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THOMAS G. FIELD
ROBERT E. TAYLOR



ELEVENTH EDITION

SCIENTIFIC FARM ANIMAL PRODUCTION

AN INTRODUCTION TO ANIMAL SCIENCE

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ELEVENTH EDITION

Thomas G. Field
University of Nebraska

Robert E. Taylor

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PEARSON

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This book is inspired by the men and women who make their living from the land and from applying not only the principles of science but the art of husbandry to their role as stewards of land, livestock, and communities. It is offered as a resource to the many students and teachers who daily invest their time, energy and talent into the process of improving animal agriculture in the hope that one day humanity might be free of hunger.

This work is dedicated to my wife Laura and children Justin, Sean, Trae, Kate, and Coleman who have contributed their talent and support in its creation.

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Preface

Scientific Farm Animal Production is distinguished by an appropriate coverage of both breadth and depth of livestock and poultry production and their respective industries. The book gives an overview of the biological principles applicable to the animal sciences with chapters on reproduction, genetics, nutrition, lactation, consumer products, and other subjects. The book also covers the breeding, feeding, and management of beef cattle, dairy cattle, horses, sheep and goats, swine, and poultry. Although books have been written on each of these separate topics, the author has highlighted the significant biological principles, scientific relationships, and management practices in a condensed but informative manner.

TARGET AUDIENCE

This book is designed as a text for the introductory animal science course typically taught at universities and community colleges. It is also a valuable reference book for livestock producers, vocational agriculture instructors, and others desiring an overview of livestock production principles and management. The book is appropriate for the urban student with limited livestock experience, yet challenging for the student who has a livestock production background.

KEY FEATURES

Chapters 1 through 9 cover animal enterprises and products; Chapters 10 through 22 discuss the biological principles that are utilized to improve livestock and poultry production and the issues facing animal agriculture; while livestock and poultry management systems are presented in Chapters 23 through 34.

The glossary of terms used throughout the book has been expanded so that students can readily become familiar with animal science terminology. Many of the Key Terms in the text are included in the glossary. Additionally, key words are provided at the end of each chapter as an aid to student learning.

Photographs and figures are used throughout the book to communicate key points and major relationships. The visual aspects of the text should help students expand their global and macro view of the livestock industry as well as better understanding how theory is put into practice.

At the end of each chapter, a set of questions are provided that are designed to facilitate an in-depth understanding of the material. Students are encouraged to utilize the questions to assist them in making connections between concepts and to better integrate relationships to allow for not only listing the facts but creating a framework for the application of knowledge.

NEW TO THIS EDITION

This text continues to blend the various disciplines of science with contemporary management practices and industry trends to build a cohesive discussion of animal agriculture. The following improvements have been made to this edition:

- The input of nearly 20 reviewers was utilized to assure accuracy, clarity, and effective delivery of material.
- Demographic, industry data, and consumer trends have been updated.

- Photos and illustrations have been upgraded to enhance the reader experience.
- Management chapters have been revised to reflect the most current protocols and technologies used by the industry.
- More attention has been given to the issues and challenges confronting the livestock and poultry industry.
- Significant revision has been accomplished to provide a comprehensive but more clear communication of science based principles and relationships.
- Financial and enterprise-based cost and return data has been integrated to facilitate better understanding of the economic consequences of management decisions.
- The text effectively balances science and practice as it applies to the livestock and poultry industry.

INSTRUCTOR'S RESOURCES

An online Instructor's Manual, PowerPoint slides, and TestGen are available to Instructors at www.pearsonhighered.com. Instructors can search for a text by author, title, ISBN, or by selecting the appropriate discipline from the pull-down menu at the top of the catalog home page. To access supplementary materials online, instructors need to request an instructor access code. Go to www.pearsonhighered.com, click the Instructor Resource Center link, and then click Register Today for an instructor access code. Within 48 hours of registering, you will receive a confirmation e-mail including an instructor access code. Once you have received your code, go to the site and log on for full instructions on downloading the materials you wish to use.

ACKNOWLEDGMENTS

Appreciation is expressed to the reviewers of the eleventh edition, who offered suggestions to strengthen the book. They are Bonnie Ballard, Gwinnett Technical College; Angela Beal, Bradford School, Vet Tech Institute; Dennis Brink, University of Nebraska-Lincoln; Anne Duffy, Kirkwood Community College; Brian Hoefs, Globe University; Chip Lemieux, McNeese State University; Farabee McCarthy, The University of Findlay; Kasey Moyes, University of Maryland; Mary O'Horo-Loomis, State University of New York at Canton; Margi Sirois, Wright Career College; Bonnie Snyder, Central New Mexico Community College; Melissa Stacy, Rockford Career College; Brett VanLear, Blue Ridge Community College; Peg Villanueva, Vet Tech Institute @ International Business College—Indianapolis; Elizabeth Walker, Missouri State University; Julie Weathers, Southeast Missouri State University; Jennifer Wells, University of Cincinnati; Cynthia Wood, Virginia Tech; and Brenda Woodard, Northwestern State University of Louisiana.

About the Author

Dr. Thomas G. Field serves as the director of the Engler Agribusiness Entrepreneurship Program and holder of the Engler Chair in Agribusiness Entrepreneurship at the University of Nebraska—Lincoln.

He is also a noted agricultural author and a frequent speaker at agricultural events in the United States and abroad. He has consulted with a number of agricultural enterprises and organizations, and has served on numerous boards related to education, agriculture, and athletics. He is the co-owner of Field Land and Cattle Company, LLC in Colorado.

Dr. Field was raised on a Colorado cow–calf and seedstock enterprise. He managed a seedstock herd of cattle after completing his B.S. degree. A competitive horseman as a youth, he has had practical experience with seedstock cattle, commercial cow–calf production, stockers, and horses. He has a B.S., M.S., and Ph.D. in animal science from Colorado State University.

Dr. Field has received teaching awards from the USDA National Excellence in Teaching program, the National Association of Colleges and Teachers of Agriculture, the American Society of Animal Sciences, Colorado State University, and the University of Nebraska.

He is married to Laura and father to Justin, Sean, Trae, Kate, and Coleman.

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Animal Contributions to Human Needs

In many ways the history of civilization is told in the application of human creativity to the task of feeding, clothing, and raising the standard of living for the world's various societies via animal agriculture. Over the ages the relationship between humans and domesticated animals have shaped history, impacted economies, altered the outcomes of war, sped the exploration and settlement of new territories, revolutionized agriculture and transportation, provided entertainment through sport, and etched itself into nearly every aspect of civilization. For example, the domestication of horses transformed the range of land movement for human beings. And with the stability that agriculture provided human communities came time for intellectual and cultural pursuits. Livestock have been incorporated into the telling of the human story through expression in the form of art, literature, and music.

Domestication of livestock depends on the animal reproducing within the management decisions of human beings and the creation of a complex mutually beneficial relationship founded on the ancient concept of the good shepherd. This “contract” offers the animal protection from predators and a more consistent supply of nutrients, to name a few of the benefits, in exchange for food, fiber, draft power, and companionship as contributions to the well-being of humans. This relationship in which domesticated species and humans seem to have chosen each other is still the basis for sound management and husbandry of livestock and has allowed domesticated animals far greater survival rates than those in the wild. The timeline of livestock and poultry domestication provides context for the relationship between humans and animals of agricultural importance (Fig. 1.1).

Table 1.1 outlines the major domesticated livestock species, their approximate numbers, and their primary uses. Chickens are the most numerous (20.7 billion), followed by cattle (1.43 billion), sheep (1.09 billion), ducks (1.08 billion), and swine (967 million).

CONTRIBUTIONS TO FOOD NEEDS

When opportunity exists, most humans consume both plant and animal products (Fig. 1.2).

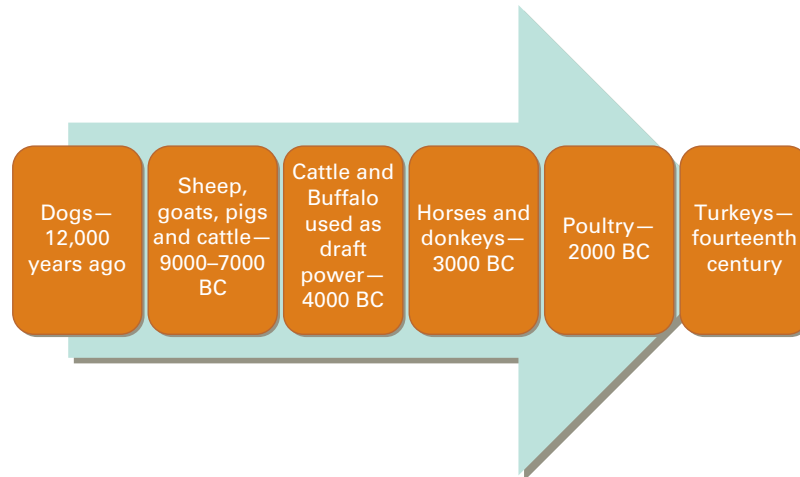
The contribution of animal products to the **per-capita calorie and protein supply** in food is shown in Table 1.2. Animal products constitute approximately 16% of the calories, 37% of the protein, and 45% of the fat in the total world food supply. Large differences exist between developed countries and developing countries in total daily supply of calories, protein, and fat.

learning objectives

- Describe the global distribution of livestock
- Quantify the role of animal products in the global food supply
- Evaluate differences in food production and agricultural productivity between developed and developing nations
- Compare food expenditures for at-home and away-from-home consumption in the United States
- Compare food consumption across diverse nations and cultures
- Describe changes in the U.S. agricultural productivity
- Describe the nonfood contributions of livestock

Figure 1.1

Timeline for the domestication of livestock and poultry.



For example, consumers in developed nations derive 26% of their calories from animal products with just over one-half of their total protein and fat supply from animal products. Consumers in developing nations derive 13% of their calorie supply, 29% of their protein, and 41% of their fat from animal products. The United States ranks higher than the world average for percent of calories and protein from animal sources but about average for percent of fat from animal products.

Table 1.1
MAJOR DOMESTICATED ANIMAL SPECIES—THEIR NUMBERS AND USES IN THE WORLD

Animal Species	World Numbers (mil)	Leading Countries or Areas with Numbers ^a (mil)	Primary Uses
Ruminants			
Cattle	1,426	Brazil (213), India (211), United States (93), China (83), Ethiopia (53)	Meat, milk, hides
Sheep	1,093	China (139), India (74), Australia (73), Iran (49), Sudan (39)	Wool, meat, milk, hides
Goats	924	India (157), China (142), Pakistan (61), Nigeria (57) Bangladesh (53)	Milk, meat, hair, hides
Buffalo	195	India (113), Pakistan (32), China (24)	Draft, milk, meat, hides
Camels	27	Somalia (7), Sudan (5), Kenya (3), Niger (2)	Packing, transport, draft, meat, milk, hides
Nonruminants			
Chickens	20,708	China (5,230), United States (2,080), Indonesia (1,427), Brazil (1,268), Iran (900)	Meat, eggs, feathers
Swine	967	China (464), United States (66), Viet Nam (27), Germany (27), Spain (25)	Meat
Turkeys	468	United States (248), Chile (32), France (24), Italy (24), Russian Fed. (17)	Meat, eggs, feathers
Ducks	1,108	China (809), Vietnam (98), Indonesia (49), Malaysia (49), Bangladesh (44)	Meat, eggs, feathers
Horses	58	United States (10), China (7), Mexico (6), Brazil (5), Argentina (3)	Draft, riding, sport, occasionally meat
Donkeys and Mules	54	China (9), Ethiopia (7), Mexico (6), Pakistan (5), Egypt (3)	Draft, transport

Source: Adapted from USDA and FAO.

**Figure 1.2**

Meat, milk, and eggs are nutrient dense foods that meet the needs of both domestic and global consumers. The livestock industry and food supply chain must align with consumer demand to assure continuation of a successful business model.

Source: Kirill Kedrinski/Fotolia.

Table 1.2**ANIMAL PRODUCT CONTRIBUTION TO PER-CAPITA CALORIE, PROTEIN, AND FAT SUPPLY**

Country	Total Kilo Calories	Animal Products		Total Protein (g/day)	Animal Products		Total Fat	Animal Products	
		Kilo Cal	%		g/Day	%		g/Day	%
Australia	3,176	1,049	33	107	71	66	138	72	52
Bangladesh	2,103	67	3	45	6	13	22	4	18
Brazil	2,985	615	21	80	41	51	89	42	47
China	3,029	583	19	85	30	35	84	49	58
Egypt	3,346	256	8	93	18	19	60	18	30
Germany	3,451	1,035	30	95	57	60	152	82	54
India	2,428	194	8	57	10	17	48	13	27
Japan	2,762	569	21	92	51	55	83	35	42
Kenya	1,965	234	12	50	15	30	47	15	32
Mexico	3,165	583	18	88	38	43	89	4	46
Nigeria	2,850	87	3	65	8	12	68	6	7
United Kingdom	3,334	1,002	30	98	55	56	145	77	53
United States	3,772	1,043	27	114	73	64	151	71	47
Developed	3,260	857	26	99	55	55	119	62	52
Developing	2,679	348	13	69	22	29	63	26	41
World Average	2,805	459	16	76	28	37	75	34	45

Source: Adapted from USDA, FAO.

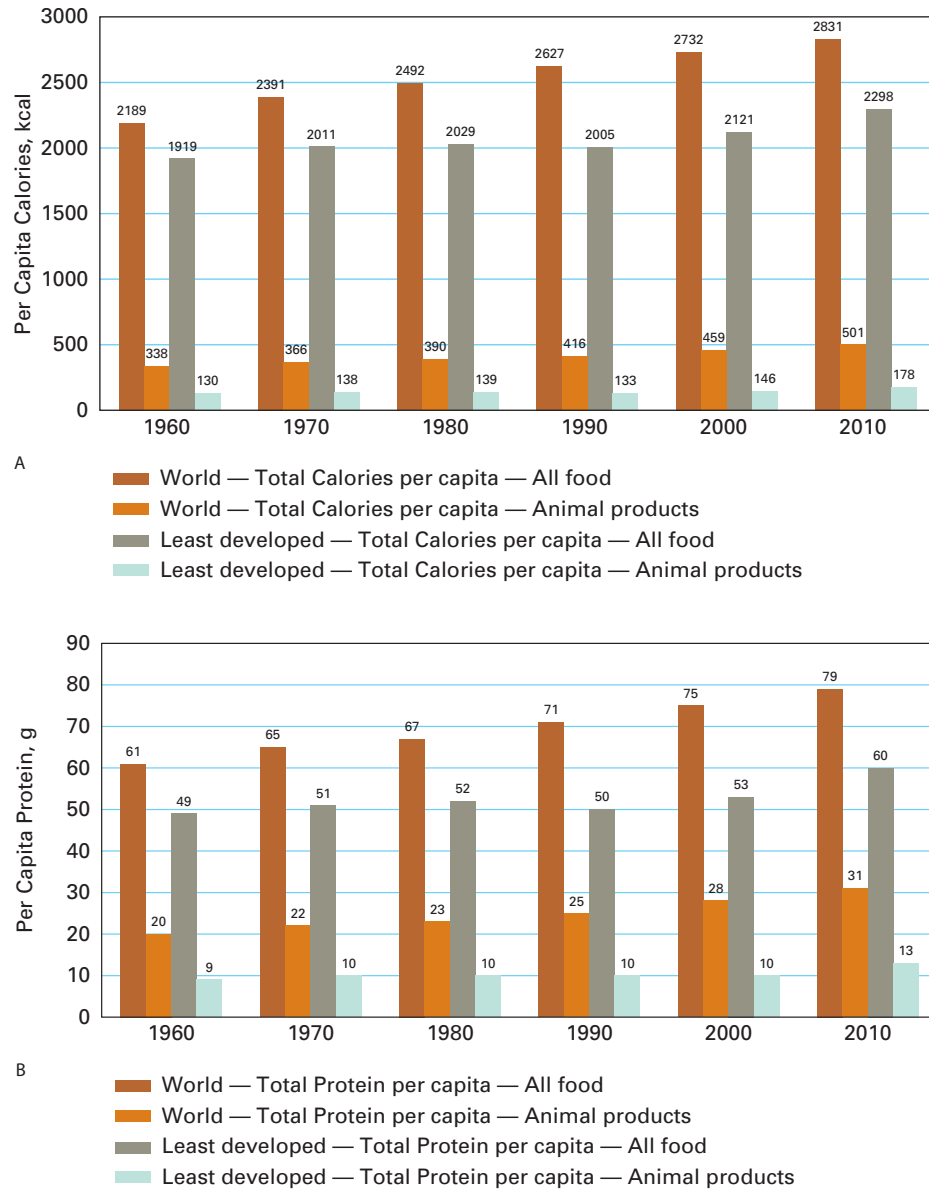


Figure 1.3
Caloric and protein intake from animal products.

Source: Adapted from USDA.

Changes in per-capita calorie supply and protein supply during the past 40 years are shown in Figure 1.3. Per-capita caloric supplies of both calories and protein have increased in most areas of the world. The contribution of animal products to the per-capita protein supply has increased in most of the world. The large differences among countries in the importance of animal products in their food supply can be partially explained by available resources and development of those resources. Most countries with only a small percentage of their population involved in agriculture have higher standards of living and a higher per-capita consumption of animal products. Comparing Table 1.3 with Table 1.2, note that the countries in Table 1.3 are listed by percentage of population involved in agriculture.

Agriculture **mechanization** (Fig. 1.4) has been largely responsible for increased food production and allowing people to turn their attention to professions other than production agriculture. This facilitates the provision of many goods and services, raises standards of living, and allows for the creation of more diverse economies.

Table 1.3
POPULATION INVOLVED IN AGRICULTURE IN SELECTED COUNTRIES

Country	Population (mil)	Population in Agriculture ^a (mil)	Percent of Economically Active Population in Agriculture ^b
United States	316	5	1
United Kingdom	63	1	1
Germany	82	2	2
Australia	23	1	4
Japan	126	2	1
Brazil	198	20	10
Mexico	116	20	17
Nigeria	167	39	23
China	1,385	825	59
India	1,258	597	47
Bangladesh	152	66	43
Kenya	43	30	70
Least developed nations	871	552	63
Low-income, food-deficit nations	2,874	1,360	47
World Total	7,052	2,621	37

Source: Adapted from USDA and FAO.

^aAgricultural population is defined as all persons depending for their livelihood on agriculture. This comprises all persons actively engaged in agriculture and their nonworking dependents.

^bIncludes all economically active persons engaged principally in agriculture, forestry, hunting, or fishing.



Figure 1.4

The mechanization of agriculture has enabled a relatively small proportion of the human population to provide for a growing world market. Source: Tom Field

Note that 50% of the people in developing nations are engaged in agriculture while only 7% of the citizens in developed countries are active in the agricultural sector.

The tremendous increase in the productivity of U.S. agriculture (Table 1.4) has lowered the relative cost of food as vividly demonstrated in Table 1.5. Historical data show that agricultural productivity doubled in the 100-year span of 1820–1920. For example, at the turn of the century a team of horses, one handler, and a moldboard

Table 1.4
PRODUCTIVITY CHANGES IN SEVERAL FARM ANIMAL SPECIES IN THE UNITED STATES

Species and Measure of Productivity	1925	1950	1975	2000	2012
Beef cattle	955	976	1,039	1,210	1,280
Average liveweight at finishing (lbs)					
Sheep					
Average liveweight at finishing (lb)	86	94	102	133	141
Dairy cattle					
Milk marketed per breeding female (lb)	4,189	5,313	10,500	17,192	21,148
Swine					
Average liveweight at finishing (lb)	235	243	245	259	275
Broiler chickens ^{a, b}					
Liveweight at marketing (lb)	2.8	3.1	3.8	5.0	5.7
Turkeys ^{a, b}					
Liveweight at marketing (lb)	13.0	18.6	18.4	25.8	29.5
Laying hens ^a					
Eggs per hen per year (no.)	112	174	232	257	271

Source: Adapted from USDA Annual Agricultural Statistics.

^aFeed required per lb. of weight gain or per dozen eggs was reduced by more than half over the same time period.

^bTime to market was reduced by more than half over the same time period.

Table 1.5
EXPENDITURES FOR FOOD IN THE UNITED STATES (GROSS DOLLARS AND AS PERCENT OF PERSONAL DISPOSABLE INCOME)

Year	At Home		Away from Home		Total	
	(\$ bil)	(%)	(\$ bil)	%	(\$ bil)	(%)
1930	15.8	21	2.3	3	18.1	24
1940	13.5	18	2.4	3	15.9	21
1950	35.7	17	7.6	4	43.3	21
1960	51.5	14	12.6	3	64.0	17
1970	75.5	10	26.4	4	102.0	14
1980	180.8	9	85.2	4	266.0	13
1990	314.5	7	175.2	4	489.6	11
2000	431.6	6	292.9	4	724.4	10
2010	622.3	6	454.9	4	1,077.2	9.9
2012	677.5	6	512.4	4	1,189.9	10

Source: USDA.

plow could plow 2 acres per day. Today, one tractor pulling three plows, each with five moldboards, plows 110 acres per day, accomplishing the work that once required 110 horses and 55 workers.

Livestock productivity since 1925 has progressively increased to extraordinary levels. The mix of animal enterprises on U.S. farms has shifted from a typical situation involving a vast number of species being raised on an average farm in the 1920s to contemporary scenarios where animal agriculture is considerably more specialized. These improvements in productivity have occurred primarily because people had an incentive to progress under a free-enterprise system.

Table 1.6
CONTRIBUTIONS OF VARIOUS FOOD GROUPS TO THE WORLD FOOD SUPPLY

Food Group	Calories (%)	Protein (%)
Cereals	50	45
Roots, tubers, pulses	8	7
Nuts, oils, vegetable fats	11	4
Sugar and sugar products	8	2
Vegetables and fruits	7	5
All animal products	16	37
Meat	7	16
Eggs	1	3
Fish	1	7
Milk and dairy	5	10
Other	2	1

Source: Adapted from USDA and FAO.

In the United States, releasing people from producing their own food has given them the opportunity to improve their per-capita incomes. Increased per-capita income associated with an abundance of animal products has resulted in reduced relative costs of many animal products with time. U.S. consumers allocate a smaller share of their disposable income for food than do people in many other countries. For example, per-capita expenditures for food as a percent of household expenses in Canada, France, Mexico, South Africa, and China are 9.2, 13.7, 24.2, 20.6, and 34.9%, respectively.

Table 1.6 shows that cereal grains are the most important source of energy in world diets. The energy derived from cereal grains, however, is twice as important in developing countries (as a group; there are exceptions) as in developed countries. Table 1.6 also illustrates that meat and milk are the major animal products contributing to the world supply of calories and protein.

Most of the world meat supply comes from cattle, swine, sheep, goats, chickens, and turkeys. There are, however, twenty or more additional species that collectively contribute about 6.5 billion pounds of edible protein per year or approximately 10% of the estimated total protein from all meats. These include the alpaca, llama, yak, horse, deer, elk, antelope, kangaroo, rabbit, guinea pig, capybara, fowl other than chicken (duck, turkey, goose, guinea fowl, pigeon), and wild game exclusive of birds. For example, the Russian Federation cans more than 110 million pounds of reindeer meat per year, and in Germany the annual per-capita consumption of venison exceeds 3 pounds. Peru derives more than 5% of its meat from the guinea pig.

Meat is important as a food for two scientifically based reasons. The first is that the assortment of amino acids in animal protein more closely matches the needs of the human body than does the assortment of amino acids in plant protein. The second is that vitamin B₁₂, which is required in human nutrition, may be obtained in adequate quantities from consumption of meat or other animal products but not from consumption of plants.

Milk is one of the largest single sources of food from animals. In the United States, 99% of the milk supply comes from cattle, but on a worldwide basis, milk from other species is important. Domestic buffalo, sheep, goat, alpaca, camel, reindeer, and yak supply significant amounts of milk in some countries. Milk and products made from milk contribute protein, energy, vitamins, and minerals for humans.

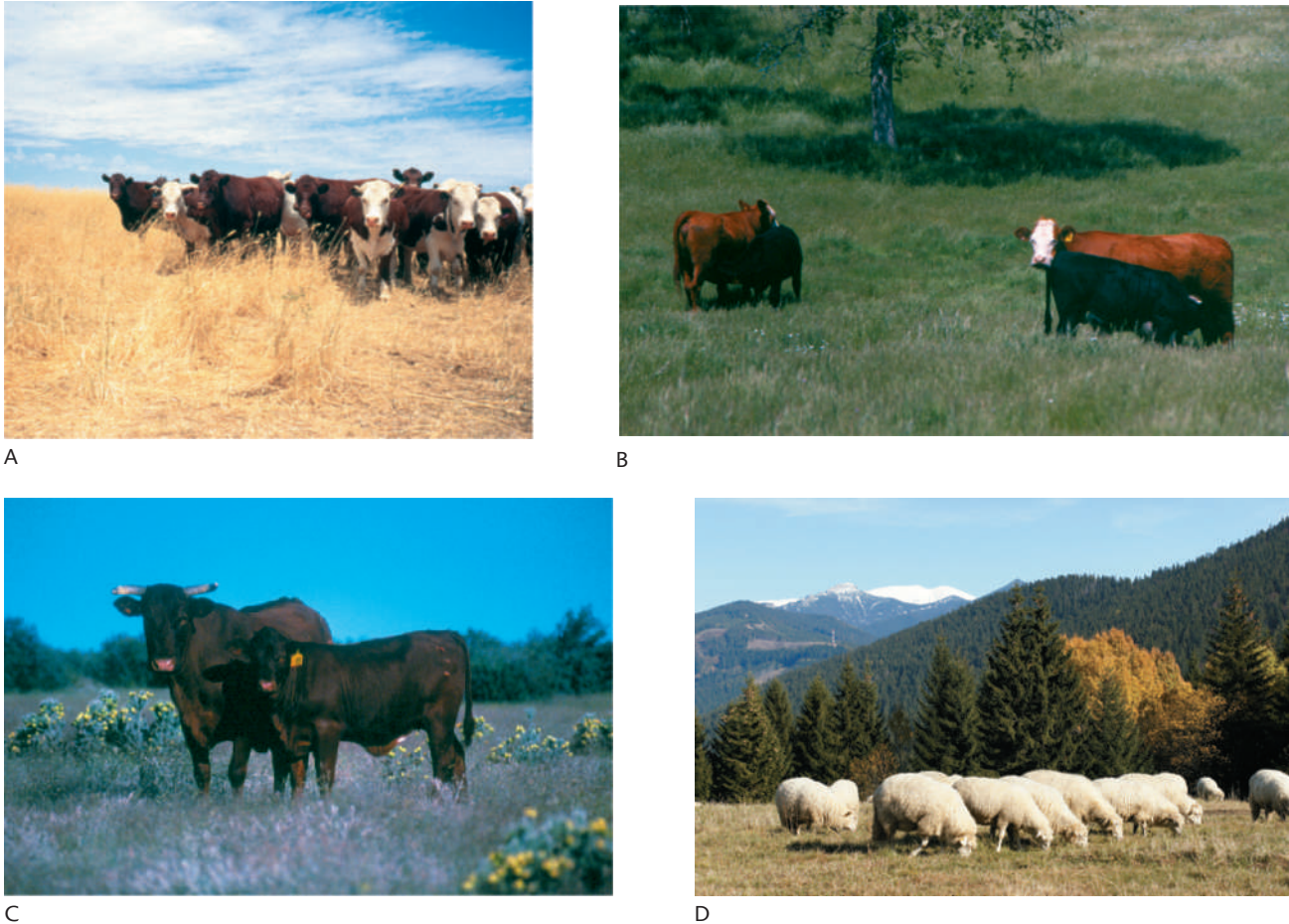


Figure 1.5

Ruminant animals produce food for humans by utilizing grass, crop residues, and other forages from land that cannot produce crops to be consumed directly by humans. (A) Cattle grazing stubble in New South Wales, Australia. (B) Cattle grazing hillsides in Georgia. (C) Cattle grazing native range in Arizona. (D) Sheep grazing native range. Source: 1.5 a-c: Tom Field. 1.5 d: Dalajlama/Fotolia.

Besides the nutritional advantages, a major reason for human use of animals for food is that most countries have land areas unsuitable for growing cultivated crops. Approximately two-thirds of the world's agricultural land is permanent pasture, range, and meadow; of this, about 60% is unsuitable for producing cultivated crops that would be consumed directly by humans. This land, however, can produce feed in the form of grass and other vegetation that is digestible by grazing ruminant animals, the most important of which are cattle and sheep (Fig. 1.5). These animals can harvest and convert the vegetation, which is for the most part indigestible by humans, to high-quality protein food. In the United States, about 385 million acres of rangeland and forest, representing 44% of the total land area, are used for grazing. Although this acreage now supports only about 40% of the total cattle population, it could carry twice this amount if developed and managed intensively.

Ruminant **animal agriculture** therefore does not compete with human use for production of most land used as permanent pasture, range, and meadow. On the contrary, the use of animals as intermediaries provides a means by which land that is otherwise unproductive for humans can be made productive (Fig. 1.6).

People are concerned about energy, protein, population pressures (Fig. 1.7), and land resources as they relate to animal agriculture. Quantities of energy and

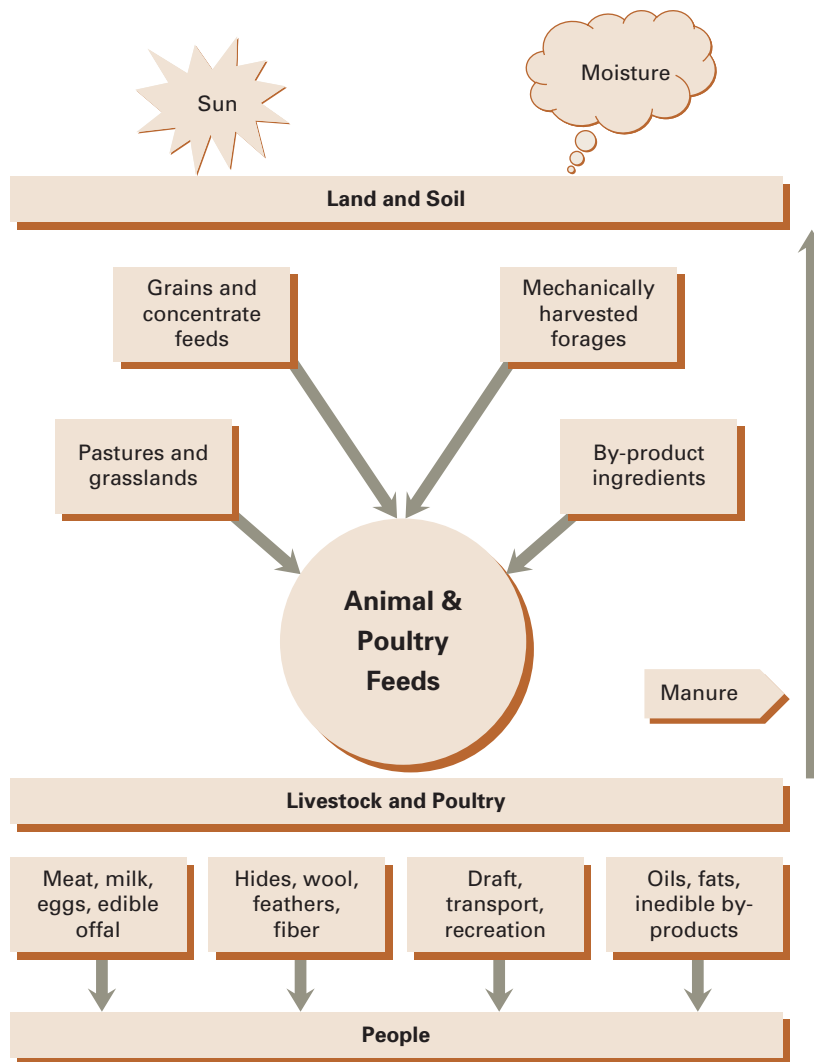


Figure 1.6
A graphic illustration of the land-plant-ruminant-animal-human relationship.

protein present in foods from animals are smaller than quantities consumed by animals in their feed because animals are inefficient in the ratio of nutrients used to nutrients produced. More acres of cropland are required per person for diets high in foods from animals than for diets including only plant products. As a consequence, animal agriculture has been criticized for wasting food and land resources that could otherwise be used to provide persons with adequate diets. Consideration must be given to economic systems and consumer preferences to understand why agriculture perpetuates what critics perceive as resource-inefficient practices. These practices relate primarily to providing food-producing animals with feed that could be eaten by humans and using land resources to produce crops specifically for animals instead of producing crops that could be consumed by humans.

Hunger continues to be a challenge in some regions of the world. The factors that contribute to the hunger problem are varied and complex. Hunger takes two forms—chronic persistent hunger and famine. **Chronic persistent hunger (CPH)** results from a combination of poverty, climatic change, political instability, water shortages, loss of soil fertility, poor infrastructure (transportation, storage facilities, banking services, etc.), and illiteracy. Note that food scarcity is not a significant contributing factor to CPH.