) are used and ultimately transformed into the final output (product) or outputs. The farmer must choose the levels of each input — seed, fertilizer, feeds — that will, when transformed by the production process, produce the quantities and qualities of outputs that best satisfy the farmer's goals.

This relationship between factors of production and output can be expressed as:

$Y = f(X_1, X_2, X_3 \ldots X_n)$,

where Y is the output that is obtained as a result of using inputs X_1, X_2, etc. In the above equation, Y is used to denote a quantity of output, such as bushels of grain, pounds of meat, or dozens of eggs, while X_i represents units of specific inputs, such as pounds of fertilizer or tons of hay.

The quantities X and Y are called variables because variations in one of these quantities are associated with variations in the other. The expression $Y = f(X)$ means that Y is a function of X (that X affects Y). The production function is a mathematical statement about the relationship between X and Y once these two variables are defined.

Three basic relationships are studied in production economics:

- factor-product relationship — output (product) is related to a single variable production input (factor) given a set of fixed inputs
- factor-factor relationship — output (product) is related to two or more variable production inputs (factors)
- product-product relationship — the relative quantity of two or more outputs (products) is related to a fixed quantity of inputs (factors)

Factor-Product Relationship

For the first relationship — where one input is varied and the levels of the other inputs are kept constant — the relationship between variable input (factor) and output (product) can be expressed as:

$$Y = f(X_1/X_2, X_3 \ldots X_n),$$

where the bar (/) means that only one input (factor X_1) is varied while all other inputs (X_2 to X_n) are held constant. The nature of the relationship between a single input and output can be constant productivity, increasing productivity, or decreasing productivity. The following sections introduce several of the concepts which apply to factor-product relationships.

Marginal product. Marginal product is the change in the output (product) due to a change in the variable input; or put another way, it is the rate at which the variable input is transformed into output. The symbol "Δ", known as delta, indicates a change in a variable. Thus, ΔY means the change in output Y, ΔX means the change in input X, and $\Delta Y/\Delta X$ means the change in the amount of Y due to a specified change in the level of X. In economics, the concept of marginality is commonly used in decision-making. It is applied to production decisions about choosing an input, deciding what quantity of the input to use, and deciding how much output to produce. Decisions are based on the value of an additional (marginal) quantity of output compared to the cost of the additional input required to produce the marginal output.

Constant marginal product. Under constant marginal productivity, for a range of input levels, the application of each additional unit of input (for example, a certain amount of fertilizer per hectare of pasture land) yields equal increments in output. This relationship is uncommon in agriculture; it is most likely to exist where the initial doses of variable resource are small. An example of constant marginal product is provided in table 3.1 and figure 3.2.

Table 3.1. Constant marginal productivity of fertilizer

Fertilizer		Total Product		Marginal Product
X (kg)	ΔX (kg)	Y (kg)	ΔY (kg)	$\Delta Y/\Delta X$
10		1,444		
	10		108	10.8
20		1,552		
	10		108	10.8
30		1,660		
	10		108	10.8
40		1,768		

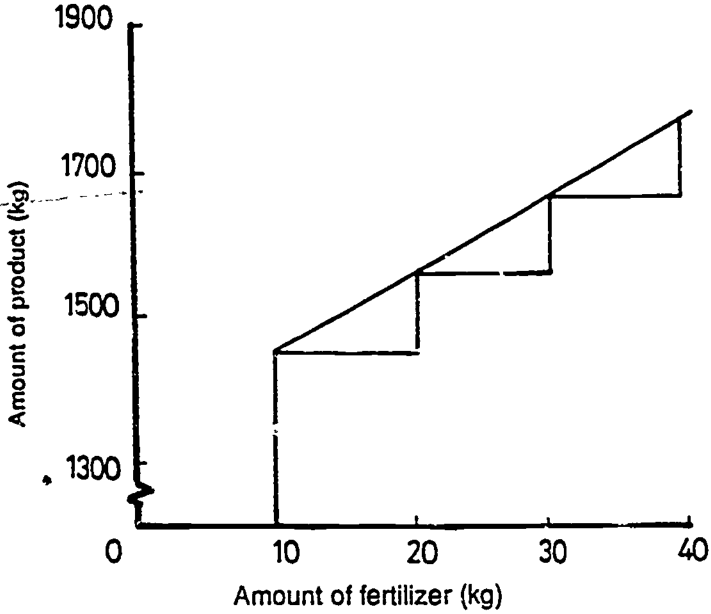


Figure 3.2. Constant marginal productivity.

Increasing marginal product. Occasionally there are instances in farming where, for a range of input levels, additional increments of input result in increasing increments of output. This type of relationship between input and output is possible when the fixed input is in excess in relation to the variable resource (see table 3.2 and figure 3.3).

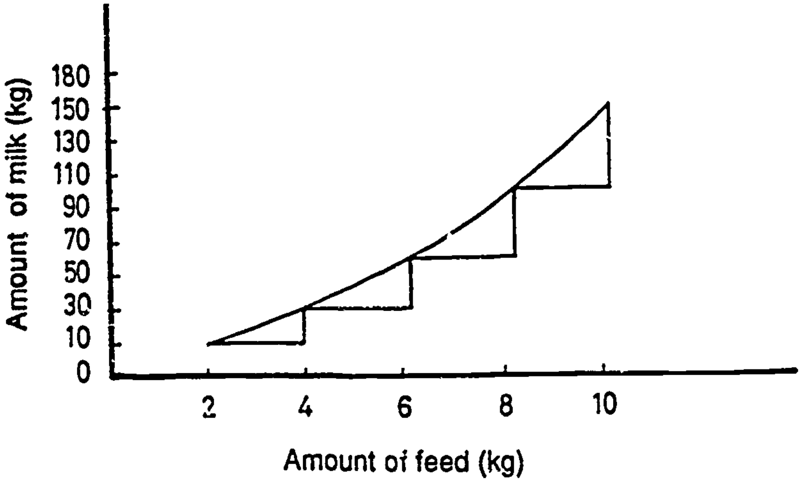


Figure 3.3. Increasing marginal productivity.

Table 3.2. Increasing marginal productivity of feed.

Feed		Milk		Marginal Product
X (kg)	ΔX (kg)	Y (kg)	ΔY (kg)	ΔY/ΔX
2		10		
	2		20	10
4		30		
	2		30	15
6		60		
	2		40	20
8		100		
	2		50	25
10		150		

Decreasing marginal product. Decreasing marginal product is the most typical factor-product relationship for the range of input levels of interest in agricultural production. In this relationship, the application of each additional unit of input yields an incremental output which is less than that from the previous increment in input (see table 3.3 and figure 3.4).

Production may respond to increasing inputs with a combination of the properties described above. The general classical production function combines the phases of increasing marginal productivity with decreasing marginal

Table 3.3. Decreasing marginal productivity of concentrate feeding.

Concentrate		Milk of crossbred cow		Marginal Product
X (kg)	ΔX (kg)	Y (kg)	ΔY (kg)	ΔY/ΔX
2		5.89		
	2		3.52	1.76
4		9.41		
	2		3.00	1.50
6		2.41		
	2		2.62	1.31
8		15.03		

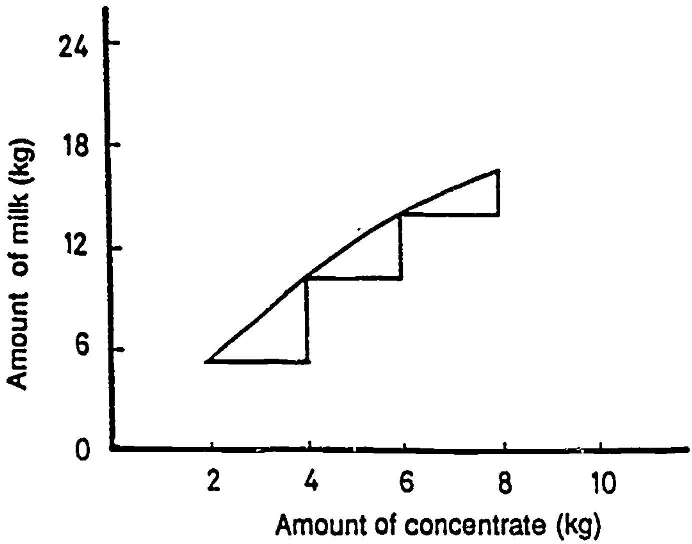


Figure 3.4. Decreasing marginal productivity.

productivity. In the production relationship illustrated by table 3.4 and figure 3.5, increasing marginal product occurs with up to 5 units of input X. From 5 to 8 units of input, decreasing marginal product prevails, with total output increasing at a decreasing rate. If more than 8 units of input are applied, total product decreases and marginal products are negative.

Relationships among marginal products. The following relationships hold between marginal product and total product as the level of input increases (see figure 3.5):

- when total product is increasing at an increasing rate, marginal product is positive and increasing
- when total product is increasing at a decreasing rate, marginal product is positive but decreasing
- when total product is maximum, marginal product is zero
- when total product is decreasing, marginal product is negative

Average product. This is the ratio of output to input; that is, Y/X, where Y is total output and X is total input. The following relationships exist between average product (AP) and marginal product (MP) (see figure 3.5):

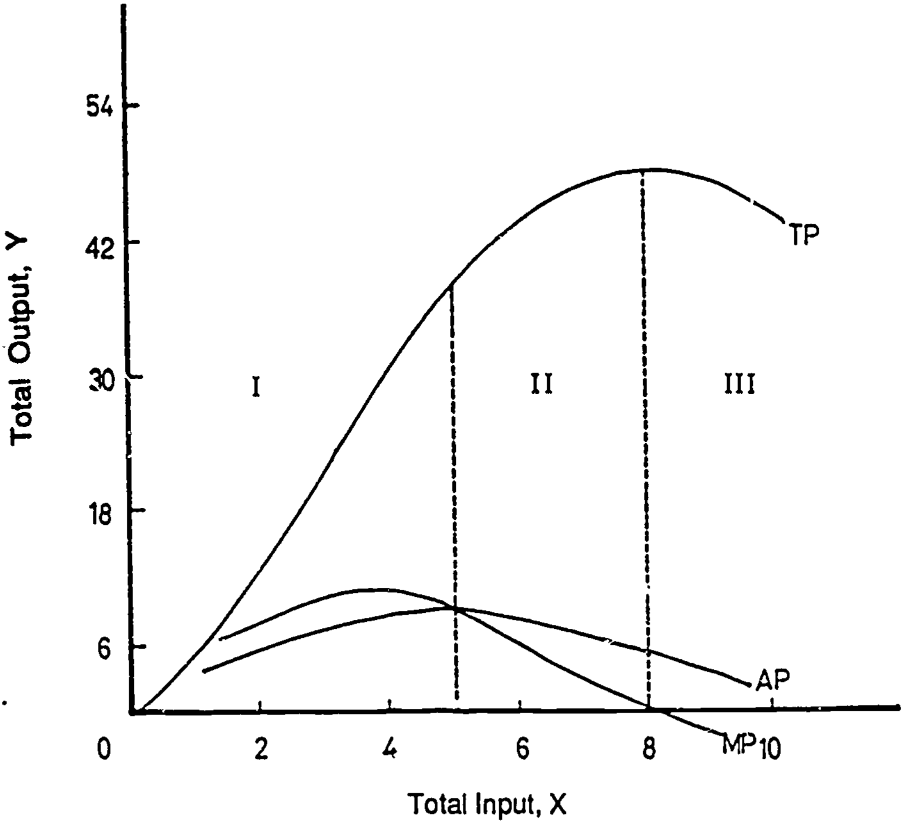
- when MP > AP, AP is increasing
- when AP = MP, AP is at maximum
- when MP < AP, AP is decreasing

Average product measures the technical efficiency of a process. Therefore, when average product is increasing (MP > AP), farmers should expand their input level because at this level of productivity, output will increase at an increasing rate.

Table 3.4. Input-output relationship indicating increasing and decreasing production.

Amount of feed		Total product		Marginal product		Average product
X	ΔX	Y	ΔY	ΔY/ΔX		Y/X
0		0				0.0
	1		4	4		
1		4				4.0
	1		6	6		
2		10				5.0
	1		8	8	I	
3		18				6.0
	1		9	9		
4		27				6.8
	1		10	10		
5		37				7.4
	1		5	5		
6		42				7.0
	1		4	4	II	
7		46				6.6
	1		2	2		
8		48				6.0
	1		−2	−2		
9		46			III	5.1
	1		−4	−4		
10		42				4.2

I — product increasing at increasing rate
II — product increasing at decreasing rate
III — product decreasing



TP = Total Product
AP = Average Product
MP = Marginal Product

I - Total Product increasing at increasing rate
II - Total Product increasing at decreasing rate
III - Total Product decreasing

Figure 3.5. Stages of production and the relationships between MP and AP.

Zones of factor-product relationships. The classical production relationship may be partitioned into three zones (see figure 3.5). These zones are important because only one of them represents efficient use of the variable input to be used. Zones I and III are known as zones of irrational production. Irrational production is a situation in which resources could be rearranged to give either greater production from the same outlay or the same production from smaller aggregate outlay of fixed and variable resources.

Using resources in a way that restricts production to zone I is uneconomical. If the level of variable input causes production to occur in zone I, then the farmer is using too little of the variable resource given the level of fixed inputs that are available. It is necessary to increase the amount of input used at least up to the point of highest average product (AP); that is, up to the border between zones I and II. If the amount of the variable input available falls short of what is required to reach the border between zones I and II, more products can be obtained by shifting some of the fixed resources to other uses. Greater total output (the total of all possible products) can be realized by applying the variable input to a smaller set of fixed resources.

It is similarly irrational to apply additional inputs beyond the point where production begins to decrease; that is, beyond the border between zones II and III. In zone III, the marginal product is negative — too much variable input is being used relative to the set of fixed inputs. It is possible to rearrange the resources so equal or greater output can be achieved with smaller aggregate outlays of fixed and variable resources. Given the set of fixed inputs, what may be done in this situation is to use less of the variable resource.

Zone II is the **zone of rational** production. It is the area of economic relevance — to maximize economic returns, the variable resource should be combined with the fixed resources at a rate that causes production to be within this zone. To locate the precise economically efficient level of use for the variable resource within this zone, the rate of transformation of input to output (that is, the production function) must be known as well as the input-output price ratio or choice indicator.

Maximum profit occurs when added return ($\Delta Y \times P_Y$) equals added cost ($\Delta X \times P_X$), and production is occurring within zone II of the production relationship. Symbolically, this principle of profit maximization can be stated as follows:

Profit is maximum when: $\Delta Y \times P_Y = \Delta X \times P_X$ or $\Delta Y/\Delta X = P_X/P_Y$,

where P_Y is the price of output, P_X is the price of input, $\Delta Y/\Delta X$ is the marginal product, and P_X/P_Y is the ratio of prices. If the added return ($\Delta Y \times P_Y$) is greater than the added cost ($\Delta X \times P_X$), it is profitable to increase the level of the variable resource to the point where added return is equal to added cost. Of course, if added cost exceeds added return, then it is profitable to decrease the use of the input.

In a real farm situation, farmers frequently use lower levels of resources than are optimal for many reasons, such as:

- The farmer does not understand the value of the resources or is unsure of the nature of the input-output relationship.
- Future prices and yields are uncertain, so the farmer discounts future returns.
- The farmer has too little capital to buy the level of inputs necessary to maximize profits.

Factor-Factor Relationship

In the factor-product relationship discussed above, one input varies while all others are fixed. This section discusses the factor-factor relationship, which involves a number of variable inputs (factors). It can be expressed as follows:

$$Y = f(X_1, X_2 / X_3, X_4 \ldots X_n),$$

where at least two inputs, factors X_1 and X_2, are variable. In a factor-factor situation, the most common objective is to obtain the least-cost combination of inputs to realize a required level of output.

Isoproduct curves. A farmer can use different combinations of inputs to produce the same level of output. Table 3.5 lists examples of different combinations of two resources (X_1 and X_2) that produce the same level of output (10 units per hectare). It must be remembered that there will be limits to the substitution of inputs. A given output level cannot be produced without some minimum level of inputs. Plotting the input levels on a graph produces an isoproduct curve (see figure 3.6). The isoproduct curve is also referred to as an isoquant or equal quantity curve.

Table 3.5. Isoproduct schedule.

Input combination		
X_1	X_2	Output
20.0	2.5	10
15.0	5.0	10
10.0	8.0	10
5.0	13.0	10

Factor substitution. Factor-factor marginal relationships, like factor-product marginal relationships, can be increasing, constant, or decreasing. Paralleling the reasoning used in the factor-product situation, logic will indicate that the only situation of economic interest is the case where the marginal rate of substitution between inputs is decreasing. In either of the other cases a minimum amount, usually none, of the more expensive input will be used.

The situation where a given incremental amount of one input substitutes for fewer and fewer units of another is referred to as a diminishing marginal rate of substitution between inputs. Examples of decreasing rates of input (factor)

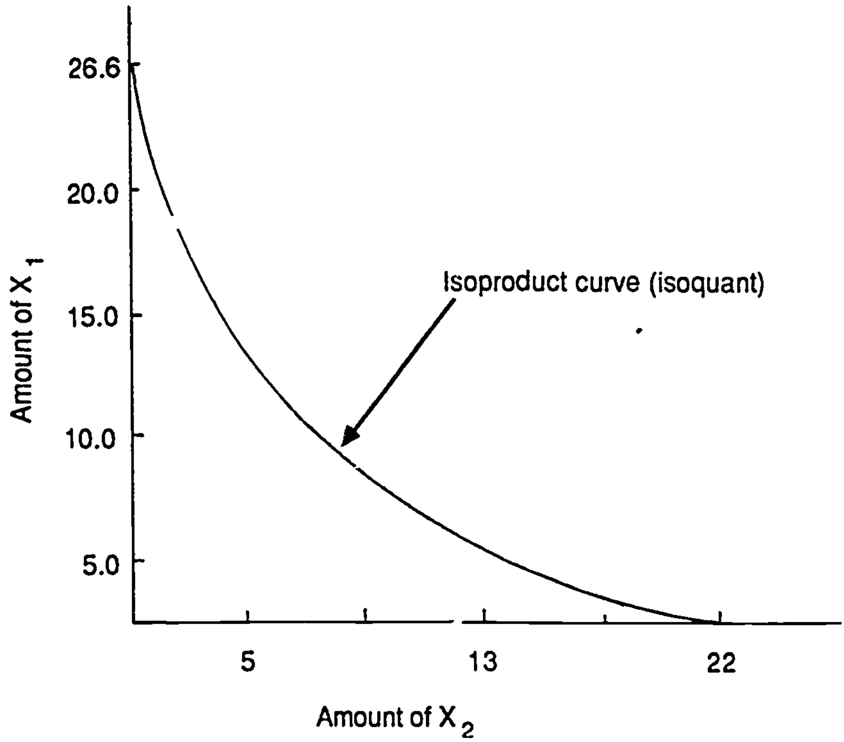


Figure 3.6. Isoproduct curve.

substitution are common in agriculture. This relationship is demonstrated in dairy feed rations (table 3.6 and figure 3.7), where various combinations of two inputs, concentrate (X_1) and berseem (X_2), are used to produce 6.5 kilograms/day of milk from a crossbred cow.

Table 3.6. Decreasing marginal rates of factor substitution.

Amount of concentrate X_1 (kg)	ΔX_1	Amount of berseem X_2 (kg)	ΔX_2	$-\Delta X_1/\Delta X_2$	P_{X2}/P_{X1}*	Total Cost (Rs)
6.32		5			0.1	341
	−2.59		5	0.52		
3.73		10			0.1	237
	−0.96		5	0.19		
2.77		15			0.1	214
	−0.52		5	0 10		
2.25		20			0.1	213
	−0.34		5	0.07		
1.91		25			0.1	221

*Given the price of concentrate, P_{X1}, is Rs 50 per kilogram, and the price of berseem, P_{X2}, is Rs 5 per kilogram.

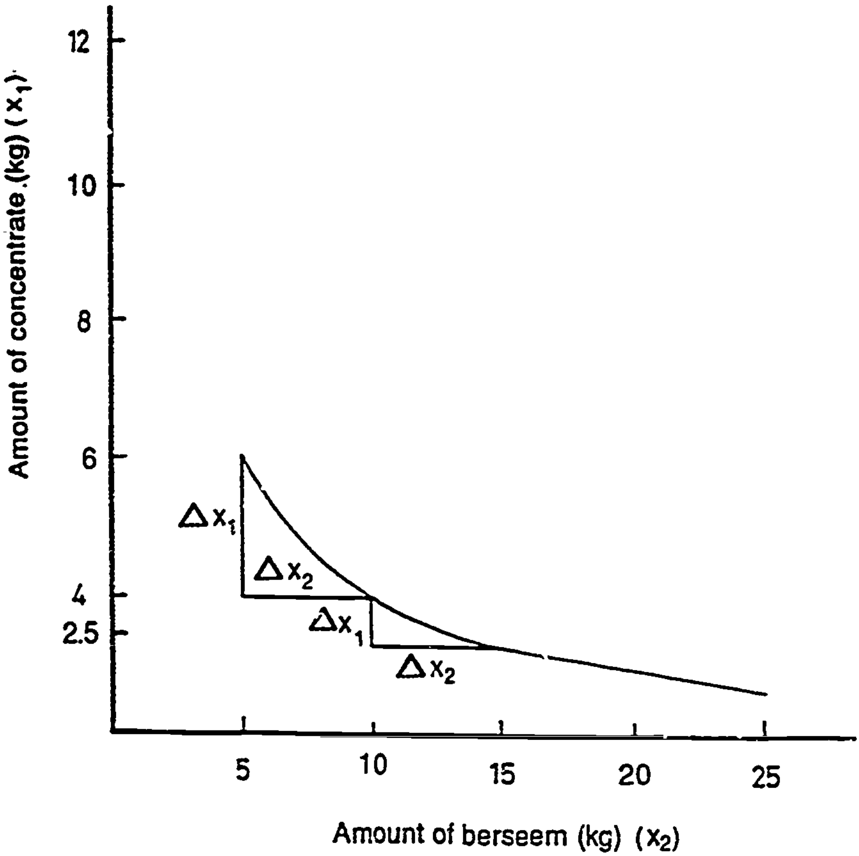


Figure 3.7. Decreasing rate of factor substitution.

Least-cost combination of resources. The relative price differences of a variety of inputs in an animal production system, and the output price of a final product, e.g., meat, hides, milk, will help the farmer to decide what amount of a particular input or combination of inputs will be required to produce a certain level of output. The farmer looks for the least-cost combination of input resources that can be used to produce a certain amount of output, e.g., milk or meat (Donaldson, 1984). In order to identify the least-cost combination of animal rations needed to produce a certain level of milk (from the data in table 3.6), two types of information are needed:

- the marginal rate of factor substitution, $-\Delta X_1/\Delta X_2$
- the inverse ratio of the input prices, or the inverse factor price ratio, P_{X2}/P_{X1}

The least-cost combination of inputs is obtained when the marginal rate of factor substitution is equal to the inverse factor price ratio, that is when:

$-\Delta X_1/\Delta X_2 = P_{X2}/P_{X1}$ or $-\Delta X_1 P_{X1} = \Delta X_2 P_{X2}$

When the value of the marginal input added ($\Delta X_2 P_{X2}$) is equal to the value of the marginal input reduced ($\Delta X_1 P_{X1}$), the resource mix is optimal. Graphically, this condition is met when the slope of the isoproduct curve, $\Delta X_1/\Delta X_2$, is equal to the slope of the isocost line, P_{X2}/P_{X1}, where the isocost line is found by graphing $P_{X1}X_1 + P_{X2}X_2 = C$. Equal slopes are obtained by moving the isocost line parallel until it touches the isoproduct curve (see figure 3.8).

Using the marginal rate of factor substitution calculated in table 3.6 for various levels of concentrate and berseem, and using input prices of Rs 50 per kilogram for concentrate and Rs 5 per kilogram for berseem, it is possible to calculate the least-cost combination of these inputs that would maximize profit for 6.5 kilograms/day of milk per cow. The application of the least-cost principle indicates that this quantity of milk will be produced at minimum cost if the animals are fed a ration of 2.77 to 2.25 kilograms of concentrate combined with 15 to 20 kilograms of berseem.

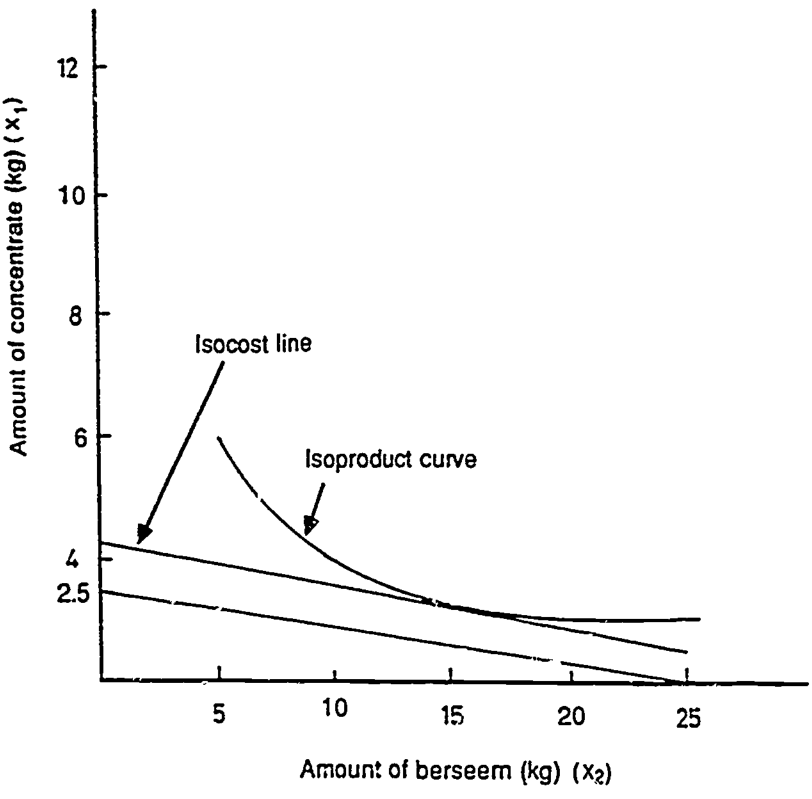


Figure 3.8. Least-cost combination of two inputs.

More specifically, the principle of factor combination says that inputs should enter the farm plan as long as their expected contribution to net farm income exceeds the opportunity cost of the resources used. A common application of this important economic concept is the least-cost ration-formulation procedure used to develop rations for dairy herds, poultry farms, etc. The general principle can be extended to all types of production processes.

Product–Product Relationship

In a product-product relationship two outputs (products) can be produced given a fixed quantity of inputs (factors). The major objective is to determine the optimal combination of outputs to produce for a given set of inputs. Since the total cost is fixed (because a fixed amount of inputs are used), the farmer will want to maximize total revenue from production of the two outputs. Marginal analysis is then used to decide on the best combination of outputs. Two outputs can be complementary, supplementary, or competing for resources.

Product transformation curves. A farmer uses a fixed quantity of inputs with the goal of producing the greatest total revenue from two outputs. Table 3.7 gives examples of different combinations of two outputs, Y_1 and Y_2. Plotting these combinations of outputs on a graph produces a product transformation curve with a slope equal to $\Delta Y_1/\Delta Y_2$ (see figure 3.9).

Table 3.7. Product-product relationship at fixed levels of inputs.

Corn Y_1 (bu)	ΔY_1	Soybeans Y_2 (bu)	ΔY_2	$-\Delta Y_1/\Delta Y_2$	P_{Y2}/P_{Y1}*	Total Revenue (US$)
170		0			2	510
	−10		10	1.0		
160		10			2	540
	−15		10	1.5		
145		20			2	555
	−25		10	2.5		
120		30			2	540
	−35		10	3.5		
85		40			2	495
	−40		10	4.0		
45		50			2	435
	−45		10	4.5		
0		60			2	360

*Given the price of corn, P_{Y1}, is US$3.00 per bushel, and the price of soybeans, P_{Y2}, is US$6.00 per bushel.

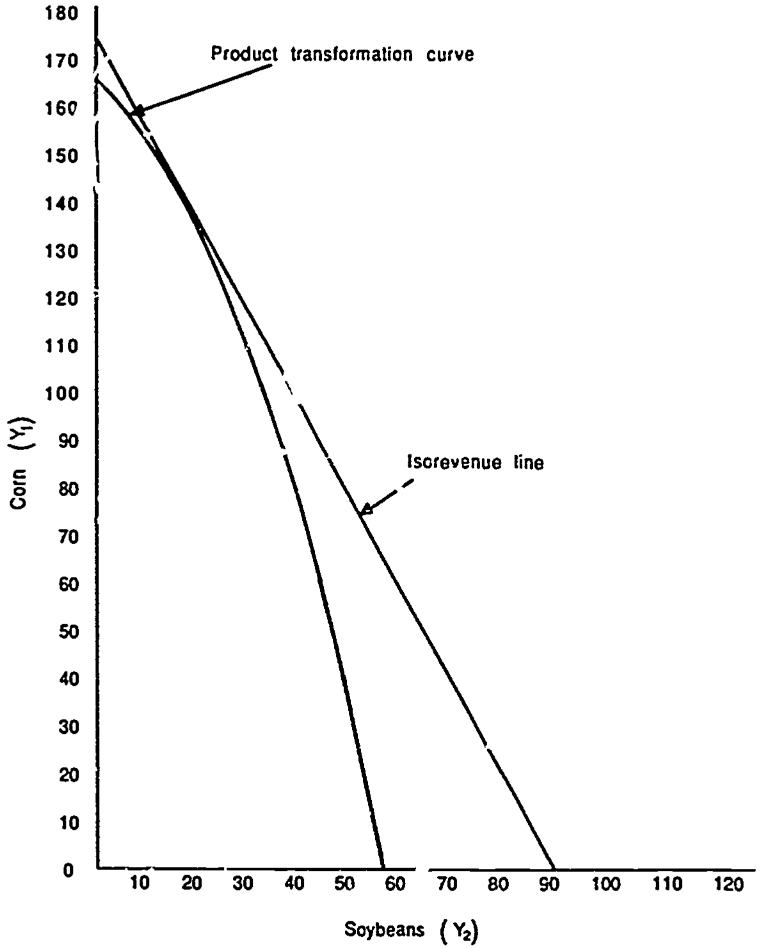


Figure 3.9. The optimum output combination.

Isorevenue line. Different combinations of products generate different amounts of revenue (see table 3.7). The total revenue can be determined by the following equation:

$R = Y_1P_{Y1} + Y_2P_{Y2}$,

where R is total revenue, Y_1 is product 1, P_{Y1} is the price of product 1, Y_2 is product 2, and P_{Y2} is the price of product 2. The unit price for each product is assumed to remain constant at different levels of output. The optimum output combination is attained when the ratio of the change in outputs is equal to the inverse product price ratio:

$-\Delta Y_1/\Delta Y_2 = P_{Y2}/P_{Y1}$ or $-\Delta Y_1P_{Y1} = \Delta Y_2P_{Y2}$

When the value of the additional output produced ($\Delta Y_2 P_{Y2}$) is equal to the value of the incremental output given up ($\Delta Y_1 P_{Y1}$), the product mix is optimal. This occurs when the slope of the isorevenue line, P_{Y2}/P_{Y1}, is equal to the slope of the product transformation curve, $\Delta Y_1/\Delta Y_2$ (see figure 3.9). In the example used, the optimum combination of outputs approximately occurs when $Y_1 = 145$ bushels of corn and $Y_2 = 20$ bushels of soybeans, generating a total revenue of US$555.00 per hectare (see table 3.7).

Supplements, complements, and competitive enterprises. Enterprises are complementary when increasing the production of one enterprise also increases the productivity of the other. This is illustrated by region A-B in figure 3.10, where both Y_1 and Y_2 are increasing. Complementary relationships exist when one enterprise produces an element that is required in another enterprise. For instance, legume production is complementary to other crop production because it fixes nitrogen in the soil that can be used by another crop. Two enterprises are unlikely to remain complementary over the entire product transformation curve. This is due to the fact that this curve represents maximum efficiency of utilized inputs, and increasing utilization of one input prevents use of that same input for another farming activity. For example, increased use of land (input) for cattle grazing prevents the use of that land for crop production.

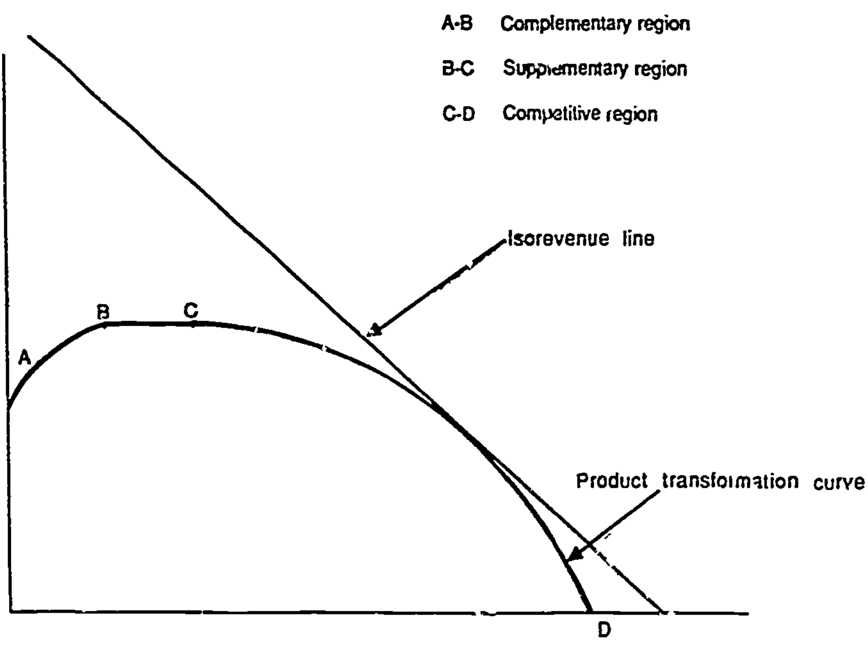


Figure 3.10. Hypothetical product transformation curve.

Two enterprises are supplementary when an increase in the level of one does not affect the production of the other; that is, the enterprises do not compete with each other. This is depicted by region B-C in figure 3.10, where Y_2 increases without affecting the production of Y_1. Supplementary enterprises use noncompetitive resources which are stated to be idle. For example, on a small farm, keeping one or two milk cows or a few chickens may be supplementary to the main enterprises because the family labor that is used to produce these items does not reduce the productivity of the major farm activities. However, it is unlikely for two enterprises to be supplementary over the entire product transformation curve because, at some point, they will start to compete for resources.

As long as both products have positive prices, it is never economic to produce in the range where two product are supplements or complements. In either case, production should be increased until the optimal point in the competitive range of the product transformation curve is reached. In figure 3.10 this would be the point in region C-D, where the isorevenue line is tangent to the slope of the product transformation curve.

Identifying Costs and Benefits

Most of the analyst's time is spent identifying applicable costs and benefits of the new treatment being tested on the farm. These costs and benefits must be confirmed through the on-farm tests.

First, local input costs — labor rates, transportation costs, and marketing costs such as taxes — should be estimated. Costs of noncash inputs such as family labor, forages, and household wastes are more difficult to estimate. An important concept relevant to estimating input costs is that of opportunity cost. The **opportunity** cost principle states that the cost of any choice (such as using some resource in a particular activity) is the value of the best alternative that is forgone. For example, if a farmer can earn a profit of US$75 from raising sheep and US$95 from raising goats, the opportunity cost of raising sheep is US$95. Since this exceeds the potential profit from raising sheep, the farmer should raise goats. If the farmer persists in raising sheep, it should be with the realization that US$20 profit has been lost. In either case, the farmer makes money, but the earnings would be greater from raising goats. Of course, it is up to the farmer to decide in what terms to measure opportunity cost — it could be measured in leisure, for instance, as easily as in money. However, each unit of land, labor, and capital should be used where it will have the greatest return, in whatever way that return is measured. This principle of determining the value of farm resources is extremely important in identifying relevant costs and, hence, in working out an efficient farm organization.

An often confusing distinction in cost identification is between stocks and **flows.** A bathtub half full of water, with the faucet turned on and the plug removed, can be used to illustrate these two variables. The level of water in the tub is a stock — an amount that is just there. It could be expressed as so many gallons of water The amount of water entering through the faucet and the amount leaving through the drain are both flows. Each of them could be expressed as so many gallons per minute or per hour. A flow always has a time dimension — there is so much flow per period of time. A stock does not have a time dimension — it is just so many tons or gallons, or, in a farming situation, so many sheep or goats. The cost of a stock is generally the opportunity cost associated with that stock. The cost of a herd, for example, might be the interest that would be earned on a sum of money equal to the market value of the herd since this would represent the opportunity cost of the herd. Flows, on the other hand, such as milk production during a certain time interval, are valued at their full market price.

It is often difficult to determine the field price of inputs and outputs. It is important to know whether animals should be valued per kilogram of live weight or by the head based on physical inspection (which is often preferred). Therefore, the market must be analyzed before evaluating the technology. Similarly, care should be taken when costing inputs such as labor (Price, 1982). Often the marginal cost of an additional animal is negligible in terms of care and management, especially under traditional management systems. If a new technology requires treating the animal individually (for example, vaccination), the labor input should be valued at its opportunity cost. In addition, "leisure labor" activities such as watering, giving medicine, arranging for mating, and feeding should be differentiated from "hard labor" activities such as plowing, transporting grain, and transplanting seed (Amir and Knipscheer, 1987a). Hard labor requires more physical skill and energy; therefore, it is not appropriate to cost an hour spent in leisure labor at the same rate as an hour spent in hard labor. Labor wages should not be arbitrarily discriminated on the basis of the age or sex of the laborer.

In raising small ruminants, the production characteristics that farmers consider most important include the animals' reproductive capacity, mortality, ability to gain weight, and milk production. These variables must be valued since farmers want to know how the new technology will influence them. Minor benefits, such as manure, must also be given a value. If a market price is not available, manure can be given a value equal to the reduced use of artificial fertilizer (including transportation charges). It is generally easier and perhaps more relevant to develop budgets for herds than to estimate cost per animal (Amir and Knipscheer, 1987a; Carkner et al., 1981). Tables 3.8 through 3.10 show the costs and benefits that must be considered in deriving partial budgets, gross margins, and cost-of-production estimates. Correct valuation of benefits is crucial since overestimating the value of benefits can lead to erroneous conclusions.

Table 3.8: Checklist of costs involved in producing ruminants and pigs.

Type of cost	Form of cost
PRIMARY COSTS	
VARIABLE COSTS	
FEED COSTS	
Concentrates	Cash
Grass and hay	Cash/noncash
Minerals/supplements	Cash
Grain	Cash/noncash
Water	Cash/noncash
OTHER COSTS	
Medicines/vaccines	Cash
Veterinary services	Cash
Breeding fees	Cash/noncash
Supplies	Cash
Milk hauling/marketing	Cash/noncash
Transportation	Cash/noncash
Utilities	Cash
Hired labor	Cash
Other labor (family/exchange)	Noncash
Stock replacement	Cash/noncash
FIXED COSTS	
Housing/bedding	Cash/noncash
Beginning stock	Cash
Land rent	Cash/noncash
Depreciation	Noncash
Taxes, interest	Cash/noncash
SECONDARY COSTS	
Destruction of crops	Cash/noncash
Trampling of land	Noncash
Noise, disease	Noncash
Foul odor (animal and/or manure)	Noncash
Threat to safety of small children	Noncash

Table 3.9. Checklist of benefits of producing ruminants and pigs.

Type of benefit	Form of benefit
PRIMARY BENEFIT	
Milk	Cash/noncash
Meat	Cash/noncash
Work (large ruminants)	Cash/noncash
Hides	Cash/noncash
Manure	Cash/noncash
Horn and/or hooves for feeds	Cash/noncash
Horn and/or hooves for art	Cash/noncash
Meat and milk by-products	Cash/noncash
Transport (large ruminants)	Cash/noncash
Capital asset	Cash
Reproduction	Cash/noncash
SECONDARY BENEFIT	
Urine	Noncash
Weeding/grazing	Noncash
Aesthetic value	Noncash
Religious value	Noncash
Pet value	Noncash
Entertainment and sports	Noncash
Research	Noncash

Table 3.10. Checklist of benefits of producing ducks and chickens.

Type of benefit	Form of benefit
PRIMARY BENEFIT	
Meat	Cash/noncash
Eggs	Cash/noncash
Feathers	Cash/noncash
Manure	Cash/noncash
Reproduction	Cash/noncash
Bills and bones for feeds	Cash/noncash
Sports (cockfighting)	Cash/noncash
SECONDARY BENEFIT	
Aesthetic value	Noncash
Pet value	Noncash
Research	Noncash

SUMMARY

This chapter has introduced several economic concepts which can be used for analyzing the results of OFAR. Not only can agricultural economics be applied to the stages of new technology testing, it can also be applied to farming decisions, such as what animal system a farmer should have or what feed supplements should be used. When applied to real-life farming situations, production economics can help farmers achieve maximum productivity. Although relationships on the small farm can be analyzed by using basic economic principles, care should be taken when making broad recommendations based on case studies or a few trials. In addition to the economic analysis of a new technology, close attention must also be paid to the farmer's response to the new technology and acceptance of it. If a technology is not being accepted by a particular group of farmers, something fundamental may have been missed in the initial analysis. When determining costs, it is important to find out whether the farmer agrees with the cost assessment and the values assigned to benefits. The key to any economic analysis is not to miss the big picture or the primary costs and benefits.

CHAPTER 4

USING STATISTICS IN ON-FARM ANIMAL RESEARCH

PURPOSE

Statistical analysis of On-farm Animal Research (OFAR) involves the organization and interpretation of data sets. Unfortunately, the experimental designs that produce the best statistical data are often too complicated to be practical when used during OFAR. Therefore, the debate on appropriate statistical methods for OFAR continues. Knowing certain fundamentals of the subject, however, can help in the selection of sample farms and animals, and understanding certain statistical concepts can improve the validity of research results.

Since this chapter describes the steps used for selecting a sample, computing a statistical analysis, and testing a hypothesis, a basic knowledge of frequency distributions is assumed.

OBJECTIVES

After completing this chapter, the reader should be able to:

- Describe the basic sampling techniques that are used in OFAR.
- Compute simple statistics such as mean, median, mode, variance, and standard deviation, and utilize statistical tests for analyzing data.
- Describe the steps used in hypothesis testing.
- Apply the steps in testing a hypothesis to examples of OFAR.

SOME STATISTICAL CONCEPTS

Statistics is a branch of mathematics dealing with the collection, organization, and interpretation of sets of data according to well-defined procedures. Statistical evaluation is the tool whereby data can be systematically analyzed so that conclusions can be drawn. Since the statistical procedures are well defined, statistical analysis lends credibility to the conclusions drawn by researchers.

Since practicality and the cooperation of farmers are often the greatest considerations in choosing experimental units, statistical evaluation does not receive enough attention in OFAR. Researchers, however, feel that a practical approach in choosing experimental units lacks a theoretical framework which does not allow for standard statistical analysis in order to derive meaning from experimental data. Basic skills in using simple statistics such as mean, median, mode, variance, standard deviation, and hypothesis testing are essential for the serious researcher or extension worker involved with OFAR.

Sampling

In most cases, it is impossible to collect data from every member of the group being tested (the population), either because of the group's large size or the high cost of gathering data. Statisticians remedy the problem by sampling. Sampling is the process or technique of choosing the sample. A sample is a number of individual units (such as goats, cows, calves, roosters, or farms) selected from all those units that compose a particular population. The members of the sample must accurately reflect the variations within the population so that the inferences made about the population based on what is observed with the sample are valid and reliable.

Sampling is a hard job — it must be done systematically and scientifically with the following considerations in mind:

- purpose of the investigation
- size of the population
- cost of gathering statistical data
- time available
- nature of data to be gathered

Nonrandom Sampling

Nonrandom samples are chosen by purposely selecting units without the use of a population list. The usual nonrandom sampling method that applies to OFAR is purposive sampling: the researcher establishes criteria that the units, such as farms or animals, must meet, and those units that meet the criteria are chosen. For example, a researcher may wish to study the effects of feeding a mineral supplement to lactating native cows that are at least 5 years old. Since not many of the villagers raise cattle, few cows satisfy the age criterion. Therefore, the researcher chooses for the sample all farms that have cows that are at least 5 years old until the desired quantity of experimental units has been reached.

Probability Sampling

In probability sampling, the sample is chosen in such a way that the probability of a particular individual being included in the sample is known. Probability sampling includes random, systematic, stratified, and multistage sampling procedures. The chief advantages of probability sampling are 1) the risk of sampling bias is minimized and 2) it is possible to make inferences about the population from which the sample was drawn.

Random sampling. In random sampling, each member of the population has the same probability of being chosen. A list of the population is needed, and each member of the population is assigned an identification number. The random sample is then drawn by using a list of random numbers to choose individuals from the population. This method is easy to implement and appropriate if the population is concentrated in a small area. The method does not work well if it is difficult to obtain a population list or if the selected units are geographically dispersed and therefore expensive to reach.

Systematic sampling. Systematic sampling involves working backward and forward through the population list from a random starting point and choosing individuals at a specified interval. Systematic sampling achieves similar results to random sampling, but utilizes the following equation:

$K = N/n$,

where K is the specified interval for choosing individuals rounded down to a whole number, N is the number in the population being sampled, and n is the required sample size. This technique is quicker and easier to use than random sampling which is an important consideration if samples are drawn in the field. However, if the population list is not in random order, and especially if there are periodic regularities in the list, systematic sampling can lead to bias.

Stratified sampling. Stratified sampling can be used when the population to be sampled consists of groups with distinct characteristics. The population is grouped according to the chosen characteristics, and a sample is drawn from each group using either the random or the systematic method. For example, if a researcher wishes to compare milk-yield performances of cows, the farms can be grouped according to the breed of cows being raised, and from each group a random or systematic sample can be drawn.

Multistage sampling. Multistage sampling involves at least two steps. First, a list of villages in the study area is obtained and is used to draw up a sample of villages. Then, a list of the farms within each chosen village is used to choose a sample of farms. When multistage sampling is based on geographical units, the savings in travel time and costs can be substantial. Furthermore, the entire potential population does not have to be researched. From the second stage on, only the population for the units that were selected at the earlier stage have to be identified.

Sample Survey

The sample survey is used to identify the many farm settings in which inferences about the larger population are required. In OFAR relatively small numbers of farmers are asked to participate in the survey for data collection. There are three important advantages to using sample surveys:

- Economy: The sample survey requires less time and money because only a limited number of farmers are included in the research survey.
- Accuracy: With smaller numbers of farmers included in the research project, more detailed information can be collected.
- Adaptability: A wide variety of topics, particularly those involving detailed information, can be investigated.

Measuring Central Tendency

Central tendency is the degree to which experimental data or observations cluster near the center of a frequency distribution. Measures of central tendency are used to 1) describe the performance of a group and 2) compare the performances of more than one group. Simple measures of central tendency used in the analysis of OFAR dat include the mean, mode, and median.

The mean is the value that is obtained by adding a series of terms and then dividing their sum by the value equal to the number of terms (Weinberg et al., 1981). The symbol for mean is $\bar{X}$. For example, a study might be conducted on a flock of sheep that have the following ages: 8, 9, 7, 8, 8. To find the mean age, the terms are added together and divided by the number of terms:

$$\bar{X} = \frac{8 + 9 + 7 + 8 + 8}{5}$$

$$= 8$$

Since the mean is the most commonly used measure of central tendency, it is often called the average.

The median is the value of the term for which one-half of the remaining terms are less and one-half are greater. The median thus divides the distribution of the terms into two equal parts. In the same example used above, the median is equal to 8, which is the middle value when the terms are arranged from smallest to largest:

$7 \; 8 \; \underline{8} \; 8 \; 9$

When there is an even number of terms, the median is the mean of the two middle values.

The mode is the value of the term that appears most frequently (Weinberg et al., 1981). In a grouped frequency distribution, the mode is the midpoint of the interval with the highest frequency. The mode in the example used above is equal to 8 since this is the value that occurs most often. Therefore, in the sheep study example, the mean, median, and mode all have the same value.

Measuring Spread

Measures of central tendency are concerned only with the center of a distribution of terms — not with the arrangement of the terms in relation to the center, known as the spread. The standard deviation and its square, the variance, are the most reliable measures of spread (other than taking into account every item in the distribution).

Variance is a description of the degree of clustering about a central point. The formula for variance is:

$$SD^2 = \frac{\Sigma(X_i - \bar{X})^2}{n - 1},$$

where SD^2 is the variance, Σ is the sum, X_i stands for each of the terms in the population, $\bar{X}$ is the mean, and n is the number of observations in the study. The standard deviation is the square root of the variance:

$$SD = \sqrt{SD^2}$$

The variance and standard deviation of the previous example are determined as follows:

Age (X_i)	($X_i-\bar{X}$)	($X_i-\bar{X})^2$
8	$8-8= 0$	$0^2=0$
9	$9-8= 1$	$1^2=1$
7	$7-8=-1$	$-1^2=1$
8	$8-8= 0$	$0^2=0$
8	$8-8= 0$	$0^2=0$
$\Sigma = 40$		$\Sigma = 2$

Now, since $n = 5$, $\bar{X} = 8$, and $\Sigma(X_i - \bar{X})^2 = 2$, the variance is:

$$SD^2 = \frac{\Sigma(X_i - \bar{X})^2}{n - 1}$$

$$= \frac{2}{5 - 1}$$

$$= 0.5$$

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And the standard deviation is:

$$SD = \sqrt{SD^2}$$
$$= \sqrt{0.5}$$
$$= 0.71$$

An alternate approach utilizes the following equation:

$$SD^2 = 1/n{-}1\ [\Sigma X_i^2 - (\Sigma X_i)^2/n]$$

Using the same example above:

Age (X_i)	X_i^2
8	64
9	81
7	49
8	64
8	64
$\Sigma = 40$	$\Sigma = 322$

The variance is then:

$$SD^2 = 1/n{-}1\ [\Sigma X_i^2 - (\Sigma X_i)^2/n]$$
$$= 1/4\ (322 - (40)^2/5)$$
$$= 0.5$$

And the standard deviation is:

$$SD = \sqrt{SD^2}$$
$$= \sqrt{0.5}$$
$$= 0.71$$

The standard deviation and the variance are the only measures of spread that can be used for statistical inference. They can be treated mathematically and used for further analysis. When it is inconvenient to extract the square root, the variance is the preferred measure. However, when the variance is so large that further computations and analysis are inconvenient, the standard deviation is preferred.

The standard deviation is a measure of absolute variability in a set of items. In many situations, however, relative variability is a more significant measure. The most commonly used measure of relative variability is the coefficient of variation (CV) which is the ratio of the standard deviation to the mean expressed as a percentage (Neter et al., 1978):

$$CV = (SD/\bar{X}) \times 100$$

HYPOTHESIS TESTING

Hypothesis testing is another important aspect of statistical analysis which should be utilized in the evaluation of OFAR. A hypothesis is a tentative statement or explanation of certain observed facts that is used as a basis for further investigation or argument. Most hypotheses begin with a question about some practical problem. In searching for an answer, evidence is considered and guesses are made. These guesses narrow down to likely answers which become hypotheses; these hypotheses can then be tested. If they are found to be statistically true, they are accepted; if they are found to be false, they are rejected.

The two kinds of hypotheses are the null hypothesis (H_0) and the alternative **hypothesis** (H_a). The null hypothesis states that there are no differences between the experimental and control situations; it is the starting point of the testing process. The null hypothesis is the working hypothesis and it is this hypothesis that is either accepted or rejected. The rejection of the null hypothesis implies acceptance of the alternative hypothesis, H_a. To summarize:

- rejection of H_0 implies acceptance of H_a
- acceptance of H_0 implies rejection of H_a

Production System Modeling

A production system model is the simplified representation of the production activities on a farm (such as the representation of a farming system in figure 1.2, Chapter 1). The model is used to generate hypotheses in the context of a particular study. Before a hypothesis can be accepted or rejected because of the evidence supplied by a model, the model must be determined to be valid and verifiable. Valid means that the model's response and the real system's response are identical or at least very similar. If the responses are not identical, it is clear that the model must be reevaluated. All this suggests that the validation process must be conducted only on the farms of those producers who collaborate in the experiment and that the experiment station plays no role. That is, it is possible to have two valid models when the response they provide is similar to the one provided by a specific real system; however, if the system is modified and the response varies, either one model or both may fail to produce a response identical to the response of the new system. If such is the case, this would indicate errors in the conception or calculation of system components.

Verifiable means that the response predicted by the model can be confirmed by testing. It is better to conduct verification at the experiment station than on the farm because of the many measurements involved. However, the final decision would depend on the degree of complexity of the model and the mechanism chosen to verify it. The verification of the model makes it possible to determine the degree of reality of the internal mechanisms of the model. When a model is verified and validated, it can be used to predict the behavior of the system when the system is modified. This is not possible with only validation.

Decision Errors

There is always the risk of making an error when decisions about a proposed hypothesis are based on sample data. The two types of decision errors are Type I and Type II errors. A Type I error (or alpha error) is committed when a null hypothesis is rejected that is true and an alternative hypothesis is accepted which is false. A Type II error (or beta error) is made when a null hypothesis is accepted that is false and the rejected alternative hypothesis is actually true.

Significance Level

The probability of making a Type I error in a test — the maximum value of the probability of rejecting a null hypothesis that is actually true — is the significance level of the test. For tests that involve a statistical decision, it is customary to use a significance level of 5% or 1%. A 5% significance level means that there are about 5 chances in 100 of rejecting the null hypothesis when it should be accepted. Thus, a 5% significance level implies 95% confidence in the decision. A 1% significance level means that there is 1 chance in 100 that the decision is wrong, or 99% confidence that the decision is right.

Because of the high variability of observed values during OFAR (see table 1.2, Chapter 1), some OFAR researchers advocate the acceptance of a low significance level, such as 10% or 20%. These researchers are willing to accept only a 90% or 80% confidence in their conclusions because they often have obtained additional information, not included in their data set, which supports their decisions, such as th opinions or observations of farmers. Typically, OFAR will yield much useful information of this t in addition to that contained in the trial data set.

Statistical Tests for Analyzing Data

The decision about whether the null hypothesis is true or false is based on the results of one of several tests used to analyze data. There are many statistical procedures and tests used to evaluate data, and the following are descriptions of the tests that are often used in OFAR. In order to fully understand the differences among each test, it is recommended that a handbook on statistics be consulted.

t-Test

The t-test, or student t-test, is used to estimate the reliability of an experiment by determining how consistently the experiment will measure a given parameter. Each parameter that is measured in OFAR is likely to be fairly close to its actual value, with the spread of observed values around an actual value yielding a **probability distribution**, or, in the case of a t-test, a t distribution. Results of a t-test performed on a set of data are compared with critical limits of standard t distributions, presented in most statistical handbooks as tabular values in a t distribution table. The critical limits of the t distribution depend on 1) the significance level chosen for the test and 2) the degrees of freedom, defined as the number of observations in the data collection that are free to vary after the sample statistics have been calculated. The calculations involved when using the t-test are illustrated with the examples at the end of this chapter.

Alternatives vs Controls

An **alternative** group is designated as the group receiving the experimental treatment. The control group is then the group which is receiving no experimental treatment but is otherwise being treated similarly to the alternative group. Comparison between alternatives and controls can be carried out on one farm or among several farms. In theory, any experimental treatment could be tested by dividing a herd into alternatives and controls. The main difficulty with this approach is that it does not allow for observation of the effects the treatment may have on the global performance of the system. However, it may be worthwhile to divide the herd when it is feasible to compare the results of the experimental treatment on the same farm, particularly when it is necessary to confirm that the results obtained at the experiment station can be duplicated under conditions having a wider variability.

When a technology is tested at several farms, the number of farms to be selected for the test depends on the extent of the differences to be demonstrated and the variability of parameters. A critical aspect in any statistical evaluation is the duration of the experiment. Since circumstances can vary from year to year, the effects of some treatments become evident only in the long term, therefore, the more time an experiment covers, the more reliable it should be. For the findings to be accurate, a study should last over the lifetime of the animal. Few projects are this long, for several reasons. Primarily, farmers do not like to let their farms be used as controls for a long time when they can see that the alternative has been successful on other farms. Secondly, a farmer may adopt some technology during the study period that is different from the one being studied and thus invalidate the comparison.

Before and After Tests

Sequential evaluations, or before and after tests, reduce the problem of variation between farms; however, they do not modify the effects of the time factor and, in some cases, make it even more critical since they require a follow-up before the alternative to be evaluated can be introduced. Before and after tests include the following variations.

Sign test. The sign test is a nonparametric test that is easy to use and has great intuitive appeal. As its name suggests, the sign test is based on the plus or minus signs of the response difference, D. The statistic utilized in the sign test is denoted as S and has the following relationship:

S = number of pairs in which treatment A has a higher response than treatment B = number of positive signs among the response differences, $D_1, D_2, \ldots D_n$

When the two treatment effects are alike, the response difference, D_i, for each pair of data is as likely to be positive as it is to be negative. When it is assumed that there will be no difference between pairs of data (the H_0 hypothesis), the number of positive signs and negative signs is expected to be about equal.

For example, an OFAR study may be conducted to determine whether feeding concentrate to cattle affects the number of hours that the animals can work. The sample includes 24 head of cattle, and the cattle's number of working hours are recorded weekly for 12 weeks. Treatment A is adding concentrate to the cattle's diet; treatment B is not adding concentrate to the diet. The two hypotheses are:

H_0: There is no difference in the number of hours that cattle work under treatment A and treatment B; that is, for 12 pairs of data, $S = 6$.

H_a: There is a difference in the number of hours that cattle work under treatment A and treatment B; that is, for 12 pairs of data, $S > 6$ or $S < 6$.

The following table of data was compiled (continues at top of next page).

Treatment A (with concentrate)	Treatment B (without concentrate)	D_i Difference
26.4	24.3	+2.1
10.3	9.8	+0.5
15.8	16.9	−1.1
16.5	17.2	−0.7
32.5	30.5	+2.0
8.3	7.9	+0.4

Treatment A (with concentrate)	Treatment B (without concentrate)	D_i Difference
22.1	22.4	−0.3
30.1	28.6	+1.5
12.9	13.1	−0.2
12.6	11.6	+1.0
27.3	25.5	+1.8
9.4	8.6	+0.8

Eight of the 12 terms in the differences column are positive (+); that is, $S = 8$. Therefore, since $S > 6$, H_0 is rejected and H_a is accepted.

Wilcoxon signed-ranks test. The Wilcoxon signed-ranks test is similar to the sign test except it measures the amount of change. In the Wilcoxon test, the differences between the pairs of terms are ranked disregarding their signs — negative values are ranked as if they were positive. (Differences of zero are not ranked. For tied scores, the mean of their ranks is used for each score; for example, if there are two scores of 10 that fall at ranks 6 and 7, both scores of 10 must be assigned the rank 6.5.) Then two sums are calculated: T^+, the sum of ranks associated with positive-difference scores, and T^-, the sum of ranks of negative-difference scores. Drawing from the previous example, then, the terms are ranked accordingly:

Rank:	1	2	3	4	5	6	7	8	9	10	11	12
Term:	0.2	0.3	0.4	0.5	0.7	0.8	1.0	1.1	1.5	1.8	2.0	2.1
Sign:	−	−	+	+	−	+	+	−	+	+	+	+

$$T^+ = \text{Sum of the ranks associated with positive observations}$$
$$= 3 + 4 + 6 + 7 + 9 + 10 + 11 + 12$$
$$= 62$$
$$T^- = \text{Sum of the ranks associated with negative observations}$$
$$= 1 + 2 + 5 + 8$$
$$= 16$$

If the null hypothesis of no difference in treatment effects is true, then the response differences for each pair of data, $D_1, D_2, \ldots D_n$, will constitute a random sample from a population that is symmetric about zero. On the other hand, if the alternative hypothesis that treatment A is better than treatment B is true, then the distribution is shifted from zero toward positive values. Under H_a, not only are more plus signs anticipated, but they are also likely to be associated with larger ranks.

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Results Obtained vs Results Expected

The results obtained vs results expected test involves predicting the behavior of the alternative and comparing this prediction with conditions on real farms where the alternative has been introduced. This procedure eliminates the need to have control farms and makes it possible to shorten the test period. Accuracy can be increased if the expected solution is not estimated in a general way for all farms on which it is to be applied but, rather, on each farm where the evaluation is to be conducted. The behavior of the alternative is predicted on the basis of the production system model, and the test is conducted to detect the degree of correspondence between the model and the real system.

Steps in Testing a Hypothesis

The procedure for testing a hypothesis is as follows:

1. Formulate the null hypothesis (H_0) that there are no significant differences between the items being compared and state the alternative hypothesis (H_a) that will be accepted if the null hypothesis is rejected. For example, in a study to determine if native or crossbred cattle produce more milk, the hypotheses will be:

   H_0: The mean milk yield of native cattle is equal to the mean milk yield of crossbred cattle.

   H_a: The mean milk yield of native cattle is not equal to the mean milk yield of crossbred cattle.

2. Choose a significance level.

   This value is usually expressed as a decimal value; so for a significance level of 5%, the value used would be 0.05.

3. Describe the kind of statistical test to be made.

4. Obtain the tabular value for the statistical test from a distribution table in a statistical handbook.

5. Gather and analyze data.

   Using the same example described above, the following data will be gathered:

Production of seven native cows in kilograms/day:

10, 8, 7.5, 7, 6.5, 8, 8.

Mean production:

$$\frac{10 + 8 + 7.5 + 7 + 6.5 + 8 + 8}{7} = 7.86$$

Production of seven crossbred cows in kilograms/day:
10, 8.5, 10.5, 7.5, 8, 9, 10.

Mean production:

$$\frac{10 + 8.5 + 10.5 + 7.5 + 8 + 9 + 10}{7} = 9.07$$

6. Make a decision.
   a. Reject H_0 if the absolute computed value is equal to or greater than the absolute tabular value.
   b. Accept H_0 if the absolute computed value is less than the absolute tabular value.

In the same example, the mean milk yield of native cows is 7.86 kilograms/day, and the mean milk yield of crossbred cows is 9.07 kilograms/day. The difference between the means is 1.21 kilograms/day. Since there is a statistical difference between the mean milk yield of native cattle and the mean milk yield of crossbred cattle, the null hypothesis (H_0) should be rejected and the alternative hypothesis (H_a) should be accepted.

APPLYING STATISTICS TO ON-FARM ANIMAL RESEARCH

Experimental Design

Procedures for designing animal experiments vary because the characteristics of different animal-production systems vary, as do management control, number of animals, and farmers' cooperation in the experiments. Animal experiments must be designed according to these factors as well as type of trial; availability of time, money, and experts (especially statisticians and economists); nature of farm; and level of generality desired (see figure 4.1). Animal-production studies and crop-production studies require greatly different methodologies. In a crop-production study, a field can easily be subdivided so treatments can be isolated for study. A herd of animals, on the other hand, is more difficult to manage. This is particularly true on small farms, which often do not have pens or divided pastures. OFAR must be designed to use samples that are small enough to be manageable in terms of cost and monitoring — 30 to 40 large ruminants, for example, or 80 to 100 small ruminants (see figure 4.2). Some guidelines for designing experiments involving large ruminants are shown in table 4.1.

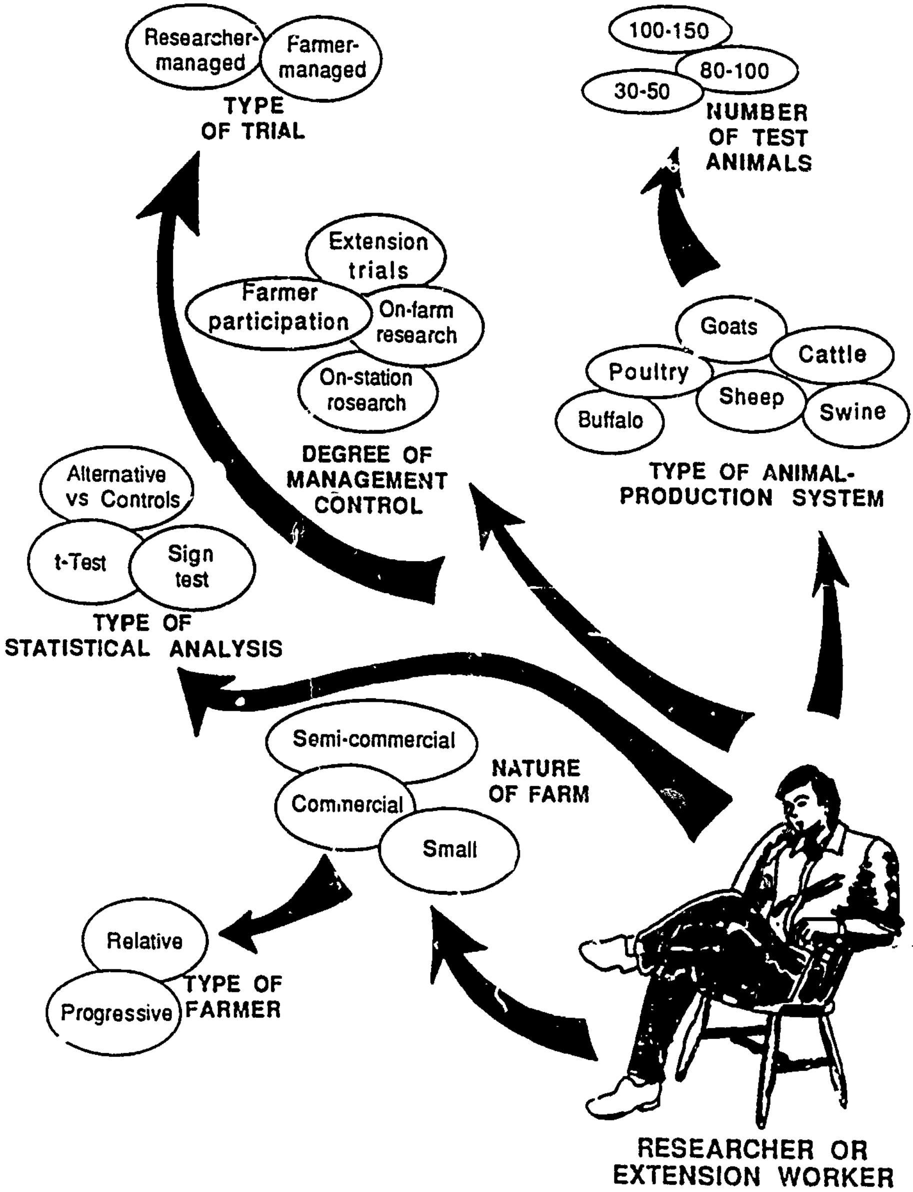

Figure 4.1. Choices in experimental design.

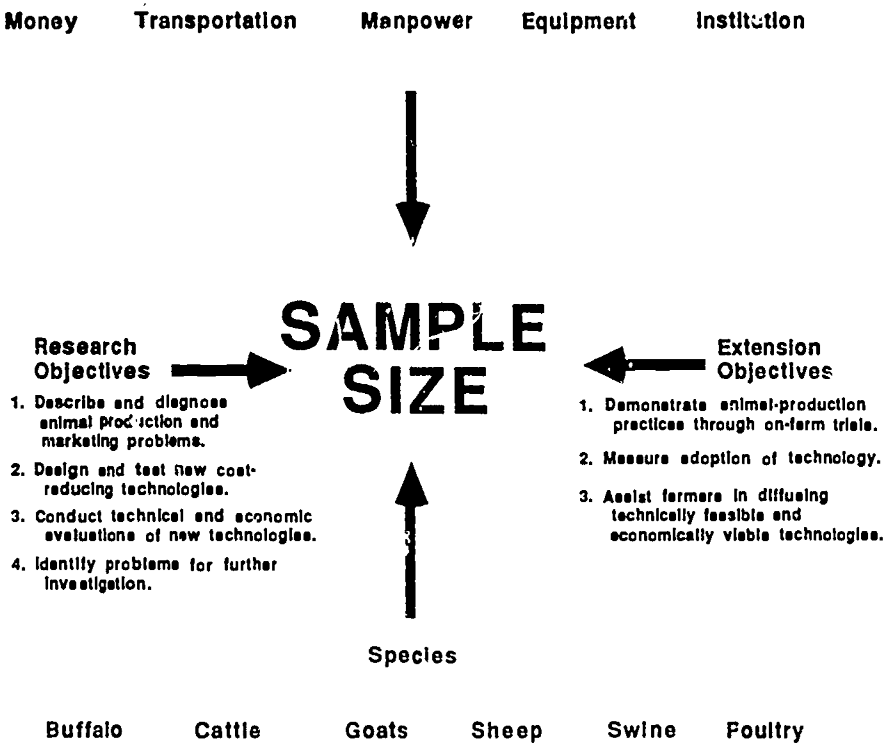

Figure 4.2. Factors that determine sample size.

Table 4.1. Guidelines in designing livestock experiments for large ruminants.

Livestock	Type of trial	Number of animals	Criteria for choice of animal	Factors affecting sample selection	Selection of farmer
Buffalo	Draft power * New yoke design	40	* Breed * Age * Sex	* Difference in breed, age and sex may present variation in results. * If the effect of breed, age, and sex is desired or required, new yolk design should be tested against breed, age, and sex one at a time. * Researcher can utilize large sample size since buffaloes are used seasonally.	* Farmers using buffaloes for draft only. * Farmers having at least management practices.
Cattle	Feeding * Milk production	30	* Breed * Age * Stage of lactation	* Different breeds of cattle produce different amounts of milk. * Age and stage of lactation can affect variation in milk yield.	* Farmers with similar milking practices.

Experimental Error

Sometimes, animals treated with the same technology do not have similar responses. This is called experimental error. Every experiment must be conducted in such a way that a measure of experimental error is available; that is, the test must be repeated, or replicated, and the results must be compared. The desired degree of experimental control may be more difficult to achieve in an animal-production study. If, for example, a farmer notices that the experimental treatment (say, administering drugs against parasites) has a very positive effect on growth, he may simply decide to give that treatment to the control group. This has proven to be the case on many occasions.

To adequately replicate treatments on large ruminants, proper sampling techniques should be employed in order to obtain a representative number of animals that are similar in age, management, or breed. In the case of a single intervention, different levels of the treatment should be replicated, with one to two animals on each farm serving as a control. The statistical means obtained from the experimental results can then be compared to test the significance of the treatments. A simple t-test or another of the statistical tests used to analyze data may be used. This approach is justified as farmers are more interested in comparing the performance of the new trials with their existing practices. The farmer is the final judge of the technology. Whereas researchers can only rely on the experimental results from a given instance in time (i.e., the duration of the experiment), the farmer knows the past history of the farm and its animals. Therefore, no matter how significant or nonsignificant the statistical results are the farmer must see the technology perform. Since farmers have a different vantage point, they rarely measure productivity the same way that researchers do (Amir et al., 1985).

Examples of Hypothesis Testing in On-farm Animal Research

The following three examples illustrate the degree to which statistical analysis can be successfully applied to OFAR.

Example 1

Suppose an experiment is conducted to determine whether feeding molasses to oxen increases their weight during peak work periods. The six villages that have the most oxen are identified using a multistage sampling method. A purposive sampling technique is used to select the farmers. Half of the oxen (15) are fed molasses, and half are controls. Their weights are checked once a month.

1. Formulate the null hypothesis (H_0) and state the alternative hypothesis (H_a).

   H_0: Feeding molasses to oxen does not increase their weight during peak work periods.

H_a: Feeding molasses to oxen increases their weight during peak work periods.

2. Choose a significance level.

   0.05

3. Describe the kind of statistical test to be made.

   t-test

4. For the t-test,

   a. Compute the degree of freedom.

      $df = n_1 + n_2 - 2$,

      where n_1 is the number of items in the first sample and n_2 is the number of items in the second sample.

      $df = 15 + 15 - 2$

      $= 28$

   b. Obtain the tabular value for the statistical test from a distribution table in a statistical handbook. From a t distribution table this value is:

      1.703

5. Gather and analyze data. Data are listed in the table below:

	Net weight gains, oxen fed molasses (kg/year)			Net weight gains, oxen not fed molasses (kg/year)		
	X	$(X - \bar{X})$	$(X - \bar{X})^2$	Y	$(Y - \bar{Y})$	$(Y - \bar{Y})^2$
	45.00	−9.47	89.68	30.00	−6.33	40.07
	56.00	1.53	2.34	38.00	1.67	2.79
	29.00	−25.47	648.72	31.00	−5.33	28.41
	63.00	8.53	72.76	42.00	5.67	32.15
	78.00	23.53	553.66	52.00	15.67	245.55
	45.00	−9.47	89.68	38.00	1.67	2.79
	26.00	−28.47	810.54	33.00	−3.33	11.09
	54.00	−0.47	0.22	48.00	11.67	136.19
	44.00	−10.47	109.62	23.00	−13.33	177.69
	32.00	−22.47	504.90	18.00	−18.33	335.99
	77.00	22.53	507.60	36.00	−0.33	0.11
	55.00	0.53	0.28	48.00	11.67	136.19
	88.00	33.53	1124.26	37.00	0.67	0.45
	52.00	−2.47	6.10	46.00	9.67	93.51
	73.00	18.53	343.36	25.00	−11.33	128.37
$\Sigma =$	817.00		4863.72	545.00		1731.35

t = t-test value

$\bar{X}$ = mean weight gain of oxen fed molasses

$\bar{Y}$ = mean weight gain of oxen not fed molasses

X_i = sum of weight gains of oxen fed molasses

Y_i = sum of weight gains of oxen not fed molasses

SD_x^2 = variance for oxen fed molasses

SD_y^2 = variance for oxen not fed molasses

n = population

n_1 = population of oxen fed molasses

n_2 = population of oxen not fed molasses

6. Perform the following calculations:

a. Mean

$$\bar{X} = X_i/n = 817/15 = 54.47 \qquad \bar{Y} = Y_i/n = 545/15 = 36.33$$

b. Variance

$$SD_x^2 = \frac{\Sigma(X_i - \bar{X})^2}{n - 1} = \frac{4863.72}{15 - 1} = 347.41 \qquad SD_y^2 = \frac{\Sigma(Y_i - \bar{Y})^2}{n - 1} = \frac{1371.35}{15 - 1} = 97.95$$

c. Standard deviation

$$SD_x = \sqrt{SD_x^2} = \sqrt{347.41} = 18.64 \qquad SD_y = \sqrt{SD_y^2} = \sqrt{97.95} = 9.90$$

d. Coefficient of variation

$$CV_x = (SD_x/\bar{X}) \times 100 = (18.64/54.47) \times 100 = 34.22\% \qquad CV_y = (SD_y/\bar{Y}) \times 100 = (9.90/36.33) \times 100 = 27.25\%$$

e. t-test

$$t = \frac{\bar{X} - \bar{Y}}{\sqrt{\left[\frac{(n_1 - 1)\,SD_x^2 + (n_2 - 1)\,SD_y^2}{(n_1 + n_2) - 2} \times \left(\frac{1}{n_1} + \frac{1}{n_2}\right)\right]}}$$

$$= \frac{54.47 - 36.33}{\sqrt{\left[\frac{(15 - 1)(347.41) + (15 - 1)(97.95)}{(15 + 15) - 2} \times \left(\frac{1}{15} + \frac{1}{15}\right)\right]}}$$

$$= \frac{18.14}{\sqrt{\left[\frac{4863.7 + 1371.3}{28} \times \frac{2}{15}\right]}}$$

$$= 3.329$$

7. Make a decision.

Since the absolute computed value, 3.329, is greater than the tabular value 1.701, the null hypothesis (H_0) is rejected and the alternative hypothesis (H_a) is accepted; that is, feeding molasses to oxen increases their weight during peak work periods.

Example 2

Suppose an experiment is conducted to determine whether new milking practices recommended by researchers produce more or less milk than farmers' traditional milking practices. Multistage sampling is done to locate the farms that raise the most milk cows. Farms are selected using a purposive sampling method. The result is that 30 native cows are chosen to be used in the experiment.

1. Formulate the null hypothesis (H_0) and state the alternative hypothesis (H_a).

   H_0: When farmers use recommended milking practices, their animals' milk yields are the same as if the farmers used traditional milking practices.

   H_a: When farmers use recommended milking practices, their animals' milk yields differ from yields that are produced by traditional practices.

2. Choose a significance level.

   0.05

3. Describe the kind of statistical test to be made.

   t-test

4. For the t-test,

   a. Compute the degree of freedom

   $df = n_1 + n_2 - 2,$

   where n_1 is the number of items in the first sample and n_2 is the number of items in the second sample.

   $df = 15 + 15 - 2$
   $= 28$

   b. Obtain the tabular value for the statistical test from a distribution table in a statistical handbook. From a t distribution table this value is: 1.701

5. Gather and analyze data. Data are listed in the table below.

	Milk yield, traditional practice (kg/day)			Milk yield, recommended practice (kg/day)		
	X	$(X - \bar{X})$	$(X - \bar{X})^2$	Y	$(Y - \bar{Y})$	$(Y - \bar{Y})^2$
	4.10	−0.05	0.00	5.20	−0.09	0.01
	4.30	0.15	0.02	5.00	−0.29	0.08
	3.80	−0.35	0.12	4.75	−0.54	0.29
	4.50	0.35	0.12	6.00	0.71	0.50
	3.75	−0.40	0.16	5.10	−0.19	0.04
	3.50	−0.65	0.42	4.00	−1.29	1.66
	4.60	0.45	0.20	6.00	0.71	0.50
	4.65	0.50	0.25	5.75	0.46	0.21
	4.70	0.55	0.30	6.00	0.71	0.50
	3.70	−0.45	0.20	5.20	−0.09	0.01
	3.75	−0.40	0.16	5.40	0.11	0.01
	3.65	−0.50	0.25	5.00	−0.29	0.08
	4.00	−0.15	0.02	5.75	0.46	0.21
	4.50	0.35	0.12	5.00	−0.29	0.08
	4.70	0.55	0.30	5.25	−0.04	0.00
$\Sigma =$	62.20		2.64	79.40		4.18

t = t-test value
$\bar{X}$ = mean milk yield under traditional milking methods
$\bar{Y}$ = mean milk yield under recommended milking methods
X_i = sum of milk yields under traditional milking methods
Y_i = sum of milk yields under recommended milking methods
SD_x^2 = variance for milk yield under traditional milking methods
SD_y^2 = variance for milk yield under recommended milking methods
n = population
n_1 = population of cows milked under traditional methods
n_2 = population of cows milked under recommended methods

6. Perform the following calculations:

a. Mean

$$\bar{X} = X_i/n = 62.2/15 = 4.15$$

$$\bar{Y} = Y_i/n = 79.4/15 = 5.29$$

b. Variance

$$SD_x^2 = \frac{\Sigma(X_i - \bar{X})^2}{n - 1} = \frac{2.64}{15 - 1} = 0.19$$

$$SD_y^2 = \frac{\Sigma(Y_i - \bar{Y})^2}{n - 1} = \frac{4.18}{15 - 1} = 0.30$$

c. Standard deviation

$$SD_x = \sqrt{SD_x^2} = \sqrt{0.19} = 0.44$$

$$SD_y = \sqrt{SD_y^2} = \sqrt{0.30} = 0.55$$

d. Coefficient of variation

$$CV_x = (SD_x/\bar{X}) \times 100 = (0.44/4.15) \times 100 = 10.6\%$$

$$CV_y = (SD_y/\bar{Y}) \times 100 = (0.55/5.29) \times 100 = 10.4\%$$

e. t-test

$$t = \frac{\bar{X} - \bar{Y}}{\sqrt{\left[\frac{(n_1 - 1)\,SD_x^2 + (n_2 - 1)\,SD_y^2}{(n_1 + n_2) - 2} \times \left(\frac{1}{n_1} + \frac{1}{n_2}\right)\right]}}$$

$$= \frac{4.15 - 5.29}{\sqrt{\left[\frac{(15 - 1)(0.19) + (15 - 1)(0.30)}{(15 + 15) - 2} \times \left(\frac{1}{15} + \frac{1}{15}\right)\right]}}$$

$$= \frac{-1.14}{\sqrt{\left[\frac{2.66 + 4.20}{28} \times \frac{2}{15}\right]}}$$

$$= -6.31$$

7. Make a decision.

   Since the absolute computed value, 6.31, is greater than the tabular value, 1.701, the null hypothesis (H_0) is rejected and the alternative hypothesis (H_a) is accepted; that is, when farmers use recommended milking practices, their animals' milk yields differ from yields that are produced by traditional practices.

Example 3

Suppose a researcher wants to determine whether milk cows in Karnal, India, have different milk yields than milk cows in Faisalabad, Pakistan. For 2 months, milk yields are measured daily for 20 native milk cows at each location, and the average (mean) daily milk yield is recorded.

1. Formulate the null hypothesis (H_0) and state the alternative hypothesis (H_a).

   H_0: The average daily milk yield of native cows in Karnal, India, is the same as the average daily milk yield of native cows in Faisalabad, Pakistan.

   H_a: The average daily milk yield of native cows in Karnal, India, is different from the average daily milk yield of native cows in Faisalabad, Pakistan.

2. Choose a significance level.

   0.05

3. Describe the kind of statistical test to be made.

   t-test

4. For the t-test,

   a. Compute the degree of freedom

   $$df = n_1 + n_2 - 2,$$

   where n_1 is the number of items in the first sample and n_2 is the number of items in the second sample.

   $$df = 10 + 10 - 2 = 18$$

   b. Obtain the tabular value for the statistical test from a distribution table in a statistical handbook. From a t distribution table this value is:

   1.734

5. Gather and analyze data. Data are listed in the table below.

	Average daily milk yield, India (kg/day)			Average daily milk yield, Pakistan (kg/day)		
	X	$(X - \bar{X})$	$(X - \bar{X})^2$	Y	$(Y - \bar{Y})$	$(Y - \bar{Y})^2$
	1.00	−3.95	15.60	7.00	0.20	0.04
	8.00	3.05	9.30	5.00	−1.80	3.24
	6.00	1.05	1.10	6.00	−0.80	0.64
	1.00	−3.95	15.60	5.00	−1.80	3.24
	6.00	1.05	1.10	6.00	−0.80	0.64
	6.00	1.05	1.10	8.00	1.20	1.44
	3.50	−1.45	2.10	5.00	−1.80	3.24
	2.00	−2.95	8.70	10.00	3.20	10.24
	8.00	3.05	9.30	8.00	1.20	1.44
	8.00	3.05	9.30	8.00	1.20	1.44
$\Sigma =$	49.50		73.20	68.00		25.60

t = t-test value
$\bar{X}$ = mean milk yield in Karnal, India
$\bar{Y}$ = mean milk yield in Faisalabad, Pakistan
X_i = sum of milk yields in Karnal, India
$Y_i.$ = sum of milk yields in Faisalabad, Pakistan
SD_x^2 = variance for milk yield in Karnal, India
SD_y^2 = variance for milk yield in Faisalabad, Pakistan
n = population
n_1 = population of cows milked under experiment in Karnal, India
n_2 = population of cows milked under experiment in Faisalabad, Pakistan

6. Perform the following calculations:

a. Mean

$\bar{X} = X_i/n$
$= 49.5/10$
$= 4.95$

$\bar{Y} = Y_i/n$
$= 68.0/10$
$= 6.80$

b. Variance

$$SD_x^2 = \frac{\Sigma(X_i - \bar{X})^2}{n - 1} \qquad SD_y^2 = \frac{\Sigma(Y_i - \bar{Y})^2}{n - 1}$$

$$= \frac{73.2}{10 - 1} \qquad = \frac{25.6}{10 - 1}$$

$$= 8.13 \qquad = 2.84$$

c. Standard deviation

$$SD_x = \sqrt{SD_x^2} \qquad SD_y = \sqrt{SD_y^2}$$

$$= \sqrt{8.13} \qquad = \sqrt{2.84}$$

$$= 2.85 \qquad = 1.68$$

d. Coefficient of variation

$$CV_x = (SD_x/\bar{X}) \times 100 \qquad CV_y = (SD_y/\bar{Y}) \times 100$$

$$= (2.85/4.95) \times 100 \qquad = (1.68/6.80) \times 100$$

$$= 57.6\% \qquad = 24.7\%$$

e. t-test

$$t = \frac{\bar{X} - \bar{Y}}{\sqrt{\left[\frac{(n_1 - 1)\,SD_x^2 + (n_2 - 1)\,SD_y^2}{(n_1 + n_2) - 2} \times \left(\frac{1}{n_1} + \frac{1}{n_2}\right)\right]}}$$

$$= \frac{4.95 - 6.80}{\sqrt{\left[\frac{(10 - 1)(8.13) + (10 - 1)(2.84)}{(10 + 10) - 2} \times \left(\frac{1}{10} + \frac{1}{10}\right)\right]}}$$

$$= \frac{-1.85}{\sqrt{\left[\frac{73.17 + 25.56}{18} \times \frac{2}{10}\right]}}$$

$$= -1.767$$

7. Make a decision.

Since the absolute computed value, 1.767, is greater than the tabular value, 1.734, the null hypothesis (H_0) is rejected and the alternative hypothesis (H_a) is accepted; that is, the average daily milk yield of native cows in Karnal, India, is different from the average daily milk yield of native cows in Faisalabad, Pakistan.

SUMMARY

The utilization of statistical analysis has become increasingly important when evaluating OFAR. Although it is at times difficult to apply statistics to OFAR due to the complexity of experimental designs, certain basic concepts can and should be employed. These include the selection of suitable sampling methods as well as the determination of the central tendency and spread for a set of data. In addition, techniques needed to properly test a hypothesis are vital to determining the success of OFAR and lending meaning to the results of experimental research.

CHAPTER 5

SCREENING TECHNOLOGIES FOR PROFITABILITY

PURPOSE

This chapter examines the need to screen new animal technologies at the research station before they are tested on the farm. Factors that must be considered in the screening process are the economic feasibility of the new technology as well as the needs of the small farmer. In other words, a new technology must be deemed profitable, and the small farmer must be able to benefit from the increased profitability. Therefore, the improvements in productivity that are obtained through new technologies must be screened to insure that they are absolutely superior to the practices existing on the small farm.

OBJECTIVES

After completing this chapter, the reader should be able to:

- Explain why technologies should be screened.
- Describe the perspectives which should be taken when screening new technologies.
- Describe some models which can be used to screen new technologies for economic feasibility.
- State some ways in which the screening process can be improved.

WHY TECHNOLOGIES SHOULD BE SCREENED

The proper screening of new animal technologies is an important step in achieving success in On-farm Animal Research (OFAR). The complexity and high cost of developing new technology for OFAR have been responsible for the stagnation in productivity of the most common farm animals. Due to the limited resources for technology generation and on-farm testing, it is important that animal experiment stations develop effective screening procedures.

Consequently, animal scientists have argued for more extensive technology screening that takes into account whether the new technology meets the following criteria (Fitzhugh et al.; 1982):

- ecological suitability of livestock for environmental conditions in the area, such as water, temperature, forages, and feedstuffs

- adaptability of the technology within the overall agricultural system
- availability of services for livestock production, such as veterinary supplies, minerals, feed supplements, and livestock market
- profitability of the technology within an acceptable level of risk
- realization of results at the farm level soon after implementation
- productivity of land, labor, and capital under present constraints of the production systems

PERSPECTIVES TO SCREENING

Although standard procedures are not available for screening the technologies used in research, screening at the research station should take into account types of production systems, types of agricultural practices, local resources, and the market situation. In addition, the feasibility of interregional transfer of technology should not be overlooked, especially for large ruminants such as buffalo. The complexity of the environment determines whether overall or only partial effects of the technology on the system will be studied. In addition, on-farm testing is deemed appropriate for verifying responses to technology on different types of farms.

The Economic Perspective

The future of OFAR is closely linked to the economic viability of new technologies, but animal scientists rarely are trained to analyze how economic variables influence the supply and demand of new technology. Rather, they tend to generate technology within narrowly defined research scenarios. They then concentrate on promoting the new practice, believing that if it is good, it will work. This approach to screening is not acceptable. Before on-farm testing begins researchers should determine whether the increased produce generated by the new technology will be consumed on the farm or sold. The need to include economic analysis to identify feed by-products for animals at an early stage has been stressed by Potts (1982). Similar arguments have been made about crop technology development (Harrington, 1984; Byerlee and Collinson, 1980). In other words, the market potential of the technology must be defined and the profitability of the new technology must be determined.

The economic perspective to technology screening requires a farm-management approach to screening technology. That is, the following questions must be answered:

- What should be produced?
- How should it be produced?

- How much should be produced?
- How should it be marketed?

If the new technology is expected to increase animal productivity and the product has to be marketed, the farmers' decision to experiment with the technology must rest on market demand for the increased output and feasibility of marketing the increased production. The answers to the above questions differ significantly on small farms.

The results of testing at the research station should always be analyzed from an economic perspective before on-farm testing proceeds. Unless economics are considered at the experiment station, testing a technology on the farm will reap little benefit. Since livestock economists usually are not available at research stations, animal scientists in developing countries must be trained in the basic techniques of data evaluation, or they must be ready to hire economists to help with the analysis.

The Small-farm Perspective

Many animal technologies that are tested at the farm were not conceived with any particular client group in mind, and animal research conducted in developing countries often lacks a small-farm perspective. Even when the research results are deemed useful by certain decision-makers, the results often fail to focus on the broader needs of the farm community (often the small and resource-poor farmers). New animal-production technologies are designed to increase yield, which is an appropriate goal for some clients, particularly commercial and semicommercial farmers, but higher-productivity systems that use inputs that are not available in rural areas or are difficult to administer are inappropriate for the small farmer. However, since many of these new inputs are effective at the research station, they become candidates for on-farm testing.

More attention must be paid to developing better animal-production technologies while keeping the perspective of the small farm in mind. In developing countries most research institutes that deal with animals offer information and services in veterinary medicine, stock improvement, and husbandry practices. These services are often not available to resource-poor farmers living in remote areas, and clients of these services are usually semicommercial farmers who benefit from such investment based on market potential. In addition to this, the beneficiaries of new animal-production technology are mostly commercial or semicommercial farmers who live near the cities. An increase in animal productivity either benefits the urban population or the farmers residing near the city who take advantage of the market.

Previous studies indicate that poor understanding of animal production systems decreases effective participation in OFAR. When animal specialists are part of the farming systems team, their input is often disciplinary rather than focused on actual farm needs. This bias is partly responsible for the current lack of participation and interest among animal scientists in OFAR. The result is that animal productivity on small farms tends to remain unchanged, even though it has been clearly demonstrated that sound animal husbandry practices can double the productivity of farm animals (NDRI, 1984).

If animal research is to address the needs of small farmers, its focus must change. It would be inappropriate (and probably undesirable) for animal research centers to develop only technology for small farms. Rather, it is recommended that a variety of technologies (both imported and locally developed) be screened to match different sets of clients. Suitability and need can then be determined through Farming Systems Research (FSR) and extension.

For example, suppose three new feeds are targeted for on-farm testing in the Philippines. Feed A is expensive but can improve milk yields up to 30% and bring in an additional ₱200 per month. This technology requires heavy fixed investment in grinders and storage and, therefore, a higher initial cost. Feed B improves yields about 20%, costs little, and brings in an extra ₱160 per month. Feed C improves yields 40% with a net return of ₱125 per month. Feed A probably is not suitable for small farmers who are short of cash, have poor means of obtaining inputs, and face difficulty in marketing the produce. Feeds B and C have lower net returns but are widely available and inexpensive; therefore, they are more suitable for use on small farms than feed A.

A conceptual model for screening animal technologies is presented in figure 5.1. Although this model is independent of the approaches used to gather descriptive information from the farm (that is, rapid rural appraisal or formal farm survey), it recognizes the need to pay attention to the farm as a unit — the animal component can be isolated if its interactions with the rest of the farm are understood. The model emphasizes identifying the clients of new technology and analyzing the priorities of their needs.

ECONOMIC ANALYSIS AS A SCREENING TOOL

Simple economic concepts can be used to screen technologies for different client groups. The objective should be to obtain valid information on treatment responses at different input levels in order to estimate appropriate economic parameters. Potential factor substitution (see Chapter 3) can then be investigated in the light of the new technology. Only after the technology can be categorized for different groups (based on market potential, resource endowments, etc.), should research results be tested at the farm level.

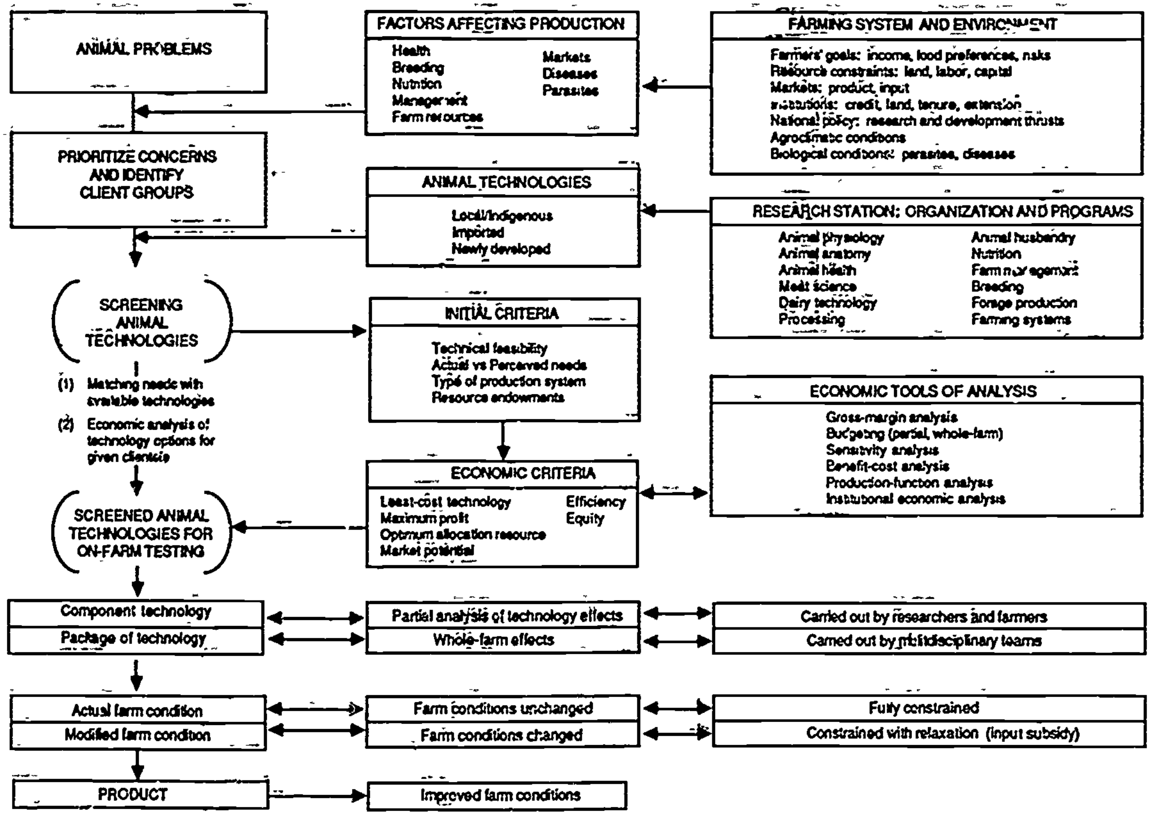

Figure 5.1. A model for screening animal technologies. (Source: Amir, P. and H.C. Knipscheer, 1987 a.)

Although the need to develop bioeconomic models to screen new technologies has been stressed (Fitzhugh, 1978), data are so limited that such complex models can be developed only in advanced countries — they become mere academic exercises when applied to developing-country situations. Even though they can guide research and identify weaknesses in a production system, such models have rarely been used to evaluate new technology. Considering the shortage of money and labor at animal research stations, simple procedures for screening technology for profitability appear to be more appropriate.

Several researchers have used the demonstration farm model established at research stations to screen technology. The demonstration farm simulates real-life situations. In India, this approach has helped determine the economic value of new dairy technology for different sizes of farms (Patel, 1981). The clear bias in this approach is the tendency to include crop management practices at the optimal level. Not only is the best cropping pattern utilized, the farmer working on the station has access to other technologies that may undermine the real potential of the practice being tested. However, if the objective is to study the response to new inputs at the farm, this model can be useful.

Another approach utilizes the yield-gap model (see figure 5.2). The yield gap is the difference between the yields that are technically and economically possible and the actual yields of the majority of farmers. The yield-gap model presented by Gomez and Santos (1981) has been widely used to explain differences in performances of crop technology at the farm and research station. This model can also help illustrate the gaps in animal productivity. The factors that explain differences in the potential performance and the actual performance in the yield-gap model are management of inputs, such as labor and feed, socio-economic constraints, such as costs and risk preference, and biological differences, such as genetic variability and nutrition. The realistic comparison of the potential yield with the actual yield should be judged against the performance of the new technology on improved farms. However, the inherent difficulties in crop and animal research can limit the way potential yield can be realistically measured.

Profitability of a new technology should be verified through economic analysis of the data. Special attention should be paid to identifying the costs and benefits of the technology. In the preliminary stage, profitability should be estimated at the optimal input levels, with appropriate discount for risk. In addition, farmers should be consulted to identify the inputs, such as cash, experimental animals, and labor, that play a part in the decision to experiment with a new technology since they often view some inputs differently than researchers (particularly leisure labor input such as feeding, watering, and mating animals). An evaluation that takes into account only the cash inputs (such as gross-

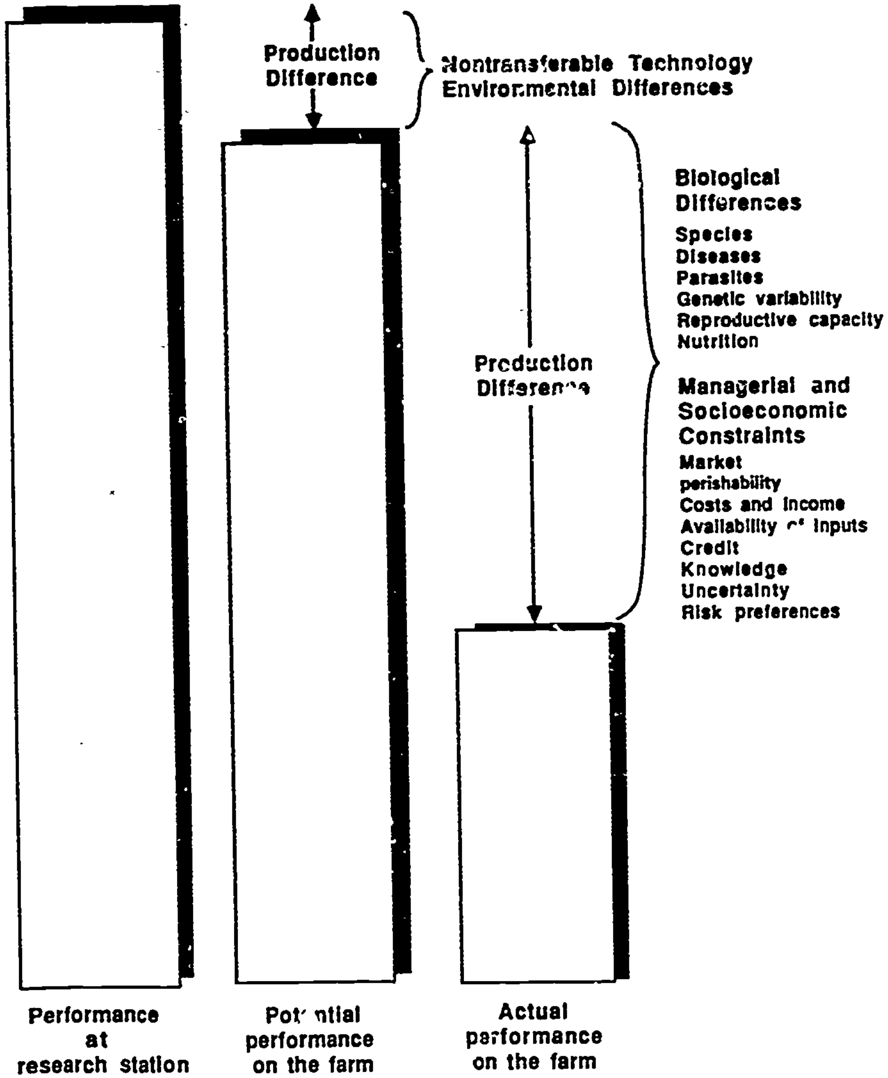

Figure 5.2. Yield-gap model applied to livestock.
(Source: Gomez and Santos, 1981.)

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Table 5.1. Choice of analytical technique for screening animal technology.

Species	Technology to be screened	Farmers' criteria	Tools of analysis*
Draft cattle and buffalo	Effects of new yoke design on draft power	Weight, durability	Benefit-cost analysis
Dairy cattle and buffalo	Effects of feeding practices on milk production	Changes in milk yield	1. Marginal analysis 2. Production function 3. Linear programming
Beef cattle	Health related		Benefit-cost analysis
Goats and sheep	Breeding management	Litter size	Gross-margin analysis
Swine	Effects of feed supplementation on weight	Physical appearance, weight	1. Partial budgeting 2. Financial analysis

*Identified through review of literature.

margin analysis) may be appropriate for certain types of treatments. Categorizing such treatments is often desirable, and table 5.1 shows how economic tools can be matched to treatments.

Equally important in the economic analysis of a new technology is the measurement of variables and identification of indicators that are used by farmers in judging the technology. The application of these tools is discussed in later chapters.

IMPROVING THE SCREENING PROCESS

If a technology is to be successful, farmers must accept it; but acceptance is seldom a screening criterion. Modeling how small farmers make economic decisions about raising animals can help experiment station researchers better serve resource-poor farmers. Research in Indonesia indicates that animal researchers can learn a lot about how farmers view and evaluate technology by meeting with the farmers regularly (Knipscheer and Suradisastra, 1986). India has used technology screening effectively because strong economics and extension support is available at the research institutes. Similarly, it may be useful to invite farmers to visit the research station before on-farm research begins.

Animal researchers should involve economists in designing the experiments so the data that are collected can be analyzed quickly and effectively. The economic implications of a new technology should be considered before an experiment is set up, especially for experiment stations in developing countries, which often have far too few financial resources and experimental animals. This approach can pay off in reduced research costs, thereby releasing resources for testing more technologies.

SUMMARY

The traditional bias of animal research stations to produce and promote technologies appropriate for commercial or semicommercial farms has kept the resource-poor farmer from receiving the benefits of animal research. Just as crop productivity has been improved by varietal breeding, animal productivity is being increased through stock improvement — an approach that is biased against the small farmer. To realistically address animal problems of the small farm, existing and new technologies that are available for commercial farms need to be adjusted to meet the needs of the small farm. Screening animal technologies according to economic feasibility is an important step in designing cost-effective technologies that can be utilized on the small farm.

CHAPTER 6

GUIDELINES FOR CONDUCTING ON-FARM ANIMAL RESEARCH

PURPOSE

A number of choices must be made when designing On-farm Animal Research (OFAR). The researcher or extension worker must decide on the type of technology to be tested and the degree of experimental control as well as the trial site and the variables which will be measured. Factors which affect the outcome of OFAR, such as the practicality of the experiment, the costs involved, and the objectives of the research, must also be considered during the design of OFAR trials. This chapter presents the guidelines which can be followed during the decision-making process and the factors which should be considered in the development of effective OFAR trials.

OBJECTIVES

After completing this chapter, the reader should be able to:

- List the advantages of conducting crop and animal research simultaneously.
- Describe some of the possible objectives of an OFAR trial.
- Identify the decisions which must made during the design of OFAR.

CROP-ANIMAL TRIALS

In many Asian farming system programs, researchers working with crops are becoming more interested in the role of crops as feed for animals. The effects on animals of a crop intervention — introducing a fertilizer, pesticide, agronomic practice, or machine — need to be analyzed. A crop variety may be high yielding, but if it requires practices that are too different from traditional practices or affects other components of the system in a negative way, farmers may reject it. The following is an example of how lack of consideration of the animal component resulted in the eventual failure of a crop trial.

IR-6, a high yielding variety of rice, produces about 100% more grain than the Basmati rice that is traditionally grown in Pakistan. When IR-6 was first introduced in the Punjab area of Pakistan in the late 1960s, farmers rapidly adopted it. In fact, it captured almost 40% of the total area under rice cultivation. However, within 2 to 3 years, the farmers were again planting Basmati, even though growing IR-6 was shown to be more profitable. A key reason that farmers reverted to growing Basmati was that animals found the straw of IR-6 unpalatable. The variety was good when viewed only as a crop, but it was not an effective component of the farming system. The plant breeder should have tested the palatability of the straw before recommending the variety. A few simple trials at the research station and some on-farm testing would have revealed the problem.

Collaborative research on crops and animals is currently being conducted by the Asian Farming Systems Program of the International Rice Research Institute (IRRI) in the Philippines. It consists of on-station research at IRRI and the University of the Philippines Institute of Animal Science and on-farm research in Santa Barbara, Pangasinan, Philippines; Batumarta, South Sumatra, Indonesia; Pumdi Bhumdi, Kaski, Nepal; and Ban Phai, Khon Kaen, Thailand. The work at IRRI concentrates on food-and-forage cropping systems, forage-crop management, and dual-purpose crops. The Institute of Animal Science works on feed technology and pesticide residues.

There are several advantages to conducting crop and animal research at the same time. Primarily, costs can be reduced if trials can be synchronized. Multidisciplinary teams of scientists can be developed, offsetting some of the effects of the shortage of skilled labor, while multiple research/extension objectives can be met. In addition, the effects on the whole farm system due to changes within the crop or livestock component can be seen, leading to an in-depth understanding of the interrelationships between the crop and animal components of the farming system.

OBJECTIVES OF AN ON-FARM ANIMAL RESEARCH TRIAL

The research objective is the first thing to consider when designing an experiment. Only when the objective is set can decisions be made about how many treatments and replications are needed to derive useful results. In the design of an OFAR trial the objectives may be the following:

- To verify the performance of a technology or practice that is new to local farmers.
- To demonstrate techniques that have been successful elsewhere, such as on commercial farms or in other countries that have comparable animal-production systems.
- To achieve results as part of a broader system, such as in a crop-livestock trial.
- To provide a field laboratory for monitoring the flow of information from the field to the research station.

DESIGNING ON-FARM ANIMAL RESEARCH

Several practical guidelines can be followed when designing OFAR (Olson et al., 1986). If animal trials are to be replicated over several years, reports should be produced each year. These can then be used as input in the following year. Care should be taken that old research trials are not duplicated. If it is already well established that digestion, feed intake, and weight will increase when animals are fed a particular supplement, there is little need to repeat the trial. Furthermore, technical, economic, and social effects are inseparable and should be studied together.

Complicated experimental designs and equipment should be used for on-station research, not for OFAR. It is usually appropriate to simulate farm conditions at the research station instead of conducting research on the farm when trials require the use of complex equipment. At the station it is easier to keep good records, evaluate multiple technologies, and control the variables. Data analysis should be kept simple (basic averages, partial budgets, benefit-cost analysis), and research results should be expressed in simple economic terms to be of benefit to other researchers, extension workers, farmers, and policymakers.

The choices which must be made when designing OFAR were first introduced in Chapter 4 (see figure 4.1). The following sections elaborate on each of these choices while describing the factors which must be considered during the decision-making process.

Choosing the Type of Trial

The purpose of the extension trial is to demonstrate to farmers the superiority of a new technique over the farmers' current practice. Often a researcher and an extension worker design a trial together to identify the best-performing technology from a set of practices. The results of these trials are used to modify the current practice and to identify supporting components of the technology. Trials should be conducted at several farms to bring out variations due to factors such as farm size and management style. Although the researcher is more interested in learning how the technology performs under farm conditions, the success of each trial can actually be measured by how many farmers adopt the new technology.

Some trials are managed by the researcher and some are managed by the farmer. In a researcher-managed trial, the researcher usually provides the test animals and all trial-associated inputs. The researcher then works closely with the farmer, guiding all aspects of the experiment. Sometimes a field assistant is posted in the area to monitor the trial. In farmer-managed trials the farmer's animals are frequently used, but the treatment inputs (such as supplements, new forages, equipment, and medicines) are provided by the researcher. Farmer-managed trials tend to be more realistic than researcher-managed trials but they often lack the control necessary to derive accurate results. Still, these trials are useful for extension purposes and, in practice, are suitable for OFAR.

Most OFAR depends on the involvement of the farmer, especially in caring for the animals, and more farmer control becomes necessary as the technology gets closer to the extension stage. As the degree of farmer control increases, however, the inherent statistical variability in OFAR increases (see table 1.2, Chapter 1). This variability augments the need for replication at each site; therefore, sample size and total trial cost will go up with increasing farmer control. Since OFAR may require that more care be taken during experimental design (Gryseels, 1988), farmer-managed trials must be planned carefully to avoid errors in execution or interpretation that may invalidate the results.

Choosing the Type of Technology

Deciding on the type of technology upon which to conduct research trials depends on a number of factors. Primarily, the cooperation of farmers is essential. If the farmer does not understand the objectives of the new technology or is not deeply committed to following the experiment through, the success of the project can be jeopardized. Therefore, the needs of the farmers must be identified through informal or formal interviews and prior studies, and their commitment to the project must be secured.

In conjunction with assessing the needs of the farmers, the nature of the farm problem must be correctly identified. This can be done through review of preliminary surveys, secondary information, and informal discussions with the farmers. Priorities can be assigned to the problems faced in a particular farming system; specific technology components can then be singled out for testing. Examples of animal problems include low weight gains, disease, reproductive problems, and poor nutrition.

Availability of inputs is another deciding factor when choosing a new technology for research testing since the inputs that were utilized at the research station, such as feed supplements, medicines, animal-traction implements, grasses, and fodders, may not be available at the farm level.

Availability of time and resources should also be taken into account. More time is needed before the results of a new animal-production technology become evident, as opposed to the results of a new crop-production technology. For example, the effects of fertilizers can be evaluated within a few months, but the performance of a hybrid ram takes years to evaluate. In addition, the availability of human, financial, and institutional resources (including skilled technicians to record data) can be deciding factors when planning a new technology. OFAR can be expensive, but costs can often be reduced by conducting trials in an area where other research activity is under way. Opportunities for marketing should also be considered when deciding on a new technology, and when economically feasible, the private sector should be encouraged to participate in the trial.

Choosing Sites

Several factors should be considered when determining the site for an on-farm trial (Van Eys et al., 1985). The site should be representative of specific agroecological conditions. It should also accurately represent the production system of the target population. The attitudes and cooperativeness of farmers are important when deciding on a site location. In addition, costs, accessibility, potential to control and supervise the trial, and cooperation of institutions such as the extension service are other factors which will help to determine the site location. Often, choosing a site is a subjective rather than objective decision. Problems related to willingness of farmers to cooperate, suitability of farms, and relevance of the research problem to the farmer may make it impossible to choose a truly random sample.

Choosing Farms

When farms are chosen by predetermined criteria (purposive sampling) rather than random selection, the target population has a few elements in common. Those farms that are representative of the majority of farms in the area should be selected. For example, when sampling small farms with buffalo, farms should be chosen where the buffalo is of the typical breed and health status of buffalo at neighboring farms.

Several factors will affect a farmer's willingness to cooperate in an OFAR trial. These include:

- levels of education, interest, and experience with animals
- goals in farming
- whether farm requires full-time or part-time work
- number of family members supported by farm
- farm size and accessibility of market
- attitude of farmer (progressive or conservative) and willingness to experiment with animals
- political and social position of farmer in the community

In addition, the demands and arrangements participating farmers must meet during the trial period and the marketability of the new technology will also affect the farmers' willingness to participate in research trials.

Choosing Experimental Animals

Decisions in selecting animals will depend on factors such as the availability of farm animals, herd structure, species, and age composition. Usually there are not enough animals on one farm to evaluate different feeding treatments or the performances of several different breeds. In practice, a farmer may prefer that certain animals undergo a treatment, such as feeding nutritional supplements to weak livestock in order to improve their health. In other cases, the farmer may prefer to withhold treatment from certain animals; for example, the farmer may not want to use the healthier of two pair of bullocks to test a new implement for fear that the animals will be injured.

Control in executing the treatment is determined by the facilities (water, labor supply, etc.) available on the farm. Several other tactics can be employed in order to execute control over the experimental animals. For example, when conducting experiments affecting the weight of poultry, the birds should be checked for disease before the trial begins, and poultry trials should be limited to four to six weeks. When testing a new vaccine, some farm animals should be injected with the vaccine and others with an innocuous solution, so the farmer does not know which animals receive the true vaccine.

Choosing Variables to Measure

Some variables that can be measured at the research station cannot be measured adequately on the farm. Therefore, it is important to examine only variables that are appropriate for study on the farm, such as the variables listed here and in table 6.1 (Fitzhugh et al., 1982):

- health — incidence and causes of morbidity and mortality
- number of animals per birth, interval between deliveries, and number of litters per life cycle
- size and growth — weight at birth, maturity, and slaughter and preweaning and postweaning growth rates
- lactation — daily milk production and duration of lactation
- production variables — number and weight of eggs, quantity and quality of sheared wool, and type and quantity of animal traction used
- duration of grazing cycle

It is also possible to draw blood samples and to measure rectal temperature and pulse rate at the farm level. However, variables should be chosen that are realistic to measure, and it should be kept in mind that there are some limitations regarding use of equipment in the field, including nonrandom errors caused by transporting equipment.

Table 6.1. Choice of variables to be measured in an OFAR trial.

Species	Technology to be screened	Main variable(s) to be measured
Draft cattle and buffalo	Effects of new yoke design on draft power	Stamina, temperature, pulse rate, physiological changes
Dairy cattle and buffalo	Effects of feeding practices on milk production	Lactation, daily milk yield, length of lactation, milk composition, feed intake, feed use, weight
Beef cattle	Health related	Fitness, incidence and causes of morbidity and mortality
Goats and sheep	Breeding management	Age at first calving, fertility, kidding interval, no. born per parturition, no. of parturitions per lifetime
Swine	Effects of feed supplementation on weight	Growth and size; weight at birth, maturity, slaughter; pre- and post-weaning growth rate; height; girth

MONITORING ON-FARM ANIMAL RESEARCH

Animals must be monitored regularly, and data about their performance must be recorded. The frequency of monitoring is often determined by the availability of funds and transportation and the scope of the experiment. Frequency also depends on the type and purpose of the trial (see table 6.2). The following are general principles for setting up a monitoring program:

- The degree of control available on each farm unit must be identified. The treatment must be administered regularly. If the treatment is going to be administered by the farmer, it is necessary to determine if a research assistant should be present.

- Farms that are difficult to reach should not be included in the trial. Maximum representation of a typical farming system (cropping pattern, soil type, farm size, animal mix, and labor availability) should be obtained.
- The need for heavy measuring devices should be avoided. If such equipment is essential, arrangements should be made to leave it with the village head.
- Important members of the village, such as the village head and the local extension officer, should be consulted early in the trial period. The objective of the trial should be explained to them, and no promises should be made that cannot be fulfilled.
- Charges for the treatment should be clearly allocated. If the treatment is a mineral supplement or a new concentrate, the researcher or extension worker usually provides the material free of charge. When benefits of the treatment begin to be apparent, farmers should be encouraged to share the cost of the treatment, no matter how small the contribution may be. If the benefits are clear, the farmer will eventually pay for all of the treatment, otherwise it is not a sustainable improvement.

Table 6.2. Monitoring schedules for different types and purposes of OFAR.

Type	Purpose	Frequency of visits	Approximate duration of trial
Feeding	Testing new feeds	15 days	4–12 months
	Testing new supplements	15 days	4–12 months
Animal traction	Testing implements on draft power	—	2 weeks
Animal health	Testing new management practices	monthly	4–6 months
Disease control	Testing new medicines	daily	2–4 months

RECORD-KEEPING SYSTEMS

Research is based on making and recording observations. In OFAR record-keeping systems are based on a number of repeated observations made over the lifetime of a research project. Records should be continuous without interruptions and/or redesigns due to budgetary or labor problems. In determining the appropriate record-keeping system to utilize, the following factors should be considered: 1) minimum research objectives, 2) turn-around time, 3) number of variables, and 4) frequency of data collection. These factors are discussed in the following sections.

Minimum Research Objectives

Record keeping requires resources. Many examples of Farming Systems Research (FSR) projects exist wherein researchers have been overcome with vast amounts of data that cannot be processed due to lack of available staff and equipment. It is better to have a small reliable data set than a huge quantity of data that is beyond the control of the researcher. It is therefore important to determine the minimum data set that can be collected by defining the research objectives of the study. The most simple animal management studies involve periodic recording of reproduction, mating, weight gains, and health care. The need for additional records depends very much on the type of research undertaken, such as the measurement of milk, carcass quality, labor input, or draft power.

Turn-around Time

Long delays between the time of data collection and the actual data reporting can make data recording expensive and inefficient. The record-keeping system should therefore be as accurate as possible and performed in a timely fashion.

Number of Variables

The number of variables, or in the case of OFAR, the number of traits, that will be measured depends on the management system to be observed. Any trait that will be measured must undergo enough variation to be of value in a record-keeping system and must have some economic value connected to it. If, because of resource constraints, the number of observed variables needs to be limited, the variables which have the greatest economic impact should be recorded.

Frequency of Data Collection

The frequency of data collection should be determined carefully since this will have a direct impact on the cost of the animal trial. Not all data needs to be recorded with the same frequency. The extent of animal monitoring (see MONITORING ON-FARM ANIMAL RESEARCH) and the frequency of data collection will determine the type of record-keeping system that is needed for an OFAR trial.

SUMMARY

In order to achieve successful results, an OFAR trial must be properly designed. Above all, the objective of the trial should be clearly defined and emphasized to insure that the experimental design will achieve the required results. This chapter has presented the many decisions facing the researcher or extension worker conducting OFAR and the subsequent factors that affect each decision. If careful consideration is given to each of these factors, particularly the practicality and cost of an experiment, then the successful outcome of an OFAR trial can be expected.

CHAPTER 7

TECHNIQUES FOR ECONOMIC ANALYSIS

PURPOSE

This chapter briefly describes and illustrates methods which can be used for the economic analysis of On-farm Animal Research (OFAR). The various techniques which are introduced, such as partial-budget analysis, break-even analysis, gross-margin analysis, and benefit-cost analysis, are useful, easy to learn, and require only limited data. Although these analytical tools do not reveal the interactions of a technology with other components of the farming system, they do indicate the profitability of a technology and thus serve an important purpose when screening new technologies for OFAR.

Since the information presented in this chapter may be unfamiliar to the noneconomist, Chapter 3 is recommended as a review.

OBJECTIVES

After completing this chapter, the reader should be able to:

- Define the term budgeting.
- Perform partial-farm analysis using partial-budget analysis, gross-margin analysis, break-even analysis, and generalized cost of production.
- Evaluate input-output budgets using benefit-cost analysis.
- With the aid of a computer, interpret results of simple production-function analysis.
- Perform whole-farm analysis using costs and returns and financial analysis.

BUDGETING

The techniques for evaluating new farming technologies are numerous. The cheapest and most frequently used is intuition, often in association with internal discussions. A more detailed and structured form of evaluation is budgeting. Budgeting is perhaps the simplest tool available for deriving preliminary estimates of profitability of single interventions. It allows the analyst to compare and weigh different plans against each other and provides a rationale for choosing one plan over all the others.

Budgeting can be defined as the tabulation of gains and losses of an operation, such as a farming operation. Gains and losses can be measured in any type of unit. Monetary units are commonly used, as this allows easy computation of total gains and total losses. However, nutritional budgets for households, measured in calories or crude protein, may also be used. Another alternative is energy budgets, measured in energy units for whole farms. Budgeting assumes the following:

Divisibility	All factors are perfectly divisible, that is, labor can be used for a fraction of an hour and draft power can be used in fractional units.
Linearity or additivity	All inputs have a linear relationship with constant marginal physical product. This means that each additional unit of input to the production process results in the same contribution to the output as the previous unit.
Perfect knowledge	The decision-maker has perfect foresight of the inputs and outputs required to produce a given activity, and all coefficients are known with certainty.
Nonnegativity	None of the activities can be produced in negative amounts nor can resources be used in negative quantities.

Some of the techniques used for the economic analysis of new farm technologies are based upon the formulation of budgets. Budgeting analysis offers an organized listing of the quantities of resources used (inputs) and products generated (outputs). Once these technical input-output relations have been specified, socioeconomic values can be tagged to these inputs and outputs. Returns to individual resources or the total resources of the farm are then calculated.

QUANTIFYING ECONOMIC BENEFITS

Several approaches are available to quantify the economic benefits of new animal technologies. In general, these can be grouped under the following headings:

- Partial-farm analysis: includes partial-budget analysis, gross-margin analysis, parametric budgeting, break-even analysis, and generalized cost of production.
- Input-output budgeting: includes marginal analysis (refer to C[1] pter 3) and benefit-cost analysis.
- Production-function analysis: utilizes regression coefficients for the estimation of marginal products and optimal input combinations (see Chapter 3), and various elasticities (see Chapter 8). (Although these techniques are useful for policy analysis, a detailed description of each is outside the scope of this manual.)

• Whole-farm analysis: includes costs and returns and financial analysis.

The strengths, weaknesses, and uses of each of these techniques are discussed in the following sections.

Partial-farm Analysis

The term **partial** indicates that the change only occurs in one component of the farm and implies that no major change in farmers' resources or overall farming plan will occur. One of the most popular types of budgeting in Farming Systems Research (FSR) is partial budgeting.

Partial-budget Analysis

A **partial budget**, also known as a **partial-profit budget**, is the tabulation of expected gains and losses due to a relatively minor change in farming method, e.g., replacing one crop variety by a new one, the introduction of fertilizer, or the use of a new tractor. It is a method of balancing and examining the total gains (benefits) and losses (costs) that will result if a change is made in a part of the farming system.

Among the general types of budgeting, partial budgeting is widely used to determine the profitability of a single intervention. Partial budgeting is used in two ways. When new technology is still in development, it is used to provide the scientist with a measure of how attractive this new technology will be for the target group of farmers. During the validation and extension phase of OFAR, partial budgeting can be used to determine if it is economically feasible to adapt the new technology.

Partial-budget analysis is simple to use and provides information about changes in costs and benefits caused by following a given practice. It requires minimal information about changes in variable costs and benefits; however, yield and price information must clearly reflect farm conditions. (The general tendency is to overestimate benefits and underestimate costs.) Since partial-budget analysis is relevant only for component technology, it is not suitable for answering questions in which several factors determine the contribution of a treatment. In the case of livestock, the true effect of the treatment on milk yield or changes in animal weight should be estimated carefully. Erroneous production coefficients may result in misleading conclusions. At times, it is more appropriate to develop partial budgets for a whole herd than for a single animal.

Performing partial-budget analysis. A good start to any economic analysis of new technologies is to clearly define the objectives of the farmers, especially as these relate to a given farm enterprise. For example, farming households might grow a number of food crops mainly for home consumption. In this case, the farmers might have a target foodcrop production in mind and will try to reach that target with minimal cost. Their objective might be to reach this target production and keep the maximum quantity of resources available for other farm operations (or off-farm jobs). Another example is the keeping of livestock. It has been argued that many farmers keep a few sheep and goats as a buffer (insurance) against bad times. Just as insurance owners try to keep the price of insurance low, farmers might try to keep their animals with minimal input (e.g., scavenging). In both of the above cases, the partial analysis of a new technology might lead to the wrong conclusions. Determining the farmers' goals is thus a good beginning in any economic analysis.

The second step is a detailed description of the change (new technology) proposed. Based on this description, it must be determined which factors will remain the same, and which factors are expected to change.

After the changes are made, they are tabulated in either gains or losses columns. These two columns are subdivided into two categories. The gains column will include added returns (any additional income that is expected) and reduced costs (any costs that are saved). The losses column includes any added costs (additional expenses) and reduced returns (foregone revenues such as opportunity costs). The difference between gains and losses is the net benefits (or losses) resulting from the change under consideration. In simpler terms:

Added returns		Added costs		Profit
+	−	+	=	or
Reduced costs		Reduced returns		Loss

The above equation may be set into a form that allows detailed itemization as follows:

Gains (A)	Losses (B)
Added returns	Added costs
Reduced costs	Reduced returns
Total A	Total B
Difference (A − B) = Profit or Loss	

The following example shows how this format can be used to solve a problem.

In a study comparing the profitability of raising native Malaysian ducks with that of raising hybrid-strain ducks, research has produced the following data:

Gain-loss components	Quantity	Price (M$)
Additional weight of hybrid ducks	235.73 kg	3.25/kg
Additional feedbags (resale)	21	1.15/bag
Manure	31% of body weight	0.05/kg
Additional feed required by hybrid ducks	873.05 kg	0.83/kg
Additional labor for hybrid ducks		10.80
Additional water required		3.00

The following partial budget shows the gains and losses associated with raising hybrid ducks rather than native ducks:

Gains (A)		Losses (B)	
Added returns (M$)		Added costs (M$)	
Weight gain	766.12	Feed	724.63
Feedbags	24.15	Labor	10.80
Manure	3.65	Water	3.00
Subtotal	793.92	Subtotal	738.43
Reduced costs	—	Reduced returns	—
Total A	M$793.92	Total B	M$738.43
Difference (A − B) = M$55.49 profit			

The next example is a partial budget analysis of a new technology used on oil palm estates in Malaysia. Earlier studies indicated that the productivity of the harvesters could be increased by using buffalo to transport fresh fruit branches within estates. The following partial budget summarizes the economics of using buffalo to haul the branches instead of having the harvesters carry the branches in baskets. In this table of data the losses are listed below the gains rather than side-by-side (table of data continues on next page).

Gain-loss components	M$ if animals kept for:		
	1 year	2 years	3 years
GAINS			
Added returns			
Weight gain	0.7560	0.6406	0.4294
Reduced costs			
Decreased labor for harvesting	1.3200	1.3200	1.3200
Decreased weeding required	0.5500	0.5500	0.5500
Baskets	0.0307	0.0307	0.0307
Subtotal of gains	2.6567	2.5413	2.3301

Gain-loss components	M$ if animals kept for:		
	1 year	2 years	3 years
LOSSES			
Added costs			
Interest on buffalo purchase	0.0998	0.0998	0.0998
Health care of buffalo	0.0235	0.0206	0.0196
Insurance	0.0470	0.0470	0.0470
Cart depreciation	0.0939	0.0939	0.0939
Cart maintenance	0.0587	0.0587	0.0587
Training buffalo	0.0396	0.0198	0.0132
Path construction	0.0733	0.0733	0.0733
Reduced returns	—	—	—
Subtotal of losses	0.4358	0.4131	0.4055
PROFIT (per acre per month)	2.2209	2.1282	1.9246

Source: MARDI, 1984.

The profits (or net differential benefits) per acre per month compared to the former system were M$2.22 (1 yr), M$2.13 (2 yr), and M$1.92 (3 yr). This same study showed that the average productivity and income of the harvesters using buffalo increased by 30% over those using the traditional system. This enabled the estate to save M$0.066 per acre/person-day or M$1.32 per acre/month on harvesting. An average daily gain (ADG) of 0.55 kilogram was attained by the buffalo. This suggests it is profitable for Malaysian oil palm estates to keep buffalo for both draft and meat.

As indicated by the two examples given above, the four types of data required for partial-budget analysis are 1) physical input and output data, 2) price data for inputs and outputs, 3) resource input requirements (land, labor, and capital), and 4) the resource basis of the farm.

A last step in partial-budget analysis is obtaining a list of all important noncash considerations that are relevant to the farmers' choice. For example, if the change in input requirements is large, a special note on cash-flow should be added. For herbicide applications, a note should be included about the risk of hazards to family members in case of careless use or storage. Other examples are changes involving farm inputs that are not always available, such as a technology involving high management skills or a technology involving subsidized prices.

Interpretation of partial-budget analysis. Although a partial budget is easy to interpret, it is rarely presented with a statement of farmers' objectives, farmers' resource base, and important noncash considerations. Therefore, care should be taken in the interpretation of partial budgets. A first consideration should be whether the best profit criterion has been used. Evaluation of technologies using gross margin per hectare imply that it is in the farmers' interest to maximize the benefits to land. Often, this is not the case. The following example of a mixed crop-livestock farming system serves to illustrate this point.

Table 7.1 gives indices for different management systems in Indonesia. This table also illustrates that performance ranking of the various management systems and breeds differs by performance criteria. Using the doe productivity criteria (DP = DRI × average weight of weaned kids, where DP is the doe productivity and DRI is the doe reproduction index), the first three management systems perform nearly equally well. However, when expressed in DP per kg doe maintained (DP/doe), the advantage of the smaller breed emerges. Assuming that the market price per kilogram live weight for young and old animals is about the same, the DP/doe index is a good index for the economic returns to capital input.

Earlier the role of livestock for farm liquidity was discussed. A herd or flock represents a quantity that can be readily exchanged for cash. Flock yields, therefore, can be interpreted as cash yields, which again implies returns to cash resources. The socioeconomic scientist, therefore, can borrow flock productivity parameters from his biological colleagues such as doe/ewe reproduction indices and doe/ewe productivity indices.

Table 7.1. Doe Reproduction Index (DRI)* and Doe Productivity Index (DP)** under different management systems in West Java, Indonesia.

Management system	DRI	DP	DP/doe***
On-station (Kacang breed)	2.39	30.80	1.16
On-station (Ettawah breed)	1.39	18.20	0.76
Specialized farmers (cross)	1.78	19.76	0.79
Village (cross)	1.39	11.18	0.51

*DRI = litter size × kid survival rate per doe per year
**DP = DRI × average weight weaned kids
***DP/doe = DP per kg doe

Source: Knipscheer, Kusnadi, and De Boer, 1984.

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When evaluating economic returns to labor, rankings of management systems may differ substantially. Taking as an example, West Java, Indonesia, where the cut-and-carry system is dominant, table 7.2 illustrates the appropriate rankings using two performance criteria: returns to capital (second column) and returns to labor (third column). Economic goat productivity measurement thus differs according to the economic criteria used for evaluation. In this example, returns to land are not calculated. In the cut-and-carry system, grasses are cut from public, communal, and other fallow land and brought to confined animals. Labor is therefore a major constraint.

Table 7.2. Economic returns to goat farmers in two West Javanese villages (1981–1982).

Village	DRI*	Returns to capital (Income/doe**)	Returns to labor (Income/hour**)
Cirebon	1.31	21,498	44
Bogor	1.47	16,171	56

*See table 7.1.
**Expressed in Indonesian rupiahs, US$1.00 = Rp 625 in 1981–1982.
Source: Knipscheer, Kusnadi, and De Boer, 1984 (BPT/SR-CRSP Survey 1981–1982).

Many of these considerations are also valid for other types of budget analysis such as gross-margin analysis. The reader should thus be aware of the assumptions underlying numerous budget presentations.

Advantages and disadvantages of partial-budget analysis. Partial-budget analysis has several advantages. Primarily, it is simple. It can be performed with a hand calculator or with pencil and paper. In addition, it is easy to learn and can readily be taught to extension workers or farmers. Since it examines only net changes in costs and benefits, partial-budgeting is effective for assessing the economic viability of single-intervention technologies. It implies a minor change in the farmers' whole farm operation, and this is usually the way farmers adopt new technologies: stepwise and partial rather than by shocks or revolutions.

Partial-budget analysis requires less data than whole-farm budgeting since aspects of the operation that remain constant are not examined. Nearly any other form of economic analysis involves collecting at least the same information as one needs for conducting a partial-budget analysis. In many cases, firm conclusions about the adaptability of new technologies can be drawn after only a partial analysis without going into more cumbersome details of whole-farm analysis.

The greatest danger of using partial budgeting is neglecting the limited resources of the farmers. Technologies are often analyzed without the economist realizing the effect on the farmers' resource base. There are two reasons why this mistake is made. First, nearly all new technologies involve an increase in purchased inputs by farmers. The availability of cash, however, is a notorious constraint to smallholders. Secondly, land-intensive technologies are promoted which generally require a higher labor input per land unit (hectare). It is often wrongly assumed that labor is readily available or can be diverted from other tasks (farming, household, and off-farm activities) to the farming system component under consideration.

Another disadvantage with partial-budget analysis is the lack of understanding of the farmers' objectives. It is now well understood that farmers behave very rationally. However, this does not necessarily mean that they are concerned with maximizing the returns of one given crop enterprise. For example, it may be possible to demonstrate to farmers the increase in benefits by applying fertilizer to their cassava fields. They even can be provided credit for the purchase of fertilizer. Nevertheless, they may apply it to their rice crop as this crop is more important to them, or they may sell it to their neighbors to buy medicine for their families. The key point is that the partial view of a farming system might obscure the secondary character of a given farm component.

Another limitation is the lack of a time analysis. During the process of tabulation, all factors are arranged as occurring during the same time period. Timeliness of farm activities, however, is an important aspect. In order to realize how adoption of a new technology affects other farm operations, it is important to know if labor required will occur during one peak period, such as one week, or be spread out over a longer time frame, such as three months. Similarly, the time for various farming activities (planting, weeding, and harvesting) is limited. It is necessary to know at what time and for what duration resources are required. By the same token, the problem of cash-flow tends to be overlooked. The longer the period between investments and returns, the less likely that farmers will be attracted to a new technology.

Using small-scale input/output data for a larger scale operation assumes linearity of the factors involved. Thus, it may be assumed that farmers can grow three times as much grass on 3 hectares as they can grow on 1 hectare. These kinds of assumptions are often not true because of differences in timing, quality of land, or increase in danger of diseases or even problem in marketing the products. The assumption that an expansion of a unit of resource (e.g., animal) will increase the profit proportionally is therefore in many cases questionable. Similarly, the increase in management skill required by many new technologies often fails to be considered.

Although a partial budget gives an indication of what "better" is, it does not indicate what is "the best." For example, feeding 5 kilograms of soybean meal to a cow on a daily basis will be better (more profitable) than feeding no supplement at all. However, the goal is to determine the rate of feeding (3, 4, 5, 6, etc., kilograms/cow/day) at which farmers will maximize their profits. In other words, what daily rate of feeding is the best? Partial-budget analysis is therefore useful for the following types of trials:

- where a single component must be analyzed (for example, a feed supplement, forage, or medication)
- where inputs and outputs are measurable and easy to price
- where animals' yields vary little between farms (for example, when farms use the same species and similar breeds and have equal access to the market)
- where profitability is the major concern rather than issues such as equity and income distribution
- where fixed costs do not change

In the above cases the new technology affects only one of the components of the farming system and the anticipated change is a minor change from the present system. In many such cases a number of factors (resource base, resource requirement) can be assumed to be fixed and therefore excluded from the analysis. Thus, partial-budget analysis is most appropriate for cases where only crops or products requiring similar noncash resources and similar investment resources are compared.

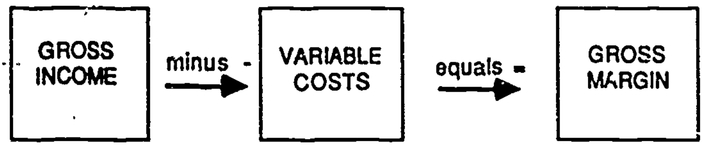
Partial budgeting is also appropriate for conducting an economic evaluation of new technologies which are not yet well developed. In this case, a technology is not yet well defined and only a general notion about the feasibility of such a technology is useful. The merit of the partial budget lies more in the tabulation of the factors that would be affected by the technology, rather than the values (prices) attached to these factors.

Gross-margin Analysis

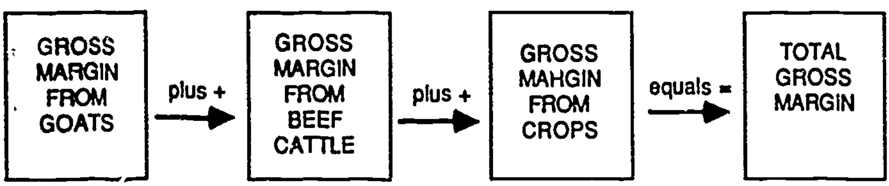
Traditionally, farmers make management decisions by intuition and some calculations. In the future, however, intuition will not be enough. For their farms to survive, farmers must formulate plans that are technically feasible and economically efficient. Gross-margin analysis is one technique that can help farmers calculate the profitability of alternative plans.

Gross margin is the difference between the gross income of a farm activity and its variable costs; that is, it is the estimate of returns above variable costs for a given activity. Total gross margin is the sum of the gross margins of all of the farm's activities. Gross margins are usually expressed in units of some common resource; for example, gross margin per head is used to measure the efficiency of animal-production activities (see figure 7.1).

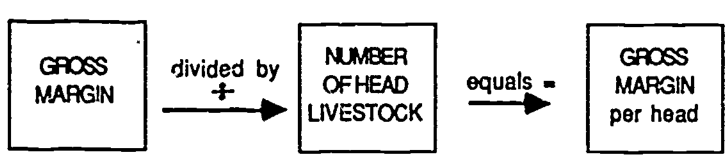
The gross margin is the farm's returns above variable costs:



If the farm has more than one activity:



The gross margin for an activity divided by the units of that activity gives the per unit gross margin:



To get Net Farm Income, fixed or 'overhead' costs are subtracted from Total Gross Margin:

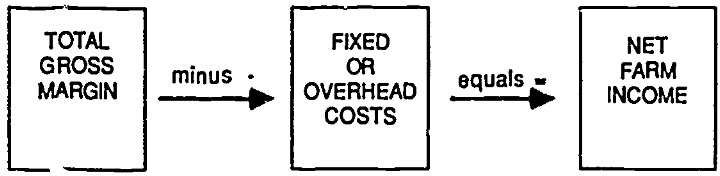


Figure 7.1. Steps in gross margin analysis.

Gross-margin analysis is similar to partial-budget analysis in many ways. It is calculated as total gains over variable costs. Variable costs are the expenses that vary directly because of the technology applied, e.g., feed costs, medicines, transportation costs, equipment repair, etc. Total gains generally are the total values of the animal products or other farm products.

Performing gross-margin analysis. The following example illustrates gross-margin analysis. A sheep operation in Syria maintains a stocking rate of 20 ewes per hectare for 31 days. The sheep receive the following diets in rotation: barley/fallow, barley/barley, barley/vetch, and barley/lathyrus.

The gross margins are as follows:

	Rotation			
	Barley/ fallow	Barley/ barley	Barley/ vetch	Barley/ lathyrus
Gross revenue (S£/ha):				
Barley	743	1542	1271	1271
Milk from increased forage production	0	0	1393	1286
Total	743	1542	2664	2557
Variable costs (S£/ha):				
Barley	291	900	877	877
Forages	0	0	754	747
Total	291	900	1631	1624
Gross margin (S£/ha)	452	642	1033	933
Gross margin (US$/ha)	116	165	265	239

Source: Thomsom, E. F., R. Jaubert, and M. Oglah, 1985.

Interpretations of gross-margin analysis. In using gross-margin analysis, it is tempting to conclude that farm profit can always be increased by expanding the enterprises that have high gross margins per unit at the expense of those that have lower returns. This may not be true because of resource and other constraints. If the number of animals with high per-unit gross margins is increased without regard to the constraints, fixed expenses probably will increase, perhaps to the point that the increase in total gross margins is more than offset.

Linearity in gross income and variable expenses should not be assumed. Since the format inherent in gross-margin analysis does not consider nonlinearities, when such nonlinearities are obvious, partial-budget analysis is more appropriate (Dillon and Hardaker, 1980).

Advantages and disadvantages of gross-margin analysis. One of the advantages of this method is that gross-margin analysis can be easily used in the ranking of more than one technology. It lends itself to the analysis of the results of different treatments in research trials. By comparing the gross margin for each treatment, the most promising treatments can be selected, i.e., the treatments (technologies) with the highest gross margin. When combined with a break-even analysis, conclusions can be drawn about the significance of differences between treatments. Treatments can be ranked and scientists might focus further research on the most profitable treatments.

The disadvantages of gross-margin analysis are the same as those of partial budgeting. However, the danger of inappropriate use is greater. Because gross-margin analysis is such an easy method of giving an economic meaning to experimental results, it is more often used without farmers' perspectives, i.e., without reference to farmers' objectives or resources. Using experimental input/output data will usually result in the use of inflated production levels, i.e., the estimated benefits will be unrealistically high.

Break-even Analysis

In partial budgets, or in any other budget, there are always a few key factors which affect the balance of gains and losses. Parametric budgeting is used to analyze the consequence of any change (fluctuation or variation) in the quantity or quality of these key factors. A common application of parametric budgeting is the break-even analysis, which determines the level at which the gains and losses are equal. This level of values and quantities is known as the **break-even point**. Generally, break-even analysis is done by manipulating the most uncertain key factor.

An example of break-even analysis is the determination of timing for culling of dairy herds. In this case, the farmer estimates at what point in the life of a cow the maintenance cost of the cow will be equal to the value of the products from the cow. As with all livestock, productivity generally decreases with age, and the break-even point signifies the time at which a farmer should sell the animal. A similar analysis exists for farm equipment. Maintenance and operation costs for equipment will increase over time, while benefits derived from equipment usage will decrease. Above the break-even point, benefits are higher than the costs, and at the break-even point they are equal. Below the break-even point, costs will be higher than revenues and the use of the equipment becomes economically unfeasible.

Break-even analysis is used to trace the effect of a change in assumptions. If a relatively small change in yield of a given technology results in a zero balance between added benefits and losses, these technologies can be considered nearly equal in profitability. The choice of technology in that case is rather irrelevant to the farmers, and it is very likely that the farmer will maintain his existing operation.

Break-even analysis can also be used to compare gross margins (total benefits minus variable costs per crop enterprise). The break-even analysis can be used to measure how sensitive the results of the gross-margin analysis are to changes in some of the critical assumptions.

Performing break-even analysis. In small crop-livestock farming systems, farmers want as much information as possible about the profitability of various farm activities or enterprises. Break-even analysis offers two types of information: break-even price and break-even output. **Break-even price** is the price at which the farm's given level of output, if sold, would enable the farmer to at least recover costs. **Break-even output** is the level of production that would enable the farmer to recover costs if the products were sold at the given or prevailing price. As break-even analysis is a variation of gross-margin or partial-budget analysis, the same set of data is required. However, for the break-even analysis, the FSR practitioner might try to obtain historical data on the variability of prices and/or the yields of crops or farm products. These changes can be compared with the current yields and prices by break-even analysis.

Break-even analysis involves all the steps for conducting partial analysis. In addition, it is useful to make an explicit list of assumptions and identify the most critical ones. The final step is the calculation of a series of gross margins assuming various values for these critical factors.

Interpretation of break-even analysis. Break-even analysis in association with partial budgeting or gross-margin analysis can be used as a measure of risk. The analysis yields the minimum or maximum value of a critical factor at which a new technology is expected to become or stop being beneficial to the farmer. The following is an example of the break-even analysis of ommercial broiler enterprise in India.

An Indian extension worker wanted to determine the break-even price of raising 10 broiler chickens. He knows that the total cost of production (including the farmer's labor) is Rs 198 and feels fairly sure that total production will reach 10 kilograms. The price that the raiser must get for the chickens in order to break even is determined by the following:

Since break-even price is the price at which sold output will equal total cost of production,

Total cost of production = Rs 198 = sold output
Sold output = break-even price × total production
Rs 198 = break-even price × 10 kg
Break-even price = Rs 198/10 kg = Rs 19.8/kg

A price of Rs 19.8/kg will assure the farmer full recovery of the costs incurred in producing the broilers. Any price the farmer can get that is higher than Rs 19.8/kg is profit.

Advantages and disadvantages of break-even analysis. One of the advantages of break-even analysis is that instead of calculating a fixed value, the results of a budget analysis can be assessed in terms of probabilities. In other words, an estimate is made of the probability that an actual value will be above or below the established break-even level. Thus, one can assess the possibility of the proposed change being profitable, assuming all other budget components can fairly well be predicted. In addition, it is usually easier to assess the probability of an uncertain coefficient exceeding or falling below a specified value than it is to assess an expected value for that coefficient. If the break-even value is very high or very low, conclusions can be made about the profitability of the change with a high degree of confidence. Limitations to the use of break-even analysis are similar to those of partial budgeting and gross-margin analysis.

Generalized Cost of Production

The generalized cost of production (GCP) summarizes a crop, livestock, or poultry enterprise for a specific period of time, usually a season or year. While the title only suggests the cost aspects of production, the returns are also considered.

Performing GCP. The steps in using GCP are as follows:

1. All of the relevant variable costs associated with the production of a commodity are identified and valued at the nominal market price (not corrected for inflation). This implies that the GCP method is closer to accounting than economics.
2. Land, labor, capital, and management are valued at existing rates. Cost of capital should include a depreciation allowance as well as credit charges on loaned capital.
3. Cash and noncash returns received by the farmer are valued at market prices.
4. Profit is calculated by subtracting costs from returns. Returns minus costs provides an estimate of "accounting profit." Other ratios can be used to express returns to different factors of production, such as returns to animal, returns to land, or returns to labor.

Advantages and Disadvantages of GCP. GCP is simple and used extensively in developing countries to estimate profitability. It is useful for identifying costs and returns on the farm; hence, it is a starting point for the farm manager in formulating a farm plan. Government agencies use GCP year to year to review price and input-subsidy policy. Moreover, GCP can be applied at different levels of sophistication — some use the concept without getting involved with calculations of rates of depreciation or with valuing in-kind payments.

GCP is restrictive in that it derives cost-of-production estimates for a specific farm and managerial level. Since no two farms are alike it becomes difficult to compare profitability among farms. Moreover as input and output prices change, the estimates have to be revised.

Tables 7.3, 7.4, 7.5, and 7.6 illustrate GCP. In table 7.3, returns to animal are used as selection criteria. In table 7.4, accounting profit is calculated. Tables 7.5 and 7.6 compare the costs of keeping female cows and buffalo until reproductive age.

A similar concept — costs-and-returns analysis — is presented later in this chapter. The main difference between the two techniques is in their treatment of depreciation allowance, valuing managerial services, etc.

Input-output Budgeting

Animal experiments generate a great deal of data about the relationships between inputs and outputs, especially for inputs such as feed, medicine, labor, and equipment. Animal-feeding experiments often generate data relating feed inputs or stocking rates to animal output. The input-output alternatives that are compared usually are related to the different treatments used in an experiment or set of comparable experiments. However, data on differing input-output combinations may be available from farm surveys, and such data may also be appraised by input-output budget analysis.

Under whole-farm analysis, discussed later in this chapter, procedures are outlined for estimating and performing economic analysis of input-output relationships (production functions). Less elaborate and direct economic appraisal of data for farmer recommendations are presented here. Partial budgeting is known as input-output analysis when it is applied to the analysis of input-output data (Dillon and Hardaker, 1980).

The aim of input-output budget analysis is to derive farm recommendations that are consistent with the farmers' desires to increase income, avoid undue risk, and make the best possible use of scarce investment funds. Input-output budget analysis has four specific techniques: 1) net benefits and marginal analysis, 2) minimum returns analysis, 3) price variability and sensitivity

Table 7.3. Average cost of maintenance per day and per liter of milk for cattle and buffalo (in Indian rupees).

Cost component	Purebred zebu cattle		Purebred exotic cattle		Crossbred cattle		Murrah buffalo	
	Per day	Per liter	Per day	Per liter	Per day	Per liter	Per day	Per liter
Feed	4.86	0.90	5.98	0.78	8.07	0.83	4.83	1.21
Labor	2.97	0.55	3.03	0.39	3.02	0.31	2.77	0.69
Supervision	0.20	0.04	0.20	0.03	0.20	0.02	0.20	0.05
Replacement	0.89	0.16	1.09	0.14	1.20	0.12	1.45	0.36
Vet. care and medicine	0.21	0.04	0.53	0.07	0.31	0.03	0.12	0.03
Misc.	0.84	0.15	0.87	0.11	0.85	0.09	0.84	0.21
Gross cost	9.97	1.84	11.70	1.52	13.65	1.40	10.21	2.55
Net cost	9.74	1.80	11.42	1.84	13.37	1.37	9.91	2.48
Average yield per cow per day	5.42		7.70		9.76		4.00	

Source: Cost of milk production at NDRI Farm, Karnal, India, 1985. NDRI Publication No. 175.

Table 7.4. Estimated cost of turkey production and profit at 16 weeks (per single bird).

Input		Output	
Fixed costs (US$)		Average wt.:	4.48 kg
Price of poultry	3.70	Sale price to supermarket:	US$3.50/kg
Electricity and water	0.50	Sale proceeds:	US$15.68
Housing depreciation	0.10		
Equipment depreciation	0.05		
Labor	0.10		
Dressing and packaging	0.20		
Variable costs (US$)			
Feed	6.08		
Vaccination/medication	0.10		
Total Costs (US$)	10.83		

Note: From the above figures, based on the mortality rate of 8%, the average cost is US$10.85 per bird; hence, net profit is US$4.83 per bird.

Source: Rearing of turkeys in plantations. In: Proc. of Seminar on Integration of Animals with Plantation Crops, 1978.

Table 7.5. Estimated cost of rearing one female breeding buffalo to maturity in Pakistan.

Cost components	0-1 yr age (Rs)	% of the total	1-3.55 yr age (Rs)	% of the total	Overall cost (Rs)
Value of calf at birth @Rs 5/kg live weight	200.00	11.17	—	—	200.00
Milk given to calf	763.20	42.65	—	—	763.20
Green fodder	305.50	17.07	1817.71	40.17	2123.21
Dry fodder	64.42	3.60	383.29	8.47	447.71
Concentrates	25.42	1.43	151.24	3.34	176.66
Shed expenses	69.72	3.89	414.83	9.17	484.55
Vet. expenses	4.56	0.26	27.13	0.60	31.69
Labor	268.41	15.00	1597.03	35.29	1865.44
Death losses @ 10% & 3%	88.12	4.93	133.71	2.95	221.83
Gross costs	1789.35	100.00	4524.94	100.00	6314.29
Income from hides	3.10		1.05		4.15
Value of farmyard manure	41.06		95.81		136.87
Net cost	1745.19		4428.08		6173.27

No. of heifers = 127
Average at maturity (yrs.) = 3.55
(1st fruitful service)
Ave. cost at maturity (Rs) = 6173.27

Note: Data collected from the village livestock keepers of nine districts of canal-irrigated areas in the Punjab and based on the sample survey conducted during the year 1982–83.

Source: Zafar, 1985.

Table 7.6. Estimated cost of rearing one breeding cow to maturity in Pakistan.

Cost components	0-1 yr age (Rs)	% of the total	1-2.58 yr age (Rs)	% of the total	Overall cost (Rs)
Value of calf at birth @Rs 5/kg live weight	100.00	9.04	—	—	100.00
Milk given to calf	504.90	45.62	—	—	504.90
Green fodder	174.57	15.77	643.58	37.78	818.15
Dry fodder	36.81	3.32	135.71	7.97	172.52
Concentrates	14.53	1.31	53.55	3.14	68.08
Shed expenses	69.72	6.30	256.60	15.05	326.32
Vet. expenses	4.56	0.41	16.81	0.99	21.37
Labor	153.38	13.86	565.45	33.20	718.83
Death losses @ 8% & 2%	48.32	4.37	31.95	1.87	80.27
Gross costs	1106.79	100.00	1703.65	100.00	2810.44
Income from hides	0.90		1.20		2.10
Value of farmyard manure	23.46		57.29		80.75
Net cost	1082.43		1645.16		2727.59

No. of heifers = 16
Average at maturity (yrs.) = 2.58
(1st fruitful service)
Ave. cost at maturity (Rs) = 2727.59

Note: Data collected from the village livestock keepers of nine districts of canal-irrigated areas in the Punjab and based on the sample survey conducted during the year 1982–83.

Source: Zafar, 1985.

analysis, and 4) benefit-cost analysis. This discussion will focus on the last technique, benefit-cost analysis.

Benefit-cost analysis is a form of input-output analysis that is useful for on-farm trials. It is very similar to gross-margin analysis, except that cash and noncash costs and benefits are used to derive the appropriate benefit-cost ratio. As seen in figure 7.2, benefit-cost analysis uses four measures of profitability:

- total net benefits — overall farm profit, or total benefits minus total costs

- net cash benefits — cash benefits minus cash costs
- benefit-cost ratio — total benefits divided by total costs
- returns to capital — cash benefits divided by cash costs

Benefit-cost analysis is potentially valuable for assessing the impact of on-farm technologies. It can be used at different levels of sophistication, letting the researcher or extension worker incorporate the subjective judgments of the farmer. In quantifying the benefit or cost of a technology, values must be assigned to marginal improvements in income and the change in welfare. An

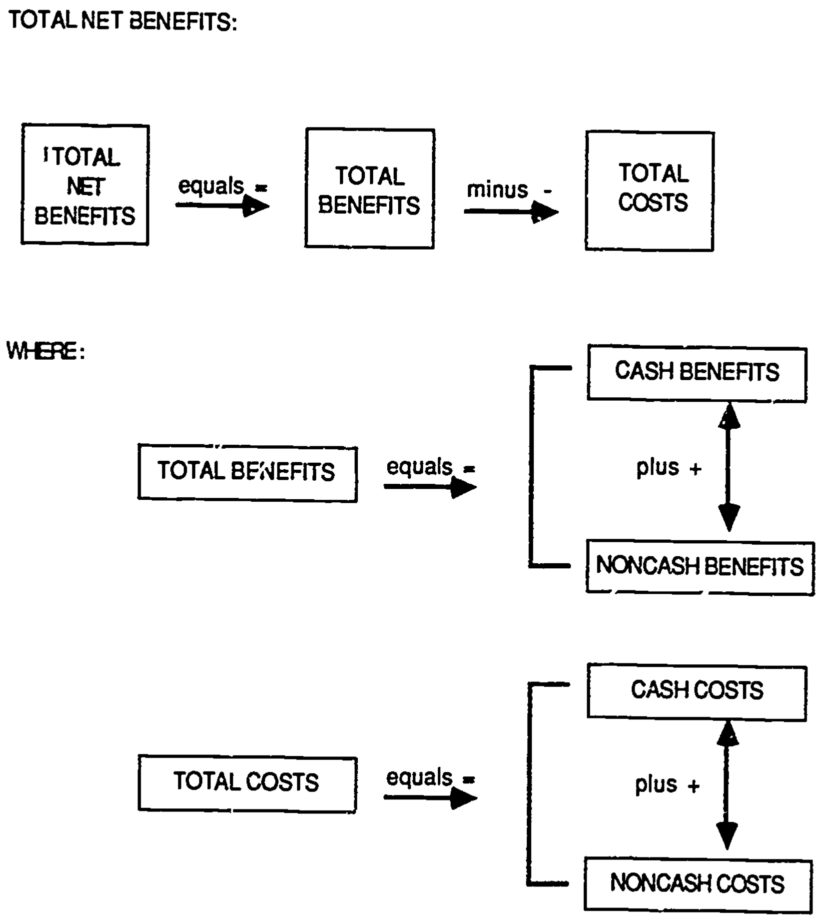


Figure 7.2. Benefit-cost analysis used for measures of profitability.

important criterion in this type of quantification is the farmer's willingness to pay for the technology component. Often it is difficult for the farmer to respond directly to this question. First, the farmer usually does not know about the market price or availability of the technology. Second, it is difficult to attribute marginal changes in productivity to a single factor when a number of interventions are being tested simultaneously. When a single intervention is tested, the farmer can provide insight into the value of that intervention to the overall resource allocation and value system.

For example, in many developing countries, veterinary services are subsidized or free, especially at government-operated facilities, for artificial insemination,

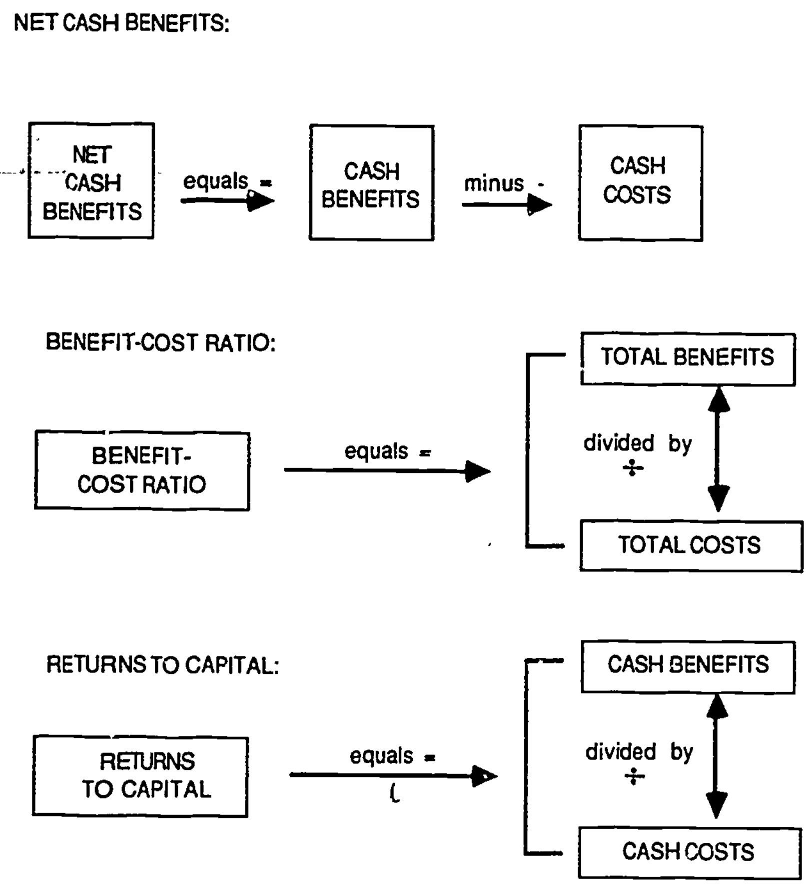


Figure 7.2. continued

vaccination, and castration. When animal health treatments require costly medicines, farmers share the costs. In conducting benefit-cost analysis, the real price of new health practices must be determined carefully because farmers only adopt preventive measures when they are faced with drastic reductions in productivity or with the potential death of their animals.

The following example illustrates benefit-cost analysis. Two feeding technologies for fattening hogs in the Philippines are being compared. Under the current practice, the farmer feeds the hogs kitchen refuse. The technology used for comparison is feeding the hogs commercial feed. Research has produced the following data:

	Farmer's practice	New technology
TECHNICAL DATA		
Breed type	XB	XB
Feeding system	Tethering	Trough
Feeds	Kitchen refuse	Commercial feed
Quantity	850 kg	720 kg
No. of head	3/yr	3/yr
Labor requirement	43 days	59 days
Fattened live weight	50 kg	65 kg
Manure collected	158 kg	163 kg
ECONOMIC DATA		
Price of stock (XB)	₱200/head	
Price of commercial feeds	₱3.50/kg	
Value of kitchen refuse	₱1.50/kg	
Wage rate	₱15/day	
Value of manure	₱0.45/kg	
Price/kg fattened live weight	₱30/kg	

This analysis of benefits and costs can be compiled (continues next page):

Item	Farmer's practice		New technology	
	Quantity	Value (₱)	Quantity	Value (₱)
BENEFITS				
Cash				
Liveweight sales	150 kg	4,500	195 kg	5,850
Noncash				
Manure	158 kg	71	163 kg	73
TOTAL BENEFITS		4,571		5,923

Item	Farmer's practice		New technology	
	Quantity	Value (₱)	Quantity	Value (₱)
COSTS				
Cash				
Stock	3 hd	600	3 hd	600
Commercial feed	—	—	720 kg	2,520
Noncash				
Feed (kitchen refuse)	850 kg	1,275	—	—
Labor	43 days	645	59 days	885
TOTAL COSTS		2,520		4,005
TOTAL NET BENEFITS[a]		2,051		1,918
NET CASH BENEFITS[b]		3,900		2,730
BENEFIT-COST RATIO[c]		1.81		1.48
RETURN TO CAPITAL[d]		7.50		1.88

[a]Total net benefits = total benefits minus total costs
[b]Net cash benefits = cash benefits minus cash costs
[c]Benefit-cost ratio = total benefits divided by total costs
[d]Return to capital = cash benefits divided by cash costs

The above is a typical example of benefit-cost analysis. Total net benefits under both technologies are approximately the same, but the return to capital (cash input) under the traditional technology (farmer's practice) is superior to that under the new technology. Therefore, although total benefits increase under the new practice, given the scarcity of cash, farmers will not adopt this new technology.

Production-function Analysis

Small farmers generally have little control over the climatic, economic, and social environment in which they work. Nevertheless, they must decide what products to produce, how to produce them, and how much to produce. Production-function analysis is a method of making production decisions by estimating and analyzing the range of possible combinations of input factors, such as land, labor, and capital, that may be changed to reach a specific output level. Dillon and Hardaker (1980) define a production function as a function that shows the quantitative relationship between inputs and outputs for some production process.

The production-function approach can be used to study the economic profitability of a technology. Conceptually, the objective of production-function analysis is to study the marginal contribution of each variable input to the total product. With the introduction of a new technology, the analyst tries to estimate the shift in the production function. A typical single input-single output production function is illustrated in figure 7.3. In this case, the value of the shaded area would be studied and attributed to the new technology. Regression coefficients are then used to measure the extent of the impact of each of the inputs (the so-called independent variables) on the output or yield (the dependent variable).

Performing Production-function Analysis

An example of a multifactor production function is expressed mathematically as follows:

Y = f[fodder, concentrates, management level, breed, age,
lactation, udder disease, pregnancy status] + e,

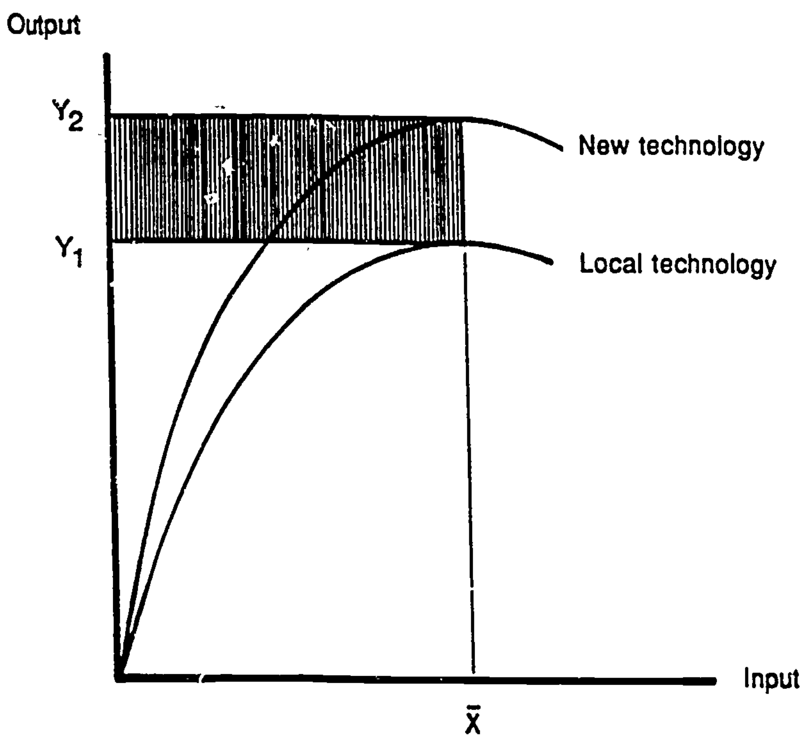


Figure 7.3. A typical single input-single output production function.

where Y is the milk yield in liters/day; fodder is the green and dry fodder intake, measured in total digestible nutrients (TDN) or kilogram weight; concentrates include mineral supplements, measured in TDN; breed is equal to 1 if cross, 0 if indigenous; lactation is equal to the stage of lactation; udder disease is equal to 0 if present, 1 if absent; pregnancy status is equal to 1 if pregnant, 0 if not pregnant; and e is the error margin.

Production-function analysis can be conducted on 40 to 50 farms at different levels of treatment with researcher-managed experimental control. The data must be organized for standard multiple regression, and the relevant production-function parameters, such as marginal product, values of marginal product, input demand, and supply elasticities, must be estimated. The estimated marginal value products can be compared to the price of the product to determine the efficient level of input use.

The following example uses regression results from a study conducted on Indian and Pakistan milk animals. Data were collected in 1986 by surveying 100 farmers from two districts in the Indian and Pakistan Punjab provinces. Table 7.7 shows that the present milk yield of buffalo in the Karnal area is influenced by animal age, stage of lactation, early milk yield, number of large animals in the herd, amount of fodder fed, and amount of labor used per animal.

Table 7.7. Estimated milk production function for Indian buffalo.

Variables	Regression coefficients	t-value
Dependent variable = Present milk yield of buffalo		
Constant	−6.78	
Independent variables		
Animal age (years)	+0.60	(6.60)
Stage of lactation (early = 1; late = 0)	−0.64	(14.0)
Early milk yield (kg/day)	+0.74	(9.37)
No. of large animals	+0.68	(4.62)
Amt. of fodder per animal (kg/day)	+1.28	(1.95)
Amt. of labor per animal (hrs/day)	+0.86	(5.73)
R^2	0.97	

Note: t-Values greater than 2 imply significant coefficients.

Source: Amir et al., 1987.

The magnitudes of the regression coefficients indicate the extent to which specific independent variables increase or decrease milk yield. The variables that increase milk yield the most are amount of fodder fed to the animal (1.28), labor input (0.86), early milk yield (0.74), and animal age (0.60). The signs of the regression coefficients indicate the direction of the effects of the independent variables on the dependent variable. The variables that are positively correlated with present milk yield are animal age, early milk yield, number of large animals in the herd, amount of fodder fed per animal, and amount of labor input per animal. This means that increases in milk yields can be expected from animals that are older, better cared for, and better fed. The only variable that is negatively correlated with milk yield is stage of lactation. This means that milk yield increases in the early stages of lactation, but decreases in the later stages.

Advantages and Disadvantages of Production-function Analysis

Production-function analysis is appropriate for experiment station data, such as screening new technologies by comparing growth curves of animal herds under various types of management. Although this approach has limited value for analyzing farm data, since it is difficult to aggregate farm inputs and outputs, it can help identify patterns of resource allocation on farms and diagnose the weaknesses of farm systems by defining the contributions of inputs to total output.

Production-function analysis can only be carried out with computer support. Standard programs are available for microcomputers that will estimate the necessary statistical parameters. Therefore, this approach is recommended in those situations where there is access to the services of an economist.

Dillon and Hardaker (1980) point out several cautions in the use of production-function analysis. The production function is a physical relationship. Taking account of all the input factors that influence output (such as feed, climate, and labor) it defines the production possibilities open to the farmer. In an ideal world the farmer could combine this information with information on prices and opportunity costs to 1) judge what combination of inputs would be best to use and 2) study the effects on production and input use of alternative government policies influencing prices and the quantity of resources available.

Information from production-function analysis can never be perfect because:

- There will always be uncertainty about the effects of uncontrolled factors such as weather and disease.
- The production function must be estimated statistically from data that may be inadequate.
- The estimated production function can be interpreted only as an average relationship across some set of observations.

- Prices and opportunity costs may not be known with certainty.
- Every farm and farmer is unique. Resource qualities and amounts vary between farms. Farmers vary in their managerial skill, their assessments of opportunity costs and uncertainty, and their preferences about the possibilities open to them.

For the above reasons, information based on production-function analysis must be interpreted cautiously. It can be useful for extension and policy purposes, especially when supplemented with macroeconomic and other microeconomic analyses. It is usually inappropriate for small farms involving a subsistence component and where farmers have to operate in a delicate balance with their physical, economic, and social environment.

Whole-farm Analysis

In whole-farm economic analysis, the farm is considered as a complete entity. The whole crop-and-animal production program is reviewed, and the overall use of farm resources is considered. The analyst is concerned with evaluating consequences of changes in the farm's organization or methods of production. Sometimes the changes are minor, such as using a new pasture type, or the changes can be radical, as when land of little agricultural value is brought into intensive production (Dillon and Hardaker, 1980). Whereas in partial-farm analysis, some aspects of the production system are taken as given and the budget analysis considers only the aspects of the operation that are directly affected by the proposed change, profit budgets prepared in whole-farm analysis take account of all farm income and expense items. Whole-farm analysis includes costs and returns and financial analysis.

Costs and Returns

The costs-and-returns table is a common approach to constructing a whole-farm budget (see table 7.8). Whole-farm budgets are drawn up to show the anticipated consequences of a proposed farm plan. The budget is constructed for the whole farm to allow for calculation of overall performance measures. Cost-and-returns analysis accounts for both cash and noncash costs and fixed and variable costs (unlike partial budgets, which do not include fixed costs).

Financial Analysis

Financial analysis is a form of evaluation that emphasizes the time value of money for on-farm animal trials. Its use is justified since money is a scarce resource and financial analysis considers the present value of money as higher than its future value. This consideration is rationalized because most people

Table 7.8. A cost-and-returns analysis for different types of animal technologies (in Indonesian rupiahs).

Item	Assumption	Traditional[a]	Low cost[b]	High cost[c]
Fixed costs				
Building	8 years	5,000	15,625	15,625
Equipment[d]	p.m.	0	0	0
Animals[e]	4%	7,500	7,500	7,500
Variable costs				
Feed and other	0	750	0	21,000
Minerals/month	250	0	12,000	33,168
Medicine/month	200	0	14,400	20,400
Noncash costs				
Labor	25 mi/day/head			
Total cash costs		13,250	49,525	97,693
Returns				
Young stock[f]		0.9	1.1	1.7
Value of weight gain[g]		85,750	145,000	217,800

Note: US$1.00 = Rp 1100 in 1985.

[a]Assumes meat production of 52 kg.

[b]Assumes meat production of 88 kg.

[c]Assumes meat production of 132 kg based on data provided by RIAP, Sei Putih, per animal cost of Rp 3902/year.

[d]Some minor expenses for drenching equipment.

[e]Animals will keep their value against inflation. Assumes cost replacement stock equals value called stock.

[f]Surviving kid/lamb per parturition.

[g]Ten month interval average weight gain/day/head multiplied by Rp 1650 per kg.

Source: Research Institute for Animal Production, Ciawi (Bogor), Indonesia.

would prefer to receive money now rather than later, or a larger sum of money is expected as a reward for waiting.

Just as it is important to know the interest that can be earned on cash, similarly, in agricultural undertakings, it is important to know whether the initial investments will earn a return in the future. Establishing an animal enterprise is usually costly, and income is not generated until later. The economic feasibility of such projects is determined by discounting all costs and benefits for the projected duration of the activity. Discounting costs and benefits permits the determination of the value today of an amount of money received sometime in the future, i.e., at the end of the project. Present values can then be readily compared, letting the farmer identify the best use of available capital. This method is most suited to analyzing animal-breeding experiments and other long-term animal research. However, because of its financial nature, nonmarket ›le inputs and outputs are excluded from the analysis.

The most important consideration in any discounting exercise is to select an appropriate interest rate; for example, to get the present value of US$100 to be repaid in 1 year at a interest rate of 12%, the following formula should be used:

$$FV = PV(1 + r)^t \qquad \text{or} \qquad PV = \frac{FV}{(1 + r)^t},$$

where FV is the future value, PV is the present value, r is the interest rate (expressed in decimal form), and t equals the time horizon for discounting (for example, t = 1 for 1 yr and t = 2 for 2 yrs).

If, for example, an analyst wanted to determine the pro..itability of a small-scale sheep enterprise planned for 3 years of operation, financial analysis could be performed, with discounting, using a 10% interest rate as follows:

Year	Gross returns 1	Gross costs 2	Discount factor 3	Discounted returns 1 × 3	Discounted costs 2 × 3
1	2,000	5,000	0.909	1,818	4,545
2	4,000	2,500	0.826	3,304	2,065
3	6,000	2,500	0.751	4,506	1,877
TOTALS:	12,000	10,000		9,628	8,487

Net present value = total discounted returns − total discounted costs
= 9,628 − 8,487
= 1,14!

Benefit-cost ratio = total discounted returns ÷ total discounted cost
= 9,628 ÷ 8,487
= 1.13

Looking at the nondiscounted costs and returns of the sheep enterprise, the estimated net returns are 12,000 − 10,000 = 2,000. However, the discounted net returns (net present value) are only 1,141. The net present value is lower than net returns because the opportunity cost of investing the money was accounted for as a cost.

The **benefit-cost ratio** in financial analysis is the ratio of discounted returns to discounted costs. Its value indicates that for every unit of cost incurred, there will be a corresponding 1.13 units of return. The **internal rate of return** is the interest rate at which net present value is zero. By trial and error, it was determined to be approximately 37% for this example. When net present value is zero, total discounted returns equal total discounted costs. This implies the internal rate of return is the rate of return on investment provided by the enterprise. Stated another way the internal rate of return is the maximum interest that the farmer can pay for the inputs used if the farmer is to recover his investment and operating expenses and still break even (Gittinger, 1982).

SUMMARY

This chapter has been a survey of the various techniques available for economic analysis of new technologies. These can be used for screening technologies for profitability at the research station or for determining the benefits resulting from a new on-farm trial. The strengths and weaknesses of each technique have been discussed. These should be kept in mind when the researcher or analyst is performing an economic analysis so that the appropriate technique is chosen based on the economic data that is available, the scope of the research, and the results which are desired. By having a variety of analysis techniques which can be utilized, the results of an OFAR trial can accurately be determined.

CHAPTER 8

MARKETING

PURPOSE

Because farmers' production decisions are based mostly on market considerations, researchers and extension workers concerned with animal production must be knowledgeable about marketing issues. Often, farmers ignore new technology — even when it appears to be better than their current practices — due to market limitations. Production and marketing should be considered together, so that one becomes an incentive to enhance and promote the other. By examining and analyzing the costs associated with marketing animals, the gains resulting from new animal-production technology can be determined.

OBJECTIVES

After completing this chapter, the reader should be able to:

- Define market, marketing, and marketing system.
- Explain demand and supply elasticities.
- Determine equilibrium price for animals and animal products by graphing a supply-and-demand schedule.
- Define and describe the different costs and margins involved in the marketing system.

THE MARKET

A **market** is a place where buyers and sellers meet to trade. It may be local, regional, national, or international. In developing countries, many animal markets are literally no more than a patch of open ground. A perimeter fence is sometimes built to confine the animals if convenience justifies the expense. Pens are provided for pigs and other small stock. In more developed marketing systems, there may be a watering-point, shelter for farmers and animals, loading ramps, scales, and other amenities. Marketplaces are usually owned and controlled by the local public authority. Capital costs of market installations and costs of running the market (such as water supplies, maintenance, and supervision) are recovered through a market fee assessed on the animals that are sold. These fees will vary according to the services provided by the market authority.

A good market for livestock is a place where a producer can take or send animals and be reasonably sure of receiving offers from a number of buyers. A trader views a market as a place where stock can be bought in a short time without having to travel long distances to many producers. The basic function of the market is thus to bring together sellers and buyers to trade under convenient conditions at a prearranged time and place. If there are any official controls over prices, quality, or terms of sale, they can be more easily exercised at such a center. If the market is not regulated, prices tend to reflect supply and demand conditions prevailing in the marketing system.

The place where animal producers can sell their animals or by-products should be considered when designing On-farm Animal Research (OFAR). Participating in the research involves risk. A farmer who owns only one cow, for example, accepts a big risk by participating. First, the cow's life may be at stake since the effects of the new technology on the cow are not certain. Second, if the technology improves the cow's production, it may be difficult to market the extra goods. For instance, if the new technology increases the cow's milk production, the farmer may not find a market for additional milk. Therefore, researchers must know that there is or will be a ready market for the produce. This information can then be used to encourage farmers to cooperate actively in OFAR.

Marketing

Marketing includes all the activities performed in moving commodities from the producer to the consumer. It also includes all the exchange activities of buying and selling; all the physical activities performed to give the commodity increased utility; and all the auxiliary activities such as financing, risk-bearing, and disseminating information to participants in the marketing process. Marketing is thus a result of specialization and trade in the economic system.

Marketing has the following three basic functions:

Exchange function	Involves the transfer of ownership of products through buying, selling, pricing, and renting. This usually includes price negotiations and product valuation. For example, an animal wholesaler who goes to a farm and negotiates the purchase of a hog is performing the exchange function.
Physical function	Involves physical movement as well as transformation of the commodity into more usable forms through transportation, handling, storage, processing, and packaging. Thus, a trucker who buys cattle and transports it to a wholesaler or butcher is performing a physical function.

Facilitating function — Makes possible the efficient performance of the exchange and physical functions through financing, risk-bearing, marketing information, issuing grades and standards, advertising (demand creation), and research. Often, the facilitating function is supported and performed by government agencies to increase the efficiency of the overall marketing system. When a government finances the storage of hog carcasses until they are needed, it is performing a facilitating function.

In developing countries, village marketing is very informal. In some cases, marketing is still primitive; that is, farmers barter by exchanging one product for another. (Products may even be bartered for services.) Valuation of products depends greatly on sociological factors such as brotherhood and religion. Farmers usually lack information about where and when to market their products efficiently. Their small-scale operations result in an inability to offer aggregate amounts of a product for sale to large metropolitan areas. Since farmers do not know competitive prices for their products, and often have to sell under a ceiling price set by a marketing board, they often get low prices for their goods. Farmers who are unable to transport their animals to the marketplace are also likely to get low prices.

Marketing System

A **marketing** system includes all activities involved in the flow of goods from the point of initial production to the ultimate consumer (see figure 8.1). It involves processing raw materials into final products and then distributing them to the consumer. Thus, it includes the exchange activities associated with transferring property rights to commodities, physically purchasing and allocating resources, handling products, disseminating information to participants, and making institutional arrangements for facilitating these activities. A comparison of animal and crop marketing is shown in table 8.1.

The marketing system acts as a communication channel by which the demands of the consumers are transmitted to the producers through the pricing mechanism. Prices signal producers, intermediaries, and consumers to buy or sell a commodity and what quantities to buy or sell. The dynamics of an animal marketing system can be viewed as follows: Animal production is the result of the farm household's application of energy and skill, purchased and non-purchased resources, and available technology. Through the efforts of the household, surplus products enter the marketing system. At the other end of the two-way path of influence is the consumer, whose desires dictate to a major extent the activities of the marketing system.

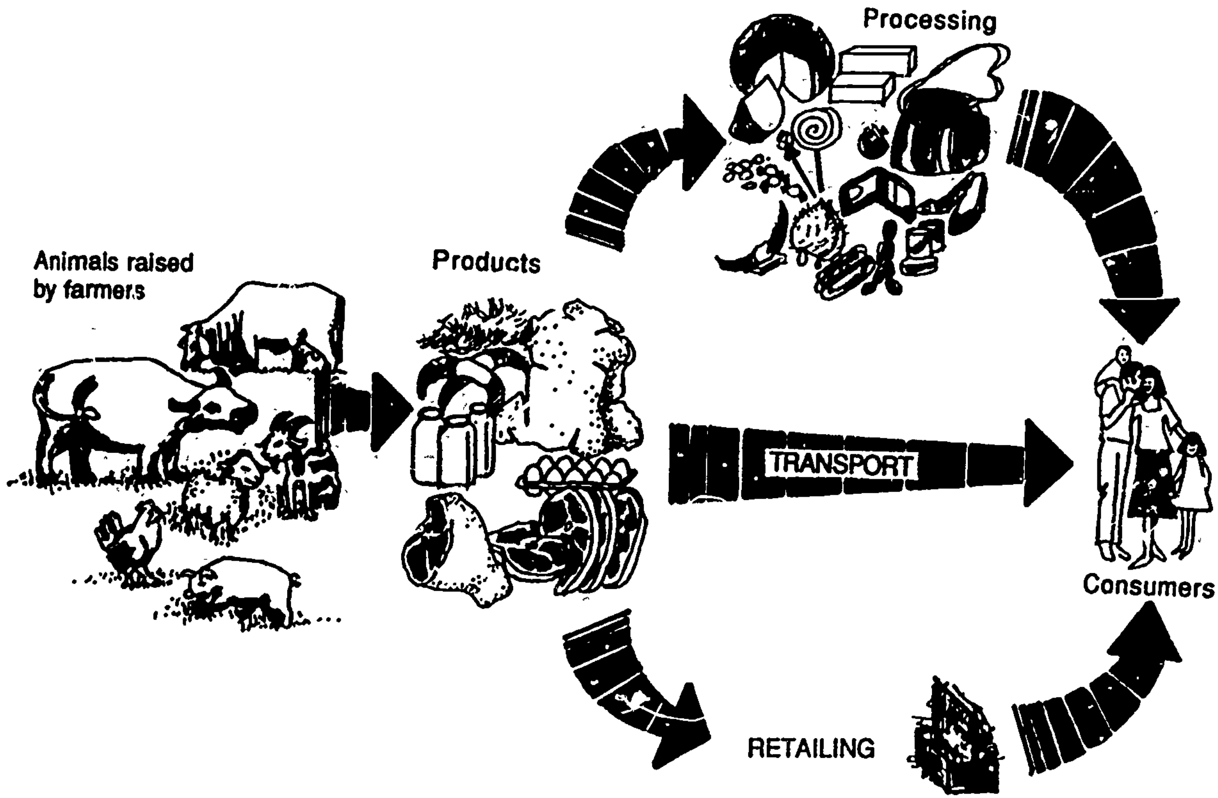


Figure 8.1. Movement of products from producers to consumers.

Table 8.1. Comparison of characteristics of animal and crop marketing.

Factors	Animals	Crops
Valuation of product	Difficult	Relatively easy
Grading system	Less standardized	More standardized
Market organization	Less organized	Organized

Marketing channels are routes through which products pass as they are moved from the farm to the consumer. For example, in the Philippines chickens pass through five channels: assembler-wholesalers, wholesalers, wholesaler-retailers, cooperatives, and retailers. On the other hand, cattle marketing in Cebu, Philippines, involves only wholesaler, intermediary, and retailer. In this city, 50% of the producers sell their cattle to wholesalers, 30% to intermediaries, and 20% to retailers. The wholesalers transport their cattle to the city in their locality for slaughter or ship them live to Manila. Two-thirds of the retailers take their cattle to the city for slaughter. Three-fourths of the intermediaries sell their cattle to local buyers and wholesalers, and one-fourth sell their cattle to retailers.

Animal Marketing System

From a single animal, a farmer can produce and market many products, such as meat, milk, traction, power, manure, and hides (see table 8.2). As animal-marketing systems develop, the need for marketing skills and operations increases.

Table 8.2. Marketable animal products.

Animal	Marketable product
Sheep	Milk, hides, hooves, meat, wool
Poultry	Meat, feathers, eggs, manure
Horses and donkeys	Power, manure
Goats	Meat, milk, butter, ghee, skin, hooves, manure, mohair
Rabbits	Meat, fur, mohair
Cattle and buffalo	Meat, milk, power, manure, horns, hides, hooves
Hogs	Meat, lard

In some cases, several functions may be carried out by one person or company acting as a market integrator, such as a meat processor/wholesaler. Market integration can help reduce the risks associated with fluctuations in the price of animals and retail cuts of meat. In addition, it is easier for the larger firms resulting from market integration to provide specialized management and the capital necessary for investments in plant and equipment, which can reduce the cost of marketing the product. In some cases, producer cooperatives can supply a broader base for raising capital while providing several marketing functions.

In addition, market facilities are needed as a point of assembly for animals. At the collector's facilities, auctions are often used to set prices and facilitate exchange; however, this is not necessary if grade standards have been established and market news services are available. Under these circumstances producers can sell and deliver directly to the slaughterhouse since the slaughterhouse buyer has a sufficient description of the animal from grade and weight specifications and information on price conditions to make a bid. Selling animals at markets is advantageous to producers when there are several buyers at the market. Competitive bidding among buyers assures the producer of getting the best price for each animal. In areas where there is no animal market or producers' association, farmers can sell directly to butcher-retailers on a live-weight or carcass-weight basis or to shippers on a live-weight basis.

Meat Marketing System

Meat marketing begins with the sale of the live animal for slaughter. In some countries, animals are fed grains for growth and finishing. In other countries, animals consume roughage, household wastes, or other feeds that are not directly usable as human food.

The finished animal is transported to the slaughterhouse for processing. When transportation facilities are limited, slaughtering operations may be centralized near large urban centers, and small operations may sell fresh meat to local consumers. In processing animals for meat, regulations concerning cleanliness of facilities and control of disease are essential for providing consumers with quality products.

Live animals and carcasses are graded according to the tastes of the consumer. The grade influences the price consumers are willing to pay for the product. Grading systems usually classify carcasses at the point of slaughter since meat is often marketed as whole or split carcasses. Table 8.3 shows common bases for grading animal carcasses and products.

Cooperative Marketing

Cooperative marketing is based on the premise that a group of producers can achieve better results by combining their efforts and resources than by

Table 8.3. Bases for grading animal carcasses and products.

Product	Basis for grading
Cattle carcass	Weight
Sheep carcass	Male or female
Buffalo carcass	Color
Goat carcass	Maturity, amount of fat tissue
Milk	Color, odor, source (cow, buffalo, goat)
Eggs	Size, color, weight, shell
Hide or skin	Weight, leather, size

operating separately. Their bargaining power is increased through control of a larger volume of supplies, especially if that volume represents a major part of the total supplies in the area. The aim of a cooperative marketing system is thus to secure better market outlets, obtain higher prices, and perform at a lower cost of operation. A corollary aim is to take over some profitable marketing functions, especially if the scale of operations permits investment in facilities and equipment. Hence, for animals, it is sometimes beneficial for cooperatives to go beyond selling and develop cooperative arrangements for slaughtering, wholesaling, and retailing meat. In the Philippines, backyard buffalo farmers get low prices for their products. If they could organize into a cooperative or association, they could create enough volume of animals to sell directly to processors. This would eliminate dealing with intermediaries and should enable the farmers to get better prices for their goods. There is a drawback to cooperative marketing, however. The estimation of the value of animals is not easy and, as one who has visited a livestock market knows, subject to heated discussion. Such debates will also take place within marketing cooperatives and may make cooperative management difficult.

PRICES

Market prices are determined by a complex and dynamic interaction between demand and supply. Prices are the mechanism by which products are allocated among different groups of consumers based on their ability to pay.

Demand

Demand is the quantity of a commodity that buyers will purchase in a given market, in a given period, and at a given price. The inverse relationship between price of a commodity and quantity demanded is called the law of demand.

Demand can refer to a schedule or a curve. A demand schedule lists the different quantities of a commodity that consumers will purchase during a certain period if the corresponding price is effective (see table 8.4). A **demand curve** is a demand schedule plotted on a graph, with price plotted on the vertical axis and quantity on the horizontal axis (see figure 8.2). Demand for a commodity is affected by factors other than price, such as the following:

- Food habits of the population. These are based on convention, taste preferences, climate, religious beliefs, and other motives. For example, in Muslim communities, demand for pork is low.
- Income. As income increases, the demand for certain commodities, e.g., red meat, also tends to increase.
- Population. Normally, population and demand have a positive correlation: as the number of consuming units increases, demand also increases.
- Perishability of the product. Because animal products, such as meat and milk, spoil quickly, sellers often drop their prices as their products age. A decrease in the price of a commodity normally increases consumption of it.
- Current price of alternative products. Demand is particularly affected by the current availability and price of alternative products. If the price of cow's milk increases, consumers tend to substitute buffalo or goat milk; therefore, the demand for buffalo and goat milk increases as the demand for cow's milk decreases.

Table 8.4. Demand schedule for pork.

Price per kilogram (Philippine pesos)	Quantity (kilograms)	Total revenue (price × quantity)
20.50	18	369.00
30.50	15	457.50
40.50	13	526.50
50.50	12	606.00

Price Elasticity of Demand

Price elasticity of demand is the responsiveness of demand to changes in price. As the price of a good changes, consumers respond by changing the amount of the good they purchase. Determining demand elasticity is important to sellers because it lets them predict the amount of revenue they can earn from selling different quantities of goods at varying prices. Total revenue depends on the

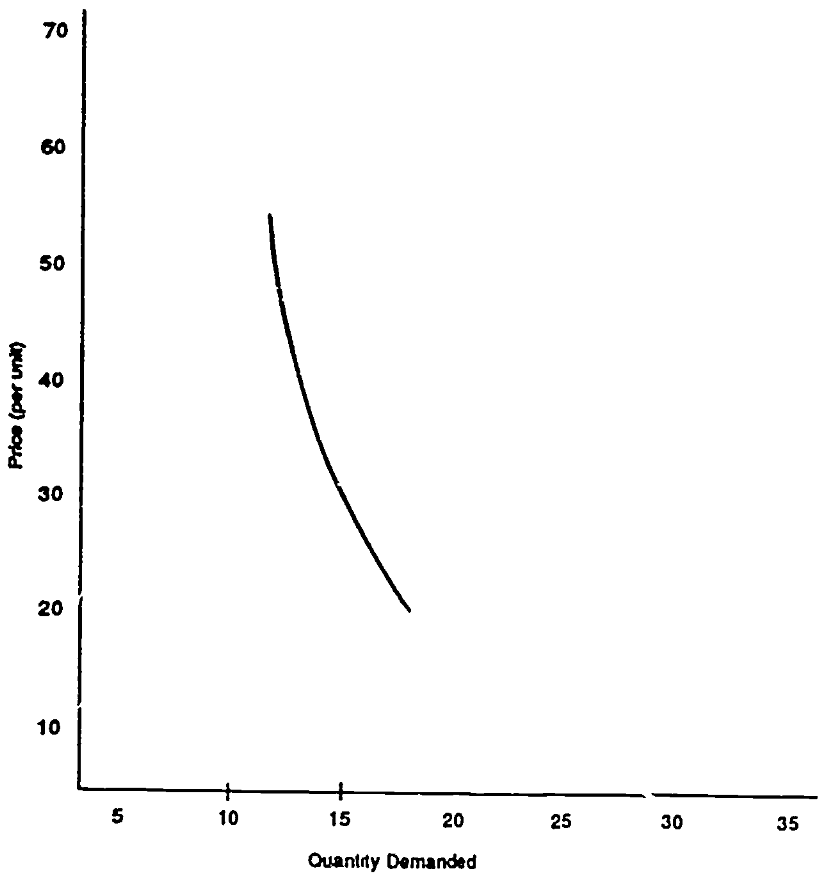


Figure 8.2. Demand curve.

increase in quantity of goods sold in response to a given price decrease. Price elasticity of demand is determined by dividing the percentage change in quantity demanded by the percentage change in price. And so:

$$E_d = \frac{\text{Percentage change in quantity}}{\text{Percentage change in price}}$$

$$= \frac{(Q_2 - Q_1)}{(Q_2 + Q_1)} \div \frac{(P_2 - P_1)}{(P_2 + P_1)} \quad ,$$

where E_d is the price elasticity of demand, Q_1 is quantity 1, Q_2 is quantity 2, P_1 is price of quantity 1, and P_2 is price of quantity 2. The computed value for E_d will always be negative, due to the inverse relation between price and quantity. Thus, if there is a positive change (increase) in price, there will be a negative change (decrease) in the quantity demanded; if there is a negative change (decrease) in price; there will be a positive change (increase) in the quantity demanded. The absolute (non-negative) value of E_d is used when classifying demand.

Demand curves can be classified in three ways depending on their elasticity:

Inelastic demand	The percentage change in quantity is less than the percentage change in price; thus, the absolute value of the elasticity is greater than or equal to zero and less than or equal to one ($0 \leq E_d \leq 1.0$). If demand for a product is inelastic, a decrease in its price decreases total revenue because the percentage decrease in price is greater than the percentage increase in quantity demanded. An increase in price has the opposite effect and will increase total revenue.
Elastic demand	The percentage change in quantity is more than the percentage change in price; thus, absolute value of the elasticity is greater than one ($E_d \geq 1.0$). If demand for a product is elastic, a decrease in its price increases total revenue, and an increase in its price decreases total revenue.
Unit elasticity	The percentage change in quantity is exactly the same as the percentage change in price; thus, the absolute value of the elasticity equals one ($E_d = 1.0$). If demand for a product has unit elasticity, an increase or decrease in price leaves total revenue unchanged.

The demand schedule for pork given in table 8.4 serves as an illustration of inelasticity of demand. Since the percentage decrease in quantity demanded is less than the percentage increase in price, an increase in the price of pork causes an increase in total revenue, and the absolute value of E_d will be less than one.

The following example illustrates the price elasticity of demand. The price of pork in 1984 averaged ₱43.00 per kilogram with per capita consumption of pork at 24 kilograms. In 1985 the price of pork increased to ₱46.00 per kilogram with per capita consumption at 20 kilograms. The price elasticity of demand for pork is determined in the following manner:

$$E_d = \frac{(Q_2 - Q_1)}{(Q_2 + Q_1)} \div \frac{(P_2 - P_1)}{(P_2 + P_1)}$$

$$= \frac{(20 - 24)}{(20 + 24)} \div \frac{(46 - 43)}{(46 + 43)}$$

$$= -4/44 \div 3/89$$

$$= -2.70$$

Thus, the absolute (non-negative) value of the price elasticity of demand for pork is 2.70. Since this value is greater than 1, pork has elastic demand. Thus, whenever the price of pork increases 1%, the quantity purchased decreases 2.70%, and total revenue decreases. When the price of pork decreases 1%, the quantity purchased increases 2.70%, and total revenue increases.

Income Elasticity of Demand

Income elasticity of demand is the responsiveness of demand to changes in income. It is equal to the percentage change in quantity demanded divided by the percentage change in income. And so:

$$Y_e = \frac{\text{Percentage change in quantity}}{\text{Percentage change in income}}$$

$$= \frac{(Q_2 - Q_1)}{(Q_2 + Q_1)} \div \frac{(Y_2 - Y_1)}{(Y_2 + Y_1)} \quad ,$$

where Y_e is the income elasticity of demand, Q_1 is quantity 1, Q_2 is quantity 2, Y_1 is income in period 1, and Y_2 is income in period 2.

When income elasticity is negative, the commodity is identified as an inferior good; when it is positive, the commodity is considered a normal good. A normal good is usually considered a superior good if its income elasticity is greater than one. Income elasticity for a good is likely to vary considerably, depending on the level of the consumer's income. Thus, a good may be superior at low levels of income, normal at intermediate levels of income, and inferior at high levels of income. The following is an example of how to determine the income elasticity of demand.

A farmer's disposable income in April 1986 was ₱1,000, with a pork consumption of 1 kilogram. In May 1986, the farmer's income increased to ₱1,200 and his pork consumption increased to 1.5 kilogram. The farmer's income elasticity of demand for pork can be determined in the following way:

$$Y_e = \frac{(Q_2 - Q_1)}{(Q_2 + Q_1)} \div \frac{(Y_2 - Y_1)}{(Y_2 + Y_1)}$$

$$= \frac{(1.5 - 1.0)}{(1.5 + 1.0)} \div \frac{(1200 - 1000)}{(1200 + 1000)}$$

$$= 0.5/2.5 \div 200/2{,}200$$

$$= 2.20$$

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Thus, the income elasticity of demand for pork is 2.20, which means that when the farmer's income increases by 1%, the quantity of pork the farmer demands increases by 2.2%, and when the farmer's income decreases by 1%, the quantity of pork the farmer demands decreases by 2.2%, assuming all other market conditions remain the same.

Supply

Supply is the quantity of a commodity offered for sale in a given market, in a given period, and at a given price. The quantity of meat placed on the market varies directly with price. The direct relationship between price and quantity supplied is called the law of supply.

Supply can refer to a schedule or a curve. A supply schedule lists the different quantities of a commodity that producers will offer for sale during a certain period if the corresponding price is acceptable (see table 8.5). A supply curve is a supply schedule plotted on a graph, with price plotted on the vertical axis and quantity on the horizontal axis (see figure 8.3). In addition to price, supply of a commodity is affected by the following factors:

- Cost of production. For example, feeds constitute 70% of the total cost of producing chicken meat in the Philippines. A 1% increase in the price of feeds reduces the quantity of chicken produced by 0.18%.
- Delayed output responses. For example, if farmers reduce the total number of breeding cows, they are cutting back production of slaughterstock for several years to come.
- Production cycles. Sheep, goats, and pigs have shorter reproductive cycles than the larger ruminants, so their period of output adjustment is shorter.
- Seasonal factors. In some countries grazing is difficult in certain seasons, such as winter or the severe dry season. During these periods, animal owners tend to sell more of their stock, causing marked seasonal increases in supply.

Table 8.5 Supply schedule for pork.

Price per kilogram (Philippine pesos)	Quantity (kilograms)
20.50	10
30.50	12
40.50	13
50.50	15
60.50	[illegible]

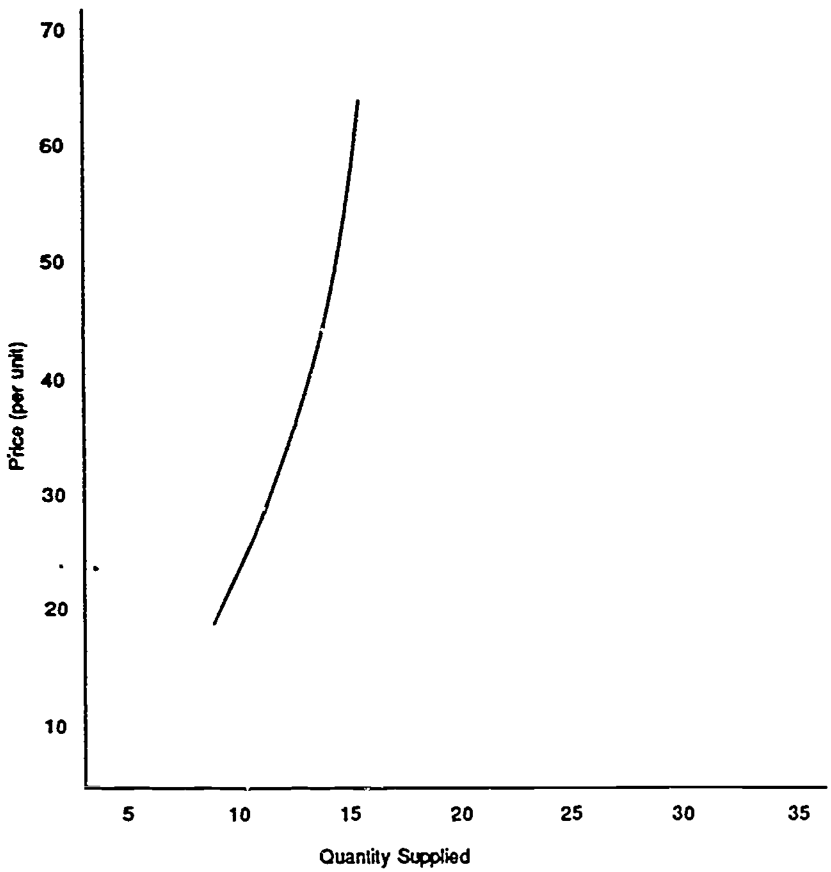

Figure 8.3. Supply curve.

- Meat production from draft and dairy animals. In areas where cattle and buffalo are kept primarily as draft animals, the supply of beef in the market depends on the number of retired draft animals that are available.
- Disease and drought. Disease and drought seriously reduce the breeding stock population, eventually leading to reductions in supply.

Elasticity of supply indicates the responsiveness of quantity supplied to changes in price. When a percentage change in price causes little or no percentage change in quantity supplied for a commodity, supply of the commodity is inelastic. When a percentage change in price causes a large percentage change in quantity supplied for a commodity, supply is lastic for that commodity. The greater the elasticity of supply, the greater is the proportionate change in quantity and the less the proportionate change in price caused by any shift in the demand curve. The formula for price elasticity of supply is the same as for price elasticity of demand. Since the relationship between price and quantity is direct, however, the computed value of E_s will always be positive.

$$E_s = \frac{\text{Percentage change in quantity}}{\text{Percentage change in price}}$$

$$= \frac{(Q_2 - Q_1)}{(Q_2 + Q_1)} \div \frac{(P_2 - P_1)}{(P_2 + P_1)} \quad ,$$

where E_s is elasticity of supply, Q_1 is quantity 1, Q_2 is quantity 2, P_1 is price of quantity 1, and P_2 is price of quantity 2.

The following example illustrates the calculation of the elasticity of supply.

The price per head of cattle in an Indian village in April 1986 was Rs 950. Twenty head were marketed in April 1986. The price per head was Rs 1,000 in May 1986. Thirty head were marketed in May. The elasticity of supply can then be determined as follows:

$$E_s = \frac{(Q_2 - Q_1)}{(Q_2 + Q_1)} \div \frac{(P_2 - P_1)}{(P_2 + P_1)}$$

$$= \frac{(30 - 20)}{(30 + 20)} \div \frac{(1000 - 950)}{(1000 + 950)}$$

$$= 10/50 \div 50/1950$$

$$= 7.80$$

Thus, the price elasticity of supply for cattle in this Indian village is 7.80. This means that when the price of cattle increases 1%, the quantity supplied increases 7.80%, and when the price of cattle decreases 1%, the quantity supplied decreases 7.80%.

Law of Supply and Demand

The law of supply and demand determines market price. A supply-and-demand schedule is shown in table 8.6. Plotting these points on a graph reveals the supply and demand curves. The point where the downward-sloping demand curve intersects the upward-sloping supply curve is the equilibrium of price and quantity (see figure 8.4). Price is determined at this equilibrium point. If supply exceeds demand, more quantity is in the market than can be sold; hence, there is a surplus of goods in the market. To increase the quantity demanded and clear the market of the surplus, the price will need to be reduced. If demand exceeds supply, there is an insufficient quantity of goods in the market; that is, there is a shortage. An increased demand for the good will therefore drive up

Table 8.6. Supply-and-demand schedule for pork.

Price per kilogram (Philippine pesos)	Quantity supplied (kilograms)	Quantity demanded (kilograms)
20.50	1,000	8,000
30.50	2,000	6,500
40.50	3,000	5,200
50.50	5,000	2,500
60.50	8,000	1,000

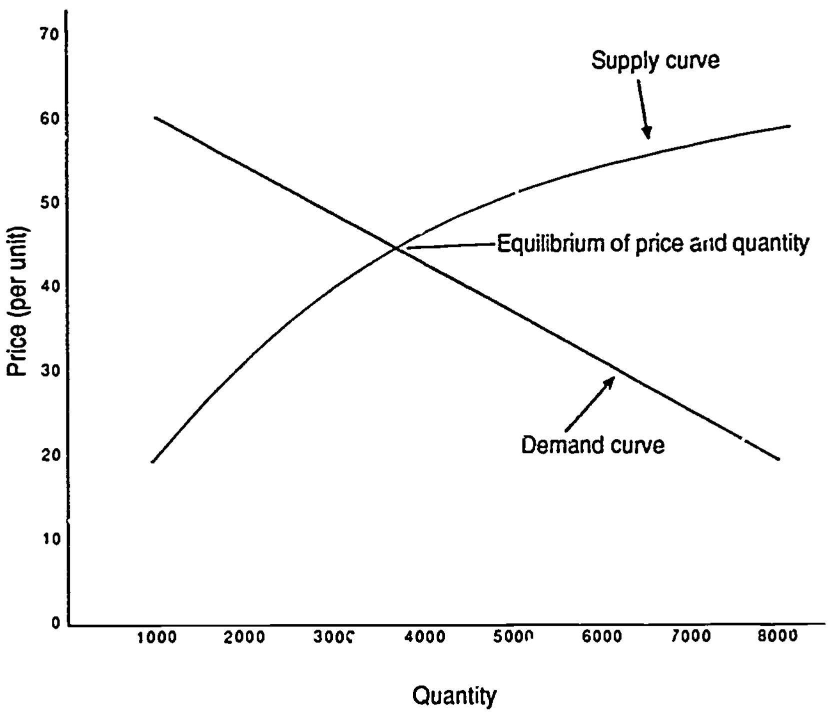

Figure 8.4. The law of supply and demand.

the price. As buyers and sellers interact, prices tend to move toward equilibrium.

COSTS AND MARGINS

Costs and margins of marketing animals reflect the efficiency of a marketing system. Since the costs of marketing are affected by the marketing channels used and the marketing services received (see table 8.7), knowing costs and margins helps animal producers determine the most efficient way to market their products.

Table 8.7. Typical costs in marketing animals.

Cost category	How incurred
Labor	Feeding, picking up, delivering, and slaughtering animals
Transportation	Gasoline and oil, vehicle rental
Storage	Electricity
Certain risks and finance costs	Risk of animals dying in transit, interest loans to purchase livestock, interest on commodity trading contracts
Other	Feeds during transport; marketing fees; slaughtering fees; taxes, licenses, permits; facilitator's fees; repairs and maintenance; costs of hauling equipment, costs of water and other materials (for example, ropes and wrappers)

The Costs of Intermediaries in the Market

The significance of the number of intermediaries operating in a market is often misunderstood. The general misconception is that the presence of many intermediaries causes consumers to pay high prices and farmers to get low prices. According to this view, the fewer intermediaries, the more efficient the market. This view is often incorrect.

Intermediaries usually cannot affect prices significantly. If they try to widen the margins by charging more than their services are worth, the demand for their services will decrease. Moreover, if farmers distributed their produce one by one to each consumer, without the use of intermediaries, the market would be exceedingly inefficient. A group of farmers could hire one trucker to haul all their produce at a fraction of what it would cost for all of them to haul their own produce. Moreover, a retailer could sell to consumers the loads brought in by several truckers more efficiently than the truckers could sell their loads separately. Therefore, in some cases, using intermediaries lowers marketing costs.

Marketing Margins

A **marketing margin** is the difference between prices at different levels of the marketing system. The margin between farm and retail is the difference between what the consumer pays and what the producer receives for the agricultural produce. It is expressed as the following:

Marketing margin = $P_2 - P_1$,

where P_2 is price at one level in the market (such as the retail level) and P_1 is price at another level in the market (such as the farm level).

Based on this definition, a marketing margin is the difference between the primary and derived demand curves for a particular product. Primary demand is determined by the response of the consumers and is based on retail price and final quantities purchased. Derived demand, on the other hand, is based on the relation between price and quantity at the point where products leave the farm or at intermediate points where they are purchased by wholesalers or processors.

The concepts of primary and derived supply are analogous to those of demand. Primary supply, however, refers to the relationship at the producer, or farm level. Derived supply is the relation between price and quantity at the consumer level.

The retail price is established at the point where the primary demand curve and the derived supply curve intersect. The farm-level price, on the other hand, is based on the point where the derived demand curve and the primary supply curve intersect. The resulting difference in the two prices is the marketing margin (see figure 8.5).

To illustrate, if the retail price of beef is ₱50.00 per kilogram, and the marketing margin is ₱40.00 per kilogram, then the farm price of beef can be determined by:

Marketing Margin = $P_2 - P_1$,

$P_1 = P_2 -$ Marketing Margin

= ₱50.00 − ₱40.00

= ₱10.00 per kilogram

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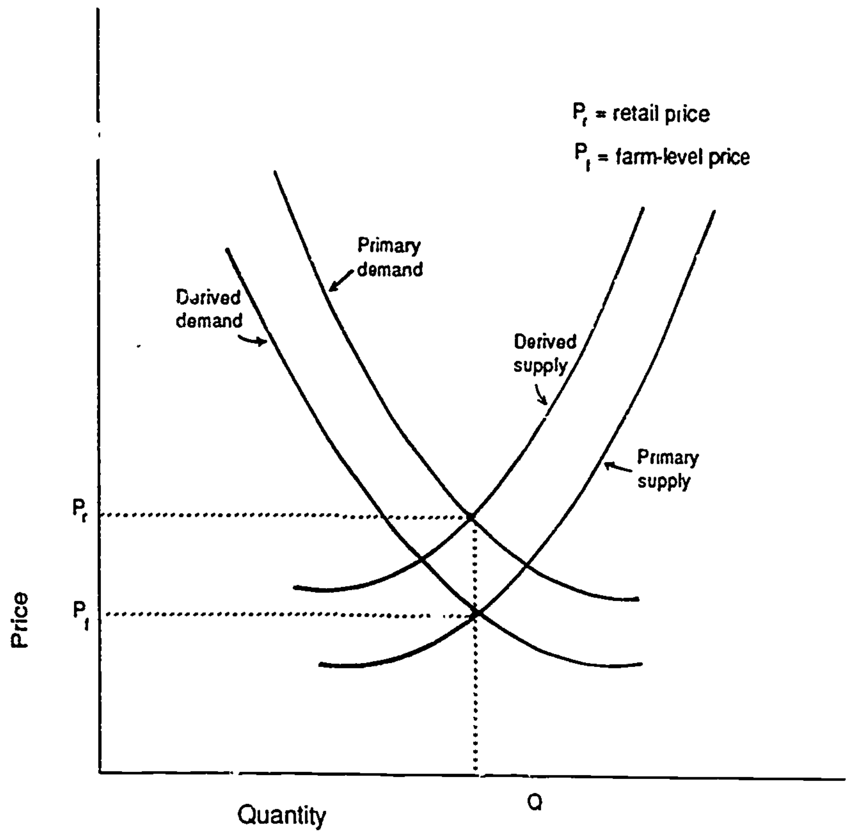

Figure 8.5. The marketing margin, (P_r -- P_f)

A marketing margin may also be defined as the price of a collection of services, such as collecting, processing, transporting, and retailing. This price is a function of supply and demand for all such services. A particular marketing margin would thus depend on the particular demand-and-supply relation for services. Margins of products differ because marketing services vary.

There are several types of margins and methods of calculating them. Some of the more common margins are the wholesale margin and the retail margin. The wholesale margin is the difference between what the processor or wholesale agent pays the producer (producer's price) and what the retailer pays the processor or wholesaler (processor's or wholesaler's price). The retail margin is the difference between what the retailer pays the processor or wholesaler (processor's or wholesaler's price) and what the consumer pays the retailer (retailer's price). When the margin is expressed in dollars and cents, it is ca. the price spread. The percentage margin is the price spread between two levels in the market divided by the buying price, expressed as a percent. The mark-up is the price spread between two levels in the market divided by the selling price, expressed as a percent. The following example illustrates how these values can be obtained.

A dairy farmer sells 12 kilograms of milk for ₱2.50 per kilogram to a processor. The processor sells the packaged milk to a retailer for ₱3.00 per kilogram (₱36.00 total). The consumer pays ₱4.00 per kilogram (₱48.00 total). The wholesale margin is determined by:

$$\begin{aligned} \text{Wholesale margin} &= \text{Processor's price} - \text{Producer's price} \\ &= ₱3.00 - ₱2.50 \\ &= ₱0.50 \end{aligned}$$

The retail margin is determined by:

$$\begin{aligned} \text{Retail margin} &= \text{Retailer's price} - \text{Processor's price} \\ &= ₱4.00 - ₱3.00 \\ &= ₱1.00 \end{aligned}$$

The total price spread between the farm and retail levels is then equal to the sum of the retail and wholesale margins:

$$\begin{aligned} \text{Total price spread} &= ₱0.50 + ₱1.00 \\ &= ₱1.50 \end{aligned}$$

The percentage margin between the wholesale and retail levels is:

$$\begin{aligned} \text{Percentage margin} &= \frac{\text{Price spread}}{\text{Buying price}} \times 100 \\ &= (₱0.50/₱3.00) \times 100 \\ &= 16.7\% \end{aligned}$$

The mark-up at the retail level is then determined by:

$$\begin{aligned} \text{Mark-up} &= \frac{\text{Price spread}}{\text{Selling price}} \times 100 \\ &= (₱1.00/₱4.00) \times 100 \\ &= 25\% \end{aligned}$$

Transportation Costs

One of the highest costs involved in marketing animals is transportation. Since total transportation costs increase with distance, transportation costs create a geographic limit for each market. Therefore, there is a certain distance from a market at which it is no longer profitable to transport goods. As a result, poor-quality products are often consumed in the immediate area of production since their lower value makes transportation to distant markets unprofitable.

The distance from a market at which transportation is profitable is called the **market area**. The radius of the market area is determined by the following equation:

$$\text{Radius} = \frac{\text{Profit per head of livestock}}{\text{Transportation cost per head per kilometer}}$$

The farther from the market area that the animals are produced, the higher is the transportation cost to the market, and the lower is the producer's profit. In addition, a price increase or decrease at the center of the market affects producers who live near the market less than those who live in outlying areas. Although the absolute price change is the same for all producers, the relative price change differs due to the transportation costs incurred by those who live further from the market area.

Not only does transportation cost determine the market area for a given market, it also affects the movement of goods between markets, or intermarket relationships. Prices in two markets for the same good should differ by no more than the transportation cost between the two markets. The dividing line at which producers do not prefer one market over another is the point at which the producer receives equal net prices by shipping to either market.

SUMMARY

Unless the results of increased animal production can be marketed successfully, a new animal-production technology will not be useful at the farm level. This is because farmers tend to view production in terms of the costs and labor needed to sell their goods. Consequently, researchers and extension workers must not lose sight of the final step in a production process; that is, marketing the product. The complexities of the market system and the relationships between supply and demand must be carefully examined before promoting a new production technology. Therefore, within the context of OFAR, successful animal-production technologies are those that increase production and increase profits.

CHAPTER 9
RISK

PURPOSE

Risk is the possibility of incurring injury, damage, or loss. In On-farm Animal Research (OFAR) it is the possibility of making a decision that may not to be in the farmer's best interest, resulting in losses or damage. Animal production involves risks associated with health, pricing, and input availability. These risks affect the farmer's decision about whether to choose a new technology. A technology that offers great potential profit may also have great risk associated with it. The researcher or extension worker must therefore try to identify the risks involved with a new technology and make the farmer aware of the potential gains and losses.

OBJECTIVES

After completing this chapter, the reader should be able to:

- Define risk and describe some of the risks associated with animal research.
- Use the beta coefficient in assessing risk.
- Perform expected value analysis.

DEFINING RISK

In the simplest terms, risk is the chance of some favorable or unfavorable event occurring. For example, a farmer bears the risk that there may be too little rain to support crops, or that prices may rise or fall in a way that makes the crop planted today unprofitable at harvest time (see figure 9.1). Events that take place in the future and that are governed by chance (probability) may be considered risky. Risk can usually be determined from evidence or experience.

Uncertainty is the state in which the probability of the occurrence of an event cannot be determined. Uncertainty defies planning or forecasting. For example, a farmer can usually determine if a farm activity will increase the chances of an animal incurring injury by assessing the risks involved, but a farmer cannot predict the chances of his donkey breaking his leg accidentally and having to be destroyed. Uncertainty is the worst problem faced by farmers. It creates frustration and insecurity, and makes it difficult for the farmer to adopt new technologies.

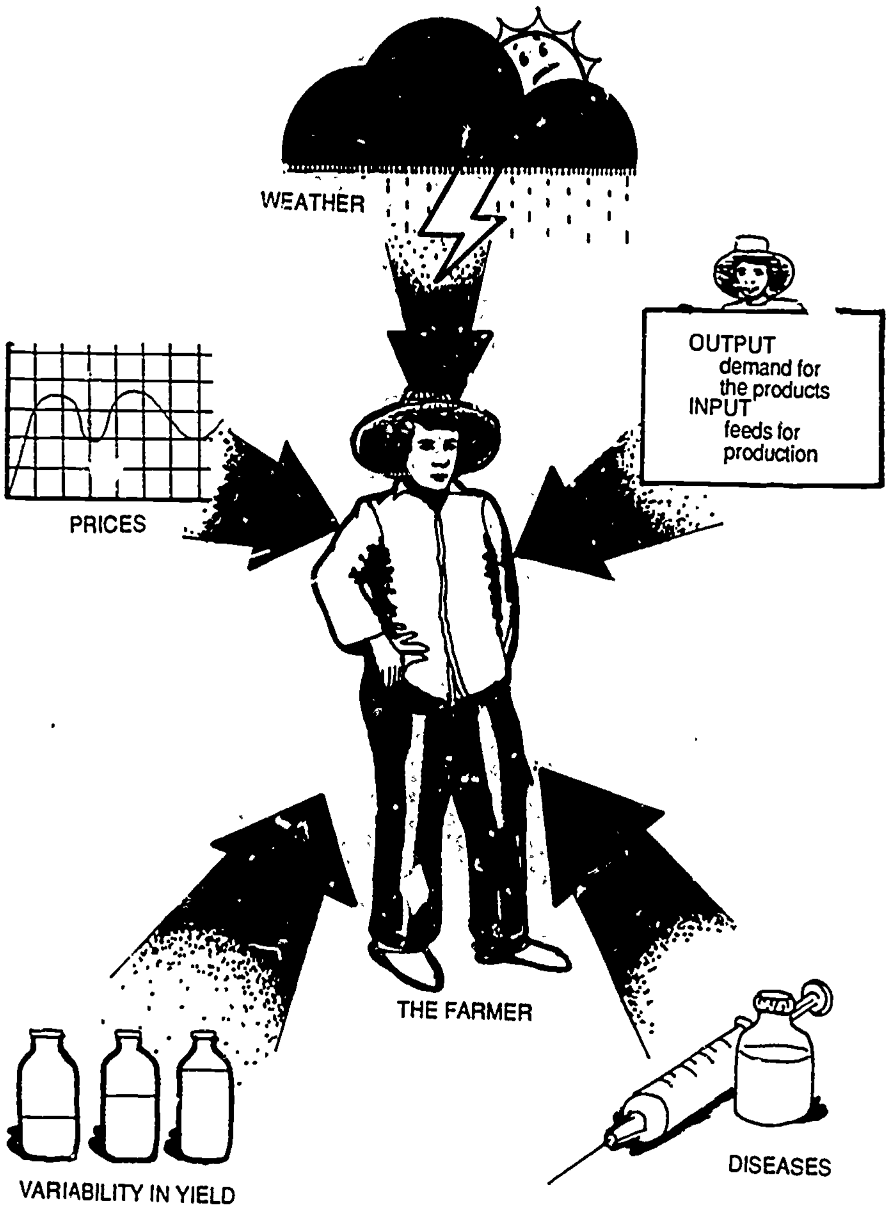

Figure 9.1. Risks facing the farmer.

Risk is universal and cannot be avoided, but attitudes toward risk vary among cultures. In Muslim societies, betting and risk taking are considered unethical, other societies believe that all events are predestined. Over the last two decades, many researchers have tried to understand the risk behavior of farmers in Asian countries. However, the models used by these researchers tend to be so sophisticated and mathematically oriented that they are difficult to use for developing applicable recommendations. Moreover, it is difficult to generalize about risk attitudes for a large number of farmers. Studies that do so use such narrow criteria they become invalid as soon as the environment (economic-geophysical-biological) changes.

For the purpose of on-farm research, the presence of risk should be acknowledged. Interest is then directed toward those technologies that are stable under farm conditions and that bear low risk — their performance does not deviate much from the average under normal conditions.

RISKS ASSOCIATED WITH ANIMAL RESEARCH

When farmers agree to allow experimentation on their animals, they face a variety of risks. Some farmers resist participating in on-farm research more strongly than others, depending on their financial positions, their expectations for the new technology, and their general attitudes toward risk. Traditional farmers are conservative and respond to new technology cautiously. However, assurances that any loss will be reimbursed and selective use of incentives often win their cooperation. Progressive farmers are looking for new opportunities and usually are willing to experiment with new technology. These farmers are often more suitable for extension trials, which may have greater chances for failure.

The two main categories of risks are yield risks and price risks. Yield risks are the risks associated with unexpected variations in yields due to such conditions as weather or pests. Price risks are the risks associated with unexpected fluctuations in price because of changes in supply and demand or a change in government price policy.

Researchers and extension workers conducting on-farm research should be sensitive to the risks associated with each treatment used during research trials. A technology may be technically and economically acceptable; but if it carries considerable risk of failure, farmers will be reluctant to experiment with it. For example, introducing purebred cows on small farms in Asia has generally been a failure. Although their milk yields are often three to four times higher than those of indigenous cows, the purebred cows adapt poorly to local conditions. Poor tolerance of unsanitary conditions, low resistance to heat, and several other stress factors make them unsuitable for most small-farm situations.

Another example is a new vaccine that shows an 80% to 90% success rate at the research station. It causes a reaction in 10% to 15% of the animals that receive it, and the reaction can be controlled only by clinical procedures. The vaccine may be a good investment for a large farmer who can afford the services of a veterinarian, but small, isolated farmers are likely to lose any animals that develop a reaction. This suggests that the risk is directly related to the possible gains and losses that can be attributed to a new technology.

Each new technology is associated with a different type of risk. These risks should be discussed with farmers before experimenting with their animals. The expected gains and potential losses should be described along with their chances of occurrence.

CONSIDERING RISK IN ANALYZING RESULTS

Risks should be assessed when screening and testing a new technology. This can be done in a variety of ways. Yield data can be revised downward to reflect difficulties in duplicating research station results at the farm. Similarly, problems of variability in market prices, losses due to spoilage of milk or meat, and potential loss of animal health should be assumed at levels that realistically represent farm conditions. Sensitivity analysis of the experimental data should take into account risks associated with credit availability, weather, price, and disease, and this analysis should be used to revise yield and cost estimates for the treatments. Farmers should be asked to identify risks associated with the treatment, and their subjective judgments should be recorded and considered in analyzing results. If traditional insurance schemes or arrangements for dealing in futures markets are available to farmers, they should be recorded during the diagnostic phase and included in the evaluation of a technology.

The Beta Coefficient

The beta coefficient (or beta ratio) is defined as the ratio of the farmer's willingness to pay for a new technology over its actual cost. It is considered to be a crude measure of the risk each farmer associates with a new technology. If the absolute value of the beta coefficient after adjustment for cost of the technology remains greater than 1, the technology stands a good chance of being accepted. However, if the value of the beta coefficient falls below 1, the technology probably will not be accepted. This type of simple measurement can be useful in getting an indication of how farmers value a technology. Better procedures for evaluating risk are available, but often they are too difficult to use in applied research. The following example illustrates the utility of the beta coefficient.

Researchers have been testing livestock improvement technology on several Indonesian farms over the past 2 to 3 years. A preliminary analysis was conducted to get the farmers' reactions to the trials. Farmers were asked how much would they be willing to pay for the technology (at the time of the interviews, farmers were receiving the technology free). The three components of the new technology were 1) an anthelminthic drench, 2) a mineral supplement mix, and 3) a pedigreed ram.

On the average, farmers reported that they would be willing to pay Rp 112 for the drench, Rp 525 for the mineral supplement, and Rp 39,722 for the ram. At 1985 prices the actual cost of the drench was Rp 200, the mineral supplement was Rp 250, and the ram was Rp 40,000. Beta coefficients were plotted for the 14 farmers participating in the trial (see figure 9.2). To improve realism and account for additional costs (market costs, researchers time, etc.), the cost figures were increased, which directly reduced the value of the ratio. Therefore, with all the additional costs accounted for, many of the beta coefficients had a value less than one. The technology thus stands a good chance of not being accepted, and more research is to be done before this technology can be released.

Expected Value Analysis

Another approach to risk assessment utilizes expected value analysis, which is the expected value of an experiment or new technology. This analysis is based on acts, choices, states, and probability. Acts are the relevant actions available to the decision-maker. Choices are the options available to the decision-maker, with one option being to do nothing. States are the possible states of nature, including the situation that may exist at a future date. For example, in one year the state of the market for live goats will either be good, fair, or poor. Probability is the chance of an occurrence. The value of probability associated with an outcome cannot be negative. nor can it exceed 1 since the sum of all probabilities associated with a set of outcomes relevant to a decision must equal 1.

The expected value of a new technology is determined by the following equation:

$$EV = CY[(PS \times PG) - (PF \times PL)],$$

where EV is the expected value, CY is the current yield, PS is the probability of success, PG is the percentage gain, PF is the probability of failure, and PL is the percentage loss.

To illustrate, a farmer is invited to participate in vaccination trials being organized by the Department of Extension. The vaccine helps increase the animal's uptake of urea and can increase milk production. Its chance of being successful is 70%, with an increased milk yield of 15%. However, some of the animals vaccinated in past trials have also experienced a drop in milk

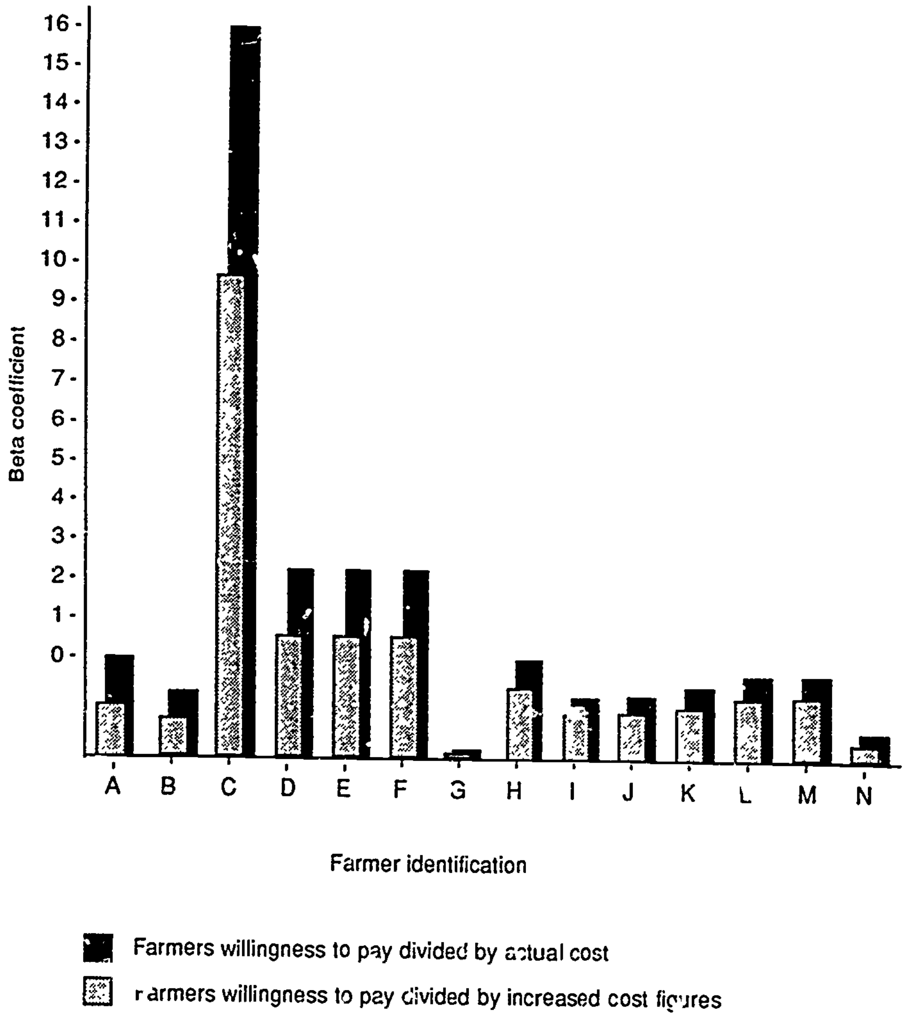

Figure 9.2. Graph of beta coefficients for a livestock improvement technology.

production of 40%. The price of milk is Rp 6/kilogram. The farmer has two cows that could be volunteered for the experiment. The first cow gives an average of 56 kilograms/week of milk; the second cow yields 43 kilograms/week. The farmer has a lot to gain if the trial is successful. Here is how the risks should be evaluated:

The variables are given the following values:

$CY_{cow\ 1} = 56$ kg/wk

$CY_{cow\ 2} = 43$ kg/wk

PS = 70%.

PG = 15%.

PF = 30%.

PL = 40%.

The expected value of the experiment can then be calculated:

Cow 1:

$$\begin{aligned} EV &= CY[(PS \times PG) - (PF \times PL)] \\ &= 56 \text{ kg/wk } [(0.70 \times 0.15) - (0.30 \times 0.40)] \\ &= 56 \text{ kg/wk } (0.105 - 0.12) \\ &= 56 \text{ kg/wk} \times -0.015 \\ &= -0.84 \text{ kg/wk} \end{aligned}$$

Cow 2:

$$\begin{aligned} EV &= CY[(PS \times PG) - (PF \times PL)] \\ &= 43 \text{ kg/wk } [(0.70 \times 0.15) - (0.30 \times 0.40)] \\ &= 43 \text{ kg/wk } (0.105 - 0.12) \\ &= 43 \text{ kg/wk} \times -0.015 \\ &= -0.645 \text{ kg/wk} \end{aligned}$$

The expected value expressed in monetary terms is simply EV multiplied by the price of milk, or:

Cow 1:

$$\begin{aligned} \text{Monetary value} &= \text{Rp } 6/\text{kg} \times -0.84 \text{ kg/wk} \\ &= \text{Rp } -5.04/\text{wk} \end{aligned}$$

Cow 2:

$$\begin{aligned} \text{Monetary value} &= \text{Rp } 6/\text{kg} \times -0.645 \text{ kg/wk} \\ &= \text{Rp } -3.87/\text{wk} \end{aligned}$$

The values of EV for both cows are negative, indicating a potential for loss. The farmer would probably allow the use of the second cow for the experiment since the potential for loss when using this cow is the lower of the two, and, in this example, the farmer would try to minimize loss.

Another example involves farmers in duck-feeding research trials. To determine optimal sample size it is necessary to work out the risks associated with the trial. On-station experiments have revealed the following:

- Ducks not receiving feed supplement = 130 grams/week gain
- Ducks receiving feed supplement = 185 grams/week gain

The following statistical information (see Chapter 4) is also available:

Ducks not receiving feed supplement:

CV = 67%

SD^2 = 0.456

Ducks receiving feed supplement:

CV = 18%

SD^2 = 0.256

Price of duck = Rp 13/kg = Rp 0.013/gram

Several conclusions can be drawn with regard to the risk involved in this study. First, after comparing the two coefficients of variation (CV), it is revealed that the ducks receiving the feed supplement show less variability among experimental units. This partial criterion implies stability of response to the treatment. Similar information is reflected by the variance (SD^2). The low variance for the improved technology indicates that the sample size does not have to be large.

Assuming that the expected value in this example is equal to the current yield and the dressing weight conversion is 70%, then the monetary value is:

Ducks without supplement:

Monetary value = 130 grams/week × 0.70 × Rp 0.013/gram
= Rp 1.18/week

Ducks with supplement:

Monetary value = 185 grams/week × 0.70 × Rp 0.013/gram
= Rp 1.68/week

Difference = Rp 0.50/week

The difference can be perceived as the benefit of administering the feed supplement to the ducks. However, economic analysis will also consider the cost side. Therefore, assuming the cost per week for 1 duck on supplement is Rp 0.15, the net benefit is Rp 0.35/week per duck.

By combining the statistical information with the economic information, the expected value would indicate that the research should be followed up at the farm level. Some additional risks which affect the expected value of the new technology are:

- Farm animal response: what type of response can be expected with the farmer's ducks?
- Time constraints: how will the farmer value the time needed to bring the feed supplement from town since it is not available at the village?

- Market considerations: can the farmer sell the ducks? Is the farmer keeping the ducks for home consumption?
- Price fluctuations: what are the tastes and preferences of consumers buying ducks? Do they buy live ducks on a weight basis or do they buy ducks through a middleman?
- Resource investments: how much does the new practice deviate from the farmer's practice? Is any fixed investment needed for feeding pens?

These and similar considerations should all be assessed when determining the expected value of a new technology and the farmer's subsequent acceptance of it.

SUMMARY

The risks pertaining to any new technology must be assessed before introducing that technology at the farm level. Although many new technologies have the potential for increasing farmers' profits, each technology also has inherent risks. These risks may be associated with fluctuations in market prices or with variations in the climate. In some cases, the risks involved with a new technology may be so great that the potential benefits cannot be rationalized. The farmer's perception of risk can be assessed by utilizing the techniques demonstrated in this chapter, including the determination of beta coefficients and expected values. Since the success of OFAR ultimately depends on its acceptance at the farm level, the ultimate objective is to minimize all potential risks associated with a new technology.

CHAPTER 10

INSTITUTIONAL CONSTRAINTS IN ASIA

PURPOSE

Several Asian livestock-development programs have a genuine interest in strengthening On-farm Animal Research (OFAR). Traditionally, however, only commercial producers have participated in animal-improvement programs. The commercial sector is considered easier to work with than the farm sector since the entrepreneurs themselves are in search of new technology and can afford the capital investment and potential risks that are involved. The small farmer, on the other hand, has limited funds and less access to market facilities. However, as this manual has demonstrated, there is clearly a need for animal research that is directed toward the goals of the small farmer Previous chapters have given this need an historical and theoretical perspective while addressing the applications, such as economic and statistical analysis, that are involved. As a conclusion to this manual, this final chapter describes the practical considerations for initiating OFAR in Asian countries. OFAR scientists will function better if they have an understanding of the institutional constraints which their directors face.

OBJECTIVES

After completing this chapter, the reader should be able to:

- Explain why, in the past, OFAR has not been directed toward the production needs of the small farmer.
- Evaluate the potential of government, semi-government, and private agencies to participate in OFAR.
- Describe the leadership requirements that are needed in order to successfully conduct research trials on farms.
- Describe the types of incentives that can be offered to encourage researchers to participate in OFAR.

ANIMAL RESEARCH IN ASIAN COUNTRIES

In most Asian countries, animal production is administered by a livestock department, which either is a part of the ministry of agriculture or is a separate ministry. The crop and livestock departments often compete with each other, and they generally communicate poorly. With the development of national agricultural research systems, the coordination of research has been facilitated. Presently, national research systems in Asia include:

- Agency for Agricultural Research and Development, Indonesia
- Bangladesh Agricultural Research Council
- Indian Council of Agricultural Research
- Malaysian Agricultural Research and Development Institute
- Pakistan Agricultural Research Council
- Philippine Council for Agricultural and Resources Research and Development

These organizations play a dominant role in planning, coordinating, financing, and, to a limited extent, conducting agricultural research. They also work closely with provincial programs. For instance, India and Pakistan have nationally coordinated programs for all major commodities. In other developing countries, such as Nepal and Sri Lanka, the departments of agriculture and livestock often coordinate research and extension work. All of these institutions have some involvement in farm-oriented research and development, but most such research to date has concerned crops, not animals.

Usually, availability of new technology is not a problem. Animal-production programs (which include traditional disciplines such as nutrition animal husbandry, breeding and genetics, physiology, and clinical medicine) pool their resources to extend services to a limited group of farms. However, it is not always resources that are lacking but purpose and direction in applied research and development programs. Certainly, farmers of limited means cannot benefit from present nutrition research since they cannot afford the cost of new inputs, such as imported hybrid cows and modern medicines. The result is that the small and isolated farmers do not share these benefits, despite the presence of a diverse set of technologies. Some of the blame belongs to the extension services. Shortages of funds, transport facilities, infrastructures, appropriate technologies, and technical personnel are decried at every national planning meeting and international workshop.

The issues, then, are applicability and cost effectiveness for a diverse group of farmers. Since the clients of experiment-station research are commercial producers, the technology that is developed hurts the small farmer by reducing product prices through increased supply; this is particularly true when the small farmer cannot adopt the improved technology due to increased input costs. This is a tradeoff between equity and efficiency based on short-term goals. Although animal operations on small farms are not as efficient as commercial operations, if selected practices are packaged in an economic manner, small farmers can take advantage of low-cost labor and on-farm residues to improve farm incomes. Moreover, improving small farm animal productivity indirectly improves health, land, draft power, use of excess labor, risk-bearing ability, and cash flows. These gains cannot be measured in terms of profit, but they are strong contributors to stability and sustainability on the farm.

In summary, to address the problems of small farmers, technology has to be designed for their participation and for application on their farms. Existing agricultural research systems do not seem to be designing technology in this way. The goal should be to encourage animal scientists to support and adopt farm-oriented research and development. While most animal scientists and planners agree with the need for increased small farmer participation in improving the animal component of farming systems, few countries have initiated any coordinated effort. An exception to this situation may be found in an Indian dairy project.

India has a clear policy on generating dairy technology that addresses a diverse group of farmers. All aspects of production, marketing, and processing are viewed from the perspective of different groups of farmers. Achievement of this goal has been stressed at all levels of the government. While efficiency or profitability are general goals, equal attention is being given to equity and balanced growth among different farm groups. To achieve similar objectives, national programs must develop mechanisms for on-farm testing of new animal technologies that are replicable to a diverse set of farm conditions and clients. Since animal research takes much longer than crop research, the questions of financial support for and continuity of the program become critically important.

MAKING THE NEEDS KNOWN

To improve OFAR, a conscientious effort must be made to persuade research managers and policymakers to invest in conducting research and designing technology that meet small farmers' needs. This concern can and should be voiced at different levels.

Academia

Undergraduate and graduate courses offered in developing countries often lack a pragmatic perspective on animal production; in fact, course subjects often have little relevance to the countries in which they are taught. They tend to be biased in favor of production, with the result that the lessons seldom can be used on resource-poor farms. This situation needs to change. Both domestically and internationally trained graduate students need to be provided with more administrative training because these graduates often get promoted out of these specialty areas into administrative positions. Students at all levels of training need to know how to teach by the demonstration method and to be able to set up and manage research and education programs.

Thailand is an excellent example of a country that has worked hard to involve faculty and students in applied farm research. The three major agricultural universities in Thailand sponsor multidisciplinary research, help build institutions, and develop courses that cater to the needs of applied researchers. Agricultural universities in the Philippines and India also participate in on-farm research, but on a more limited scale. At present on-station animal research is usually less expensive than on-farm research, but the costs of on-farm research would decline sharply if more students became involved in it, particularly if faculty and staff from different specialties worked together. The payoff of this type of research is that it provides a continuum for diagnosing, designing, testing, and evaluating new technologies.

Government Farms

Many outreach government farms provide extension facilities for nearby farmers. Currently, only influential farmers have access to these facilities. If these farms were given resources to test new technologies and develop recommendations based on economic and technical feasibility, a larger segment of the population would benefit. Sometimes costs and bureaucratic procedures prevent average farmers from using these and other services, such as animal clinics set up in villages.

National Development Projects

Perhaps the easiest way to initiate on-farm trials is through ongoing projects, especially farming systems programs. Although most of these programs are biased toward the crop component of a mixed-farming system, an animal component could be added to them at reduced cost. Indonesia and Nepal are developing strong programs focused on the animal component. While specific development projects, such as a dairy-development program, use selective incentives to promote a technology, they seldom cover a large group of farmers. Since technologies often are not adequately tested and refined for a given area, researchers and extension workers may wish to carry out on-farm trials to verify the value of new practices before disseminating them.

Private Sector

In some developing countries private sector initiative has demonstrated its effectiveness by providing comprehensive technology packages to small farmers. These technology packages include soil testing, on-farm demonstrations of fertilizer application, provision of credit and other inputs, as well as dissemination of market information. In many cases, private companies support the testing of their products at the farm level. This arrangement alleviates the cost of OFAR and brings the farmer, researcher, and extension worker into direct contact with the sponsor institution. In several instances, where new inputs are imported at a high cost, testing them rarely produces more than a research report. If the private sector is involved, it can develop an appropriate market strategy to promote the product when it receives good response.

A note of caution needs to be mentioned relative to the potential impact of the private sector on small farmers engaged in agriculture for domestic consumption. While the private sector can remove many constraints on agricultural production improvements, they generally limit themselves to cash crop or export-oriented operations and are not concerned with food crops for domestic consumption.

Farmer Associations

Farmer associations can be invited to participate in on-farm research. They can provide the needed infrastructure at the village level and promote advertisement of the research through newspapers, radio talks, and other communication media. These farmer associations can be organized to provide inputs for increased productivity, to focus research attention of relevant farm problems, and to serve as a lobbying group for improved agricultural policies.

PROVIDING LEADERSHIP

How can institutional leadership be developed for OFAR? The answer to this question will be different in each country and situation, but the essential leadership requirements and functions fall into the following three categories.

Senior Research Management

Senior managers should appraise overall goals of farm development. They should pose questions about targeting groups of farmers, choosing regions and species to develop, and budgeting resources. At the ministerial level, a clear commitment is needed to shift from a narrow disciplinary focus to a broader development focus. Senior managers also must make tough decisions about shifting limited human resources to share the responsibility of on-farm research, which is hard, lengthy and, to some, professionally less rewarding.

Middle Management

Middle managers tend to be scientists and senior extension officers who coordinate rather than perform research. They must arrange opportunities for field practitioners to share experiences, exchange materials, and identify training opportunities with colleagues from other parts of the world.

Research and Extension Officers

The people who actually perform the research often like working in multidisciplinary teams and enjoy farm work. They take pride in seeing things happen. They are strongly motivated, capable, and dedicated, and their accomplishments are measurable in terms of changed output. However, in many countries the role of the extension worker is too often regulatory and of a data gathering nature. Thus, the education and training component of their job receives little attention. This situation perpetuates the often weak link between researchers and farmers which the extension worker should be strengthening.

In addition, there has been a general failure to involve women in extension programs directed toward increased production. Most extension training for women, both as agents and recipients of extension services, relegates them to non-agricultural activities, such as homemaking skills. The important role women play in agricultural production, particularly as small farm producers, is clearly recognized but has yet to attract sufficient attention from national development planners and agricultural policymakers.

OFFERING INCENTIVES

Within its limitations, each organization must provide incentives to motivate its workers. Incentive structures tend to vary between nations and cultures, but the following elements usually are important in some way.

Financial

Money is perhaps the most common incentive used to encourage participation. Many countries provide special hardship allowances to junior scientists and field staff; but, while this incentive may get people out into the field, it does not guarantee the quality of their work. For instance, when one project leader got per diem bonuses for junior scientists who went on field trips, many people volunteered to participate in the weekly visits to monitor the trials and collect data. However, after the trials were completed, none of the junior scientists would put in the extra hours needed to process the data or write the report because they did not receive overtime pay for working at the station.

Training

Most donor-assisted projects include a training component that makes it possible to motivate young scientists to develop careers in applied research. For example, compensations may be offered, such as graduate training and opportunities to participate in national and international workshc, While this type of incentive is limited to projects that have strong financial backing, national institutions can create policies to reserve slots in such programs for scientists who are interested in multidisciplinary or applied research on animal production.

It is important that both junior and senior scientists take pride in their work and have equal opportunities to participate in professional activities. Local courses can be organized to give the staff further training, and the project staff should be encouraged to serve as trainers for other projects when appropriate.

Recognition

In nearly all countries, scientists take great pride in symbolic recognition. On-farm researchers should therefore have access to promotions equal to their counterparts. In the initial development of on-farm programs, applied researchers should perhaps be given honors and increased recognition as an incentive to undertake their field of research.

Opportunities for Publication

During the last few years, ssional journals have changed their policies toward accepting papers or d research. An article dealing with a properly conducted on-farm experiment with an acceptable degree of control stands a far better chance of being published today than 10 years ago. Moreover, several national journals and bulletin series encourage publication of applied research.

SOURCES OF INFORMATION

Since OFAR is relatively new, it has little documentation and support in developing countries. However, the situation has improved considerably in recent years. First, a series of workshops has been held to document experience around the world. Second, several international centers have initiated farming systems courses that include training in the animal component. Most technical-assistance agencies carry information to assist with training and financial support. The USDA's Office of International Cooperation and Development annually organizes courses that address the needs of dev loping-country practitioners. Many U.S., European, and Asian universities have initiated courses in farming systems research to cater to the needs of developing countries. In the United States, many universities have active international programs, such as Colorado State University, Cornell University, Kansas State University, Michigan State University, University of Arkansas, and University of Florida. Within Asia, this training is available at the Bogor Agricultural University in Indonesia; University of Agriculture, Faisalabad in Pakistan; Chiang Mai University, Khon Kaen University, and Kasetsart University in Thailand; and the University of the Philippines at Los Baños and Visayas State College of Agriculture in the Philippines. European universities with relevant programs are the University of Reading and East Anglia University, both in England, and Wageningen Agricultural University in the Netherlands.

SUMMARY

This chapter has outlined the various agencies and incentive programs that can be utilized to overcome the constraints involved in conducting OFAR. It is clear that the design and implementation of new technologies must begin to address the problems of the small farmer. In addition, researchers, extension workers, and animal scientists should be encouraged by both public and private organizations to support and adopt farm-oriented research and development. As on-farm research continues to improve the animal component of the small farm, the benefits to the small farmer, the area villages, and the general economy will become apparent. Once this pattern has been established, then OFAR can be considered a success.

GLOSSARY

Abortion: The expulsion or delivery of a fetus before it is able to survive. Young that are born dead before term are considered abortions.

Absorption: The passage of liquid and digested (soluble) food across the gut wall.

Activity budget: A summary of the technical and economic characteristics of a farm activity.

Activity gross income: The value of the output of a farm activity over some accounting period (usually a year), whether that output is sold or not.

Activity gross margin: Activity gross income minus the variable expenses attributed to that activity.

Acts: The relevant actions available to the decision-maker.

Afterbirth: The placenta and other membranes expelled after delivery of the fetus or young.

Aftermath: Any feed material that is left in the field after harvesting a crop, such as barley or wheat stubble.

Agricultural economics: An applied discipline wherein economic theory is applied to the problems of agriculture.

Agroecological analogues: See Environmental complex.

Agroeconomic zones: Zones that are defined in terms of common features, may involve such dimensions as climate, soil resources, land use, ethnic groupings, and market access.

Agronomic cooperators: Farmers who agree to have trials conducted on their farms.

Agrosystem: A system composed of farming systems, market and credit systems, and non-agricultural systems.

Alternative group: The group receiving the experimental treatment.

Alternative hypothesis (H_a): The alternative to the null hypothesis. Expresses the idea of difference or of significance of difference, in contrast to the null hypothesis.

Alpha error: See Type I error.

Amputation: The removal of a limb.

Anabolic: A constructive or building-up process.

Androgen: A male sex hormone.

Antibiotic: A substance produced by living organisms such as yeast that destroys or inhibits the growth of other organisms, especially bacteria.

Antibody: A chemical substance in circulating fluids, colostrum, and milk that contributes to immunity against a disease or infection.

Antigen: A substance that, when introduced into the blood or tissues, causes the formation of antibodies. Antigens may be toxins or native proteins.

Appetite: Expressed as the weight of dry matter consumed as a percentage of live weight.

Area-segment sampling: Sampling method that divides the project area into segments with boundaries that follow features that can be readily identified in the field. These segments are used as the sampling base.

Area-time equivalency ratio: The ratio of the number of hectare-days required in monoculture (sole cropping) to the number of hectare-days used in intercropping (multiple cropping) to produce identical quantities of each of the components.

Artificial insemination: The introduction of semen into the reproductive tract (usually the cervix or uterus) of the female by a technician.

Assimilation: The process of transforming food into living tissue.

Average: See Mean.

Average annual net benefit per marka of investment. Net benefit per marka of investment divided by project life, in years.

Average product: The ratio of output to input, Y/X, where Y is total output and X is total input.

Baby beef: Young slaughter beef animals that weigh approximately 1000 pounds and are well finished at about one year of age.

Backcross: Mating a crossbred animal back to one of the parental breeds.

Backward-linkage effect. Indirect effect of a project that causes changes in activities that provide inputs needed by the project.

Balanced ration: The daily food that provides all required nutrients in proper proportion for normal health, growth, reproduction, lactation, maintenance, or work.

Barrel: The trunk or middle part of the animal body between the forelegs and the hind legs.

Barter: A form of marketing in which products or services are exchanged for other products or services.

Basal concentrates: See Low protein concentrates.

Basal metabolism: The chemical changes that occur in an animal's body when the animal is in a thermoneutral environment, resting, and in a postabsorptive state. It is usually determined by measuring oxygen consumption and carbon dioxide production.

Base practices: Management practices that generally represent practices of farmers in a given recommendation domain. These practices are a reference for comparing potentially improved technologies against farmers' present technology in on-farm experiments.

Baseline data: Data collected before a project begins (for example, on fields, labor input, or market prices) against which a project's results can be evaluated.

Beef: The meat from bovine species other than calves. (The meat from calves is called veal.)

Before and after test: Statistical test which reduces the problem of variation between farms.

Benefit-cost analysis. A form of input-output analysis which uses cash and noncash costs and benefits to derive the appropriate benefit-cost ratio.

Benefit-cost ratio: A ratio of discounted returns to discounted costs.

Best-bet components: Components that result from the screening process that promise significant increases in incomes at reasonable levels of risks within the resources available to farmers.

Beta coefficient: A mathematical ratio used to measure the risk each farmer associates with a new technology, determined by dividing the farmer's willingness to pay for a new technology over its actual cost.

Beta error: See Type II error.

Beta ratio: See Beta coefficient.

Biological factors: Factors such as plant and animal characteristics and pest problems that influence the health and vitality of plants and animals and the quality of harvested products.

Biological feasibility: An action or project that is biologically practical based on current knowledge of the attributes of the plants or animals.

Biological system: A crop or livestock system.

Blemish: A defect or injury that mars the appearance of but does not impair the usefulness of an animal.

Block sampling: Sampling method that divides the project area into a grid system of square blocks.

Bloom: Healthy, glossy, attractive appearance shown by the animals that are doing well on feed.

Boar: A male swine of breeding age.

Boss cows: Individual cows that are stronger than the others with them and keep the weaker ones from the feed.

Bovine: Pertaining to or derived from ox, cow, or heifer. Hollow-horned animals.

Break: Weakness in wool fiber produced by animals that have suffered from sickness or overeating.

Break-even budget: A budget (usually a partial-profit budget) drawn up to establish the value of a selected planning coefficient for which gains and losses are equal.

Break-even output: The level of production that would enable the farmer to recover costs if the products were sold at the given or prevailing prices.

Break-even point: In budget analysis, the level of values and quantities at which the gains and losses are equal.

Break-even price: The price at which the farm's given level of output, if sold, would enable the farmer to recover costs.

Breeding diseases: The venereal diseases of cattle, such as vibriosis, trichomoniasis, and epivaginitis (epididymitis of bulls), and abortion caused by sexual contact or other means. All adversely affect fertility. (Other noninfective conditions may reduce fertility, such as inadequate nutrition.)

Broiler: A young chicken of either sex (usually 9 to 12 weeks of age) that has tender meat, smooth-textured skin, and flexible breastbone cartilage.

Broken mouthed: A condition describing aged animals that have lost one or more teeth.

Broodiness: The desire of a female bird to sit on eggs (incubate).

Browse: Woody or bushy plants.

Browsing: Eating the tender shoots or twigs of browse.

Buck: A male sheep, goat, or rabbit of breeding age.

Budget. The sum of all expected products (or increased inventories) times their respective prices less the costs of all items used in production. (Bradford and Johnson, 1953.)

Budgetary control: The process of matching the recorded progress of selected aspects of farm production against a budget.

Budgeting: The tabulation of gains and losses of an operation.

Bulky feeds: Feeds that have a large amount of fiber.

Bulling heifer: A heifer of an age for service.

By-products: Materials produced as wastes in some industrial or food-preparation process that may be used as feed.

Calf: A young male or female bovine animal.

Calorie: The amount of heat required to raise one kilogram of water 1 degree Celsius or one pound of water approximately 4 degrees Fahrenheit.

Calving interval: The period between births of two successive calves from one cow.

Capital: Wealth in any form, such as money or property, that can be used to produce more wealth.

Capital-equivalency ratio. The resource-equivalency ratio for capital, computed by using either the value of farm capital (at standardized prices) or the total cash used in the total production of crop(s) as the resource base.

Carbohydrates: Nutrients present in most plant feeds that supply energy to animals.

Carcass merit: The value of a carcass for consumption.

Carrying capacity: The number of hectares (or acres) that will carry one mature stock unit.

Casein: The major protein of milk.

Cash-flow budget. A statement of projected payments and receipts associated with a particular farm plan.

Castrate: Removing the testicles of a male animal.

Catabolic: A destructive process, such as the destruction of molecules in the animal's body.

Cattle, European. Humpless cattle, although a distinct crest may occur on bulls, especially beef breeds; generally *Bos taurus*, except for a few breeds of humpless cattle in West Africa.

Cattle, Zebu. Humped cattle, *Bos indicus*, probably originating in Southwest Asia, now spread widely through the tropics and introduced to America and Australia.

Central tendency. The degree to which experimental data or observations cluster near the center of a frequency distribution.

Chick: A young chicken of either sex.

Choice criterion. A measure adopted as a basis for comparing the consequences of alternative acts.

Choices: The options available to the decision-maker.

Climatic analysis. The analysis of data, over time, on such factors as precipitation, maximum and minimum temperatures, relative humidity, wind, and radiation.

Closebreeding: Mating a dam and son, sire and daughter, or brother and sister.

Cluster sampling: A form of multistage sampling in which all the individuals at the last stage are sampled.

Clutch: Eggs laid by a hen on consecutive days.

Cockerel: A young male chicken from about 10 weeks to 8 months of age.

Coefficient of in-breeding: A coefficient showing the relationship of the parents of an individual to one another; a measure of the amount of homozygosity created in the offspring by mating animals with related parents.

Coefficient of multiple determination (R^2): A statistic measuring the proportion of the variation in a set of data which is associated with the least-squares regression equation describing the data.

Coefficient of variation: A statistic used to measure relative variability, the ratio of the standard deviation to the mean, expressed as a percentage.

Cold-stressed weight (CSW): The weight of a carcass after being dressed (removing the entrails, head, feet, etc.) and after allowing for the drying that occurs in the first 12 to 24 hours of cold storage. (See Dressing percentage.)

Collaborating farmers: Farmers chosen or who have volunteered to cooperate with an FSR project by allowing researchers to conduct experiments on their farms or agreeing to test and evaluate new technologies themselves.

Colostrum: The first milk given by a female following delivery of her young. It is high in the antibodies that give the young protection from invading microorganisms.

Combining ability: The ability of animals of a population or line to produce superior or inferior offspring when combined with other populations or lines.

Commercial farming: Farming in which the majority of the output is sold, usually also involving appreciable use of purchased inputs.

Commodity specialists: Researchers who have been trained to work with a specific crop or animal.

Commodity-oriented research. The focusing of research on one or more crops or animals by studying them in detail. Commodities should be selected on the basis of investigations that have demonstrated their importance to the farming system.

Comparative advantage: See Principle of comparative advantage.

Comparative analysis. Comparison of the performance of a particular farm with some standard, such as the average performance of a group of broadly similar farms.

Compensatory growth: Increased growth rate in response to an austerity, such as restriction in feed intake, that the animal has recently experienced.

Complete budget: Budget that includes all costs and benefits for the farm as a whole.

Component technology: The cultural techniques used in the management of a cropping pattern. These include choice of variety, times and methods of village and crop establishment, fertilization, field-level water management, pest management, and harvest.

Concentrates: Grains or feeds that are low in crude fiber and moisture content but high in digestible nutrients.

Conception: Union of ovum and sperm and implantation of the zygote to begin pregnancy.

Condition: The state of health and well being of an animal, or the fatness of an animal.

Conditioning. The treatment of internal and external parasites of animals, or immunization against certain diseases before sending animals to the feedlot.

Constant marginal product. Occurs when the application of each additional unit of input yields equal increments in output.

Consumption unit: In FSR, the household. For small farms, may be synonymous with the production unit (farm).

Contingency allowance. Funds set aside to cover likely but unspecified events that might increase project costs.

Control group: The group that is receiving no experimental treatment but is otherwise being treated similarly to the alternative group.

Controlled grazing. Controlling the period and incidence of grazing by moving livestock to different parts of the area in a prescribed sequence.

Cost analysis: See Principle of cost analysis.

Cow: A sexually mature female bovine animal.

Crop. Plants that are planted and managed for economic purposes, producing a physical product for the farm's use or sale.

Cropping system. Crop-production activity of a farm, comprising all components required for the production of the set of crops and the relationship between them and the environment. These components include physical and biological factors, technology, labor, and management.

Cropping systems research. Research concentrating on crops, cropping patterns, and interactions between crops, between crops and other enterprises, and between the household and environmental factors beyond the household's control.

Crop-production strategy. A subset of the farm-production strategy that involves only crops as its components.

Cull: To selectively remove an animal due to its inferior quality.

Cultural practices. Farmers' techniques for activities such as land preparation, seed selection, crop establishment, and fertilization.

DRI: Doe reproductive index.

Dam: A female parent.

Debt-servicing capacity. Farm net cash flow less cash needed for family living expenses.

Decision analysis. A procedure for ensuring that a person's decisions are consistent with personal beliefs about the risks being faced.

Decreasing marginal product. Occurs when the application of each additional unit of input yields an incremental output which is less than that from the previous increment in input.

Degrees of freedom. The number of observations in the data collection that are free to vary after the sample statistics have been calculated.

Delta: The symbol "Δ", used to denote a change in the value of a variable.

Demand: The quantity of a commodity that buyers will purchase in a given market, in a given period, at a given price.

Demand curve: A demand schedule plotted on a graph.

Demand schedule: A list of the different quantities of a commodity that consumers will purchase during a certain period if the corresponding price is effective.

Demonstration farm: Farm which simulates real-life farming situations.

Determinants of cropping patterns: Environmental factors that influence the performance of cropping patterns and are not readily modifiable by changes in cultural techniques of crop production.

Development budget. A budget used when planning changes in farm methods or organization that will take some time to implement.

Development program. A schedule used in a development budget which shows anticipated inputs and outputs in dated sequence.

Development target: The selected end position for a development budget.

Digestible energy (DE): The absorbed portion of the gross energy of a feed, equal to the gross energy (GE) minus the energy lost in feces (E_{fec}):

$$DE = GE - E_{fec}$$

Digestion coefficient: The percentage of a nutrient that is absorbed from the digestive system.

Diminishing returns: See Principle of diminishing physical and economic returns.

Disciplinary research: The process of approaching the object of study from the perspective of a particular discipline, such as economics or agronomy.

Disciplinary specialists: Researchers who have been trained in a particular field of study such as agronomy, animal husbandry, agricultural economics, or rural sociology.

Discount factor. The value by which a future cash flow must be multiplied to calculate its present value.

Discount rate: The interest rate assumed for discounting.

Discounting: Process of determining the present value of future costs and benefits.

Dock: To cut off the tail.

Doe: A female goat, deer, or rabbit.

Dominance: The tendency for one gene to exert its influence over its partner after conception occurs and genes are in pairs. There are varying degrees of dominance, from partial to complete to overdominance.

Downstream FSR programs. FSR programs that identify and test possible innovations that can be easily integrated into existing farming systems by focusing on close interaction with farmers via on-farm trials; also known as site-specific FSR programs.

Drench: To give liquid medicine to animals by pouring down the throat.

Dressing percentage: The percentage of the live animal that becomes the carcass at slaughter, also known as the yield. It is determined by subtracting the losses due to removal of blood, hide, and intestines from live weight, dividing that quantity by live weight, and multiplying by 100. (See Cold-stressed weight.)

Dry cow: A cow that is not currently producing milk.

Dry period: The time from drying off to recalving. The usual aim is 2 months for a cow and 3 months for first calvers.

Dry roughages: Roughages that have low moisture content, in contrast to succulent roughages.

Dual-purpose cattle: Breeds of cattle with two productive outlets, for example, females that are good milk producers and males that are good beef animals. Also, although less frequently, breeds of cattle which combine draft and beef or draft and milk qualities.

Dung: Feces (manure) of farm animals.

Earmark: An identifying mark on an animal's ear.

Economic analysis: Analysis of project benefits and costs from the viewpoint of the economy.

Economic cooperators: Farmers who agree to supply agronomic and economic data about their farming practices.

Economic environmental factors: Factors such as (1) the availability of credit, (2) marketing potential and prices of farm products, (3) cost of hired labor, (4) costs of seeds, agricultural chemicals, and farm equipment, and (5) land ownership and tenant characteristics.

Economic feasibility: The potential of an activity to produce benefits in excess of costs.

Economics: The social relationships or organizations involved in allocating scarce resources among human wants and in using those resources to satisfy wants as fully as possible (Leftwich, 1979).

Elasticity of supply: The responsiveness of quantity supplied to changes in price.

Embryonic period: Period of prenatal growth during which the fertilized egg grows rapidly, cell differentiation occurs, and tissues, organs, and major systems are formed.

Energy: The force, or power, that is used to drive a wide variety of systems.

Energy value: Calculated by multiplying the fat content of a feed by 2.25.

Energy-efficiency index: Measures the rate at which the use of energy inputs generates outputs; comparable to the economic-efficiency index.

Enterprise: Activity undertaken to produce an output that contributes to total production or income of the farm family. Enterprises in FSR typically concern crops, livestock, processing, or upgrading agricultural commodities produced on the farm, productive non-agricultural activities carried out on the farm (such as handicrafts), and productive off-farm activities carried out by the household members.

Enterprise gross income. The value of the output of a farm enterprise over some accounting period (usually a year) whether that output is sold or not.

Enterprise gross margin. Enterprise gross income minus the variable expenses attributable to that enterprise.

Environment: External factors affecting production that the farmer finds difficult to modify (for example, rainfall, soil properties, and government agricultural policies).

Environmental complex: A union of locations that share the same values for those physical cropping-pattern determinants that have been identified. Synonymous with agroecological analogues.

Environmental factors. Factors over which the farmer has little direct control, including the physical, biological, and socioeconomic aspects of the farmer's setting.

Equity ratio: Farm equity capital divided by total farm capital. A measure of indebtedness, usually expressed as a percentage.

Estrus: A regularly recurrent period of ovulation and sexual excitement that occurs in all female mammals, except for humans.

Ether extract: The fat content of feeds. Because fat and fat-like substances are soluble in ether, fat is analyzed by using ether to extract fat content.

Ewe: A sexually mature female sheep.

Excreta: Waste matter such as urine, feces, and sweat expelled by the body of an animal.

Expected value analysis: The determination of the expected value of an experiment or new technology.

Experimental error: The error in an experiment that leads to differing responses resulting from the same experimental treatment.

Experimental variables: Variables in an experiment that the researcher tests.

Exploratory survey. A process by which the researchers traverse the target regions and informally interview farmers and other persons knowledgeable of agriculture to arrive at a tentative understanding of farmers' existing production technologies and constraints to farmers' production and income.

Extension trial. Trial with the purpose to demonstrate to farmers the superiority of a new technique over the farmer's current practice.

Extension worker: An employee of the extension service. Those who specialize in FSR are members of various FSR teams and are liaisons between research and extension.

Extensive production. An animal-production management style wherein land is substituted for labor, and animals are maintained with lower levels of input costs.

External scale effect. Indirect effect of a project that causes changes in per-unit costs or benefits to persons who are not directly associated with the project.

Extrapolation area: The domain of adaption of a cropping pattern composed of the land types to which the cropping pattern is adapted.

FSR: See Farming Systems Research.

FSR sensu stricto: A category of FSR that studies farming systems as they exist through a technically and socioeconomically in-depth analysis.

Factor-factor relationship. The relationship among the several factors (inputs) used to produce a given amount of product.

Factor-product relationship. The relationship between the several factors (inputs) used to produce a particular product and the amount of the product that is produced.

Family activity: A method of producing a crop or operating a livestock enterprise.

Family earnings. Net farm earnings plus other household income, represents the total income available to the farm family for all purposes.

Farm: An organized decision-making unit within which crop and livestock production is carried out for the purpose of satisfying the farmer's goals.

Farm budget: An arithmetic projection of the costs and benefits for a typical farm situation.

Farm case study: The detailed study of an individual farm.

Farm cash surplus: Farm net cash flow adjusted for loans received and interest and principal paid; represents the amount of cash generated by the farm and available for household use.

Farm census: Collection of selected information from all the farms comprising some population.

Farm development budget: See Development budget.

Farm equity capital: Total farm capital less farm borrowings.

Farm management: A science that deals with the proper combination and operation of production factors (including land, labor, and capital) and the choice of crop and livestock enterprises to bring about a maximum and continuous return to the most elementary operation units of farming. It concerns the sound organization and skillful operation of a farm business for the purpose of maximizing continuous benefits consistent with the objectives of the farm operator or farm household.

Farm net cash flow: Farm receipts minus farm payments.

Farm net worth: See Farm equity capital.

Farm payments: Cash paid for goods and services purchased for farm use.

Farm receipts: The value of cash received from sale of agricultural outputs.

Farm survey: Data collection from a sample of farms from a given population.

Farmer-managed trial: On-farm experiment managed by the farmer to learn how farmers implement suggested improvements.

Farmer's circumstances: Factors that affect a farmer's decisions about using a crop technology, including natural factors, such as rainfall and soils, and economic factors, such as markets, the farmer's goals, and resource constraints.

Farmer's environment: In FSR the conditions under which the farmer operates, including physical, biological, economic, and sociocultural conditions.

Farming: An activity carried out by households on holdings that represent managerial units organized for the economic production of crops and livestock.

Farming enterprises: Production activities on a farm (for example, crop production or animal production).

Farming system: A unique and reasonably stable arrangement of farming enterprises that a household manages according to well-defined practices in response to physical, biological, and socioeconomic factors and in accordance with household goals, preferences, and resources (Van Der Veen, 1986).

Farming systems research (FSR): An approach to agricultural research and development that 1) views the whole farm as a system, 2) focuses on the interdependencies among the components under the control of members of the farm household and how these components interact with the physical, biological, and socioeconomic factors not under the household's control, and 3) aims at enhancing the efficiency of farming systems by improving the focus of agricultural research in order to generate and test better technology (Shaner et al., 1982). The approach involves selecting target areas and farmers, identifying problems and opportunities, designing and executing on-farm research, and evaluating and implementing the results. In the process, opportunities for improving public policies and support systems affecting the target farmers are also considered.

Farming systems simulation. Mimicking of the operation of a farm via some type of model.

Farrow: To give birth to pigs.

Fat: A class of nutrients which represents the most potent energy source in rations. Normally composed of glycerol and three fatty acids, fat contains the elements carbon, hydrogen, and oxygen, with hydrogen present in much higher proportions than in carbohydrates.

Fat-corrected milk (FCM). An attempt to relate the energy required to produce milks of different fat contents by adjusting the yield to that of a 4% butterfat milk with the use of Gaines' formula:

$$FCM = 0.4 M + 15F,$$

where M is milk yield and F is butterfat yield.

Fattening: Feeding heavily enough so that animals accumulate fat.

Fecundity: Fertility or prolificacy. A female animal is said to be fecund or prolific if she breeds regularly.

Feed bunk: A manger for providing feed, usually hay or silage, to cattle, sheep, goats, or horses.

Feed conditions. Conditions under which animals are being fed, sometimes used to designate the level of feeding.

Feed efficiency: The amount of feed required to produce a unit of gain in weight, for poultry, this term can also denote the amount of feed required to produce a given quantity of eggs. Can also be expressed as the amount of gain made per unit of feed.

Feeder calf: A calf that is purchased to go directly into the feedlot.

Feeding standards: Numerical expressions of the amounts of nutrients necessary for the maintenance of animals such as horses, buffalo, cattle, and milking animals.

Feedlot: A lot in which animals on a finishing ration are kept.

Fetal period. Period of prenatal growth which lasts from the time that major features of the animal are recognizable until the animal's birth.

Fiber: The tough part of a feed that is not very digestible.

Field: A contiguous unit of land which is used for the cultivation of the same crop.

Field or area sampling. Sampling methods in which a field is chosen randomly and the cultivator of the field is interviewed. Fields may be chosen by randomly locating coordinates on a map of scale 1:50,000.

Field price (of an input). The total value that must be given up to bring an additional unit of input onto the field.

Field price (of an output). The value to the farmer of an additional unit of production in the field before harvest.

Field study: Informal study of a particular area or problem.

Field teams: Groups that work with farmers in their fields. Such teams often consist of agronomists, economists, and supporting technicians. Where livestock is important, an animal scientist should be part of the team; and in areas where women are responsible for growing important crops or performing critical operations, field teams should include women.

Fill: The amount of feed in an animal's digestive system.

Finance budget: A budget constructed to show the extent of necessary borrowings and the manner in which interest and principal payments on loans are to be met.

Financial feasibility: A condition that is met when cash resources are sufficient to meet cash requirements both in amounts and timing.

Finish: The degree of fatness of an animal.

Fixed costs: See Fixed expenses.

Fixed expenses: Components of total farm expenses that are not variable.

Fleshing: The physical condition of an animal or its amount of fatness.

Flow: In cost identification, an amount that has a time dimension.

Fodder: Feed for livestock.

Formal survey: A survey of randomly chosen farmers who are interviewed by trained personnel using a written questionnaire to provide quantitative data on a farmers' circumstances.

Foster mother: A cow used to suckle one or more calves that are not her own.

Free choice: The condition that exists when feed is available to animals so that they can choose the proportions they prefer.

Frequency distribution: A table or graph indicating the frequency of occurrence of particular values of a variable.

Frequent-interview survey. A type of survey involving the collection of data from a limited number of farms on a regular basis.

Freshen: To give birth to young.

Gaunt: A description of an animal's appearance meaning empty or hollow-sided.

General herd: Herd composed of all the animals in the farm, bucks, castrated males, dry does, and weanlings.

General-purpose table. A table constructed to present a summary overview or to present a large amount of primary data in a convenient form.

Generation interval The average age of the parents when their offspring are born. (Cattle — 5 years; sheep — 4 years; swine — 2.5 years.)

Genotype: The genetic makeup of an animal, a list of genes carried by the animal for one or several traits.

Gestation: The period between fertilization and delivery of young, also called pregnancy.

Goal trade-off: See Principle of goal trade-off.

Grading: The mating of an improved breed with an ordinary strain of farm animal for the purpose of producing stock approaching the merits of the superior breed.

Graph: A figure drawn on two axes representing two variables with points representing paired values of the variables connected by a line or curve.

Grazing: Eating any kind of vegetation by domestic livestock or wild animals. Sometimes limited to eating herbage, in contrast to browsing.

Grazing capacity. The maximum grazing rate possible without causing long term damage to vegetation or related resources. Usually expressed as the number of animals or cow equivalents per unit area.

Grazing incidence: The amount of grazing in an area expressed as a number of animals or cow equivalents per unit area.

Green fodder. A form of succulent roughage that includes leguminous and nonleguminous fodder.

Gross costs: Total costs of a project including investment costs and operating costs.

Gross farm income. The value of the total output of a farm over some accounting period (usually a year), whether that output is sold or not.

Gross field benefit: Net yield times field price for all products produced in a given period.

Gross margin. The difference between the gross income of a farm activity and its variable costs.

Gross-margin budget: A partial budget drawn up using enterprise gross margins.

Gross-margin planning. A version of simplified programming in which activities are selected on the basis of only one key constraint: land.

Gummers: Aged animals that have lost all their teeth.

Half-sib: A half brother or half sister. Animals that are half sibs usually have the same sire but different dams.

Hay: Forage crops such as grasses, legumes, or cereals that have been cut and dried.

Heart girth or chest girth. The distance around the chest just behind the front leg.

Heat: Estrus, season, or bulling; the time when a female is receptive to the male.

Heifer: Bovine female from birth (heifer calf) to calving.

Hen: An adult young female domestic fowl, such as a chicken or turkey.

Herd: A group of animals kept together.

High protein concentrates. Concentrates that have a high protein content, may be of plant or animal origin.

Homiothermal animals. Warm blooded animals that have a constant body temperature which is not influenced by most changes in the environment.

Homogeneous farmer groups. Those who farm under similar conditions and in similar ways, recommendations for changes in technology will likely be accepted by the majority of them. (See Recommendation domain.)

Household. The farmer and other members of the family who form a consuming and producing unit and a social organization. Households are often under the management of a single person but sometimes operate collectively. Members normally live and sleep in the same place, share meals, and divide household duties.

Household goals: Aspirations the farm family sets for, such as increased income, adequate education, and improved quality of life, which may vary from one family to another.

Household net cash income. Farm cash surplus plus other household receipts, represents the cash available to the farm family for all payments not relating to the farm.

Human wants. One of the key elements of economics, OFAR deals with the human wants of the farmer.

Hutch: A pen for small animals such as rabbits.

Hybrid vigor: The tendency of crossbred offspring to perform better in certain traits than the average of their parents.

Hypothesis: A tentative statement or explanation of certain observed facts that is used as a basis for further investigation or argument.

Inbreeding: Mating individuals of close blood relationships, usually within a breed.

Income elasticity of demand: The responsiveness of demand to changes in income.

Income-equivalent ratio (IER): The ratio of the area needed under sole cropping to produce the same gross income as 1 hectare of multiple cropping at the same management level. IER is the conversion of land-equivalent ratio (LER) into economic returns.

Increasing marginal product: Occurs when equal increments of input result in increasing increments of output.

Incubation period: The time during which a hen sits on a clutch of eggs until the young are hatched.

Informal farmer interviews: Interviews with farmers usually conducted by researchers themselves without a fixed questionnaire and with minimal use of pen and paper. The interview is structured according to a checklist of information but with flexibility to explore certain practices or problems in more depth depending on the farmers' responses.

Informal surveys: Surveys undertaken without formal sampling procedures, pretested questionnaires, and other means that permit statistical analysis of the data.

Infrastructure: The supportive features of an economy often provided by government but sometimes provided by private industry such as transportation, electricity, water, communication, and governmental organizations.

Inheritance: The transmission of genes and genetic traits from parents to offspring.

Innovative approach to OFAR: An approach to OFAR which is based on the underlying belief that farmers should be full partners in the process of technology development.

Input: A factor of production.

Input-output analysis: Partial budgeting applied to the analysis of input-output data.

Input-output coefficient: Technical coefficient specifying the quantity of some input per unit of output or the amount of output produced per unit of input.

Input-output data: Data relating the level of crop or livestock output to level of input use.

Intangibles: A part of costs and benefits that cannot be assigned any nominal value.

Intensive production: An animal-production management style wherein labor is substituted for land, and livestock are raised in confinement facilities with high levels of input costs.

Interdisciplinary: A term describing frequent interactions among those from different disciplines who work on common tasks. Interdisciplinary activities tend to have better results than if those involved had worked independently.

Internal rate of return: A rate of interest at which the net present value of an investment is zero.

Investment appraisal: Evaluation of the profitability of some investment. Commonly involves net present value or internal rate of return calculations.

Investment capital: Value of inputs (purchased or owned) that are allocated to an enterprise with the expectation of a return at a later point in time.

Investment cost: The value of resources spent on physical productive facilities that are expected to last for more than one production period.

Isocline equation: An equation describing all combinations of factors that yield a given quantity of output.

Isoquant equation: See Isocline equation.

Iterative process: An approach that involves repeating activities and calculations to arrive at improved solutions through a series of successively better approximations.

Key constraints: Constraints which have a potentially large impact on the choice of a farm plan.

Labor budget: A budget comparing labor requirements with labor availability, usually constructed seasonally.

Labor chart: A form of labor budget constructed as a figure with a calendar of working days recorded on the horizontal axis and the number of workers recorded on the vertical axis; shows the number of workers assigned to each task and the duration of that task.

Labor day: A unit of labor input or requirement, usually assumed to represent the work accomplished in 8 hours.

Labor profile: The seasonal pattern of labor requirements for a given farm activity.

Labor-equivalency ratio: The resource-equivalency ratio for labor, computed by using the amount of total available labor or the total labor used for the cropping patterns as the resource base. Results are interpreted differently when variables are measured as either a stock variable or a flow variable.

Lactation: The production of milk by the mammary glands. Usually milk is produced for 305 days from the date of calving, or from and including the fifth day after calving.

Lamb: A young male or female sheep, usually an individual less than 10 months old.

Land-equivalency ratio (LER). The area needed under sole cropping to give as much produce as 1 hectare of multiple cropping or mixed cropping at the same management level, expressed as a ratio.

Law of demand: The inverse relationship between price of a commodity and quantity demanded.

Law of supply: The direct relationship between price of a commodity and quantity supplied.

Least-squares regression: The standard statistical method for fitting continuous functions involving a single dependent and one or more independent variables, used in production-function analysis.

Leguminous fodder: Consists of the stems and leaves of legume plants.

Let-down: The release of milk from the udders by the lactating female (also called milk ejection).

Limiting factors: Agronomic factors such as weeds and pests that limit productivity. Most are related to characteristics of farmers' natural and economic circumstances (for example, the presence of weeds may reflect lack of labor availability).

Linear programming (LP): A computer-based procedure used to solve allocation problems such as farm planning and formulation of livestock diets.

Linebreeding: Mating cousins.

Live weight (LW): The weight of a live animal. With ruminants, this is difficult to obtain accurately because of the varying amounts of fodder and water consumed each day. Daily variations may be extreme. To be comparable, animals should be weighed at the same time of day on each occasion and preferably outside grazing peaks, and weighing should be repeated on three successive days.

Live weight gain (LWG): An animal's rate of gain expressed on a daily basis.

Livestock: Animals raised for home use or profit.

Livestock feed budget: A budget comparing feed requirements of farm livestock with feed available from crops and pastures; usually drawn up seasonally.

Livestock gross income: The value of livestock production in the form of animals and produce, adjusted for inventory changes.

Livestock patterns: The animal species raised by a farm family over some period.

Livestock systems: Subsystems within the farming system made up of a set of one or more animals and comprising all components required for their production, including the interactions among the animals, other household enterprises, and the physical, biological, and socio-economic environments.

Livestock systems research. A process similar to cropping systems research but with procedures that reflect the inherent differences between cropping and livestock systems.

Long-term cash-flow budget. A cash-flow budget constructed for a planning horizon of 10 years or more with intermediate cash balances, normally calculated at annual intervals.

Low protein concentrates. Concentrates that are rich in carbohydrates and low in protein content, include all grains and some grain by-products.

Macroeconomics. The study of the economic system as a whole. Macroeconomics is concerned with issues of employment, taxation, interest rates, credit, and development policy.

Maintenance. A condition in which body weight does not increase or decrease and no production or work is done.

Maintenance energy (E_{main}). The energy needed for basal metabolism, wherein the animal's tissues are neither gaining nor losing energy. Used only for the growth of young stock.

Management factors. Factors the farmer can control through management decisions including such variables as cropping and livestock patterns, crop varieties, field cultural practices, fertilization, pest control, irrigation management, harvest, sale of crop or animal products, use of labor, animal, or mechanical power; and postharvest losses.

Management practice: The use of a technological component defined by the type, amount, and timing of the component.

Marbling: The distribution of fat in muscle tissue.

Mare: A sexually mature female horse.

Margin. The difference between the cost of a given quantity of feeder cattle and the selling price of the same animals as fat cattle. For example, if a load of feeder cattle were purchased for $8.00 per hundredweight, then fed out and sold as fat cattle at $10.00 per hundredweight, the margin would be $2.00.

Marginal cost. The increase in variable cost that occurs in changing from one production alternative to another; often measured relative to adding a marginal unit of input.

Marginal net benefit. The increase in net benefit that can be obtained by changing from one production alternative to another, often measured relative to adding a marginal unit of input.

Marginal opportunity cost. The value of including a marginal unit of a given farm activity in the farm plan.

Marginal product. The change in output arising from using an additional unit of the input.

Marginal rate of return: The marginal net benefit divided by the marginal costs.

Marginal value product (MVP). The opportunity cost of a marginal unit of a resource.

Market: A place where buyers and sellers meet to trade.

Market area: The distance from a market at which transportation of goods to the market is profitable.

Market class. Animals grouped according to the use to which they will be put, such as slaughter, feeder, or stocker.

Market grade: Animals grouped within a market class according to their value.

Market integrator: The individual who carries out several marketing functions.

Marketing: The performance of activities that will result in moving commodities from the producer to the consumer.

Marketing channels. Routes through which products pass as they are moved from the farm to the consumer.

Marketing margin. The difference between prices at different levels of the marketing system.

Marketing system. All activities involved in the flow of goods from the point of initial production to the ultimate consumer.

Mark-up. The price spread between two levels in the market divided by the selling price, expressed as a percent.

Mastitis: An inflammation of the mammary gland.

Mature stock unit (MSU). Also known as livestock unit (LSU) or animal unit (AU). A means of calculating the grazing load of a herd by comparing age groups, using a cow as unity. For example:

Adult bull	1.2
Cow	1.0
Cow in-milk	1.1
Growing cattle over 2 years old	1.0
Yearling 1–2 years old	0.5
Weaners 6–9 months old	0.25
Calves under 6 months old	0.125

The literature also provides different conversion ratios depending on the breed and location of the animals.

Mean: The value obtained by adding a series of terms and then dividing their sum by the value equal to the number of terms.

Median: In a series of terms, the value of the term for which one-half of the remaining terms are less and one-half are greater.

Medium-term cash-flow budget: A cash-flow budget extending over 3 or 4 years with the intermediate cash balances calculated at quarterly or half-yearly intervals.

Metabolic energy (ME): The energy from a feed that can be metabolized in the body for maintenance, growth, production, and activity. May be estimated by subtracting the energy lost as combustible gases and urine ($E_{gas,urine}$) from the digestible energy (DE):

$$ME = DE - E_{gas,urine}$$

Microeconomics: The study of the economic activities of units such as consumers, resource owners, and business firms. Microeconomics is concerned with the flow of goods and services from business firms to consumers, the composition of the flow, and the evaluation or pricing of the component parts of the flow. It is also concerned with the flow of productive resources (or their services) from resource owners to business firms, with their evaluation, and with their allocation among alternative uses (Leftwich, 1979). OFAR is concerned with the microeconomic implications of new practices at the farm level.

Minimum-return analysis: A process carried out with each production alternative that features examining net returns to the individual treatments and selecting the alternative whose lowest return or whose lowest average return is highest among the alternatives being considered.

Mixed farming system: Farms with integrated crop and livestock activities.

Mixed systems research: A process similar to that for cropping systems research, except that the procedures reflect the inherent differences between cropping and livestock systems. Also, the researchers focus their attention directly on the interactions between crops and livestock.

Mode: In a series of terms, the value of the term that appears most frequently.

Model: A simplified representation of reality built to reflect those features of a farm, enterprise, or process that are of most importance in the context of a particular study.

Money field price (of an input): The market price of a unit of product minus harvest, storage, transportation, and marketing costs and quality discounts.

Monogastric: See Nonruminant.

Multidisciplinary: A combination of disciplines involved in an assignment but not necessarily working in an integrated or coordinated manner.

Multilocational testing: The process whereby new technologies developed in a research area are tested at other locations within the target area to learn what adjustments, if any, are needed before diffusing the technologies more broadly and intensively.

Multiphase sampling: A sampling scheme involving collection of different categories or information from different subsamples.

Multiple-cropping index (MCI): The sum of the area planted to different crops harvested during the year divided by the total cultivated area.

Multiple-cropping specialist: A person engaged in the research, design, and production of crops arranged in patterns that obtain optimum use of a farmer's resources with the goal of maximizing the return to the farmer in cash income, better nutrition, or general welfare.

Multiple-cropping system. A system in which more than one crop is grown on the same plot of land in 1 year.

Multiplier effect. The widely diffused chain of increases in incomes and expenditures, beyond the direct impact on benefits and costs, that is generated by a project.

Multistage sampling. A method of probability sampling that involves at least two sampling steps.

Multivariable production function. A production function involving several variable inputs.

Musty: Unpleasant odor of feeds that have spoiled slightly or have been improperly stored.

Net benefit curve: A curve showing the relationship between variable costs of alternatives and their expected net benefits.

Net benefits: The value of the benefits less the value of the things given up in achieving the benefits; for example, total gross fields benefit minus total variable costs.

Net cash flow: See Farm net cash flow

Net energy (NE). The most difficult energy evaluation of feeds but the most accurate for ration formulation. To determine net energy, measurements must be made of the energy in the feed, feces, gases, urine, and heat produced. The net energy is the energy remaining after subtracting the heat loss due to fermentation and metabolism from metabolic energy (ME).

$$NE = ME - heat$$

Net energy for gain (NE_g): The net energy required, in addition to that needed for body maintenance, for body tissue gain. Used only for the growth of young stock.

Net energy for lactation (NE_l). The total net energy needed for maintenance plus the last 2 months' gestation for dry, pregnant cows, also known as the net energy for producing milk (NE_{milk}).

Net energy for production (NE_p). The net energy which can be transformed into products, obtained by subtracting the maintenance energy (E_{main}) from the net energy (NE):

$$NE_p = NE - E_{main}$$

Net farm earnings. Net farm income less interest paid on borrowed capital, represents the return to all family-owned resources used in farm production.

Net farm income. Gross farm income minus total farm enterprise, the return to the farm family for their labor and management together with the return on all the capital invested in the farm, whether borrowed or not.

Net present value (NPV). The net total of the discounted values of the payments and receipts associated with a given project or farm plan.

Net returns: See Net benefits.

Net worth: See Farm equity capital.

Net yield: The measured yield per hectare (or acre) in the field minus harvest losses and storage losses where appropriate.

New farming systems development: A category of FSR that starts with the view that many tropical farming systems are so unproductive that radical restructuring rather than stepwise change is necessary; the objective is to invent, test, and exploit new systems.

New technological components: Practices or inputs that are yet to be developed or whose performance under farmers' conditions cannot be predicted with confidence. Examples are varieties yet to be created or new herbicides with which researchers have little or no experience.

Nitrogen-free extract (NFE): The more soluble part of carbohydrates that includes starch and sugars.

Noncommercial farms: Family-owned and operated farms, often associated with low cash-input farming activities.

Nonexperimental variables: Variables in an experiment that the researcher is not testing, divided into those that the researcher cannot control (such as weather) and those that the researcher can control (such as farming operations).

Nonleguminous fodder: Consists of the stems and leaves of nonlegume plants, usually contains less nitrogen than leguminous fodder.

Nonrandom sampling: Method of sampling in which individuals are chosen by purposely selecting units without the use of a population list.

Nonreturns: Females that do not go into heat and are regarded as pregnant.

Nonruminant: Animal that does not have a functional rumen. Sometimes called a monogastric.

Null hypothesis (H_o): The working hypothesis; expresses the idea of no difference or of nonsignificance of difference.

Nutritive ratio: The ratio of digestible protein to digestible nonnitrogenous nutrients (including fat) multiplied by 2.25.

OFAR: See On-farm Animal Research.

Off feed: Condition in which animals get sick from overeating or improper eating and therefore scour and stop eating.

Oil meal: Feed materials that are by-products in the manufacture of several oils and are used as livestock feeds mainly to supply protein.

On feed: Condition in which animals get accustomed to a diet and are able to eat a full feed of it and do well.

On-farm Animal Research (OFAR): On-farm research of animal production that has the following goals: 1) to describe the animal component at the farm level, 2) to systematically screen on-station technologies that can help alleviate production constraints at the farm level, 3) to test screened technologies at the farm level, and 4) to support the implications of crop interventions.

On-farm experiments: Experiments conducted in farmers' fields, usually with the immediate aim of developing technological recommendations. On-farm experiments may be managed by researchers, farmers, or both.

On-farm research: Research in farmers' fields with farmers oriented toward formulating improved technologies. Typically involves two types of interrelated activities: surveys of farmer circumstances and experiments.

On-farm research with a farming systems perspective: A category of FSR that is a practical extension of agricultural research based on the assumption that only the farmer's experience can reveal to the researcher what farmers really need.

Opportunity cost principle: The economic principle that the cost of any choice is measured by the value of the best alternative that is forgone; thus, the opportunity cost of a resource is its value in the best alternative use.

Opportunity field price (of an input): The value of the input in its best alternative use.

Opportunity field price (of an output): The money price the farm family would have to pay to acquire an additional unit of the product for consumption.

Outbreeding: Mating animals distinctly unrelated, usually with diverse type or production traits. Varies in degree depending on degree of divergence in type or production traits.

Outcrossing: Breeding animals of the same breed showing no relationship within the first four or six generations.

Output: The product.

Output parity index: Measures the parity of energy output to energy input. It combines economic and energetic approaches. Operationally, it is the ratio of the price per unit of energy output to the price per unit of energy input.

Overgrazing: Grazing that is so heavy it impairs future forage production and causes deterioration through damage to plants, soil, or both.

Ox: A castrated male bovine. This word is normally used when the animal is kept for draft purposes. (Steer is used to denote meat animals.)

Palatable feed: Feed that animals appear to like.

Parametric budget: A budget (usually a partial-profit budget) drawn up using algebraic symbols for selected planning coefficients and used to appraise the consequences of variations in those coefficients.

Parametric programming. A form of linear programming in which selected coefficients are varied over some chosen range.

Partial: A term used to indicate that the change only occurs in one component of the farm.

Partial budget: See **Partial-profit budget.**

Partial cash-flow budget: A cash-flow budget showing only those cash flows that would be changed as a consequence of some proposed change in the farm plan.

Partial-budget analysis. A form of marginal (incremental) analysis designed to show, not profit or loss for the farm as a whole, but the net farm income resulting from the proposed changes.

Partial-profit budget: A tabulation of expected gains and losses due to a relatively minor change in farming method, affecting only part of the farm.

Parturition: Giving birth (calving, lambing or farrowing).

Pasture: Area where animals can graze.

Payments: See **Farm payments.**

Percentage margin: The price spread between two levels in the market divided by the buying price, expressed as a percent.

Performance testing: Accumulation of performance data under uniform environmental conditions, upon which the selection of the individuals on the test will be based after appropriate statistical treatment.

Period of the ovum: Period of prenatal growth which lasts from the time the ovum (egg) is fertilized until the fertilized egg attaches itself to the uterine wall.

Physical factors: The more important attributes of the climate, water, and land.

Pilot production program: A program designed to test how agricultural policies and support systems function when new technologies are introduced into an area on a large scale.

Poikilothermal animals: Cold-blooded animals whose body temperatures change according to the environment.

Postnatal growth: Growth that takes place following the birth of the animal.

Postweaning phase: Period of postnatal growth that occurs after the animal no longer relies on its mother's milk for nourishment.

Premature: Live young born before term.

Prenatal growth: Growth that takes place from the time of fertilization of the ovum (egg) until the birth of the animal.

Present value: The current value of a monetary amount or cash flow to be paid or received in the future, adjusted for differences in the value of money over time arising from the opportunity cost of capital.

Preweaning phase: Period of postnatal growth during which the young mammal is nourished on milk from its mother.

Price elasticity of demand: The responsiveness of demand to changes in price.

Price risks: The risks associated with unexpected fluctuations in price because of changes in supply and demand or a change in government price policy.

Price spread: The wholesale or retail margin expressed in dollars and cents.

Primary benefits: The value of the goods and services resulting from the project and other productive activities associated with it.

Primary costs: The value of the goods and services used for the installation, maintenance, and operation of the project and other productive activities associated with it.

Primary information: Data collected specifically for the current activity.

Principle of comparative advantage: Economic principle which states that various crops and livestock should be produced in areas where physical and other resources are best suited to their production.

Principle of cost analysis: Principle whereby costs are divided into fixed costs and variable costs.

Principle of diminishing physical and economic returns: Principle which states that variable resources should be added to fixed resources as long as the added return expected from the last unit of variable resource used is just sufficient to cover the added costs of that unit.

Principle of enterprise choice: Principle which states that enterprises can enter the farm plan as long as their expected contribution to net farm income exceeds the opportunity cost of the resources they use.

Principle of goal trade-off: Principle which states that a farmer can trade off competing goals as long as the gain in satisfaction from the goal receiving increased emphasis is greater than the loss in satisfaction incurred by decreasing emphasis on the other goal or goals.

Principal of marginality. Principle which states that choices about the use of resources should be made so that the marginal gain from the slightest possible change in resource use is equal to the marginal loss implied by the change.

Principle of substitution: Principle which states that in substituting one production method for another, the savings incurred from replacing one method must be greater than the cost of the new method added.

Probability: The chance of an occurrence.

Probability distribution: The spread of observed values around an actual value.

Probability sampling: A method of sampling in which the probability of a particular individual being included in the sample is known or can be estimated with reasonable precision.

Production function: A function that shows the quantitative relationship between inputs and outputs for some production process.

Production system model: The simplified representation of the production activities on a farm.

Production unit: In FSR, the farm. For small farms, may be synonymous with the consumption unit (household).

Production-function analysis: A method of making a production decision by estimating and analyzing production functions.

Product-product relationship: The relationship among the various products (outputs) based on which combination makes the most profitable use of available resources.

Profit budget: A budget drawn up in terms of some measure of farm profit, such as net farm earnings.

Profitability: Excess of revenues over costs.

Program approach: An approach to FSR that involves institutionalizing it into the country's existing agricultural research and development programs through either coordinated efforts between all organizations that are most concerned with small-farm production or through one organization assuming primary responsibility for implementing the program.

Proindustry index (prosubsistence index): Measures the magnitude of output used as raw materials for industrial processing to support industrial workers or for direct home consumption. Comparable to the index of commercialization.

Project approach. An approach to FSR involving initiating one or more projects that incorporate FSR procedures. Projects tend to have specific scopes of work to be completed by a certain time and are disbanded upon the project's completion.

Prolific: Term describing an animal that is capable of having many offspring or large litters.

Promodernity index: Measures the extent to which energy input to the farm production process comes from goods developed through the use of mode nology or manufacturing processes, such as machinery, manufactured fertilizer, insecticides, and other agrochemicals. Since manufactured goods are normally those that farmers have to purchase, the index is comparable to the index of monetization.

Proportional cost: Costs that vary directly and proportionally with yield.

Prototype solutions: Solutions generated by upstream FSR programs which lead to major shifts in the potential productivity of farming systems in general, but are not yet fine-tuned for immediate adaptation by individual farmers.

Purposive sampling: A method of nonrandom sampling in which a sample is drawn to illustrate or represent some particular characteristics in the population.

Rainfed farming. Growing crops or animals under conditions of natural rainfall. Water may be stored in the field by bunding, as with lowland rainfed rice, but no water is available from permanent water-storage areas.

Random mating: Allowing selected animals to mate at random.

Random sampling: A method of probability sampling in which every unit in the population or subpopulation has an equal probability of being selected.

Rate of technical substitution of factor i for factor j (RTS_{ij}): The amount by which factor i must be increased if factor j is reduced by one unit if the level of production is to remain unchanged.

Ration: The feed given to an animal in 24 hours, whether it is fed at one time or in portions at different times.

Recommendation (crop production): Advice on operations, times, equipment, and materials for crop production that is presented as worthy of acceptance.

Recommendation domain: A group of roughly homogeneous farmers with similar circumstances for whom the same recommendation can be made. Recommendation domains may be defined in terms of natural factors (such as rainfall) and economic factors (such as farm size).

Reconnaissance survey: A field survey method of data collection that usually comes after secondary data collection.

Relative crop intensity index (RCII): A derivative from the cropping intensity index that measures the role of individual crops or groups within the available area-time and relative to all crops cultivated by a farmer.

Relative reproduction rate (RRR): The ratio of proportion of species 1 in the harvest mixture to the proportion of species 1 in the seed mixture divided by the ratio of the proportion of species 2 in the harvest mixture to the proportion of species 2 in the seeded mixture.

Relative-yield total ratio (RYTE): The sum of the relative yields of all species grown simultaneously. Relative yield is the ratio of the yields of all species in a mixture to the yield of that species in pure stand.

Repeatability: The tendency of animals to repeat themselves in certain performance traits in successive seasons, pregnancies, or lactations.

Representativeness: A source of bias in probability elicitation whereby too much weight is attached to the extent to which a particular event is representative of a particular class of events.

Researcher-managed trials: On-farm experiments managed by researchers to develop new technologies under farmers' conditions.

Resource endowments: The amount and quality of resources (in the forms of land, labor, etc.) available in a particular region or to a particular group of farms or to an individual farm.

Resource feasibility: The practicality of an action or project in terms of available resources such as land, labor, capital, and management.

Resources: The means available for producing goods that are used to satisfy human wants, including labor of all kinds, land, machinery, buildings, semifinished materials, fuel, power, and transportation (Leftwich, 1979). Land, labor, and capital are common resources.

Results obtained vs results expected test. Statistical test which involves predicting the behavior of the alternative and comparing this prediction with conditions on real farms where the alternative has been introduced.

Retail margin: The difference between what the retailer pays the processor and what the consumer pays the retailer.

Return to family labor: Net farm earnings less an imputed interest charge on farm equity capital.

Return to farm equity capital: Net farm earnings minus the value of family labor used on the farm, usually expressed as a percentage of farm equity capital.

Return to total capital: Net farm earnings minus the value of family labor used on the farm, usually expressed as a percentage of total farm capital (farm equity capital plus borrowed capital).

Risk: The chance of some favorable or unfavorable event occurring, occurrences that can be quantified on the basis of probability analysis.

Rotational grazing: Moving cattle methodically from one paddock to another in a rotation of paddocks, resting each in turn; the opposite of set-stocking.

Roughages: Feeds that are low in digestible energy and high in fiber such as hay, straw, roots, and silage.

Ruminant: An animal with a functional rumen compartment in the stomach, plus three other compartments.

Rural development: General development of the rural community in terms of such attributes as income, health, education, culture, and infrastructure.

R-value: Percentage of time for which land is actually cropped in a complete crop fallow cycle.

$$R = \text{crop years}/(\text{crop years} + \text{fallow years}) \times 100$$

Sample: A number of individual units selected from all those units that compose a particular population.

Sample survey: Used to identify the many farm settings in which inferences about the larger population are required.

Sampling: The process or technique of choosing the sample.

Sampling frame: A list of the members of a population from whom a sample is to be drawn.

Scarce resources: One of the key elements of economics, OFAR deals with the limited, or scarce, resources of the farm.

Scatter diagram: A figure drawn on two axes representing two variables with paired values of the two variables plotted to show the distribution of observations.

Scouring: Extreme looseness of the bowels or water feces.

Screening: The process of choosing, from among many potential technologies, a few technologies for on-farm experimentation that address critical problems and that are feasible given farmers' circumstances.

Seasonal grazing. Grazing an area only during certain time(s) of the year, roughly corresponding to one or more of the seasons.

Seasonal labor profile: See Labor profile.

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Secondary information: Information obtained from published and unpublished sources such as censuses, government reports, and research publications.

Semisubsistence farming: Farming in which both domestic use and sale account for significant proportions of the farm output.

Sensitivity analysis: A process that features changing a planning coefficient within reasonable bounds of the original estimate to determine whether the original ranking of alternatives is affected.

Sequential evaluation: See Before and after test.

Set-stocking: Keeping the same animals in one area at all times, the opposite of rotational grazing.

Shadow price: The price that would prevail in the economy if it were in equilibrium under conditions of perfect competition.

Short-term cash-flow budget: A cash-flow budget normally constructed over a 12-month planning horizon with the intermediate cash balances calculated at monthly or bimonthly intervals.

Shrinkage: Weight loss occurring in livestock during shipping or when kept from feed and water.

Sib: Brothers or sisters.

Significance level: The maximum value of the probability of rejecting a null hypothesis that is actually true; the probability of committing a Type I error.

Silage: A form of succulent roughage that has been cured and stored in a silo.

Simplified programming (SP): A method of selecting a farm plan in which the required calculations are performed without a computer.

Sire: A male parent.

Site-specific FSR programs: See Downstream FSR programs.

Slippage: The difference between technical possibilities and actual on-farm results.

Small farms: Farms which are family owned and characterized by low cash inputs and a relatively high portion of total farm output going for subsistence of the family.

Soilage: Green forage crops that are cut and fed fresh to animals.

Spread: The arrangement of experimental data or observations in relation to the center of a frequency distribution.

Springing: The signs shown by a cow indicating the approach of calving.

S-shaped growth curve: The curve that results when weight is plotted over time, which is a result of the rate at which an animal grows.

Standard deviation: The square root of the variance.

Standing hay: Grass that has matured and dried out while still standing. The nutritional value varies roughly in inverse ratio to rainfall but standing hay is never as good as properly made hay.

Starch: Carbohydrate nutrient material that supplies energy to animals.

Starch-equivalent value: The quantity of starch that will yield as much energy to the body above maintenance needs as would 100 pounds of the feed in question.

States: The possible states of nature.

Statistics: A branch of mathematics dealing with the collection, organization, and interpretation of sets of data according to well-defined procedures.

Steaming up: Feeding a cow or heifer before calving to increase her subsequent lactation.

Sterile: Condition describing an animal that cannot reproduce its kind.

Stock: In cost identification, an amount that is always present.

Stock equivalents: Units used in budgeting livestock feed whereby the energy needs of different categories of livestock are expressed in terms of a single type of livestock. (See Mature stock unit.)

Stover: What remains of the corn plant after the ears are removed.

Stratification: A process of dividing a population into homogeneous subgroups to increase sampling efficiency. Stratification follows as closely as possible the definition of recommendation domains.

Stratified sampling. A method of probability sampling in which the population is first divided into groups on the basis of one or more characteristics of interest.

Straw: Plant material that has been dried and from which the flowers or fruits have been removed.

Student t-test: See t-Test.

Succulent roughages: Roughages that have a high moisture content, as opposed to dry roughages.

Superimposed trials: Experiments composed of a small set of treatments that evaluate the performance of alternative component technology for a cropping pattern. The treatments are superimposed, generally without replication, on four or more similar cropping-pattern trial fields.

Supplement: Anything that is added to a feed.

Supply: The quantity of a commodity offered for sale in a given market, in a given period, at a given price.

Supply curve: A supply schedule plotted on a graph.

Supply schedule. A list of the different quantities of a commodity that producers will offer for sale during a certain period if the corresponding price is acceptable.

Survey: See Farm survey.

System: A conceptual artifice that includes a collection of interdependent and interactive elements that act together to accomplish a given task, an assemblage of objects and activities united by some form of regular interaction or interdependence.

Systematic sampling: A method of probability sampling involving the selection of every K-th member from a list, working backward and forward from a random starting point.

Target crop: A crop that is currently, or has potential to be, a major crop in the system and for which there are technologies that have potential to increase farm production and income.

Target region: A homogeneous region chosen for an on-farm research program. The choice of the region may depend on crop-production potential, government goals for income distribution, and the infrastructure for doing research in the region. On-farm research procedures are most efficiently implemented when focused on a homogeneous region or group of farmers.

Technical feasibility: The potential of a new technology to result in higher yielding animals or crops.

Techniques of production: One of the key elements of economics, OFAR deals with the farmer's techniques of productions, which can be used to combine resources in varying proportions to achieve optimal output.

Technological components: A specific part of a technology such as variety, fertilizer, or herbicide.

Technology: The combination of all the management practices used for producing or storing a crop or crop mixture.

Total digestible nutrients (TDN): Sum of all the digestible organic nutrients (protein, fiber, nitrogen, fat), calculated by the following formula:

$$TDN = [CP + CF + (EE \times 2.25) + NFE \times 100],$$

where CP is digestible crude protein, CF is digestible crude fiber, EE is digestible ether extract, and NFE is digestible nitrogen-free extract.

Total farm capital: The total value of the farm's assets.

Total farm expenses: The value of all inputs used in farm production.

Total field costs: The sum of field costs for all inputs that are affected by a choice, also called Variable costs.

Total gross margin: The sum of the gross margins of all the farm's activities.

Traditional approach to OFAR: A methodological approach to OFAR that hinges on conventional analysis, such as replicate trials on farmers' fields, data gathering, and evaluation.

t-Test: Statistical test used to estimate the reliability of an experiment by determining how consistently the experiment will measure a given parameter.

Turn-around time: The number of days between harvesting one crop and planting the next crop.

Two-phase sampling: A form of multiphase sampling involving data collection from two subsamples.

Two-stage sampling: A sampling procedure in which subpopulations such as villages are selected first, then units such as farmer groups are chosen within each selected subpopulation.

Type I error: The error that is committed when a null hypothesis is rejected that is true and an alternative hypothesis is accepted which is false.

Type II error: The error that is committed when a null hypothesis is accepted that is false and the rejected alternative hypothesis is actually true.

Udder: Organ in the female animal that secretes milk.

Uncertainty: The state in which the probability of the occurrence of an event cannot be determined.

Unit value: The cost of the quantity of the material capable of supplying 1% plant nutrient in 1 ton of the material; determined by dividing the cost per ton by the percentage of nutrient.

Upstream FSR programs: FSR programs that generate prototype solutions leading to major shifts in the potential productivity of farming systems in general.

Valid: A descriptive term for a system model, meaning that the model's response and the real system's response are identical or very similar.

Value added: The total value of production less the value of intermediate inputs.

Variable: A symbol representing a quantity that is capable of assuming a number of different values.

Variable costs: See Total field costs.

Variable expenses: Components of total farm expenses that are specific to a particular crop or livestock enterprise and that vary more or less in direct proportion to the scale of the enterprise.

Variable input: An input in a production process the level of which is variable, often the level used can be chosen by the decision-maker.

Variance: A description of the degree of clustering about a central point.

Verifiable: A descriptive term for a system model, meaning that the response predicted by the model can be confirmed by testing.

Village studies: A form of data collection in which some information is gathered from the full village and other information is obtained from a sample of village households.

Water-balance budget: A budget of the irrigation water needs of a crop or combination of crops.

Whole-farm budget: A budget drawn up to show the anticipated consequences, in terms of selected measures of performance, of some actual or proposed farm plan.

Whole-farm planning: Planning which involves consideration of the farm system as a whole, as distinct from partial budgeting.

Whole-farm production function. A function relating total farm output to the use of land, labor, and capital on a whole-farm basis.

Wholesale margin: The difference between what the processor pays the producer and what the retailer pays the processor.

Working capital: Capital needed for the month-to-month running of a farm, distinct from longer-term investment capital.

Yearling: An animal of either sex of 12 to 20 months of age.

Yield: An amount of production, such as the dressing percentage of a slaughtered animal, the volume of milk produced per day or per lactation, the pounds of wool clipped per ewe, or the percentage of clean wool after scourging.

Yield gap: The difference between actual farm yields and either potential farm yields or experiment-station yields.

Yield risks: The risks associated with unexpected variations in yields due to such conditions as weather or pests.

Zero grazing. A system of management under which all feed is hauled to animals that are confined to a yard or shed.

Zones of irrational production. On a graph of factor-product relationships, the areas that indicate inefficient use of the variable input.

Zones of rational production. On a graph of factor-product relationships, the areas that indicate efficient use of the variable input; the area of economic relevance.

BIBLIOGRAPHY

Abraham, P. D., C. Devendra, R. I. Hutagalung, J. C. Rajarao, K. Venugopal, Zainab Abdul Ghani, and Zainal Thamby. 1978. Proc. Seminar on Integration of Livestock with Plantation Crops. Rubber Research Institute, Pulau Pinang, Malaysia.

Amir, P. and H. C. Knipscheer. 1987a. A conceptual framework for economic analysis of small ruminant production systems. In: Devendra, C. (ed.), Small Ruminant Production Systems in South and Southeast Asia: Proceedings of a Workshop in Bogor, Indonesia, 6–10 October 1986. International Development Research Centre, Ottawa, Ont., Canada. IDRC-256e.

Amir, P. and H. C. Knipscheer. 1987b. Application of the environment-behavior-performance model in farming systems research: The case of small ruminant technology transfer. Agricultural Administration and Extension, 25(3):161–176.

Amir, P., H. Knipscheer, and A. J. De Boer. 1985. Economic analysis of on-farm animal trials. In. Proc. Farming Systems Research Socioeconomic Monitoring Tour/Workshop. International Rice Research Institute, Los Baños, Philippines.

Amir, P., E. G. Tuiza, I. M. Revilla, and M. B. Carlos. 1987. Comparative performance of cows and buffalo in Pakistan and India: A micro study. In. Proc. On-Farm Animal Research/Extension and Its Economic Analysis. Southeast Asian Regional Center for Graduate Study and Research in Agriculture, Los Baños, Laguna, Philippines.

Anderson, J. R., J. L. Dillon, and J. B. Hardaker. 1977. Agricultural Decision Analysis. Iowa State Univ. Press, Ames, IA, USA.

Bath, D. L., F. N. Dickinson, H. A. Tucker, and R. D. Appleman. 1978. Dairy Cattle. Principles, Problems, Profits. Lea and Febiger, Philadelphia, PA, USA.

Beebe, J. 1985. Rapid rural appraisal. The critical first step in a farming systems approach to research. FSSP Networking Paper 5. University of Florida, Gainesville, FL, USA.

Berg, R.T. and R.M. Butterfield. 1968. Growth patterns of bovine muscle, fat and bone. J. Animal Science, 27:611–619.

Bernsten, R. 1979. Design and Management of Survey Research: A Guide for Agricultural Researchers. CRIA/International Rice Research Institute Cooperative Program, Bogor, Indonesia.

Bernsten, R. H., H. A. Fitzhugh, and H. C. Knipscheer. 1983. Livestock in farming systems research. Paper presented at 6th Annual Farming Systems Symposium. Kansas State University, Manhattan, KS, USA.

Bhattacharyya Gouri and R. A. Johnston. 1977. Statistical Concepts and Methods. John Wiley and Sons, New York, NY, USA.

Bogart, R. 1977. Scientific Farm Animal Production. Burgess Pub. Co., Minneapolis, MN, USA.

Borel, R., M. Ruizi, D. Pezo, and A. Ruiz. 1985. A methodological approach for the development and evaluation of alternatives for animal production systems for the small farmer. In. Report of the II Workshop on Tropical Animal Production Systems. International Development Research Centre, Ottawa, Ont., Canada. IDRC-MR62e.

Bradford and Johnson 1953. Farm Management Analysis. John Wiley and Sons, New York, NY, USA.

Brannon, R. H., C. Sirirugsa, and B. T. Dean. 1979. Testing of research station results at the farm level: Lessons from a feeding trial in northeast Thailand. Trop. Sci., 21(2).

Bressler, R. and R. King. 1970. Market, Prices and Interregional Trade. John Wiley and Sons, New York, NY, USA.

Byerlee, D. and M. Collinson. 1980. Planning Technologies Appropriate to Farmers, Concepts and Procedures. International Maize and Wheat Improvement Center, Mexico City, Mexico.

Calub, A. D. 1985. Experimental design and procedures for on-farm livestock trials. In: Proc. of Socioeconomic Workshop. International Rice Research Institute, Los Baños, Philippines.

Calub, A. D. 1986. Experimental designs and procedures for on-farm animal trials. In: Proc. Farming Systems Research Socioeconomic Monitoring Tour/Workshop. International Rice Research Institute, Los Baños, Philippines.

Carkner, R. W., W. McReynolds, and S. Kraten. 1981. Estimated costs and returns for a 70 ewe flock. Farm Business Management Reports. Washington State University, Pullman, WA, USA.

Centre d'Etudes et d'Experimentation du Manchinisme Agricole. 1972. The employment of draught animals in agriculture. Food and Agriculture Organization of the United Nations. Rome, Italy.

Chambers, R. 1987 Notes and reflections on the Workshop on Farmers and Agricultural Research: Complementary methods. Institute of Development Studies, University of Sussex, Brighton, UK. (mimeo)

Church, P. E. and C. M. Gonzales. 1985. In. Proc. Farming Systems Research Socioeconomic Monitoring Tour/Workshop. Training Paper SD-14. International Rice Research Institute, Los Baños, Philippines.

Cramer, G. and C. Jensen. 1979 Agricultural Economics and Agribusiness. An Introduction. John Wiley and Sons, New York, NY, USA.

Daniels, D and B. Nestle (eds.). 1981. Resource allocation to agricultural research. Proceedings of a Workshop held in Singapore, 8–10 June 1981. International Development Research Centre, Ottawa, Ont., Canada. IDRC-182e.

De Boer, A J 1977. A classification scheme for African animal production systems and its use for research resource allocation, program design and project monitoring. Occasional Paper 7. International Livestock Centre for Africa, Addis Ababa, Ethiopia.

Devendra, C. 1987. The relevance of on-farm animal production research in Asia. In. Proc. On-Farm Animal Research/Extension and Its Economic Analysis. Southeast Asian Regional Center for Graduate Study and Research in Agriculture, Los Baños, Laguna, Philippines.

Dillon, John I and J B Hardaker 1980. Farm management research for small farmer development. Agricultural Services Bulletin 41. Food and Agriculture Organization of the United Nations, Rome, Italy.

Drilon, J D., Jr 1977 Agricultural Research Systems in Asia. Southeast Asian Regional Center for Graduate Study and Research in Agriculture, Los Baños, Laguna, Philippines.

Doll, J. P. and F Orazem. 1984. Production Economics — Theory with Applications, 2nd ed. John Wiley and Sons, New York, NY, USA.

Donaldson, L. 1984. Economic Development. Analysis and Policy. West Publishing, St. Paul, MN, USA.

Ensminger, M. E. 1962. The Stockman's Handbook, 3rd ed. Interstate Printers and Publishers, Danville, IL, USA.

Eusebio, J. A., et al. 1977. Nutrient requirements of swine under tropical humid conditions. Technical Bulletin 2(2). NSDB/NRCP/Univ., Los Baños, Philippines.

Fajardo, F. R. 1985. Agricultural Economics, 2nd ed. Rex Printing Co. Inc., Quezon City, Philippines.

Farming Systems Support Project. 1985. Animal traction in a farming systems perspective. Farming Systems Support Project Network Workshop, Kara, Togo.

Fenn, M. G. 1977. Marketing Animals and Meat, 2nd ed. FAO Marketing Guide No. 3. Food and Agriculture Organization of the United Nations, Rome, Italy.

Fitzhugh, H. A. 1978. Bioeconomic analysis of ruminant production systems. J. Animal Science, 43(3).

Fitzhugh, H. A. 1982. On-farm research involving animal component of farming systems. Winrock International Livestock Research and Training Center, Morrilton, AR, USA.

Fitzhugh, H. A. 1985. On-farm research involving the animal component in the farming systems. In: Report of the II Workshop on Tropical Animal Production Systems. International Development Research Centre, Ottawa, Ont., Canada. IDRC-MR62e.

Fitzhugh, H. A., R. D. Hart, R. A. Moreno, P. O. Osuji, M. E. Ruiz, and L. Singh (eds.). 1978. The role of ruminants in support of man. Winrock International Institute for Agricultural Development, Morrilton, AR, USA.

Fitzhugh, H. A., et al. (eds.). 1982. Research on Crop-Animal Systems. Centro Agronomico Tropical de Investigacion y Ensenanaza/Caribbean Agricultural Research and Development Institute/Winrock International, Morrilton, AR, USA.

Foley, R. C., D. L. Bath, F. N. Dickinson, and H. A. Tucker. 1972. Dairy Cattle: Principles, Practices, Problems and Profits. Lea and Febiger, Philadelphia, PA, USA.

Frio, A. 1985. Data processing from farm surveys. In. Proc. Farming Systems Research Socioeconomics Monitoring Tour/Workshop. Training Paper SD-14. International Rice Research Institute, Los Baños, Philippines.

Frio, A. 1985. Preparing the interview schedule. In. Proc. Farming Systems Research Socioeconomics Monitoring Tour/Workshop. Training Paper SD-14. International Rice Research Institute, Los Baños, Philippines.

Frio, A. 1985. Pretesting the interview schedule. In. Proc. Farming Systems Research Socioeconomics Monitoring Tour/Workshop. Training Paper SD-14. International Rice Research Institute, Los Baños, Philippines.

Gittinger, J. P. 1982. Economic Analysis of Agricultural Projects. EDI Series in Economic Development, World Bank, Washington, DC, USA.

Gittinger, J. P. 1982. Economic Analysis of Agricultural Projects, 2nd ed. Johns Hopkins Univ. Press, Baltimore, MD, USA.

Gryseels, G. 1988. Role of Livestock on Mixed Smallholder Farms in the Ethiopian Highlands. A case study from the Baso and Worena Wereda near Debre Berhan. Dissertation, Agricultural University, Wageningen, The Netherlands.

Harrington, L. W. 1984. Farming systems research: The need for a practical approach. Paper presented at 1st National Farming Systems Workshop, Bangkok, Thailand.

Hart, R. D. and C. George. 1983. A guideline for the design of farming systems project: A case study from the Eastern Caribbean. Paper presented at the 3rd Annual Farming Systems Symposium, Kansas State University, Manhattan, KS, USA.

Harwood, R. R. 1979. Small farm development: Understanding and improving farming systems in the humid tropics. Westview Press, Boulder, CO, USA.

Hassan, W. and C. Devendra. 1982. An assessment of feed resources, feeding systems, and problems concerning smallholder dairy cattle production in the milk collection center. Malaysian Agricultural Research and Development Institute, Selangor, Malaysia. Report No. 77.

Heady, E. O. 1984. Livestock Production Functions. Iowa State Univ. Press, Ames, IA, USA.

Hickman, C. G. 1980. Recording for Livestock Development. FAO/SIDA Seminar of Livestock Recording. Gabaronne, Botswana.

Higgs, R., C. Heidenreich, R. Loberger, R. Cropp and M. Mitchell. 1981. Agricultural Mathematics: Problems in Production Management, Marketing, Mechanization and Environmental Quality, 2nd ed. Interstate Printers and Publishers, Danville, IL, USA.

Hildebrand, P. E. 1978. Generating technology for traditional farmers — a multidisciplinary methodology. Asian Report 8. International Maize and Wheat Improvement Center, Mexico City, Mexico.

International Development Research Centre. 1985. Report of the III workshop meeting on Tropical Animal Production Systems, Turrialba, Costa Rica, February 22-25, 1983. Bogota, Colombia.

Jaiswal, P. L. (ed.). 1985. Handbook of Animal Husbandry. Indian Council of Agricultural Research, New Delhi, India.

Johnson, G. L., A. N. Halter, H. R. Jensen, and D. W. Thomas (eds.). 1961. A Study of Managerial Processes of Midwestern Farmers. Iowa State Univ. Press, Ames, IA, USA.

Kaufmann, R. V. 1983. Design and testing procedures in animal system research. An agropastoral example. Paper presented at workshop, "Production Systems Research for Range Animal Development." International Livestock Centre for Africa, Addis Ababa, Ethiopia.

Kearl, L. C. 1982. Nutrient requirements of ruminants in developing countries. International Feedstuffs Institute, Utah Agricultural Experiment Station, Utah State University, Logan, UT, USA.

Kearl, S. (ed.). 1986. Livestock in mixed farming systems. Research methodologies and priorities. FSSP Network Report No. 2. Farming Systems Support Project, University of Florida, Gainesville, FL, USA.

Knipscheer, H. C. and K Suradisastra. 1986. Farmer participation in Indonesian livestock farming systems by Regular Research Field Hearings (RRFH). Agricultural Administration, 22:205–216.

Knipscheer, H. C., U. Kusnadi, and A. J. DeBoer. 1984. Some efficiency measures of the productive potential of Indonesian goats. Agri. Systems, 15:1–11.

Kohls, R. L. 1961. Marketing of Agricultural Products. McMillan Co., New York, NY, USA.

Lai, K. C., C. Devendra, M. Y. Itashiw, I. Ishak Djatar, and S. Jegathesan. 1973. Preliminary findings of study of buffalo and cattle rearing in the Muda area. Malaysian Agricultural Research and Development Institute, Selangor, Malaysia. Report No. 3.

Langham, M. R. 1979. An introduction to economic principles of production. In: B. T. Tan and S. E. Ong (eds.). Readings in Asian Farm Management. Univ. of Singapore Press, Singapore, Republic of Singapore.

Leftwich, R. A. 1979. The Price System and Resource Allocation, 7th ed. Dryden Press, New York, NY, USA.

Li, Pun H. and H. Zandstra (eds.). 1982. Report of the II Workshop on Tropical Animal Production Systems. International Development Research Centre, Ottawa, Ont., Canada. IDRC-MR62e.

Lipsey, R. G. and P. O. Steiner. 1975. Economics, 4th ed. Harper and Row, New York, NY, USA.

Malaysian Agricultural Research and Development Institute. 1984. Using buffalo to haul FFB in an oil palm estate. Selangor, Malaysia. Report No. 90.

McDowell, R. E. 1977. Ruminant Products: More than meat and milk. Winrock Report. Winrock International Institute for Agricultural Development, Morrilton, AR, USA.

McDowell, R. E. and P. E. Hildebrand. 1980. Integrated Crop and Animal Production: Making the most of resources available to small farms in developing countries. A Bellagio Conference, Oct. 18–23, 1978. Rockefeller Foundation, New York, NY, USA.

Moscardi, E. and A. de Janvry. 1977. Attitudes toward risk among peasants: An econometric approach. American J. Agricultural Economics, pp. 710–716.

Mosher A. T. 1971. To Create a Modern Agriculture. Winrock International, Morrilton, AR, USA.

Mosher, A. T. 1976. Thinking About Rural Development. Winrock International, Morrilton, AR, USA.

National Dairy Research Institute. 1984. Progress Report on the Operational Research Project (ORP). Haryana, India.

National Dairy Research Institute. 1985. Cost of milk production at NDRI farm. Publication No. 175. Karnal, India.

Nelson, A. G., G. Casler, and O. L. Walker. 1978. Making Farm Decisions in a Risky World: A guidebook. Department of Agricultural and Resource Economics, Oregon State Univ., Corvallis, OR, USA.

Neter, J., W. Wasserman, and G. A. Whitmore. 1978. Applied Statistics. Allyn and Bacon, Boston, MA, USA.

Olson, H., J. McIntyre, and J. Tothill. 1986. Livestock — in mixed farming systems — research methods and priorities. Farming Systems Support Project Newsletter 4(2). University of Florida, Gainesville, FL, USA.

Pandey, R. N. and P. S. Kumar. 1981. Economic efficiency of feed resources in milk production under mixed farming systems. Indian J. Dairy Sci., 34.

Patel, R. K. 1981. Economics of livestock enterprises with special references to its employment potential. Indian J. Agricultural Economics, XXXVI(1).

Patel, R. K., S. B. Singh, and A. Kumar. 1982. Seasonal variations in feed-milk relationships and productivity of different feeds. Asian J. Dairy Sciences 1(2):141–147.

Patie, W. A. 1987. Research methodology and requirements for small ruminant production systems. In: Devendra, C. (ed.). Small Ruminant Production Systems in South and Southeast Asia: Proceedings of a Workshop in Bogor, Indonesia, 6–10 October 1986. International Development Research Centre, Ottawa, Ont., Canada. IDRC 256e.

Perin, R. K., D. K. Winkelmann, E. R. Moscardi, and J. R. Anderson. 1976. From Agronomic Data to Farmer Recommendations, An Economic Training Manual. Information Bulletin 27. International Maize and Wheat Improvement Center, Mexico City, Mexico.

Philippine Council for Agriculture and Resources Research and Development. 1985. Philippine Recommends for Goat Farming. PCARRD Technical Bulletin Series No. 24-A. National Science and Technology Authority, Los Baños, Philippines.

Poats, S. V., J. Lichte, J. Oxley, S. Russo, and P. H. Starkey. 1985. Animal Traction in a Farming Systems Perspective: A Farming Systems Support Project Workshop, March 3–8, 1985, Kara, Togo. FSSP Network Report No. 1.

Potts, G. R. 1981. Application of research results on by-product utilization. Economic aspects to be considered. In: Proceedings of a Workshop on By-product Utilization for Animal Production held in Nairobi, Kenya, 26–30 September. International Development Research Centre, Ottawa, Ont., Canada. IDRC-206e.

Preston, T. R. and M. B. Willis. 1974. Intensive Beef Production. Pergamon Press, New York, NY, USA.

Price, E. 1982. Determining the prices of agricultural inputs and products for analysis of agricultural experiments. Paper presented at a PCARRD workshop, PCARRD Headquarters, Los Baños, Philippines.

Rohrbach, D. 1981. Issues in developing and implementing a farming systems research program. Office of International Cooperation and Development, U.S. Department of Agriculture, Washington, DC, USA.

Roumasset, A. J., J.-M. Boussard, and I. Singh (eds.). 1979. Risk Uncertainty and Agricultural Development. Southeast Asian Regional Center for Graduate Study and Research in Agriculture/Agricultural Development Council, Los Baños, Laguna, Philippines.

Rumawas, F. 1984. Farming systems research. A conceptual framework. Paper presented at the Symposium on Farming Systems Research, Sukamandi, Indonesia.

Salvatore, D. 1974 Schaum's Outline of Theory and Problems of Microeconomic Theory. McGraw-Hill, New York, NY, USA.

Sastry, N. S. R. and C. K. Thomas. 1976. Farm Animal Management. Vikas Publishing House PVT, Ltd., New Delhi, India.

Shaner, W. W., P. F. Philipp, and W. R. Schmell. 1982. Farming systems research and development: Guidelines for developing countries. The Consortium for International Development. Westview Press, Boulder, CO, USA.

Shepherd, G. and G. Futrell. 1969. Marketing Farm Products, 5th ed. Iowa State Univ. Press, Ames, IA, USA.

Simmonds, W. N. 1985. Farming systems research. A review. World Bank Technical Paper No. 43. World Bank, Washington, DC, USA.

Slonin, M. J. 1960. Sampling. Simon and Schuster, New York, NY, USA.

Snowden, O. and A. Donahoo. 1960. Profitable Farm Marketing. Prentice-Hall, Inc., Engelwood Cliffs, NJ, USA.

Southeast Asian Regional Center for Graduate Study and Research in Agriculture. 1982. Asian Cases on Agricultural Research Management. Los Baños, Laguna, Philippines.

Sprague, H. G. 1976. Combined crop/livestock farming systems for developing countries of the tropics and subtropics. Agricultural Technology for Developing Countries. Tech. Series Bul. No. 19. U.S. Agency for International Development. Washington, DC, USA.

Tan, B. T., K. Andulavidhaya, I. J. Singh, J. C. Flinn, and S. E. Ong (eds). 1980. Improving Farm Management Teaching in Asia. Agricultural Development Council, Bangkok, Thailand.

Thomsom, E. F., R. Jaubert, and M. Oglah. 1985. On-farm comparisons of milk yield of Awassi ewes grazing introduced forage and common village lands in the barley zone of New Syria. International Center for Agricultural Development in the Dry Areas, Aleppo, Syria.

Tomek, W. and K. Robinson. 1972. Agricultural Product. Cornell Univ. Press, Ithaca, NY, USA.

Van Der Veen, M. G. 1985. Considerations in interview schedule preparation. Farming Systems Research Socioeconomic Monitoring Tour/Workshop. Training Paper SD-14. International Rice Research Institute, Los Baños, Philippines.

Van Der Veen, M. G. 1985. Farm case studies. International Rice Research Institute, Los Baños, Philippines (mimeo).

Van Der Veen, M. G. 1985. Farm survey management procedures. In. Proc. Farming Systems Research Socioeconomic Monitoring Tour/Workshop. Training Paper SD-14. International Rice Research Institute, Los Baños, Philippines.

Van Der Veen, M. G. 1986. Overview of farming systems research. In. Farming Systems Socioeconomic Research Training Course. Vol. 1. International Rice Research Institute, Los Baños, Philippines.

Van Der Veen, M. G. and A. L. Frio. 1984. Glossary of main farming systems and related terms. Farming Systems Socioeconomics Research Training Paper IFSR-5. International Rice Research Institute, Los Baños, Philippines.

Van Eys, J. E., S. Silitonga, I. W. Mathius, and W. L. Johnson. 1985. On-farm trials of mineral supplementation for small ruminants in West Java, Indonesia. In: T. L. Nordblom, A. E. K. Hamid Achmed, and G. R. Potts (eds.). Research Methodology for Livestock On-farm Trials: Proceedings of a Workshop held at Aleppo, Syria, 25–28 March 1985. International Development Research Centre, Ottawa, Ont., Canada. IDRC-242e.

Wahab, H. and C. Devendra. 1982. An Assessment of Feed Resources, Feeding Systems and Problems Concerning Smallholder Dairy Cattle Production in the Milk Collection Centre, Jassin, Malaca. Report No. 77. Malaysian Agricultural Research and Development Institute, Selangor, Malaysia.

Walpole, R. 1974. Introduction to Statistics. Macmillan, New York, NY, USA.

Weinberg, G. H., J. A. Schumaker, and D. Oltman. 1981. Statistics. An Intuitive Approach, 4th ed. Brooks/Cole Pub. Co., Monterey, CA, USA.

Zafar, A. H. 1985. Economics of rural dairy animals in the canal irrigated area of the Punjab, 1982–83. Livestock Production Research Institute, Bahadurnagar, Okara, Punjab, Pakistan.

Zandstra, H. G. 1983. Testing of designs of crops-animal systems. Discussion notes for the Asian Cropping Systems Network Meeting on Crop-Animal Research. International Rice Research Institute, Los Baños, Philippines.

EXERCISES

CHAPTER 1

ANIMAL RESEARCH WITHIN FARMING SYSTEMS RESEARCH

1. What are the four stages of Farming Systems Research (FSR)? Why is it important to have farmers involved in discussions of field results during the verification stage of On-farm Animal Research (OFAR)?
2. What are the pros and cons for taking a "traditional approach" to OFAR rather than an "innovative approach" to OFAR?
3. A study to investigate low productivity of pigs is being conducted in an intensive crop-growing region. Document the steps that need to be taken that would involve the local agricultural research station and the farmers in the investigation.

CHAPTER 2

ANIMAL PRODUCTION CONCEPTS

1. List the important contributions of livestock on farms in your country.
2. Describe the phases of growth for mammals and poultry.
3. List the important types of animal feeds.
4. A concentrate mixture is to contain 12% CP, with soybean meal (40% CP) as one component and grain (8% CP) as the second component. Using the Pearson Square, determine the proportions of soybean meal and grain that should be used in the concentrate mixture. Check the answer with an algebraic determination.

Solution

4.

Feed	CP	Parts	Percentage
Soybean Meal	40	4	12.5
Grain	8	28	87.5
Concentrate	12	32	100.0

The algebraic determination is as follows:

$40(a) + 8\,(1 - a) = 12$

$40(a) + 8 - 8(a) = 12$

$32(a) = 4$

$a = 0.125 = 12.5\%$

CHAPTER 3

ECONOMIC CONCEPTS

1. From the data presented in table 3.3, decide how much concentrate a farmer should purchase for his dairy cows if the price of milk is US$0.20/kg and the price of concentrate is US$0.30/kg.

2. Based on data in table 3.6, decide on the least-cost combination of concentrate and berseem a farmer should use to obtain 6.5 kilograms of milk if the price of concentrate is Rs 31/kilogram and the price of berseem is Rs 15/kilogram.

3. The prices of corn and soybeans are US$2.00/bushel and US$6.00/bushel, respectively. Recalculate the total revenue and determine the optimum combination of corn and soybeans based on the data in table 3.7. Do marginal conditions hold?

Solutions

1. Use the principle of profit maximization:

$$\Delta Y/\Delta X = P_x/P_y$$
$$\Delta Y/\Delta X = \text{US\$0.30/US\$0.20}$$
$$\Delta Y/\Delta X = 1.50$$

From data in table 3.3, the farmer could purchase from 4 to 6 kilograms of concentrate and produce from 9.41 to 12.41 kilograms of milk.

2. Use the equation for least-cost combination of inputs:

$$-\Delta X_1/\Delta X_2 = P_{x2}/P_{x1}$$
$$-\Delta X_1/\Delta X_2 = \text{Rs } 15/\text{Rs } 31$$
$$-\Delta X_1/\Delta X_2 = 0.48$$

The combination of concentrate and berseem would be approximately 3.73 kilograms and 10 kilograms respectively.

3. The following data will be obtained:

Corn Y_1 (bu)	ΔY_1	Soybeans Y_2 (bu)	ΔY_2	$-\Delta Y_1/\Delta Y_2$	P_{y2}/P_{y1}*	Total Revenue (US$)
170		0			3	340
	−10		10	1.0		
160		10			3	380
	−15		10	1.5		
145		20			3	410
	−25		10	2.5		
120		30			3	420
	−35		10	3.5		
85		40			3	410
	−40		10	4.0		
45		50			3	390
	−45		10	4.5		
0		60			3	360

*Given the price of corn, P_{y1}, is US$2.00 per bushel, and the price of soybeans, P_{y2}, is US$6.00 per bushel.

The equation for the optimum combination of outputs should then be used:

$$-\ \Delta Y_1/\Delta Y_2 = P_{y2}/P_{y1}$$
$$-\ \Delta Y_1/\Delta Y_2 = 6.00/2.00$$
$$-\ \Delta Y_1/\Delta Y_2 = 3.0$$

Marginal conditions do hold with the optimum combination of outputs equal to 120 bushels of corn and 30 bushels of soybeans.

CHAPTER 4

USING STATISTICS IN ON-FARM ANIMAL RESEARCH

1. A study is being conducted to determine whether adding a mineral supplement to buffalo's diet will increase their weight. Ten buffalo of the same breed are divided into two groups. The first group is given a mineral supplement; the second group is the control. The total weight gain for each group is calculated weekly. The results are as follows:

First group	Second group
15	25
50	20
20	25
35	40
40	50

(a) State the null hypothesis (H_o).

(b) State the alternative hypothesis (H_a).

To determine whether the mineral supplement is causing greater weight gains,

(c) Compute the means for the weight gains of each group.

(d) Using the weight-gain results and the hypotheses, state your decision.

2. Research is being conducted to determine whether breed differences affect the number of eggs chickens lay in their peak egg-laying month. The study is designed using two breeds of chickens: layers and natives. A total of 100 chickens is used in the trial: 50 of each breed. The results are shown in the following table.

(a) Find the t value.

(b) At a significance level of 0.05, is there a difference in egg production between the two breeds?

Egg production, layers			Egg production, natives		
X	$(X - \bar{X})$	$(X - \bar{X})^2$	Y	$(Y - \bar{Y})$	$(Y - \bar{Y})^2$
29.00	1.24	1.54	12.00	−4.56	20.79
30.00	2.24	5.02	15.00	−1.56	2.43
30.00	2.24	5.02	15.00	−1.56	2.43
28.00	0.24	0.06	21.00	4.44	19.71
30.00	2.24	5.02	14.00	−2.56	6.55
28.00	0.24	0.06	13.00	−3.56	12.67
27.00	−0.76	0.58	12.00	−4.56	20.79
29.00	1.24	1.54	15.00	−1.56	2.43
30.00	2.24	5.02	14.00	−2.56	6.55
29.00	1.24	1.54	13.00	−3.56	12.67
30.00	2.24	5.02	14.00	−2.56	6.55
30.00	2.24	5.02	14.00	−2.56	6.55
28.00	0.24	0.06	12.00	−4.56	20.79
27.00	−0.76	0.58	15.00	−1.56	2.43
26.00	−1.76	3.10	18.00	1.44	2.07
25.00	−2.76	7.62	15.00	−1.56	2.43
26.00	−1.76	3.10	17.00	0.44	0.19
28.00	0.24	0.06	11.00	−5.56	30.91
30.00	2.24	5.02	18.00	1.44	2.07
29.00	1.24	1.54	19.00	2.44	5.95
29.00	1.24	1.54	20.00	3.44	11.83
28.00	0.24	0.06	20.00	3.44	11.83

Egg production, layers			Egg production, natives		
X	$(X - \bar{X})$	$(X - \bar{X})^2$	Y	$(Y - \bar{Y})$	$(Y - \bar{Y})^2$
29.00	1.24	1.54	16.00	−0.56	0.31
25.00	−2.76	7.62	20.00	3.44	11.83
20.00	−7.76	60.22	15.00	−1.56	2.43
22.00	−5.76	33.18	14.00	−2.56	6.55
23.00	−4.76	22.66	12.00	−4.56	20.79
25.00	−2.76	7.62	14.00	−2.56	6.55
29.00	1.24	1.54	17.00	0.44	0.19
30.00	2.24	5.02	20.00	3.44	11.83
29.00	1.24	1.54	17.00	0.44	0.19
28.00	0.24	0.06	20.00	3.44	11.83
28.00	0.24	0.06	23.00	6.44	41.47
28.00	0.24	0.06	22.00	5.44	29.59
27.00	−0.76	0.58	21.00	4.44	19.71
27.00	−0.76	0.58	19.00	2.44	5.95
28.00	0.24	0.06	20.00	3.44	11.83
29.00	1.24	1.54	20.00	3.44	11.83
28.00	0.24	0.06	17.00	0.44	0.19
29.00	1.24	1.54	17.00	0.44	0.19
26.00	−1.76	3.10	12.00	−4.56	20.79
27.00	−0.76	0.58	16.00	−0.56	0.31
29.00	1.24	1.54	14.00	−2.56	6.55
27.00	−0.76	0.58	13.00	−3.56	12.67
28.00	0.24	0.06	16.00	−0.56	0.31
29.00	1.24	1.54	20.00	3.44	11.83
30.00	2.24	5.02	17.00	0.44	0.19
25.00	−2.76	7.62	20.00	3.44	11.83
28.00	0.24	0.06	19.00	2.44	5.95
29.00	1.24	1.54	20.00	3.44	11.83

3. It is necessary to determine the effect of commercial feed on the egg production of native-breed chickens. A study is designed using 100 native-breed chickens: 50 receive commercial feed, and 50 do not receive commercial feed. The results are shown in the following table.

   (a) Find the t value.

   (b) At a significance level of 0.05, is there a difference in egg production between chickens that receive commercial feed and those that do not?

Egg production, chickens eating commercial feed			Egg production, chickens not eating commercial feed		
X	$(X - \bar{X})$	$(X - \bar{X})^2$	Y	$(Y - \bar{Y})$	$(Y - \bar{Y})^2$
30.00	4.00	16.00	23.00	5.56	30.91
25.00	−1.00	1.00	17.00	−0.44	0.19
28.00	2.00	4.00	19.00	1.56	2.43
27.00	1.00	1.00	16.00	−1.44	2.07
28.00	2.00	4.00	15.00	−2.44	5.95
30.00	4.00	16.00	14.00	−3.44	11.83
26.00	0.00	0.00	12.00	−5.44	29.59
26.00	0.00	0.00	15.00	−2.44	5.95
25.00	−1.00	1.00	19.00	1.56	2.43
27.00	1.00	1.00	18.00	0.56	0.31
25.00	−1.00	1.00	19.00	1.56	2.43
26.00	0.00	0.00	20.00	2.56	6.55
27.00	1.00	1.00	15.00	−2.44	5.95
28.00	2.00	4.00	14.00	−3.44	11.83
29.00	3.00	9.00	14.00	−3.44	11.83
27.00	1.00	1.00	18.00	0.56	0.31
27.00	1.00	1.00	19.00	1.56	2.43
24.00	−2.00	4.00	14.00	−3.44	11.83
23.00	−3.00	9.00	18.00	0.56	0.31
24.00	−2.00	4.00	16.00	−1.44	2.07
29.00	3.00	9.00	16.00	−1.44	2.07
27.00	1.00	1.00	13.00	−4.44	19.71
28.00	2.00	4.00	20.00	2.56	6.55
28.00	2.00	4.00	18.00	0.56	0.31
22.00	−4.00	16.00	19.00	1.56	2.43
21.00	−5.00	25.00	14.00	−3.44	11.83
20.00	−6.00	36.00	15.00	−2.44	5.95
22.00	−4.00	16.00	20.00	2.56	6.55
28.00	2.00	4.00	18.00	0.56	0.31
29.00	3.00	9.00	16.00	−1.44	2.07
29.00	3.00	9.00	20.00	2.56	6.55
28.00	2.00	4.00	20.00	2.56	6.55
30.00	4.00	16.00	19.00	1.56	2.43
29.00	3.00	9.00	20.00	2.56	6.55
28.00	2.00	4.00	20.00	2.56	6.55
27.00	1.00	1.00	19.00	1.56	2.43
27.00	1.00	1.00	18.00	0.56	0.31
29.00	3.00	9.00	17.00	−0.44	0.19
25.00	−1.00	1.00	19.00	1.56	2.43

Egg production, chickens eating commercial feed			Egg production, chickens not eating commercial feed		
X	$(X - \bar{X})$	$(X - \bar{X})^2$	Y	$(Y - \bar{Y})$	$(Y - \bar{Y})^2$
23.00	−3.00	9.00	20.00	2.56	6.55
20.00	−6.00	36.00	12.00	−5.44	29.59
21.00	−5.00	25.00	15.00	−2.44	5.95
28.00	2.00	4.00	19.00	1.56	2.43
24.00	−2.00	4.00	19.00	1.56	2.43
20.00	−6.00	36.00	19.00	1.56	2.43
23.00	−3.00	9.00	17.00	−0.44	0.19
29.00	3.00	9.00	17.00	−0.44	0.19
27.00	1.00	1.00	18.00	0.56	0.31
25.00	−1.00	1.00	20.00	2.56	6.55
22.00	−4.00	16.00	20.00	2.56	6.55

Solutions

1. a. H_o: There is no difference between the two groups of animals.
   b. H_a: There is a weight difference between the two groups.
   c. first group: $\bar{X} = 32$
   second group: $\bar{Y} = 32$
   d. H_o is accepted.

2. a. Compute the degrees of freedom.
   $df = n_1 + n_2 - \text{number of samples} = 50 + 50 - 2 = 98$
   From a statistical handbook the t-value can be found. The test value at a significance level of 10% is 1.282 ($t_{.10} = 1.282$). At a significance level of 5% the t-value is 1.645 ($t_{.05} = 1.645$).

b. Means: $\bar{X} = 27.76$ $\qquad \bar{Y} = 16.56$

$$\text{Variances: } SD^2_x = \frac{\Sigma(X_i - \bar{X})^2}{n-1} = \frac{225.24}{49} = 4.60 \qquad SD^2_y = \frac{\Sigma(Y_i - \bar{Y})^2}{n-1} = \frac{486.14}{49} = 9.92$$

$$t = \frac{27.76 - 16.56}{\sqrt{\left[\frac{(49 \times 4.60) + (49 \times 9.92)}{98} \times \frac{2}{49}\right]}}$$

$$= \frac{11.20}{\sqrt{\left[\frac{225.40 + 486.08}{98} \times \frac{2}{49}\right]}}$$

$$= \frac{11.20}{0.54}$$

$$= 20.74$$

As 20.74 is greater than $t_{.05}$ (1.645) the H_o (no difference between breeds) is rejected. The conclusion is that the difference in egg production between the two breeds is statistically significant.

3. (a) $t_{.05} = 1.645$

$t_{.10} = 1.282$

(b) means: $\bar{X} = 26.00$ $\qquad \bar{Y} = 17.44$

variances: $SD^2_x = 8.29$ $\qquad SD^2_y = 6.17$

$$t = \frac{8.56}{0.54}$$

$$= 15.85$$

t is greater than 1.645. The conclusion is that the difference between the two samples is statistically different.

CHAPTER 5

SCREENING TECHNOLOGIES FOR PROFITABILITY

1. Compare the priorities of small farmers with those of commercial farmers. Focus on inputs, outputs, economic risks, and management styles of each group.
2. Why is it necessary to assess the marketing potential of products generated from new technologies before conducting OFAR? What important variables need to be measured in this assessment?
3. If a significant difference exists in the yield-gap for a technology, what steps could be taken to identify reasons for this difference?
4. Describe how new crop and livestock technologies are chosen for testing at the farm level in your country.
5. For each of the following species, list six technologies that must be screened at the research station before they are tested on farms.
   (a) Goats and sheep
   (b) Cattle and buffalo
   (c) Pigs
   (d) Chickens and ducks
6. Why are client and market so important in screening technology?
7. Agree or disagree with the following statement:
   "Higher yields and higher net returns are the best criteria for screening new practices." Discuss.

CHAPTER 6

GUIDELINES FOR CONDUCTING ON-FARM ANIMAL RESEARCH

1. Suppose sites must be chosen for testing three new yokes that have been developed at the research station for use on small farms. How can representative farms be selected? How many farms should be chosen? What are the disadvantages of testing several types of yokes at one time?
2. Suppose a farming systems program in Indonesia has found that protein deficiency is limiting the productivity of small ruminants. Trials need to be designed for the four to five promising protein supplements recommended by the provincial livestock center. What are the objectives of the research? What procedure should be used? List several impediments which may be encountered when testing the treatments.

3. A study is being conducted to determine the feasibility of introducing dairy cattle into a region of the People's Republic of China. What steps should be taken to investigate the existing crop-livestock system?

Solutions

1. First, the type of yoke most commonly used by small farmers in this area should be determined. Since the yoke's performance will be affected by the health of the animals, cropping pattern, and soil type, farms should be chosen where each of these variables is in keeping with the norm for the area. Adequate representation can be achieved by selecting 30 to 40 farmers from 2 to 3 villages. This means a lot of yokes will be needed, which may make the project too expensive. If so, only one type of yoke could be tested on each farm or the sample size could be reduced. Another possibility is staggering the experiment over time so that the same yoke can be used on more than one farm. However, this may prove to be time consuming.

2. The objectives are to find out which protein supplement(s) 1) increases the productivity of small ruminants, 2) is technically feasible for use under local conditions, and 3) is economically appropriate to the farming system.

   Therefore, changes in weight must be compared between animals that receive a supplement and animals that do not. If the focus is exclusively on the small farm group, farmers should be divided based on representative criteria. This experiment can be carried out in two villages with 15 to 20 farmers. The important variable determining the choice of the sample size and site is the frequency of weighing the animals. Since this involves considerable expense and monitoring to ensure that the treatment is being administered properly, the time horizon will be relatively long (one year) to evaluate the interseasonal performance with the supplements. A one-year time horizon is not really adequate to measure interseasonal variation since year effects will be confounded with seasonal effects.

3. Undertaking a feasibility study regarding the introduction of dairy cattle requires an in-depth analysis of the existing cropping system in order to: 1) determine the allocation of the farmer's time to crop activities and other livestock enterprises, 2) evaluate the availability of crop products and by-products for feeding the livestock throughout the calendar year, 3) determine the special linkages between crop and animal components of the farming system, and 4) evaluate the impacts of introducing dairy production on the total farming system.

CHAPTER 7

TECHNIQUES FOR ECONOMIC ANALYSIS

1. Researchers in India are testing the feasibility of raising cobb-strain broilers for nine weeks instead of six weeks. The on-farm experiment yielded the following results:

	Quantities (kg)	
	6 Weeks	9 Weeks
Inputs		
Feed	1746	2619
Weight gain	471.46	707.19
Manure	144	216

The price of feed was Rs 0.83/kilogram. Labor rates were Rs 3.60/week. Water costs amounted to Rs 1.0/week. Resale value for feedbags (without feed) was Rs 1.15/bag. The 6-week study utilized 42 bags of feed, and the 9-week study used 63 feedbags. The price for manure was Rs 0.35/kilogram. The price of the broilers was Rs 3.25/kilogram.

(a) Identify costs and returns and calculate the amounts under each treatment (6-week or 9-week production cycle).

(b) Develop a table showing the differences in quantities and values for input and output between the two treatments.

(c) Develop a partial budget for each treatment. What is the net benefit to the farmer for each treatment?

(d) What is the change in income?

(e) What is the return on investment?

(f) What can be concluded?

2. Researchers and extension workers conducted on-farm trials to determine the comparative profitability of using draft cattle vs. buffalos in Pakistan. Technical and economic data are provided below.

Data	Buffalo	Cattle
TECHNICAL DATA		
Roughage requirement	5400 kg	5400 kg
Concentrate requirement	43 kg	43 kg
Labor requirement	56 days	58 days
raising the animal	(40)	(40)
training	(9)	(11)
milking and collecting dung	(7)	(7)
Work capacity of animal	84 days	112 days
on-farm	(57)	(65)
off-farm	(27)	(47)
Milk yield	187 liters (L)	———
Dung collected for 1 year	359 kg	370 kg

ECONOMIC DATA (Prices in Pakistan rupees)

Roughage = 0.20/kg	Milk = 10/liter
Concentrate = 1/kg	Dung = 0.40/kg
Wage rate = 18/day	Interest = 30
Animal wage = 18/day	Depreciation = 35

(a) Based on this information, develop a gross margin table (include income, variable costs, gross margins, and gross margins per head).

(b) Which draft system should be recommended and why?

(c) Give any additional comments.

3. An Indian farmer is interested in raising chickens in his backyard in order to augment his farm income. The market price of broilers is Rs 20/kilogram, and the total cost of production for 10 chickens is Rs 200.

(a) Determine the minimum production he should obtain in order to break even.

(b) How should the result be interpreted?

4. A smallholder rice farmer is also engaged in a 2-cow dairy enterprise. During an on-farm trial on his and other similar farms, various quantities of feed concentrates were fed among a large number of cows. From this feed supplementation trial, the following data were obtained.

Average costs of barn and equipment:	US$15.00
Costs of concentrate feed:	US$ 2.00/kg
Farm price of milk:	US$ 0.50/liter

	Quantity								
Input (X) (kg concentrate/day)	0	1	2	3	4	5	6	7	8
Output (Y) (liter milk/day)	32	35	40	47	53	56	57	57	55

(a) What level of input should be recommended to the farmer? Try to use marginal analysis from Chapter 3. Include any additional comments.

(b) If fixed costs (barn and equipment) turn out to be US$30.00, which input should be recommended?

5. A production function for milk was estimated by Drs. R. N. Pandey and P. S. Kumar to determine the economic efficiency of feed resources in milk production under a mixed farming system. The authors estimated the following function:

$$\text{Milk per day} = 0.08176 + \underset{(7.44)}{0.04755}\ GF + \underset{(0.0503)}{0.1385}\ DF + \underset{(9.36)}{0.03557}\ CON\ ,$$

$R^2 = 0.596$

where GF is green fodder in kg/day, DF is dry fodder in kg/day, CON is concentrate in kg/day, and milk is also measured in kg/day.

(a) What does the R^2 mean? What are the figures before GF, DF, and CON? What are the figures in parentheses?

(b) Interpret this production function and give any comments.

Solutions

1. (a) The following table can be constructed.

Item	6 Weeks		9 Weeks	
COSTS: (in Indian rupees)	Quantity (A)	Value (B)	Quantity (C)	Value (D)
Feed				
0.83/kg	1746 kg	1449.18	2619 kg	2173.77
Labor				
3.60/wk	6 weeks	21.60	9 weeks	32.40
Water				
1.0/wk	6 weeks	6.00	9 weeks	9.00
Total variable cost:		1476.78		2215.17
RETURNS: (in Indian rupees)				
Weight gain				
3.25/kg	471.46 kg	1532.25	707.19 kg	2298.37
Feedbags				
1.15/bag	42 bags	48.30	63 bags	72.45
Manure				
0.05/kg	144 kg	7.20	216 kg	10.80
Total returns:		1587.75		2381.62

(b) The following table can be constructed.

	Difference	
	Quantity (C − A)	Value (in Indian rupees) (D − B)
COSTS:		
Feeds	873 kg	724.59 additional
Labor	3 weeks	10.80 additional
Water	3 weeks	3.00 additional
RETURNS:		
Weight gain	235.73 kg	766.12 additional
Feedbags	21 bags	24.15 additional
Manure	72 kg	3.60 additional

(c) The following partial budget can be developed.

PARTIAL BUDGET
Nine-week old vs. six-week old cobb-strain broilers
December 1985 — February 1986

A Added returns		B Added costs	
Weight gain	Rs 766.12	Feed	Rs 724.59
Feedbags	24.15	Labor	10.80
Manure	3.60	Water	3.00
Sub-total	Rs 793.87	Sub-total	Rs 738.39
Reduced costs		Reduced returns	
None		None	
Total A	Rs 793.87	Total B	Rs 738.39
Change (A − B) = Rs 55.48			

The partial budget is completed by computing the net benefit for each treatment:

Net benefit = Benefits (Returns) − Costs

Net benefit (6-wk treatment) = Rs 1587.75 − Rs 1476.78 = Rs 110.97

Net benefit (9-wk treatment) = Rs 2381.62 − Rs 2215.17 = Rs 166.45

(d) The change in income is determined by:

Change in income = Net benefits from new practice - Net benefits from old practice

= Rs 166.45 − Rs 110.97 = Rs 55.48

(e) The return on investment is determined by:

Return on investment = Change in income/Change in costs

= Rs 55.48/Rs 738.39

= 0.075 = 7.5%

(f) Since the change in the income is positive (Rs 55.48), the partial-budget analysis shows that it is more profitable to raise cobb-strain broilers for 9 weeks rather than 6 weeks. However, since the return on investment is low, it is very likely the farmer will prefer to use the available cash for other farm or household activities. It should also be noted that the net income the farmer receives over 18 weeks is essentially equal for the two treatments:

6-week treatment: 3 x Rs 110.97 = Rs 332.91

9-week treatment: 2 x Rs 166.45 = Rs 332.90

2. (a) The following Gross Margin Table can be developed (continues next page).

Item	Farmer's animal (Buffalo)		Cattle	
	Quantity	Value (Rs)	Quantity	Value (Rs)
a. INCOME				
Value of animal work	84 days	1512	112 days	2016
Milk	187 L	1870	—	—
Dung	359 kg	144	370 kg	148
GROSS INCOME		3526		2164

Item	Farmer's animal (Buffalo)		Cattle	
	Quantity	Value (Rs)	Quantity	Value (Rs)
b. VARIABLE COSTS				
Roughage	5400 kg	1080	5400 kg	1080
Concentrate	43 kg	43	43 kg	43
Labor	56 days	1008	58 days	1044
Interest		30		30
Depreciation		35		35
TOTAL VARIABLE COSTS		2196		2232
c. GROSS MARGIN		1330		−68
d. GROSS MARGIN PER HEAD		1330		−68

(b) The Gross Margin table indicates that the draft system utilizing buffalo is more profitable.

(c) The reproductive cycle of cattle is generally shorter than that of buffalo. However, no data have been collected, or no estimates have been made, to take reproduction (and, hence, meat production) into consideration.

3. (a) The break-even output is determined with the following:

$$\text{Break-even output} = \text{Cost of production/Price per kilogram}$$

$$= \frac{\text{Rs } 200}{\text{Rs } 20/\text{kg}}$$

$$= 10 \text{ kg}$$

(b) If the market price of liveweight broilers is 20 Rs/kilogram, and the farmer is able to produce 10 kilograms from his 10 chickens, then he will earn just enough to recover the Rs 200 he spent for raising the chickens. However, producing 10 kilograms does not allow the farmer to earn any profit from his investment, nor any returns for his labor.

4. (a) The following table can be constructed using marginal analysis.

X	ΔX	MC (US$)	Y	ΔY	MP (US$)	Total Costs (US$)	Total Revenue (US$)	Net Revenue (US$)
0			32			15	16.0	1.0
	1	2.00		3	1.50			
1			35			17	17.5	0.5
	1	2.00		5	2.50			
2			40			19	20.0	1.0
	1	2.00		7	3.50			
3			47			21	23.5	2.5
	1	2.00		6	3.00			
4			53			23	26.5	3.5
	1	2.00		3	1.50			
5			56			25	28.0	3.0
	1	2.00		1	0.50			
6			57			27	28.5	1.5
	1	2.00		0	0.00			
7			57			29	28.5	−0.5
	1	2.00		−2	−1.00			
8			55			31	27.5	−3.5

The recommended level of input is 4 kg day because at that level net revenue is maximized (US$3.5/day net revenue). Since the figures in the above table are based on average yields across farmers, any individual farmer should carefully monitor the milk yield of his own cows before determining the best level of input for his two dairy cows.

(b) The increase in fixed cost has no bearing on the farmer's decision as these costs have already occurred. It is assumed that the barn and equipment cannot be re-sold.

5. (a) The R^2 is the regression coefficient. The figures before GF, DF, and CON are also regression coefficients. The numbers in parentheses are t-values.

   (b) The function states that milk yield is determined by the amount of green fodder, dry fodder, and concentrate fed to buffalos. The coefficient preceding each variable (e.g., the value 0.04755 for green fodder) can be interpreted as the contribution to per day milk production by feeding one kilogram of that variable. The green fodder variable is statistically significant since it has a t-value greater than 2.0. Similarly, concentrate is a statistically significant variable (t-value = 9.36) while dry fodder is a statistically nonsignificant variable (t-value = 0.0503). This regression explains about 60% of the variability in daily milk yield, as the R^2 = 0.596. This implies that the authors have not included several other important variables that influence milk yield.

   The estimation of the function shows the importance of green fodder and concentrate availability on milk production. Too many other factors are deleted, however, such as whether the season is wet or dry. In addition, the example should have included the number of farms from which the data for this estimation were collected in order to establish the degrees of freedom.

CHAPTER 8

MARKETING

1. Based on the demand schedule for pork given in table 8.4, calculate the elasticity of the demand if the price increases from ₱30.50 to ₱40.50. What is the nature of the elasticity?
2. The retail price of beef is ₱50.00 per kilogram in the central market place. The processor sells directly to retail merchants at ₱40.00 per kilogram. What is the marketing margin between the processor and retail market levels? Calculate the percentage margin at the retail level. If the retail price falls by ₱5.00 per kilogram, what are the absolute price and the relative price decreases at the processor level if the margin remains unchanged?
3. The price of buffalo milk is ₱12.50 per kilogram in the center of a given market. The cost of producing milk averages ₱9.00 per kilogram. If the transportation cost is ₱0.15 per kilometer, what is the radius of the market area in kilometers? Up to what distance can the farmer transport milk for sale while still earning a profit?

4. If the price of buffalo milk in exercise 3 increases to ₱13.50 per kilogram in the center of the market, what are the absolute and relative net increases for:

   (a) producers 10 km from the center?

   (b) producers 20 km from the center?

5. The price of No. 1 hogs is ₱40.00 per kilogram. The price of No. 2 hogs is ₱35.00 per kilogram. The cost of transporting hogs is ₱0.02 for each kilogram that is moved 1 kilometer. Assuming a total production cost of ₱30.00 per kilogram, what is the profitable market area for:

   (a) No. 1 hogs?

   (b) No. 2 hogs?

6. What is marketing?

7. What are the three basic functions of a marketing system? What activities are included in each?

8. Describe the animal-marketing system in your area or country.

9. Describe the meat-marketing system.

10. How can a marketing cooperative help animal producers?

11. Define demand.

12. What factors can cause a change in demand?

13. Define supply.

14. What factors can cause a change in supply?

15. What is a marketing margin?

16. What are the types of marketing margins?

17. What is the relationship between transportation cost and distance?

Solutions

1. Use the equation for determining price elasticity of demand:

$$E_d = \frac{(Q_2 - Q_1)}{(Q_2 + Q_1)} \div \frac{(P_2 - P_1)}{(P_2 + P_1)}$$

$$= \frac{(13 - 15)}{(13 + 15)} \div \frac{(40.50 - 30.50)}{(40.50 + 30.50)}$$

$$= -2/28 \div 10/71$$

$$= -0.51$$

Since the absolute (nonnegative) value of E_d is used (0.51), the value for elasticity is less than one. Therefore, pork shows an inelastic demand, and total revenue will increase with an increase in price.

2. Use the equation for determining marketing margin:

Retail margin = Retailer's price − Producer's price

= ₱50.00 − ₱40.00

= ₱10.00

This is the price spread at the retail level.

The percentage margin at the retail level is determined by:

$$\text{Percentage margin at retail level} = \frac{\text{Price spread}}{\text{Producer's price}} \times 100$$

$$= ₱10.00/₱40.00 \times 100$$

$$= 25\%$$

If the retail price falls by ₱3.00, the absolute price decrease at the producer level is ₱3.00 per kilogram. The relative price decrease at the producer level is:

Relative price decrease = ₱3.00/₱40.00 × 100%

= 7.5%

3. The steps involved in solving this exercise are as follows:

First, the profit for the producer located at the center of the market area is found:

Profit = Retail price of milk − Cost of producing milk

= ₱12.50 − ₱9.00

= ₱3.50

Second, the radius of the market area is determined:

$$\text{Radius} = \frac{\text{Profit}}{\text{Transportation cost per kilometer}}$$

$$= \frac{₱3.50}{₱0.15/\text{km}}$$

$$= 23.33 \text{ kilometers}$$

At 23.33 kilometers from the center of the market the farmer's profit is zero. Therefore, the farmer can profitably transport milk for sale up to 23.33 kilometers.

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4. (a) Since production cost remains the same, the absolute increase in profit is found by subtracting the old price from the new price:

$$\text{Absolute increase} = \text{New price} - \text{Old price}$$
$$= ₱13.50 - ₱12.50$$
$$= ₱1.00$$

The relative increase in profit is determined by taking the difference between the old relative profit and the new relative profit and dividing by the old relative profit. This value is then multiplied by 100 to give a percentage.

$$\text{Old relative profit} = \text{Old absolute profit} - (\text{transportation cost} \times \text{distance})$$
$$= ₱3.50 - (₱0.15/\text{km} \times 10 \text{ km})$$
$$= ₱3.50 - ₱1.50$$
$$= ₱2.00$$

$$\text{New relative profit} = \text{New absolute profit} - (\text{transportation cost} \times \text{distance})$$
$$= ₱4.50 - (₱0.15/\text{km} - 10 \text{ km})$$
$$= ₱4.50 - ₱1.50$$
$$= ₱3.00$$

$$\text{Relative increase} = \frac{\text{New relative profit} - \text{Old relative profit}}{\text{Old relative profit}} \times 100$$
$$= \frac{₱3.00 - ₱2.00}{₱2.00} \times 100$$
$$= ₱1.00/₱2.00 \times 100$$
$$= 50\%$$

(b) Absolute increase in profit is the same no matter how far the producer is from the center of the market.

The relative increase in profit is determined by taking the difference between the old relative profit and the new relative profit and dividing by the old relative profit. This value is then multiplied by 100 to give a percentage.

$$\text{Old relative profit} = \text{Old absolute profit} - (\text{transportation cost} \times \text{distance})$$
$$= ₱3.50 - (₱0.15/\text{km} \times 20 \text{ km})$$
$$= ₱3.50 - ₱3.00$$
$$= ₱0.50$$

$$\text{New relative profit} = \text{New absolute profit} - (\text{transportation cost} \times \text{distance})$$
$$= ₱4.50 - (₱0.15/\text{km} \times 20\ \text{km})$$
$$= ₱4.50 - ₱3.00$$
$$= ₱1.50$$

$$\text{Relative increase} = \frac{\text{New relative profit} - \text{Old relative profit}}{\text{Old relative profit}} \times 100$$
$$= \frac{₱1.50 - ₱0.50}{₱0.50} \times 100$$
$$= ₱1.00/₱0.50 \times 100$$
$$= 200\%$$

5. Determine profit per kilogram by subtracting production cost per kilogram from price per kilogram. The radius of the market area is determined by dividing profit per kilogram by transportation cost per kilogram.

(a) $\text{Profit} = \text{Price/kg} - \text{Production cost/kg}$
$$= ₱40.00/\text{kg} - ₱30.00/\text{kg}$$
$$= ₱10.00/\text{kg}$$

$$\text{Market area} = \frac{\text{Profit/kg}}{\text{Transportation cost/kg}}$$
$$= \frac{₱10.00/\text{kg}}{₱0.02/\text{kg/km}}$$
$$= 500\ \text{km}$$

(b) $\text{Profit} = \text{Price/kg} - \text{Production cost/kg}$
$$= ₱35.00/\text{kg} - ₱30.00/\text{kg}$$
$$= ₱5.00/\text{kg}$$

$$\text{Market area} = \frac{\text{Profit/kg}}{\text{Transportation cost/kg}}$$
$$= \frac{₱5.00/\text{kg}}{₱0.02/\text{kg/km}}$$
$$= 250\ \text{km}$$

CHAPTER 9

RISK

1. List 5 types of risky and uncertain events an animal farmer in your area would face.

2. The effects of crossbreeding a new breed of goat with the local breed of goat is being researched. The new goat breed gives an average of 2.3 kids as recorded at the research station over a period of 8 years. Under farm conditions an average of 0.97 kids is recorded for local goats. The table below shows the results of some on-farm trials with goats conducted in three villages (A, B, C).

	Village A			Village B			Village C		
Farm	Kids	Does	Ratio	Kids	Does	Ratio	Kids	Does	Ratio
1	13	6	2.17	7	11	0.64	5	3	1.67
2	10	5	2.00	3	5	0.60	8	12	0.67
3	8	3	2.67	2	3	0.67	9	4	2.25
Total	31	14	6.84	12	19	1.91	22	19	4.59
Weighted average			2.22			0.64			1.53

What conclusions can be drawn from this experiment? How should risk concerns be incorporated?

3. A farmer is encouraged to participate in a vaccination trial being organized by the department of extension. This vaccine helps increase animal uptake of urea and can result in increase in milk production. The chance of this vaccine being successful is 60% with an increase of 30% in yield. However, a 40% decrease in milk production is expected if the trial fails. The price of milk is Rp 5.5 per kilogram. The farmer has two cows. The first cow gives an average of 73 kilograms/week of milk; the second cow gives an average of 44 kilograms/week. Which cow should the farmer volunteer for the experiment?

4. Farmers are being involved in a poultry-feeding trial and risk problems associated with the trial are being worked out in order to determine optimal sample size. Some information from the on-station experiments are as follows:

   Average weight of ducks without feed supplement = 126 grams/week

   Average weight of ducks with feed supplement = 174 grams/week

CV(1) = 58%	CV(2) = 31%
Variance(1) = 0.53	Variance(2) = 0.29

   Price of duck = Rs 18 per kg (use dressing weight conversion of 68%)

   What conclusions about risk can be drawn?

Solutions

2. There are strong indications that some farmers are able to manage the new goats well and obtain results similar to those at the research station. The new goats in village B however perform below the average of the local breed (0.97). See also the second farmer of village C. Why? It is quite possible that there is a risk involved in the adaptation of these new goats. Further research should focus on villages B and C. The reasons for the low performance of the new goats (disease, feed shortages, abortions, labor shortage, etc.) should be explored.

3. Probability of success (PS): 60%

   Probability of failure (PF): 40%

   Probability of gain (PG): 30%

   Probability of losses (PL): 40%

   Current yields (CY): Cow A = 73 kg/week

   Cow B = 44 kg/week

   Expected value (EV) = CY [(PS × PG) − (PF × PL)]

   Cow A: EV = 14.60 kg/week

   Cow B. EV = 8.80 kg/week

   Even if the expected value is positive, the farmer will think twice before volunteering his best cow, or any cow at all. A 40% chance of failure is quite large. A risk avert farmer with a small herd will discuss with the researcher an insurance provision in their collaborative agreement.

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4. The monetary value of the ducks are:

   Without supplement: $126 \times 0.68 \times$ Rs 0.018 = Rs 1.54/week/duck

   With supplement: $174 \times 0.68 \times$ Rs 0.018 = Rs 2.13/week/duck

   The difference in monetary benefits between the two treatments is substantial. The final decision of the farmer will depend on the cost figure. If cost-benefit analysis shows higher profits for ducks which are fed a supplement, farmers will be inclined to adopt this management strategy as at the same time the yield risk (expressed in the CV percentage) is lower. Note however that the farmer will also consider the price risks — not only the price fluctuations of the ducks, but also those of the feed supplement.

CHAPTER 10

INSTITUTIONAL CONSTRAINTS IN ASIA

1. What are the differences between efficiency and equity when discussing program goals for animal agriculture for different farm sizes. How should animal research topics be prioritized?
2. What are common administrative constraints to conducting on-farm research? Develop recommendations on how these constraints could be removed.
3. List strategies for encouraging recently trained scientists to become involved in OFAR.