

1993

The impact of land tenure on the use of sustainable agricultural practices

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**The impact of land tenure on
the use of sustainable agricultural practices**

by

Daniel M. Koster

**A Thesis Submitted to the
Graduate Faculty in Partial Fulfillment of the
Requirements of the Degree of
MASTER OF SCIENCE**

**Department: Economics
Major: Agricultural Economics**

Signatures have been redacted for privacy

**Iowa State University
Ames, Iowa**

1993

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INTRODUCTION

Agricultural production in the United States today is quite unlike that of fifty years ago, when farm production systems were diversified and agricultural chemical use was virtually non-existent. At that time, farmers tended to mix crop and livestock production and grow a variety of crops in rotation. This form of agricultural production was both labor and land intensive. Between 1945 and 1985 agricultural productivity doubled as off-farm inputs were introduced into the production process. Several institutional, economic and technological forces have acted together to transform agriculture into its present highly specialized, capital- and purchased-input-intensive state (Wolcott et al., 1991). These forces have driven farmers to become highly dependent on borrowed capital, fossil fuels, and commercial fertilizers and pesticides.

Table 1 displays an index of trends in major input subgroups in U.S. agriculture from 1920 to 1984. As can be seen in this table, purchased inputs, mechanical power and machinery and agricultural chemical use have all increased substantially over the years, while non-purchased inputs and farm labor have decreased. Purchased inputs were close to two times greater in 1984 than they were in 1950, while non-purchased inputs, including operator and unpaid family labor, operator-owned real estate, and other capital inputs, were close to two times less. Also, agricultural chemical use was over six times greater in 1984 than in 1950. This trend was opposite that of farm labor which was four times less in 1984 than in 1950 (U.S. Department of

Table 1. Index Trends of Major Input Subgroups in Agriculture (1977 = 100).

Year	Non-Purchased Inputs■	Purchased Inputs★	Farm Labor◇	Mechanical Power and Machinery◁	Agricultural Chemicals▷◁	Feed, Seed & Livestock Purchases⊘	Taxes and Interest▲
1920	198	37	485	27	5	23	62
1930	195	43	463	34	6	27	76
1940	175	50	417	36	9	39	74
1950	166	60	309	72	19	58	83
1960	131	74	206	83	32	77	95
1970	107	88	126	85	75	96	102
1980	98	107	92	101	123	114	100
1981	97	107	90	98	129	108	99
1982	95	103	87	94	118	106	99
1983	91	96	79	89	105	106	99
1984	89	103	80	88	120	106	95

■ Includes operator and unpaid family labor, and operator-owned real estate and other capital inputs.

★ Includes all inputs other than nonpurchased inputs.

◇ Includes hired, operator, and unpaid family labor.

◁ Includes interest and depreciation on mechanical power and machinery repairs, licenses, and fuel.

▷◁ Includes fertilizer, lime, and pesticides.

⊘ Includes nonfarm value of feed, seed, and livestock purchases.

▲ Includes real estate and personal property taxes, and interest on livestock and crop inventory.

Source: U.S. Department of Agriculture, 1987

Agriculture, 1987). Overall, Table 1 gives a good idea of how much more dependent U.S. agriculture has become on purchased off-farm inputs.

Table 2 depicts the trends in planted acres from 1950 to 1990 for nine of the basic crops grown in Iowa. As is shown in this table, corn acres have increased by 2.9 million acres and soybean acres have increased by 6.0 million acres since 1950. During this same period of time, oats, barley, and rye acres have decrease substantially, with only oats showing any measurement in 1990. Also, since 1960 the number of acres devoted to all hay and alfalfa have fallen by 1.5 million acres and 400,000 acres, respectively (U.S. Department of Agriculture, 1991). Overall, this table shows how agriculture in Iowa today has turned away from using diversified cropping systems and toward a cropping system which emphasizes corn and soybeans.

One of the most widespread trends in U.S. agriculture has been the substitution of purchased inputs for farm-produced inputs. The substitution of commercial fertilizers and pesticides for animal manures and cultural practices to control insects and weeds has contributed to this increased reliance upon purchased inputs. Much of the increase in farm productivity since World War II is directly related to the use of commercial fertilizers and pesticides. As a result, in the last half of the 20th century there has been a steady growth in commercial fertilizer and pesticide use. Currently 97% of the corn in the United States is treated with chemical fertilizers (U.S. Department of Agriculture, 1992). Figure 1 shows how the use of nitrogen, phosphate, and potash has

Table 2. Trends in Planted Acres for Nine Basic Crops in Iowa (1,000 acres)

Year	Corn	Soybeans	All Hay	Alfalfa	Oats	Wheat	Barley	Rye	Sorghum
1950	9,865	1,921	3,648	1,147	6,457	262	60	14	2
1960	12,469	2,543	3,544	2,110	4,239	138	27	30	63
1970	10,668	5,857	2,502	1,762	2,571	43	5	22	49
1980	14,000	8,300	2,270	1,760	1,300	100	0	19	30
1990	12,800	8,000	2,000	1,700	1,300	80	0	0	0

0 Measurement was discontinued

Source: United States Department of Agriculture, 1991

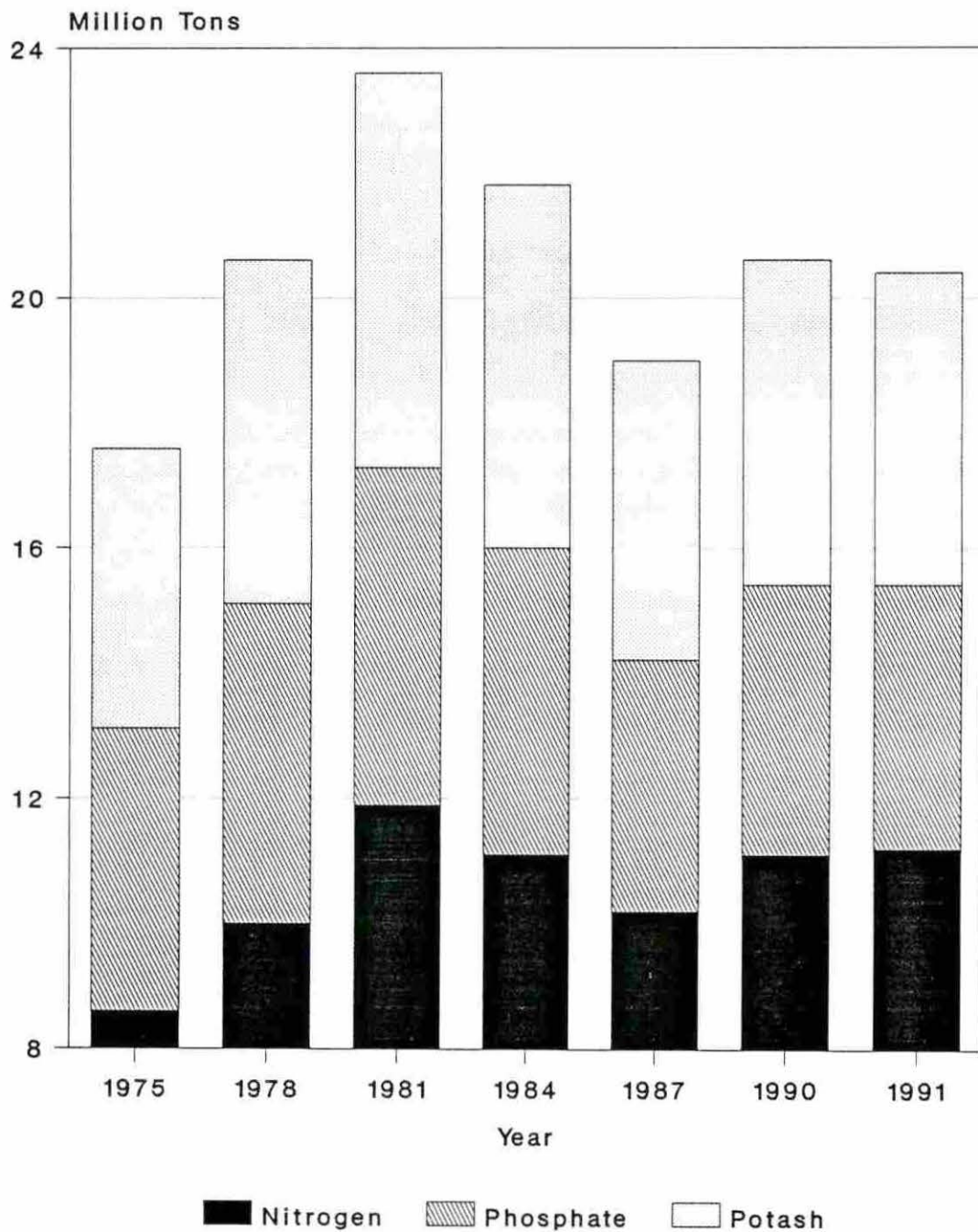


Figure 1: Primary Nutrient Use for Agriculture in the United States (U.S. Dept. of Agriculture, 1992)

changed over the past three decades. From 1975 to 1981, commercial fertilizer use in the United States increased from almost 18 million tons to over 23 million tons per year. Since 1981, its use has declined and leveled off to around 20.5 million tons per year (U.S. Department of Agriculture, 1992).

Along with the high use of commercial fertilizer, 96% of the corn and soybean acreage in the U.S. is treated with a herbicide (U.S. Department of Agriculture, 1992). Figure 2 illustrates how pesticide use has changed since the mid-1960s. Since chemical pesticides were introduced, use increased at an exponential rate until the mid-1980's. From 1966 to 1982, the use of herbicides increased from just around 100 million pounds of active ingredient (a.i.) to almost 450 million pounds of a.i. During that same period, insecticide use actually dropped, while fungicide use stayed relatively constant. During the mid-1980s chemical pesticide use leveled off and in some instance decreased, but since then the use has steadily risen (U.S. Department of Agriculture, 1991). Now, because of this increase in the use of chemicals and other purchased inputs, farmers are experiencing declining soil productivity, decaying environmental quality, and reduced profitability. Also, an increased risk in human health and ecological well-being has resulted with the detection of agricultural chemicals in underground water supplies and the long term effects of chemical exposure to producers and consumers (Lasley, et al. 1990).

In industrialized countries such as the United States, farmers have been able to use technologies to overcome field and farm differences. These

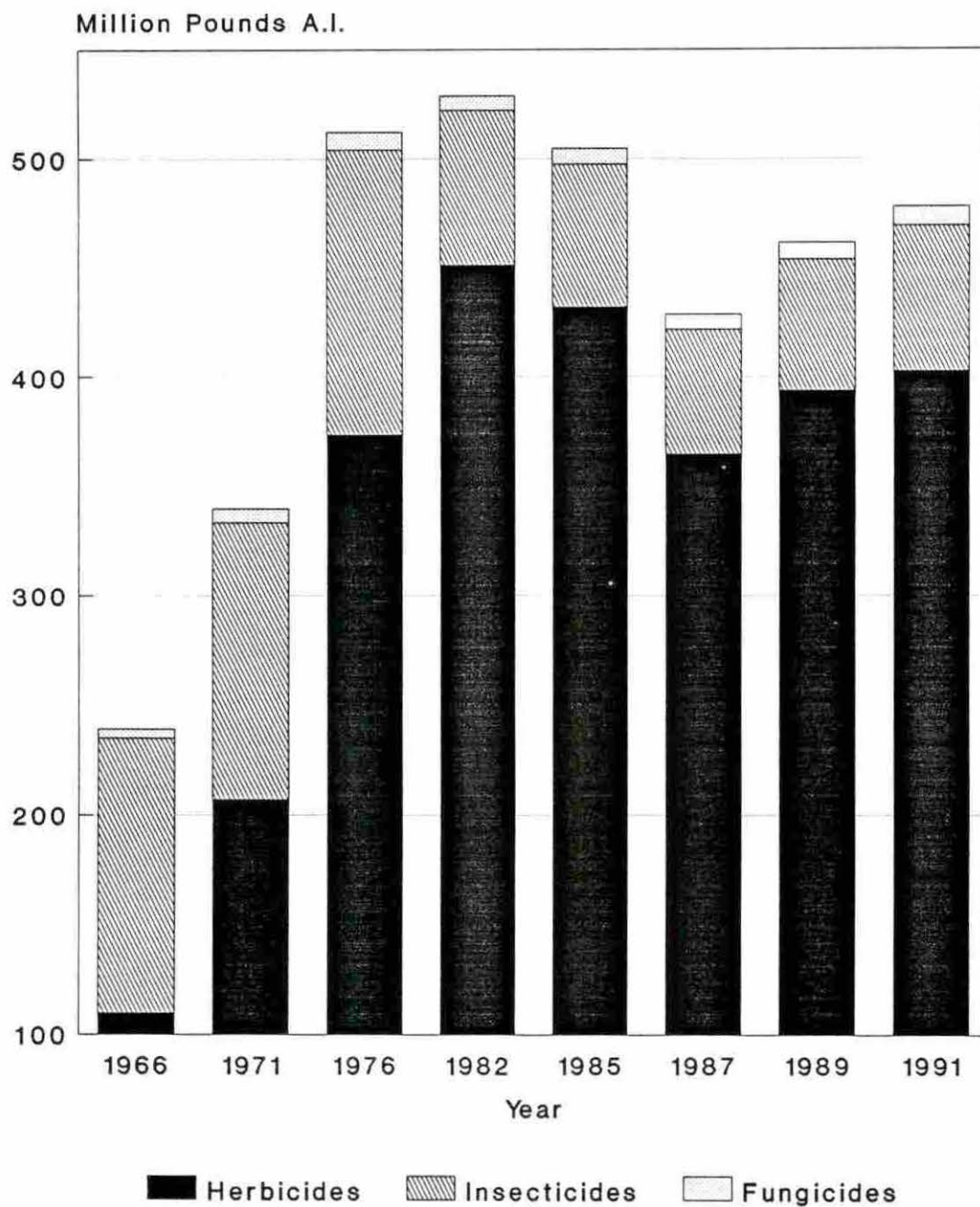


Figure 2. Pesticide Use Estimates for Agriculture in the United States (U.S. Dept. of Agriculture, 1991)

technologies were broadly accepted because many of the farmers had the resources and the capital to be able to dominate the natural components of the environment with irrigation, chemicals, and mechanization. Furthermore, our agricultural policies, supported for many years by the notion that farmers should "get big or get out" encouraged these type of technologies. Recently, with the rising concerns for a more sustainable agricultural system, there is pressure to reduce the use of fossil fuels, the amount of irrigation water, and off-farm chemicals. Policy makers are beginning to change the incentives which encourage the use of these broadly adaptable technologies. These factors will influence the kinds of technologies farmers will be able to use (Hildebrand, 1990). Keeping all of these factors in mind, the intent of this research is to address the issue of land tenure and determine its impact on the production practices agricultural producers choose to use.

CURRENT SITUATION

According to Batie and Taylor (1989), conventional agriculture can be defined as a production system that employs a full range of pre- and post-planting tillage methods, inorganic fertilizers, chemical pesticides, antibiotics, and hormones. The belief is that this system has become too concentrated in ownership; too reliant on technology, petroleum-based inputs, and credit; too specialized; too ecologically unsound; and too dependent on federal subsidies (Batie and Taylor, 1989). The conventional system has separated itself from nature and viewed it as something that must be dominated, emphasized technology and formal social institutions over natural systems, and failed to see how human societies fit into and are dependent on larger natural systems (Allen et al., 1991).

Sustainable agriculture as a concept tends to be more of a preventive innovation, its relative advantages in both the short- and long-run. Many factors determine how the current situation in agriculture affects the adoption of sustainable practices. The relative low cost of off-farm inputs such as commercial fertilizers, pesticides, and fossil fuels; current commodity programs which give incentives for monocropping; and concerns for environmental well-being weigh heavy on the production decisions of all farmers (Parr et al., 1990).

The primary problem is that farmers do not have to recognize environmental costs. Also, input prices are not determined with long run considerations such as depletion included. Given these price and cost

inefficiencies, it is clear why the movement toward a more sustainable system has been slowed. As a general rule, the specific provisions of the U.S. commodity program place farmers, particularly cash grain farmers wishing to include a hay, small grain, or green manure crop in their rotations, at a distinct disadvantage. Consequently, most sustainable farmers either forego participation in these programs or participate marginally and sporadically. U.S. commodity programs also tend to encourage chemical-intensive, monoculture cropping systems by focusing program benefits on only a few crops (Duffy and Chase, 1989). Corn and other feed grains, wheat, and cotton receive over three-fourths of all crop subsidies. These same commodities also account for approximately two-thirds of U.S. agrichemical use (Parr et al., 1990). Overall, both the markets and current U.S. commodity programs tend to direct resources away from nonsupported commodities and toward supported commodities.

Most of the recent research conducted on the topic of sustainable agriculture has been based on either production systems, public policy, or social and cultural concerns (Gardner et al., 1990). The importance of the relationship of these fields to sustainable agriculture as practice is quite evident, but what is not so evident is the impact of land ownership on sustainability, especially if a person's interest in the land is only for immediate financial gain. The 1987 Census of Agriculture reported that 21,747 of the 105,180 farms in Iowa are fully rented. These fully rented farms have over six million total acres. The

census also found that 35,207 farms in Iowa are partly rented. This means over 54% of the farms are operated by persons who rent some or all of the land on which they farm (U.S. Department of Commerce Bureau of the Census, 1989). Farmers who rent land and who have no security in the lease they hold may not be interested in farming in a sustainable way; they tend to want to get all they can from the land in the short run. Pesticides may be overused and essential maintenance neglected and the ability of that land to produce for future generations could be eroded away. By contrast, farmers that own the land on which they farm are more likely to work it in a sustainable way (Madeley, 1992). The basic concern is that land tenure could have a major impact on the adoption of agricultural practices which are more sustainable.

Sustainable Agriculture Defined

The concerns expressed most often by the general public about the adverse effects of the U.S. agriculture production system are:

- The increased cost of and dependence on external inputs of chemicals and energy.
- The continued dangers from excessive soil erosion and nutrient runoff losses.
- The contamination of surface and groundwater from fertilizers and pesticides.
- The hazards to human and animal health and to food quality and safety from agricultural chemicals.
- The demise of the family farm and rural communities.

Because of these concerns, questions have been increasingly raised in

recent years about the long-term sustainability of the U.S. agricultural production system, which has become so dependent on nonrenewable resources and exploitive of the natural resource base (Parr et al., 1990).

According to Parr et al. (1990), three misconceptions about sustainable agriculture commonly arise. The first involves the idea that sustainable agriculture represents a return to agriculture practiced in the 1930s. This is simply not true because sustainable farmers use modern equipment, certified hybrid seeds, soil and water conservation techniques, conservation tillage, and the latest innovations in livestock feeding and handling. The second misconception involves the idea that low input farming methods result in low output. Contrary to this belief, most sustainable producers insist that their crop yields are equal to or even higher than their more conventional neighbors. The final misconception is that sustainable farmers are really farming at the lower end of the crop response curve. Yet, in many cases sustainable farmers' productivity levels are high enough to place them at or near the top of the curve.

Keeping these misconceptions in mind, it is important to provide a strong definition for what is meant by sustainable agriculture. According to the 1987 Iowa Groundwater Protection Act, "sustainable agriculture is the appropriate use of crop and livestock systems, and agricultural inputs supporting those activities, which maintain economic and social viability while preserving the high productivity and quality of Iowa's land." Three of the most common

definitions involve sustainability as land stewardship, sustainability as food sufficiency, and sustainability as community (Lowrance et al., 1986). Although all of these definitions serve the interests of their particular disciplines, they fail to fully cover the entire scope of what sustainability is. As a result, the definition used for this research will involve four levels; agronomic sustainability, microeconomic sustainability, ecological sustainability, and macroeconomic sustainability (Lowrance et al., 1986).

Agronomic sustainability refers to a tract of land's ability to maintain productivity over an extended period of time. This period of time is not absolutely defined, but it involves such factors as soil formation rates, length of land tenure, practices of management, and the geographic location. According to Keeney (1990), agronomic sustainability is based on sound principles. Such areas as erosion control, weed management, maximum efficiency in the use of on-farm and purchased inputs, minimal leaching of pollutants, maintenance of soil fertility, and use of biological and cultural principles throughout the farming operation must be included in this list (Keeney, 1990).

Microeconomic sustainability refers to a single farm's ability, as the basic economic unit, to stay in business and provide a family living (Lowrance et al., 1986). This involves the farm's ability to shift its productive resources to different operations such as alternative crops and livestock in order to survive. Ecological sustainability involves the ability of a life support system to maintain the quality of the environment. In the case of agriculture, this deals with the

system's ability to produce food without severely damaging the soil and water supply. Without ecological sustainability, agricultural practices would soon endanger the health and welfare of all mankind. Finally, macroeconomic sustainability involves the ability of the national production system to compete in both domestic and foreign markets (Lowrance et al., 1986).

In looking at the definition of sustainable agriculture three major goals emerge. The first goal involves helping agricultural producers and the industry return and maintain a profit (Korsching and Malia, 1991). An industry can not be sustainable if it is unable to maintain profits that will allow it not only to survive, but to grow as well. The second goal involves the idea of decreasing harm to the environment and personal health caused by agricultural practices (Korsching and Malia, 1991). A sustainable system is only as healthy as the individuals it is designed to serve. The final goal is to provide a basis for a sustainable community by offering a way for people to stay on the land and be less dependent on government payments for survival (Korsching and Malia, 1991).

Table 3 compares the characteristics of conventional and sustainable systems. In a conventional system the use of fossil fuel energy is quite high, whereas a sustainable system attempts to minimize this use (Stinner and Blair, 1990). Through the high use of inorganic fertilizers, chemical pesticides, and monocropping, conventional agriculture is believed to have a lower labor/management need than sustainable agriculture, but the reality is

Table 3. Comparison of Characteristics Between Conventional and Sustainable Systems.

Characteristic	Conventional	Sustainable
Fossil fuel energy	High	Low
Labor/management	Low?	High? (more complex)
Fertilizer	Inorganic	Organic
Pest control	Chemical	Biological and cultural
Tillage	Lower	Lower
Diversity in crop rotation	Low	High
Nutrient cycling	Physical/chemical control	Biological control
Integration of animals	Low	High

Source: Stinner and Blair, 1990

sustainable systems are more complex and have only a slightly higher labor/management requirement. In a conventional system, fertilization and pest control is accomplished through inorganic or chemical means. Conversely, sustainable systems hope to achieve the same results using organic and/or biological and cultural practices using chemical fertilizers and pesticides only when absolutely necessary (Stinner and Blair, 1990).

Tillage requirements for both the conventional system and the sustainable system tend to be low, but this hasn't always been the case. Conventional systems have traditionally been associated with more intense tillage equipment, but with new technologies showing the economic and environmental benefits of reducing tillage, conventional systems have also reduced tillage input (Stinner and Blair, 1990).

Sustainable systems are also associated with a high diversity in the use of crop rotations. Conversely, conventional systems tend to emphasize the production of crops in one or two crop rotations. Finally, conventional systems tend not to integrate animals into their production. In the case of sustainable agriculture, the integration of animals is essential for the success of the entire system (Stinner and Blair, 1990). Overall, farmers who are using their internal resources, including soil fertility, labor resources, and management skills, to the fullest extent are practicing the kind of land stewardship that could be termed sustainable agriculture (Keeney, 1990).

Currently, there are a wide variety of practices which are considered

sustainable. Conservation tillage practices such as minimum tillage, ridge tillage, and no-tillage are considered sustainable in nature because they can serve to reduce soil erosion and increase energy efficiency. Conservation tillage is not just a concept, but a package designed to conserve soil and water, sustain high satisfactory returns, minimize degradation of soil and the environment, and maintain the resource base (Lal et al., 1990).

Integrated Pest Management (IPM) is a process which allows producers to maximize the effectiveness of biological and cultural controls of pests, while using chemical controls only when necessary and with a minimum of environmental disturbance (Luna and House, 1990). Biological control can be defined as the manipulation of parasites, predators, and pathogens to maintain pest populations below economically injurious levels. Cultural controls involve mechanical operations, such as tillage or burning, and crop and soil management practices, such as crop rotations, timing of planting and harvesting, trap cropping, and cropping system diversification (Luna and House, 1990). When necessary, the proper use of chemical controls involves precise timing of the application and the most effective method of application such as banding over broadcasting. Banding allows the producer to get the most control at the point of seeding while minimizing environmental problems caused by pesticide runoff and leaching.

In the case of nutrient management, losses due to leaching, denitrification, and ammonia volatilization must be minimized while maximizing

nutrient input through biological nitrogen fixation, utilization of on farm sources and nutrients available in the soil, and recycling of nutrients from off farm sources (King, 1990). With the increased costs of chemical fertilizers and the potential dangers from leaching or runoff, nutrient management has become an extremely critical subject. Management systems are available to greatly increase the efficiency of nutrient use. Many of these include nutrient credits for manure or legumes, better handling of animal wastes, application of fertilizer close to the time of maximum crop use to avoid losses, and soil testing to ensure maximum efficiency of nutrient use (Keeney, 1990).

One of the major components of sustainable agricultural systems is the use of crop rotations. Crop rotations are important in a sustainable system for the purpose of soil improvement, weed and insect management, and plant disease prevention (Francis and Clegg, 1990). Table 4 presents the average nitrogen fixation rates by various legumes used in diverse crop rotations. Among these legumes, alfalfa and various clovers tend to provide the most effective nitrogen fixation which is just one of the many benefits of using diversified crop rotations.

Normally the profitability of rotations requires the use of ruminant animals in the farming system. An alternative would be to develop additional markets for legumes. The problem is that there is no guarantee that these markets would provide a consistent profit (Keeney, 1990). Today's agricultural environment complicates the use of crop rotations because of the specialization

Table 4. Average Nitrogen Fixation by Legumes.

Legume	Nitrogen Fixed (kg/ha)
Alfalfa	217
Ladino clover	200
Sweet clover	133
Red clover	128
Kudzu	120
White clover	115
Cowpeas	100
Lespedeza	95
Vetch	90
Peas	72
Soybeans	65
Winter peas	56
Beans	45
Peanuts	44

Source: King, 1991

of cash grain farmers, the lack of immediate markets for hay or animals put on pasture, and the broad participation by farmers in government price support programs for feed grains (Francis and Clegg, 1990). These policies and programs are detrimental to a system that wishes to use crop rotations to improve the productivity of a land and protect the environment.

The goals of sustainable agriculture and the needs of farmers using sustainable systems are not being met by research and information programs and farm policies that emphasize specialization, intensive production, and the extensive use of chemicals. Federal funds to conduct research and extension programs in low-input sustainable agriculture are less than one percent of the total public expenditure on agricultural research. Over the years, most of the research conducted by public agriculture and the extension service has dealt with increased productivity and profitability through greater reliance on purchased inputs (Korsching and Malia, 1991). According to Bultena (1991), the speed with which agriculture producers accept and adopt sustainable agricultural practices is determined by social, economic, and political factors and the availability of the new farming practices. More emphasis needs to be placed on those practices and policies which would make the agricultural system more sustainable.

Trends in Land Tenure

Before discussing the various aspects and trends of land tenure in both the United States and the state of Iowa, it is important to define the

terminology involved:

- Land tenure refers to all relations of control between persons and the land.
- Tenancy is those property rights which are surrendered by the owner to the user at a set price for a particular time period. Renting, leasing, and tenancy will be used as synonymous for this research.
- Tenure group is a group of people holding a particular relationship to the land. The three tenure groups to be used for this research are full owners, part-owners, and full renters.
- Full owners are farmers who own all the land they operate.
- Part-owners are farmers who own part of the land they operate and rent the remaining.
- Full renters are farmers who rent all the land they operate.

The two primary methods of land leasing are the cropshare contract and the cash rent contract. In the cropshare contract, operators pay nothing until harvest at which time they pay the landowners with a portion of the crop, hence the name "crop" share. In the cash rent contract, operators usually pay for the use of a parcel of land prior to planting and then retain ownership of the entire crop at harvest. In a few cases, arrangements are made where the contract is part crop share and cash rent.

In the United States, about 60 percent of the land area is in private, that is, nongovernmental, ownership. Virtually all of the intensively used, highly priced, land is privately held. Nearly two-thirds of this private land is in agriculture. Only 3 percent of cropland is owned by government of any kind. In total area, the predominant private landowners are farmland owners. About

60 percent of these operate at least some of the land they own. Farm operators own about 65 percent, and nonoperator landlords own about 35 percent of the land in farms (Wunderlich, 1987). Traditionally, ownership is the preferred form of land tenure. The preference reflects a belief that owned land is more efficiently used, or more responsibly cared for. To some ownership represents achievement, security, or both. If land ownership is regarded as virtuous, tenancy is perceived as a symptom of a faulty agricultural structure (Wunderlich, 1987).

Recently, in the face of stresses in U.S. agriculture, the role of land leasing has been reexamined. Declines in land values, such as those witnessed after 1981, have created insecurities in ownership, especially when accompanied by debt. The financial requirements of modern agriculture, the shrinking number of farm units, and the risks of production and prices suggest a need to distribute both burdens and risks somewhat more widely than among farm operators only. Leasing emerges as one the most prevalent ways to meet this need (Wunderlich, 1987).

Leasing has been a part of the American agricultural system for a long time. Since the early 1900s, the percentage of land in agriculture that is rented has varied between 35 and 45 (Wunderlich, 1987). Today's farmers handle hundreds of thousands of dollars each year which forces them to become skillful financial managers on top of all their other chores and headaches. In today's agriculture the family farm has had to become a family farm business.

Escalating costs and shrinking per-unit profits have forced most farmers to keep increasing their volume of business, and the only way to accomplish this is by either buying land outright or by renting it from neighbors who have stopped farming, but are not yet ready to sell the land (Hart, 1991).

According to Hart (1991), farmers in the Corn Belt have expanded their operations by renting land rather than by buying it. This is evident because the average acreage rented by part-owner farmers in the region has increased far more rapidly than the acreage they own, and the acreage they own is only slightly greater than the acreage owned by full-owner farmers. Many farmers have concluded that they are better off using their money for operating expenses instead of paying it out in interest on overpriced land.

Every five years the United States Bureau of the Census conducts its Census of Agriculture. In Iowa, percentage of farms fully owned, partly owned, and fully rented has remain relatively constant since the mid-1970s as shown in Figure 3. According to the 1987 census of agriculture, 45.8% of the farms in Iowa are fully owned, 33.5% are partly owned, and 20.7% are fully rented (U.S. Dept. of Commerce Bureau of the Census, 1989). Although fully owned farms make up the majority of farms in Iowa, Figure 4 shows that partially owned farms hold a majority of the acreage, with fully-owned farms coming in at a distant second and fully rented farms holding a close third place. More than half (54.5%) of the land in Iowa is operated by part owners even though they account for only a third (33.5%) of all farms. An important detail to note

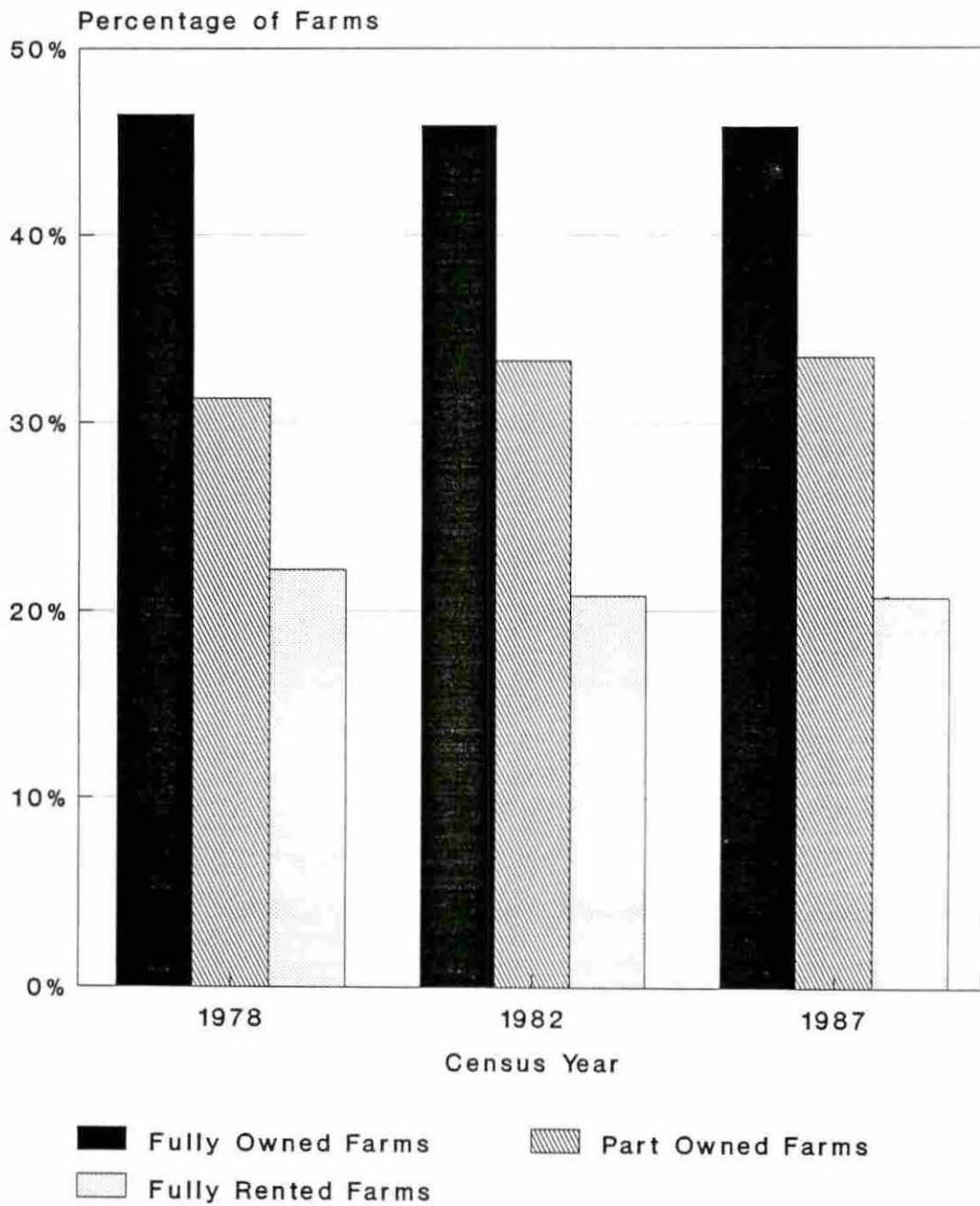


Figure 3. Percentage of Farms in Iowa by Tenure Type (U.S. Dept. of Agriculture, 1989)

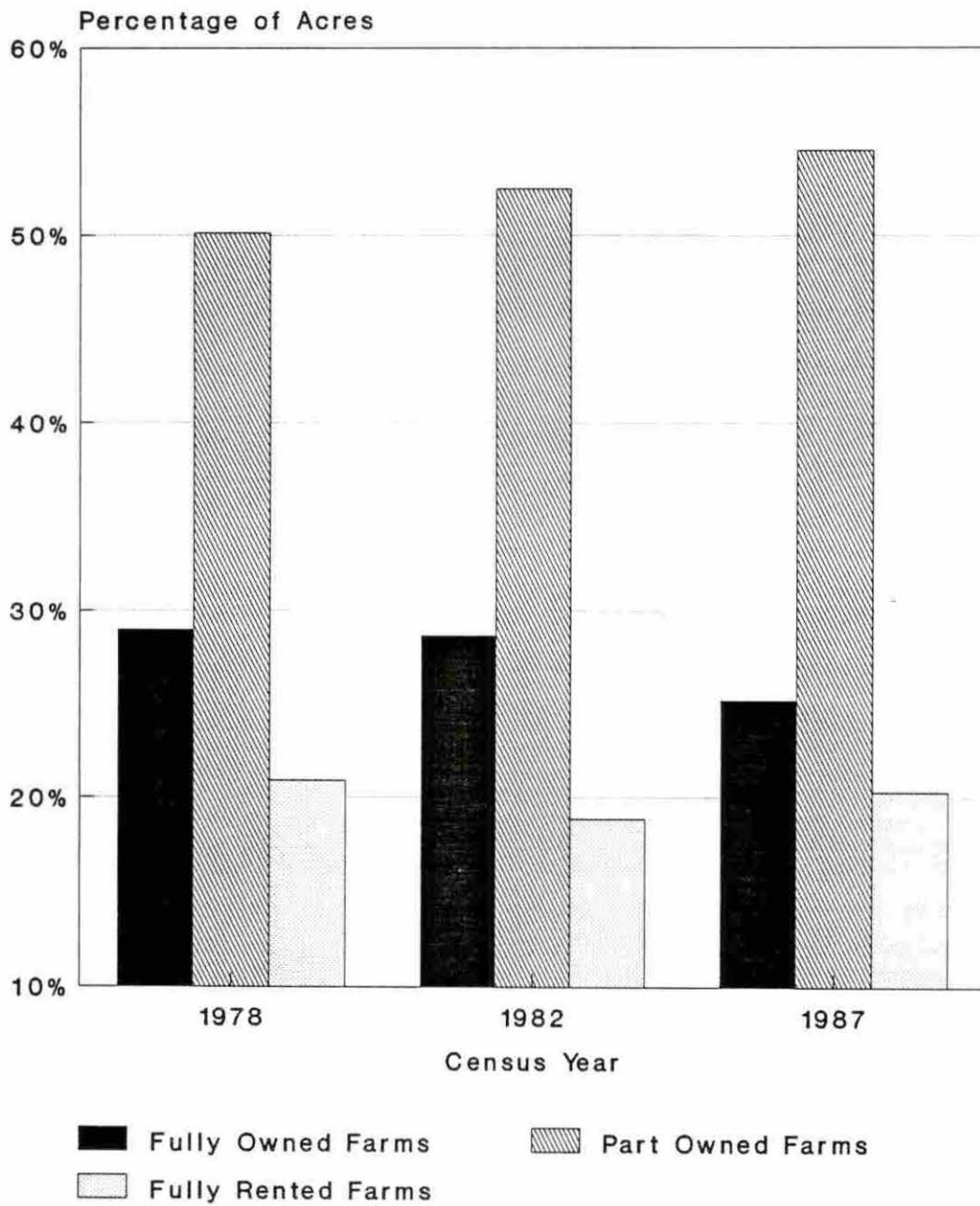


Figure 4. Percent of Acres in Iowa Farms by Tenure Type (U.S. Dept. of Agriculture, 1989)

is that in over the 10 years covered in Figure 4 the gap in the number of acres held between fully owned farms and fully rented farms dropped from 2.7 million acres to 1.6 million acres.

Probably the most startling revelation comes in the area of average farm size. As Figure 5 shows, average size for both partially owned farms and fully rented farms has been steadily increasing since the mid-1970s, while average farm size for full owners has stayed relatively constant. Average farm size grew from 425 acres to 490 acres for partially owned farms and 250 acres to 295 acres for fully rented farms, while fully owned farms stayed relatively constant at around 165 acres. Finally, Figures 6 and 7 depict the relationships and trends in sales for the three land tenure categories. Figure 6 shows percentage sales for the full ownership group has steadily decreased since the mid-1970s, while the part ownership group's sales steadily increased and full tenant group's sales held steady. Figure 7 shows the same is true of average sales per Iowa farm for the three tenure groups. Overall, the impact of rental arrangements has increased over the years and should continue to do so as farmers see renting as a viable way to increase their farm size. With the growing prominence of farmland leasing and the variety of lease terms used, the economics of land tenure is of increasing importance (Aplan et al., 1984).

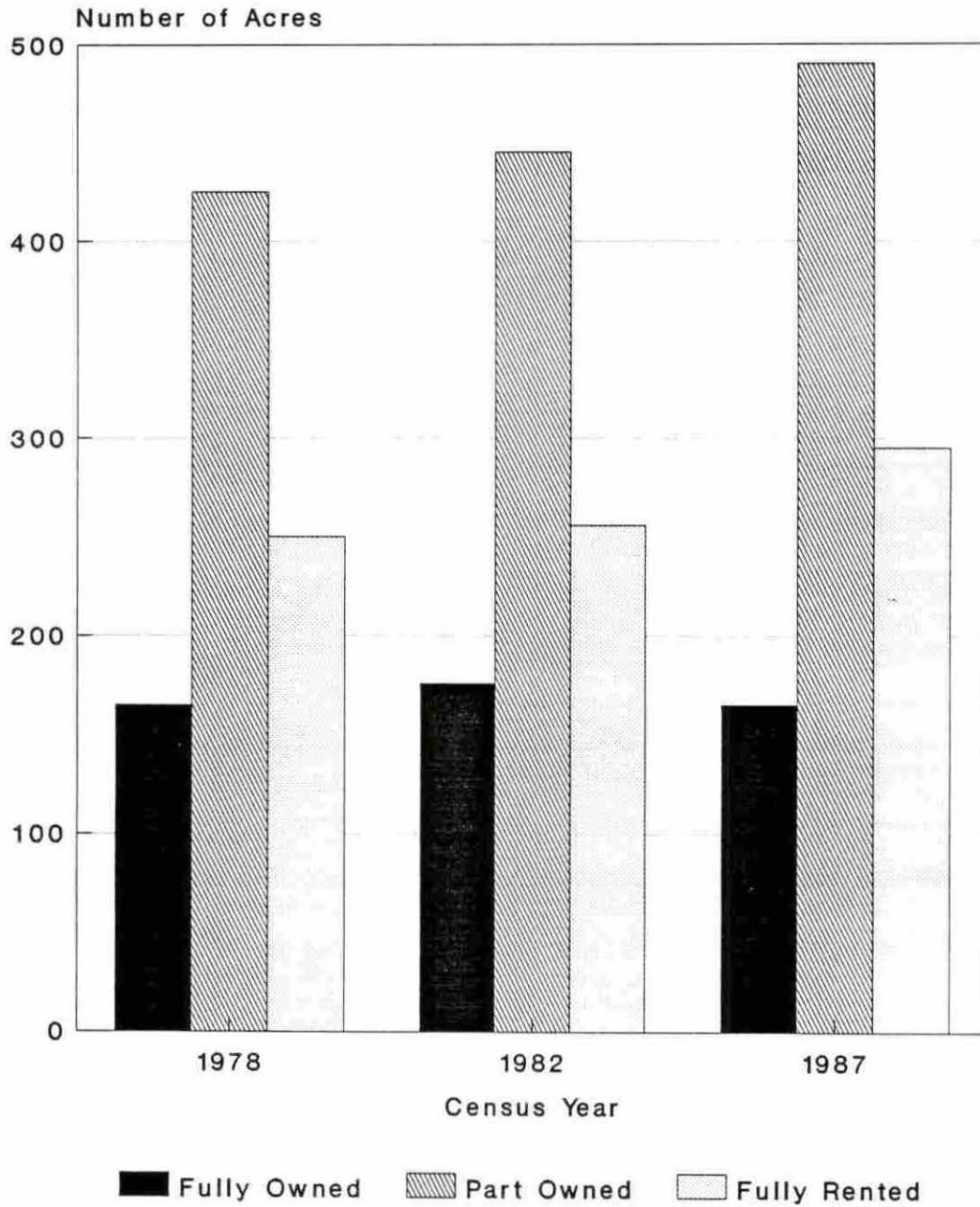


Figure 5. Average Farm Size in Iowa by Tenure Type (U.S. Dept. of Commerce, 1989)

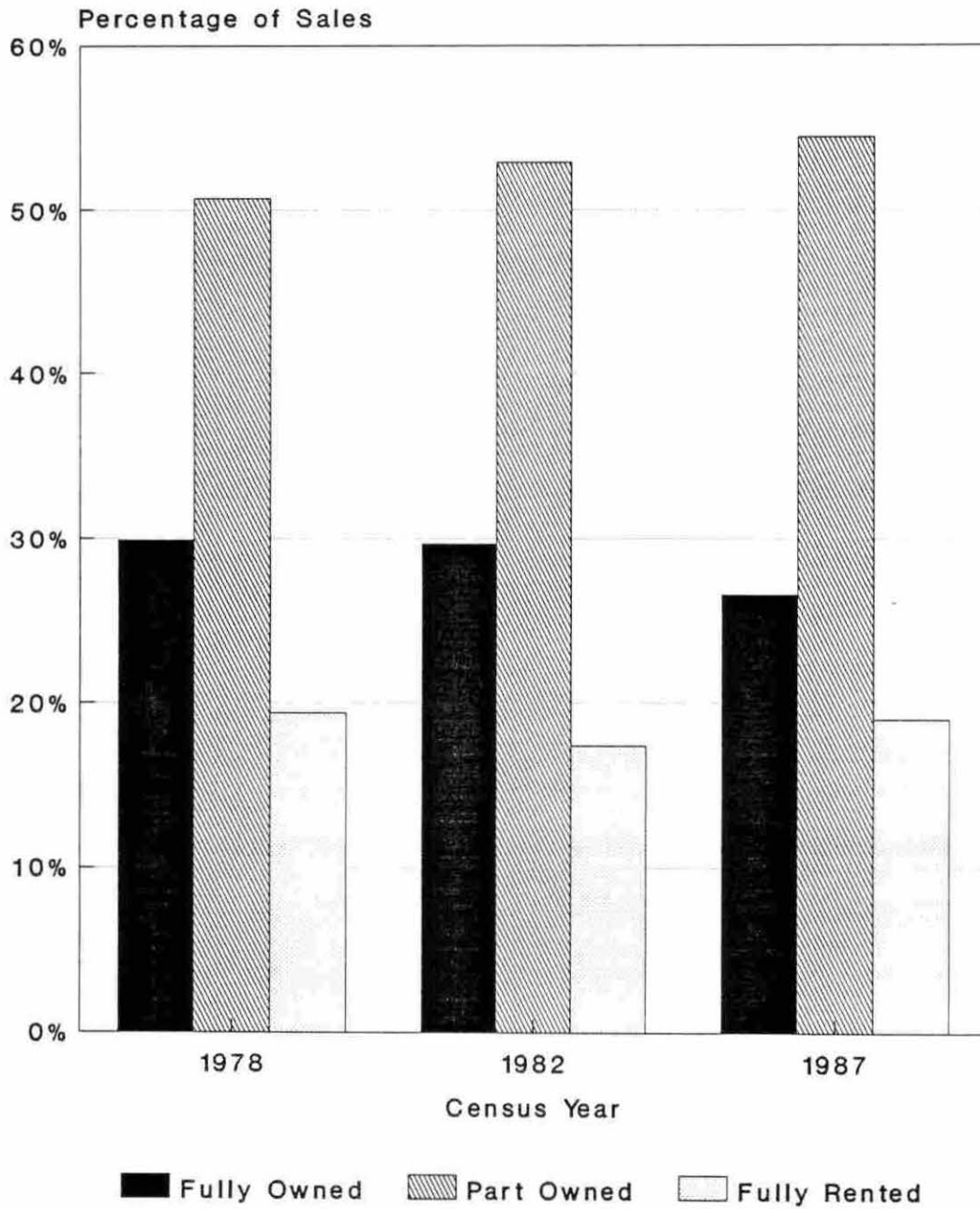


Figure 6. Percentage of Sales for Iowa Farms by Tenure Type (U.S. Dept. of Commerce, 1989)

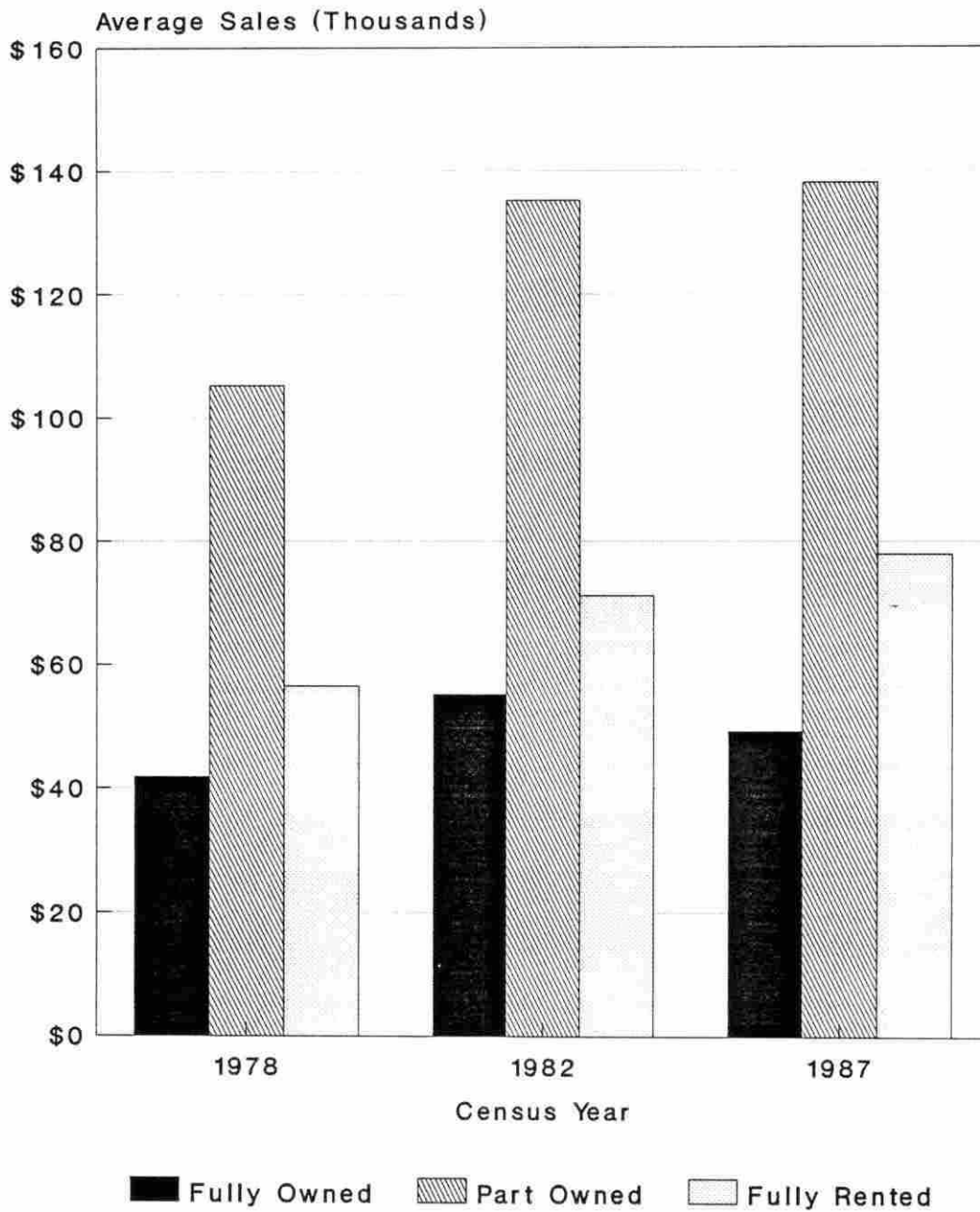


Figure 7. Percentage Sales Per Iowa Farm by Tenure Type (U.S. Dept. of Commerce, 1989)

PROBLEM SITUATION

A farming system is not just a simple sum of all of its components, but rather a complex system filled with multiple interactions. The main inputs of this system are some degree of soil cultivation; provision of plant nutrients; methods of crop protection against pests; and suitable crop rotations to maximize productivity (Edwards, 1990). To be sustainable, the agriculture system must produce adequate amounts of safe high-quality food, protect the renewable and nonrenewable resources, and be both environmentally safe and profitable (Reganald et al., 1990). The speed with which farmers accept and adopt sustainable agricultural practices is determined by social, economic, and political factors and the availability of new farming practices (Bultena, 1991). The effect of land tenure and land tenancy is one of these such factors that could hinder the acceptance and adoption.

Although the number of U.S. farms has declined substantially over the past five decades, the number of farmland owners and the proportion of rented farmland have remained relatively constant (Boxley, 1985). As noted above, currently over one-fifth of the farms in Iowa are operated by persons who do not own land and over one-half of the farms in Iowa involve some type land leasing arrangement. Tenant farmers also make up over twenty percent of the land used in U.S. agriculture and make up over twenty percent of the dollar sales of agricultural products (U.S. Department of Commerce Bureau of the Census, 1989). With such a large percentage of land in this state, and the

country as a whole, involved in rental agreements, it is important to determine if land tenancy influences the adoption of agricultural practices that are considered sustainable.

Leasing is often seen as a flexible but less secure form of land tenancy than ownership. Agricultural land leases are predominantly year-to-year in duration and usually subject to relatively short notice in their establishment prior to the production season. Typically, annual leases are automatically renewed and the rental arrangements continue for many seasons (Wunderlich, 1987). According to the Census of Agriculture, tenants who operate only rented land average 10.7 years on their present farms. Renters who own at least some of the land they farm average 17 years on their present farming operation.

A recent analysis of the relationship between tenure and conservation investment for a sample of U.S. landowners showed that full owners were more likely to invest in conservation practices than those who rented out their land. Past research has also shown that there are three potential problems associated with tenancy that may hamper the adoption of sustainable practices. The first factor deals with the instability of tenancy. In a survey of farmers and land owners in New Jersey, the insecurity and uncertainty over the continued use of rented land and the perceived lack of interest on the part of the landlord were the major concerns expressed by the farm operators. Use of year-to-year, indefinite leases and oral agreements attests to this instability (Derr, 1987). Both parties involved in a lease may be reluctant to tie their hands for a long

period of time because of general economic uncertainties and because of uncertainty about frictions between themselves arising from the execution of the lease. This instability and uncertainty shortens the effective planning horizons and raises the discount rate of the tenant, thereby discouraging investments in sustainable systems that usually exhibit much longer-run net benefits. Because shorter planning horizons and higher discount rates make long-run investments less attractive, lower conservation expenditures would be expected (Ervin, 1982).

A tenant who is uncertain about the future of a lease may find it more profitable to mine the land rented. Consequently, tenure arrangements often affect the likelihood of investment in sustainable practices. This was believed to be the major contributor to the inverse relationship found between land rented and the investment into sustainable agriculture in a study performed at Pennsylvania State University (Young and Shortle, 1984).

The second factor affecting the adoption of sustainable practices for owned versus rented land is associated to the costs of sustainable practices. In almost all leasing arrangements there is a lack of provisions for allocating costs and returns from sustainable practices between landlords and tenants. If all expected revenues and costs associated with the actions of the tenant are incident on this tenant, then the tenant would have no reason to alter the utilization plan because of the fact that the land is rented and not owned (Ervin, 1982). Sustainable practices involve alternative inputs and management

requirements that tenants may not find beneficial to their production and profitability goals (Ervin, 1986). These goals are often driven by current farm programs and policies that emphasize specialization, intensive production, and the extensive use of chemicals (Korsching and Malia, 1991). If the costs and benefits of sustainable agricultural investments are not shared between the owner and the tenant, sustainable practices are less likely to be used.

The final factor associated with the adoption of sustainable practices deals with the relationship of absentee ownership. Absentee landowners can influence the adoption of sustainable practices in three distinct ways. These include the overt rejection of efforts to carry out sustainable plans, the abandonment of sustainable practices on land being leased out, and the idea of the "convenient excuse" which involves the renter saying that the landlord won't allow it (Dillman and Carlson, 1982).

Overall, farmers who rent land and who have no security may not be interested in working it in a sustainable manner. Consequently, they may want to get all they can from the soil in the short run. So land might be pumped with chemicals, and essential maintenance neglected. As a result, the ability of that land to produce for future generations could be eroded away. Conversely, farmers who own the land they farm are more likely to work it a sustainable fashion (Madeley, 1992). They tend to have more of a personal interest in the land they farm and consequently have more of an interest in its future productivity.

The overall belief of people in favor of sustainable agriculture is that present day agriculture cannot persevere if it continues to waste soil, oil, and water while destroying the human spirit, the family farm, and the character of rural life (Bidwell, 1986). The goals of sustainable agriculture are to return a profit, decrease harm to the environment and to personal health, and provide a basis for a sustainable community by offering a way for people to stay on the land and be less dependent on federal payments for their livelihood (Lockeretz, 1988). Looking at the problem situation, the question becomes if tenancy acts as a barrier to the achievement of sustainable agricultural goals.

MATERIALS AND METHODS

The data for this study came from the Farm Equipment and Tillage Practices Survey which was approved by the ISU Human Subjects Committee and conducted by Iowa Agricultural Statistics in conjunction with the Leopold Center for Sustainable Agriculture at Iowa State University and the Iowa Department of Agriculture and Land Stewardship. Computer support and technical assistance was provided by Iowa State's Center for Agriculture and Rural Development. The Iowa State University Extension Service helped organize this effort (Duffy and Thompson, 1991).

The survey used was conducted in the personal interview format. The enumerators received two days of extensive training on the survey prior to interviewing. These interviews were conducted during January and February 1990 for the 1989 crop year. Results presented here come from 1,181 respondents statewide. Farmers were randomly selected using both list and area frame sampling. The survey provides statistical reliability to the Crop Reporting District. The 1,181 respondents represent approximately 95,000 farms. There was a slight undersampling and representation of extremely small farms (Duffy and Thompson, 1991).

The survey consisted of nine distinct sections. Section one covered general farm information including planted acres, livestock on the farm, and gross sales derived from crops and livestock. Section two involved fuel storage and use for both farm and non-farm operations. Section three consisted of

grain storage and handling. Included in this section were storage, hauling, handling, and drying of grain. Section four dealt with manure and included storage, handling, spreading, credits taken, and adjustments made. Section five covered trends in tillage practices which included changes made since 1984 and conservation measures on highly erodible land. Section six covered fertilizer use and section seven involved pesticide use. Fertilizer use included the analysis, application rate, form, and timing. Pesticide use included application method, form, and timing. Section eight consisted of a machinery and implement inventory which included tractors, self-propelled equipment, autos, trucks, and field implements.

For the interests of this study, section nine provided most of the data needed. This section involved field data including land tenure, total acres, crop, rotation, predominant soil type, and percent of slope. This section then went into individual crop operations for each parcel of land which incorporated data from sections six through eight.

Objective

This research has been designed to meet the following objective:

- To determine if land tenancy has an effect on the practices agricultural producers choose to use.

The design of this research is to split agricultural producers into their basic tenure groups and determine if affiliation in a particular group will affect management choices of certain agricultural practices.

Tenure Groups

The comparative interests of this study are based on the operational characteristics of the farm managers involved. With this in mind, land was first split into that which was classified as owned and that which was classified as rented. Then the survey sample was split into three farm management tenure types: fully owned farms, partially owned farms, and fully rented farms, with partially owned farms split into two land groups: owned land and rented land. Using these basic management relationships with the land, comparisons of agricultural practices were made for three contrasting tenure situations: all owned land versus all rented land, fully owned farms versus fully rented farms, and owned land versus rented land for partially owned farms.

Figure 8 compares the percent of farms that fall into one of three tenure types found in the Farm Equipment and Tillage Practices Survey versus the 1987 Census of Agriculture. Because of the slight undersampling of extremely small farms, the percent of full owners found in the survey sample is lower than that found in the census data. Figure 9 compares the average size of the farms that fall into the three tenure types for the Farm Equipment and Tillage Practices Survey versus the 1987 Census of Agriculture. Again, because of the undersampling of extremely small farms the average number of acres is larger for the survey sample versus the census data. The average size of fully owned farms in the survey is roughly 65 percent of that of full renters. This corresponds with the census data which shows that the average size of fully

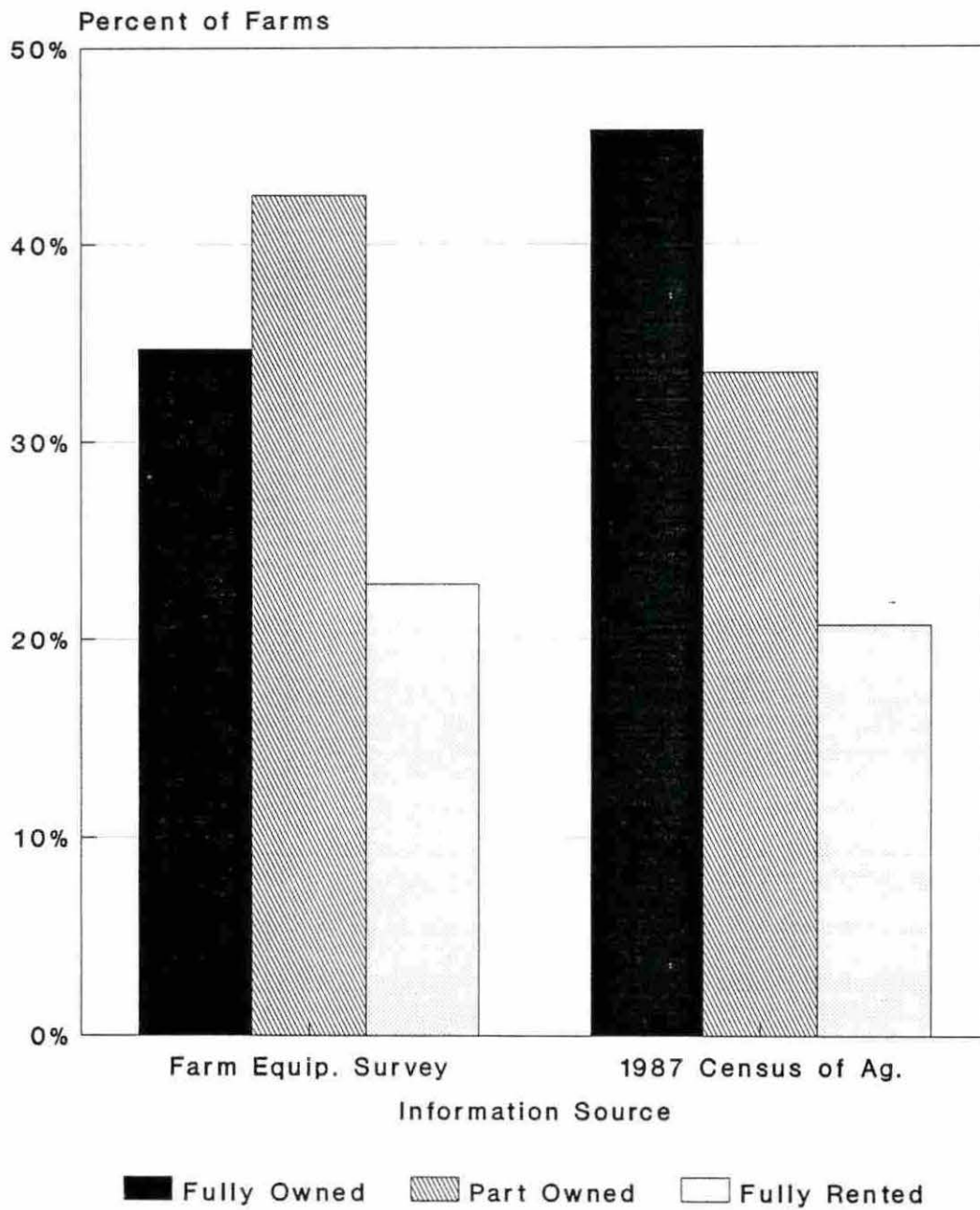


Figure 8. Survey Versus Census: Percentage of Iowa Farms in Each Tenure Category

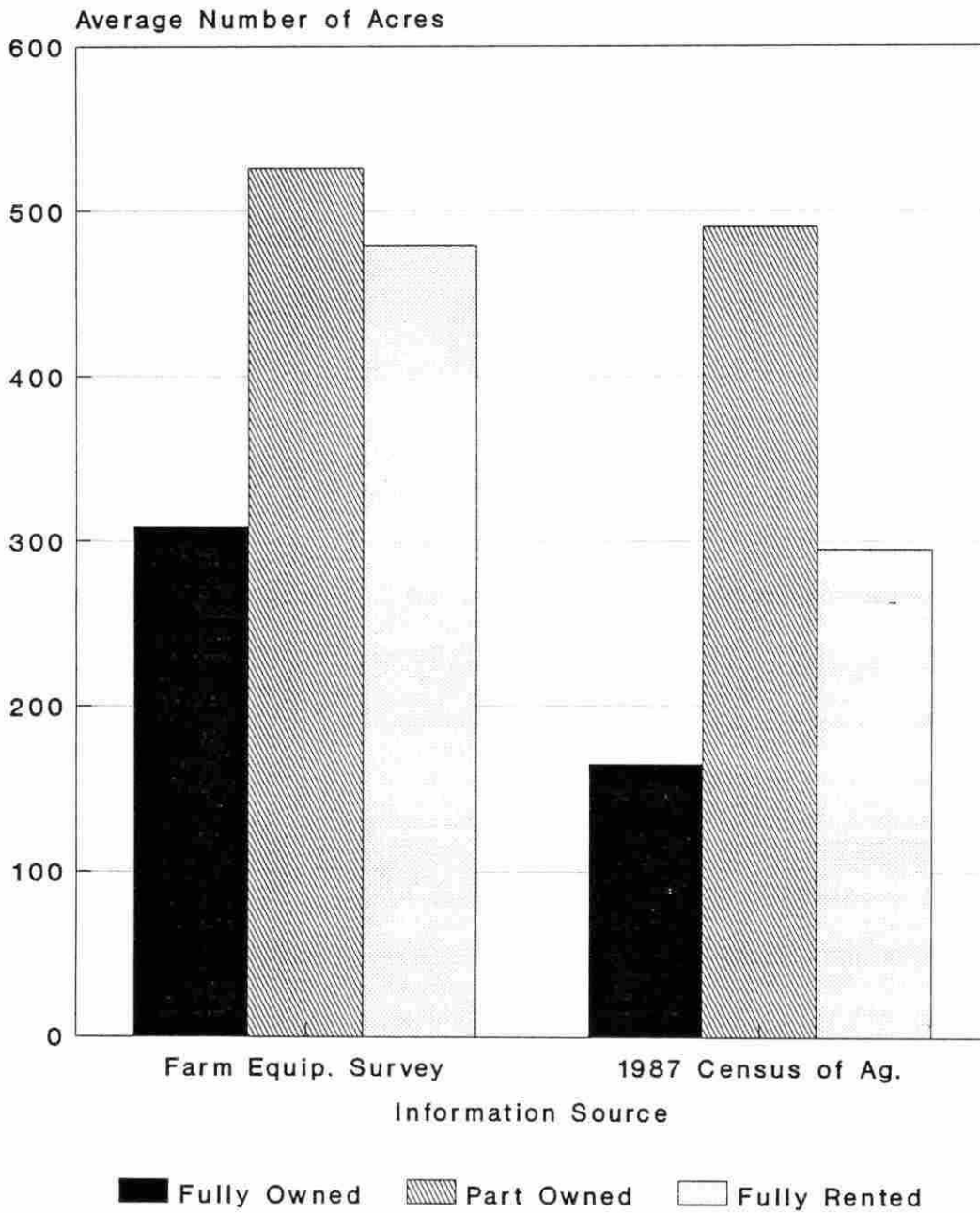


Figure 9. Survey Versus Census: Average Size of Iowa Farms in Each Tenure Category

owned farms is roughly 60 percent of that of fully rented farms.

Figures 10 and 11 cover some of the agricultural demographics found in the survey sample. Figure 10 gives the percentage of farms which fall into one of three farm types by land tenure category. Farms with at least 80% of their sales from crops are considered crop farms, farms with at least 80% of their sales from livestock are considered livestock farms, and all farms in between are considered crop and livestock mix farms. Fully rented farms have the largest percentage of crop farms (41%), part owned farms show the greatest percentage of crop and livestock mix farms (59%), and fully owned farms show the highest percentage of livestock farms (20%).

Figure 11 gives a summary of the farm size comparisons for the three tenure categories. Farm size was split into five groups according to row crop acres. As expected, fully owned farms had the greatest percentage of farms in the extremely small farm group (0 to 159 row crop acres) with partially owned farms holding a higher percentage of larger farms and fully rented farms landing in the middle. Overall, this information shows the survey has provided a very representative sample of the true population of Iowa farmers.

Agricultural Practices

To determine how agriculture practices differ based on the farm and land tenure situations, four basic areas of production were examined. These areas included mechanical practices, pesticide practices, fertilizer use, and crop rotation use.

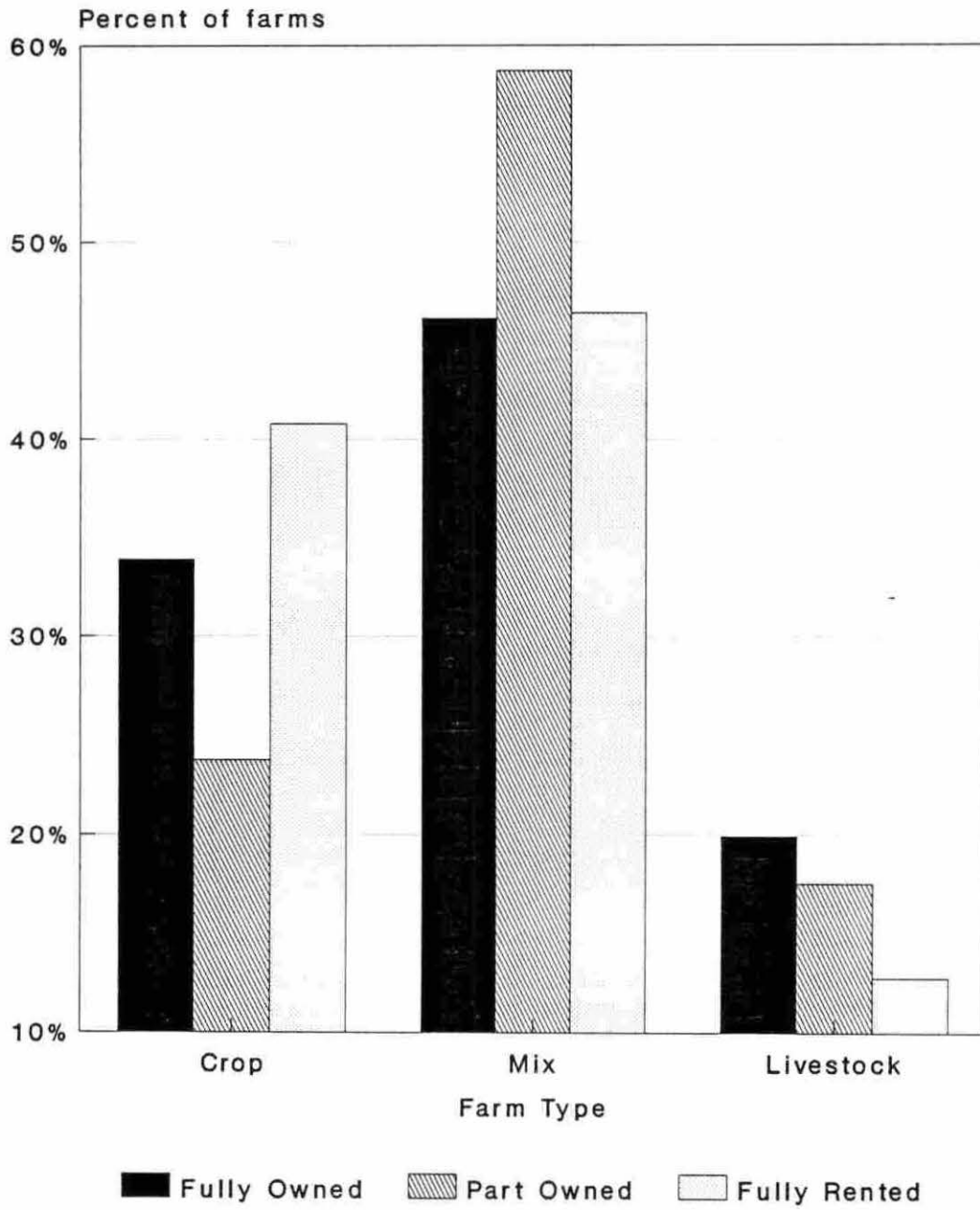


Figure 10. Percent of Farm Types by Land Tenure Category
 Note: Sales of 80% or greater constitute a crop of livestock farm

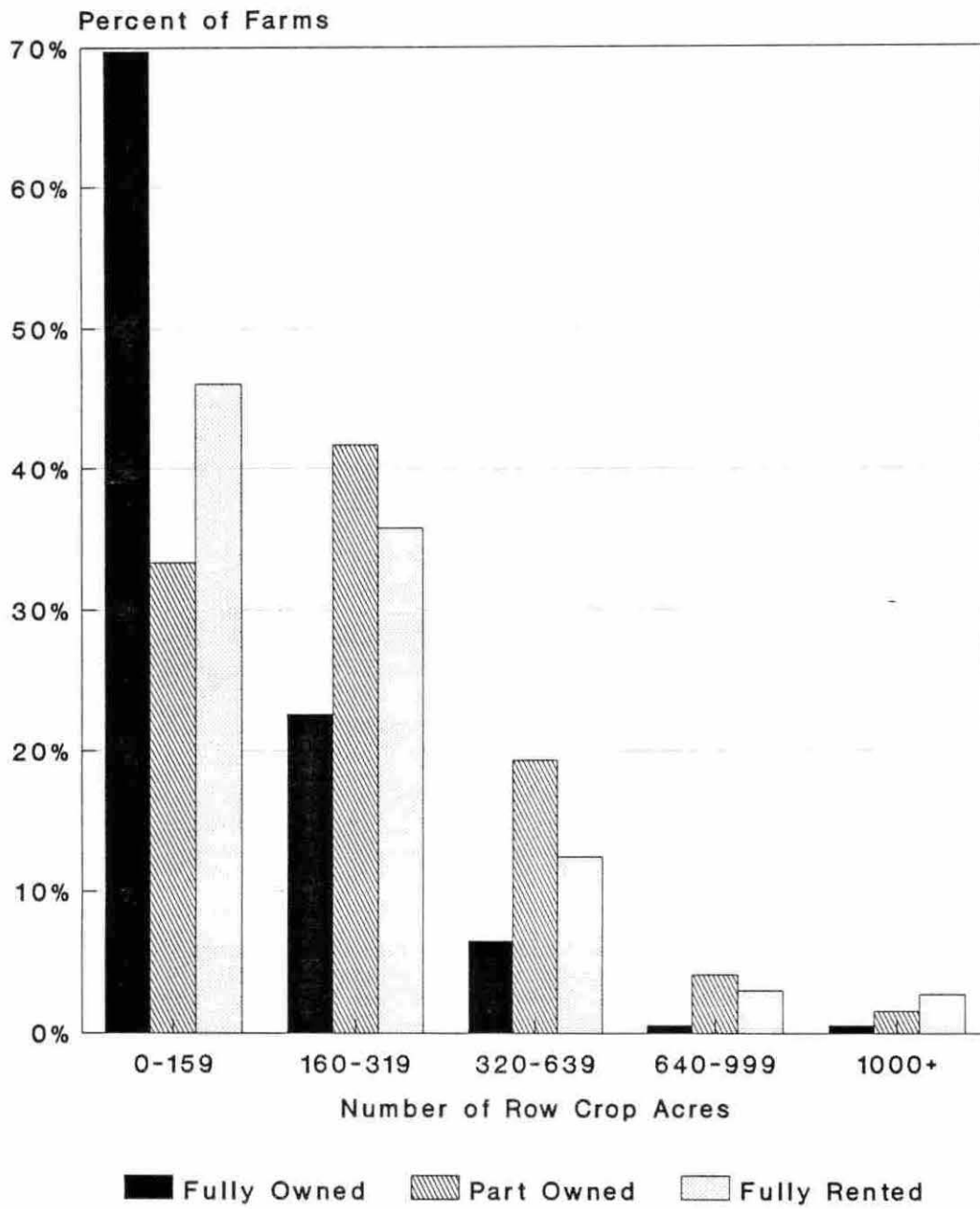


Figure 11. Farm Size by Land Tenure Category

Mechanical practices were compared based on the primary tillage equipment used and number of trips over a field. The primary tillage equipment included in this comparison were the moldboard plow, chisel plow, field cultivator, and tandem disk. Comparisons were made for fields with continuous corn rotations, rotated corn following soybeans, and soybeans following corn. The goal of this comparison was to determine if one sample group, such as fully rented farms, tended to use more intensive tillage practices with greater frequency than an opposing sample group, in this case fully rented farms, or vice versa.

Number of trips over a field was compared using a means test. This test was conducted for fields with continuous corn rotations, rotated corn following soybeans, and soybeans following corn. The goal of this test was to determine if one sample tenure group used more trips on average than its opposing sample tenure group. More trips over a field can lead to more compaction of the soil, but more importantly, it also leads to an increase in the use of fossil fuels because of the increased energy needed for more intensive tillage practices (Lal et al., 1991).

Pesticide practices were compared based on method of application, pesticide form, and timing of application. Method of application was split into four different categories for comparison: broadcasting, banding, incorporation, wicker sprayer, and other. The comparisons were based on frequency of use for each method of application by opposing tenure group samples. The intent

of this comparison was to determine if farm or land tenure classification had an effect on the type of application method a manager chose to use.

For this study, pesticide forms were split into six separate categories: Liquid, granular, powder, wettable powder, emulsion, and other. The comparisons were based on frequency of use for each pesticide form category by contrasting tenure group samples. The intent of this comparison was to determine if farm or land tenure classification has an effect on the pesticide form a farm manager chose to use.

In order to compare pesticide timing, the data was split into four timing categories: preplant, planting, pre-emergence, and post-emergence. The comparisons were based on the frequency of use for each timing of application category by contrasting tenure group samples. The intent of this comparison was to determine if farm or land tenure classification had an effect on the pesticide timing a farm manager chose to use.

For the purpose of this research, fertilizer use was compared for contrasting tenure groups based on the actual amounts of nitrogen, phosphorus, and potassium used by individual farm managers. These actual rates were compared using a comparative means test. The intent of this comparison was to determine if farm or land tenure classification had an effect on the actual use rates of nitrogen, phosphorus, and potassium. Also, because of the increased interest in the use of nitrogen and its detection in the ground water supply, actual rates of nitrogen used by contrasting tenure groups were

compared for rotated corn for the three most common crop rotations found in the survey: continuous corn, rotated corn-soybeans, and rotated corn-oats-meadow. The intent of this comparison was to determine if the farm or land tenure situation had an effect on the actual use rates of nitrogen for corn in the three most common rotations.

Finally, crop rotations used were compared for contrasting land tenure groups. For the interest of this research, crop rotations were split into eight categories: continuous corn (CC), rotated corn-soybeans (CSb), rotated corn-oats-meadow (COM), rotated corn-oats-soybeans (COS), permanent pasture (PP), set aside (SA), conservation reserve program (CRP), and other. A frequency of use test was used to determine the percentage distribution of use for these eight crop rotation categories. The intent of this part of the research was to determine if the farm or land tenure situation had an effect on the decision to use different crop rotations. Crop rotations with leguminous crops are considered beneficial in that they provide a natural barrier to insect and weed problems and aid in nitrogen fixation and nutrient replenishment (Francis and Clegg, 1990).

Statistical Tests Used

In order to make any definitive statements about any differences found in the research findings, tests for significant difference were done for all comparisons. For all instances in which a frequency comparison was used, a Likelihood Ratio Test for significant difference in frequency data was performed

which yields a Chi-squared statistic (Agresti, 1990). A summary and explanation of this test is shown in Appendix A. In any case where a means comparison test was used, significant difference was measured using either the Studentized t-Test for Independent Sample Means with Equal Variances or the Studentized t-Test for Independent Sample Means with Unequal Variances depending on comparative variability of the two samples measured (Ott, 1988). These tests are summarized in Appendices B and C respectively. To determine if the variances of two compared samples were homogeneous, an F-Test for Homogeneity of Population Variances was used (Ott, 1988). A summary of this test is shown in Appendix D. For each statistical tests performed in this research, an alpha value of 0.05 was used.

RESULTS

The results of this study will be presented for the agricultural practices compared in the following order: mechanical practices, pesticide practices, fertilizer use, and crop rotation use.

Mechanical Practices

The percentage distributions of primary tillage equipment used on continuous corn rotations for the three separate tenure comparisons are shown in Figures 12, 13, and 14. Figure 12 shows that the distributions of tillage equipment used for all owned land versus all rented land were essentially the same. Of the four primary tillage equipment compared, moldboard plows were used 11.1% of the time for all owned land and 9.1% of the time for all rented land. Chisel plows use was 13.7% of the time for all owned land as compared with 12.9% of the time for all rented land. This same closeness in percentage of use was evident for field cultivators and discs as well, with field cultivator use approximately 30% and disc use roughly 46% for both all owned land and all rented land. The Likelihood Ratio Test for significant difference in frequency data yielded a chi-squared of 4.49 with three degrees of freedom, which shows that no significant difference between the use of these four primary tillage instruments existed for all owned land versus all rented land.

Figure 13 shows that the distribution of use for the four basic tillage equipment listed was essentially the same for fully owned versus fully rented farms. Fully owned farms had a tendency to use a greater proportion of

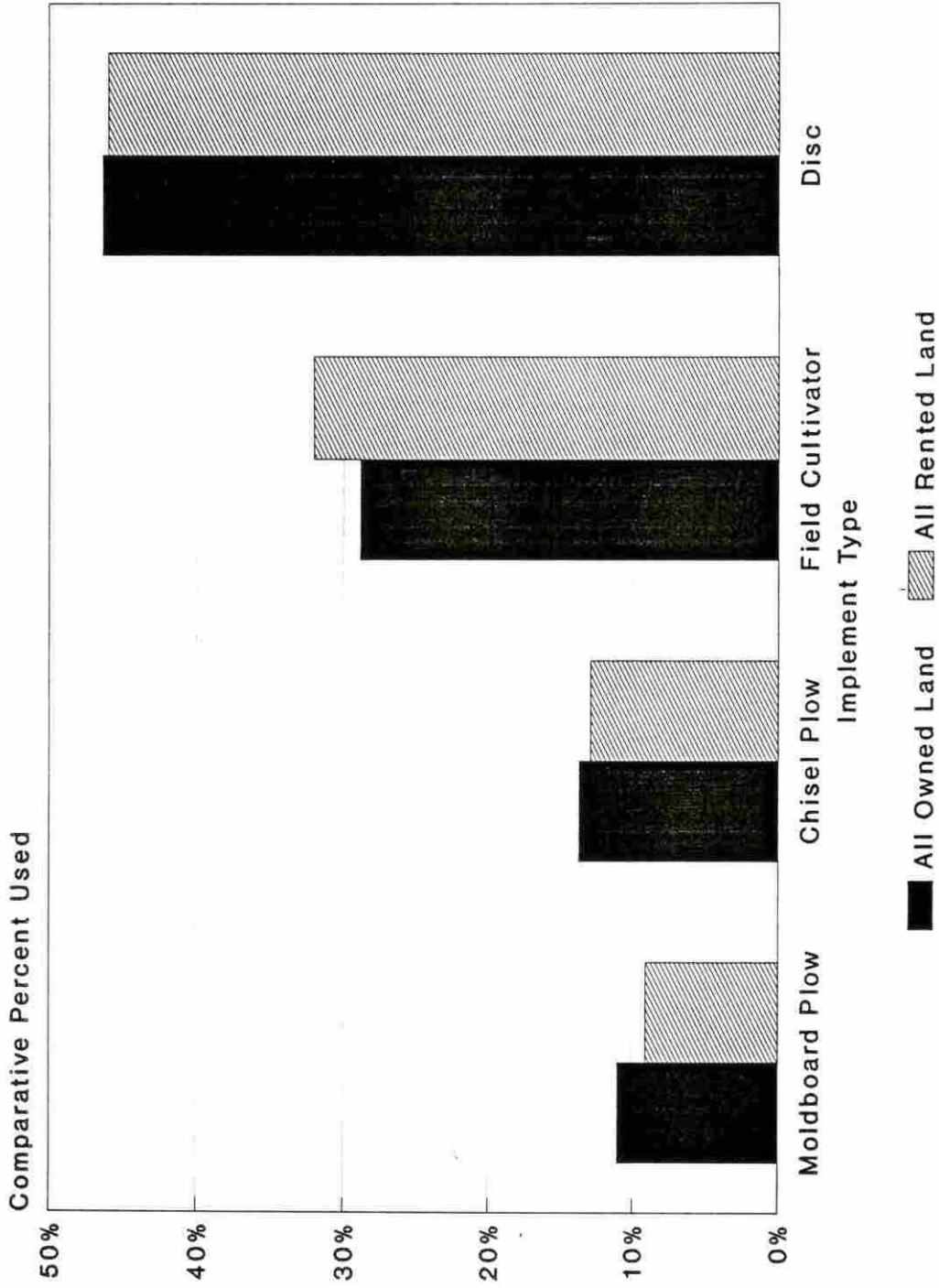


Figure 12. Percentage Distribution of Tillage Equipment Use on Continuous Corn for All Owned Land Versus All Rented Land.

Note: $\chi^2 = 4.49$ with 3 degrees of freedom; no significant difference found

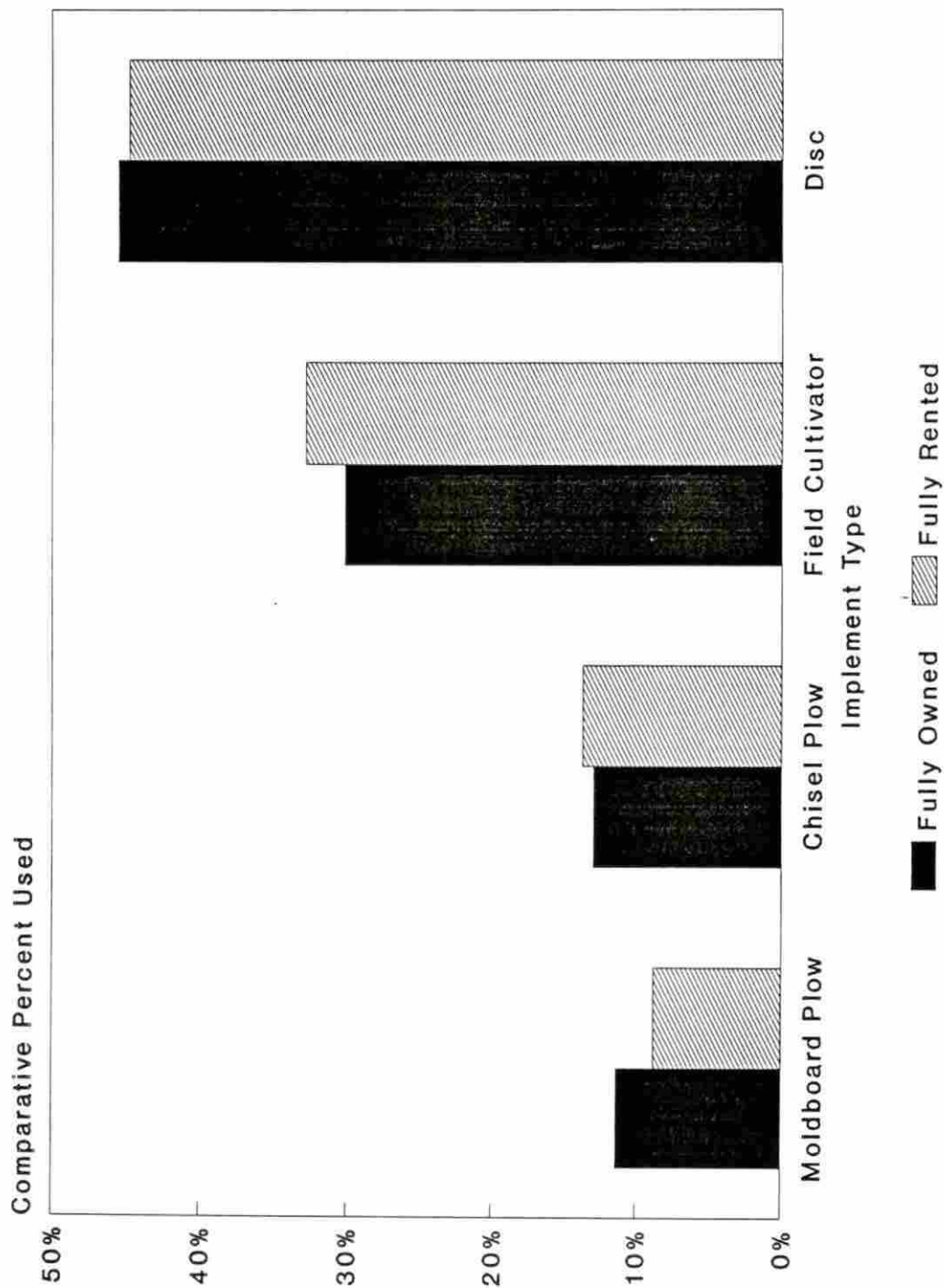


Figure 13. Percentage Distribution of Tillage Equipment Use on Continuous Corn for Fully Owned Versus Fully Rented Farms.

Note: $\chi^2 = 4.666$ with 3 degrees of freedom; no significant difference found

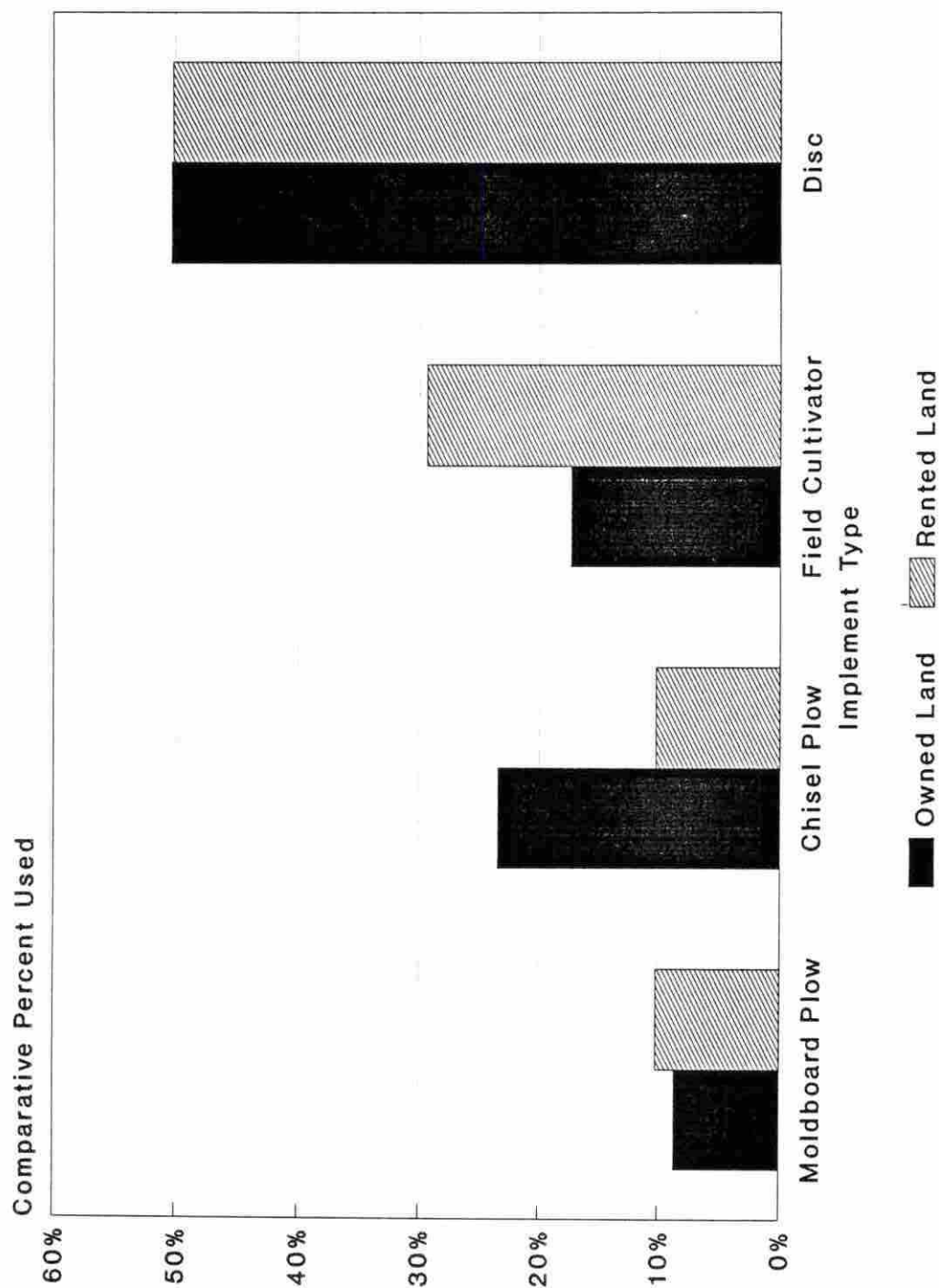


Figure 14. Percentage Distribution of Tillage Equipment Use on Continuous Corn by Part Owners for Owned Versus Rented Land.

Note: $\chi^2 = 13.86$ with 3 degrees of freedom; slight significant difference found

moldboard plows than did fully rented farms, with a total 11.4% of the use distribution devoted to moldboard plows as apposed to 8.8% for fully rented farms. Fully rented farms, on the other hand, had a tendency to use a slightly greater percentage of field cultivators than did fully owned farms (32% to 30%). Yet, the use distributions for fully owned farms versus fully rented farms were found not to be significantly different by the Likelihood Ratio Test which yielded a Chi-squared value of only 6.34 with three degrees of freedom.

Figure 14 shows that, for part owners, chisel plow use tended to be greater on owned land than on rented land and field cultivator use tended to be greater on rented land than on owned land. Chisel plow use accounted for 23.5% of the total use of the four primary tillage implements listed for owned land. This contrasted greatly with the 10.2% on rented land. Contrarily, field cultivator use accounted for 29.4% of the total use on owned land as apposed to the 17.4% found for rented land. Moldboard plow and disc use were almost identical for both owned and rented land. Evidence shows that part owners tended to substitute field cultivator use on rented land in some cases. The differences in use frequencies were found to have a slight significance by the Likelihood Ratio Test which yielded a Chi-squared value of 13.86 with three degrees of freedom.

Percentage distribution in the use of the four primary tillage instruments on rotated corn following soybeans are shown in Figures 15, 16, and 17.

Figure 15 gives a summary of how the distribution in tillage use was relatively

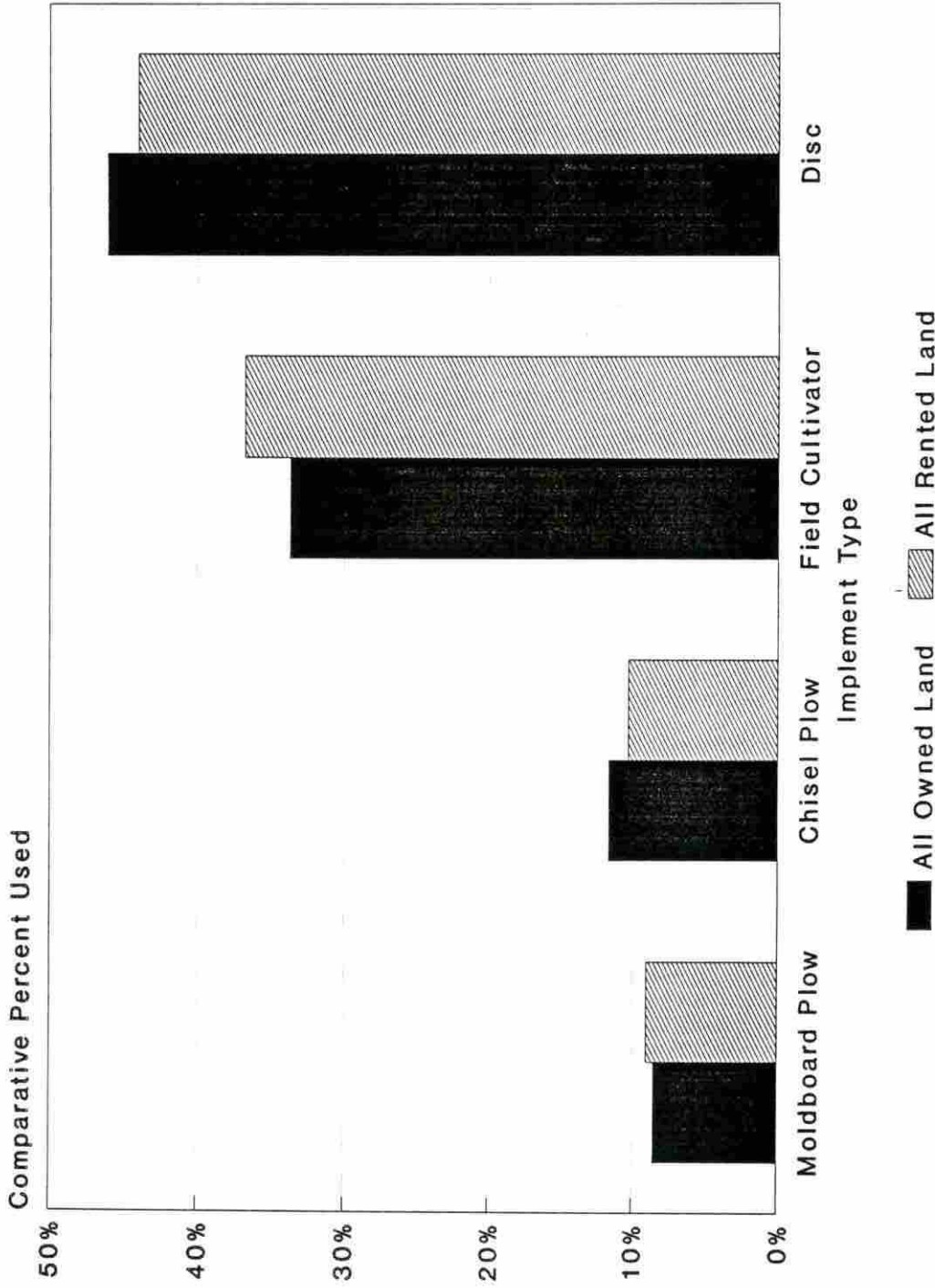


Figure 15. Percentage Distribution of Tillage Equipment Use on Rotated Corn Following Soybeans for All Owned Land Versus All Rented Land.
 Note: $\chi^2 = 6.92$ with 3 degrees of freedom; no significant difference found

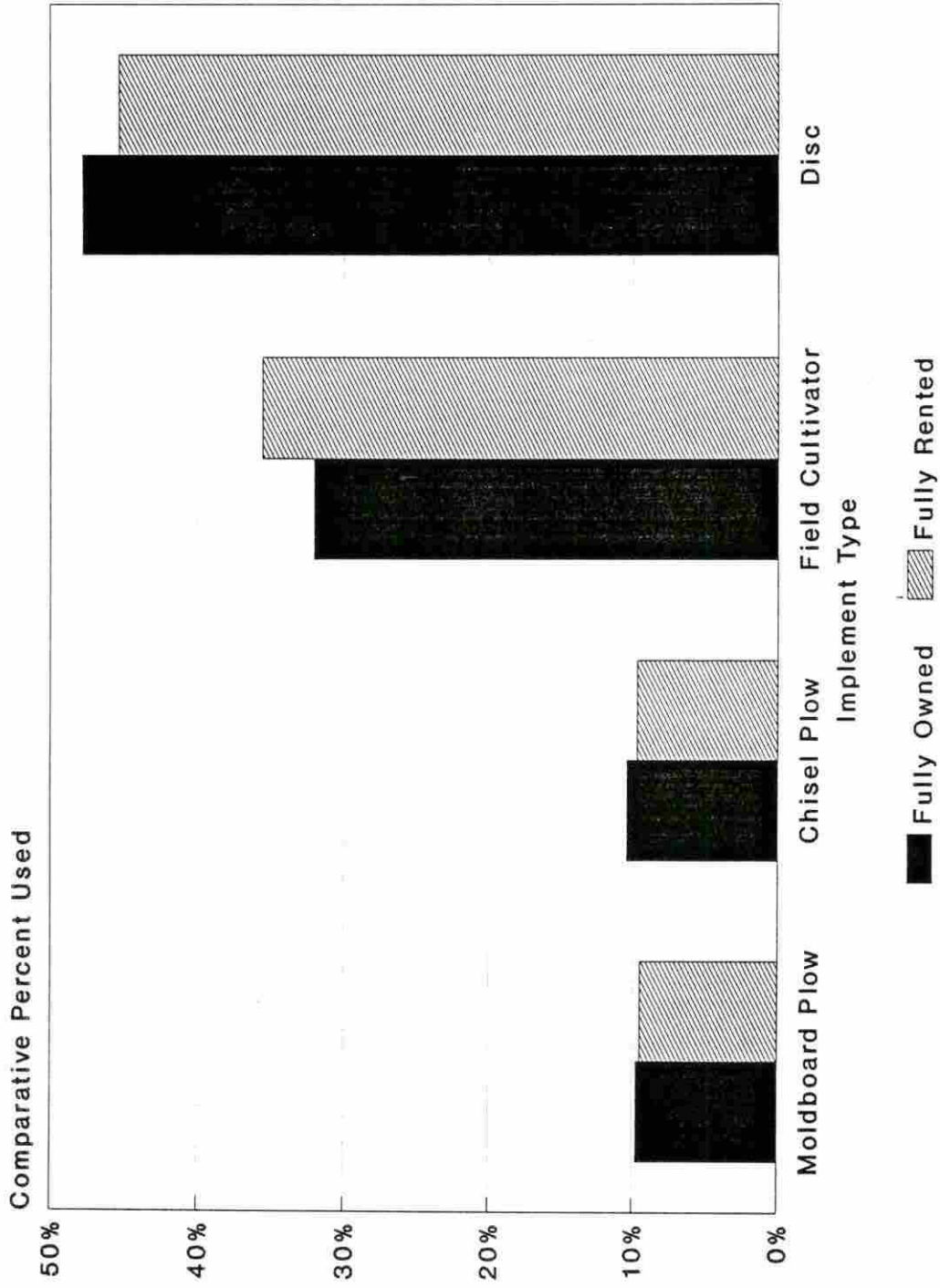


Figure 16. Percentage Distribution of Tillage Equipment Use on Rotated Corn Following Soybeans for Fully Owned Versus Fully Rented Farms.

Note: $\chi^2 = 4.617$ with 3 degrees of freedom; no significant difference found

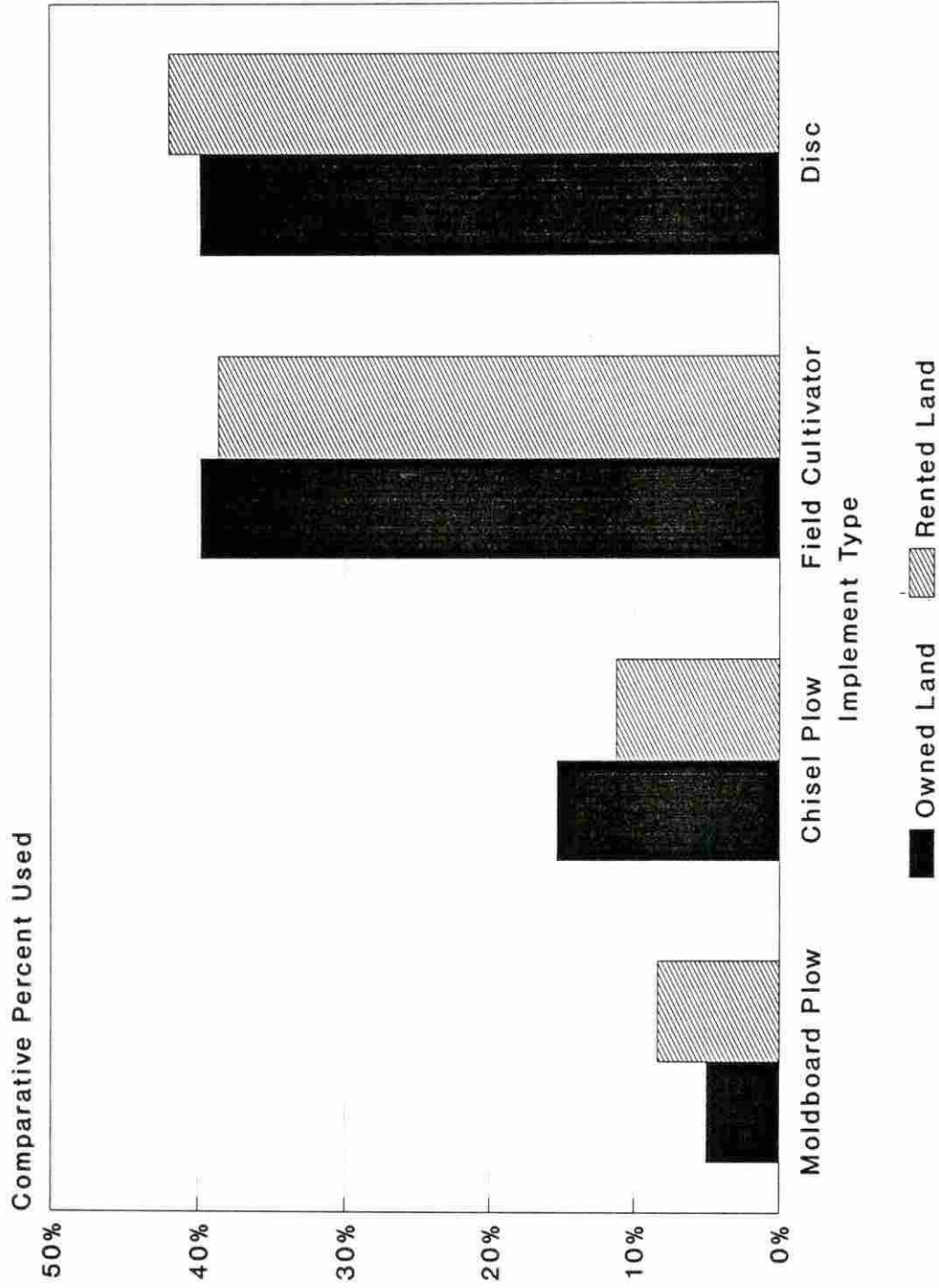


Figure 17. Percentage Distribution of Tillage Equipment Use on Rotated Corn Following Soybeans by Part Owners for Owned Versus Rented Land.
 Note: $\chi^2 = 11.28$ with 3 degrees of freedom; slight significant difference found

equal for all owned land versus all rented land. Slight variations were found in field cultivator and disc use, with differences of only 3% higher for field cultivator use on all rented land and only 2% higher for disc use on all owned land. The Likelihood Ratio Test yielded a Chi-squared of 6.92 with three degrees of freedom. This shows there was no significant difference for the percentage distribution in the use of primary tillage equipment on all owned land versus all rented land.

Figure 16 shows the percentage distribution of primary tillage equipment for fully owned versus fully rented farms. As with Figure 15, slight differences were found for both field cultivators and discs, with field cultivators holding a greater percentage (3.4% greater) on fully rented farms and discs holding a greater percentage (2.5% greater) on fully owned farms. Yet, as with that of all owned land versus all rented land, no statistically significant difference was found for primary tillage practices on fully owned farms versus fully rented farms. The Likelihood Ratio Test yielded a Chi-squared of only 4.617 with three degrees of freedom.

As shown in Figure 17, The percentage distribution of primary tillage use on rotated corn following soybeans for partially owned farms was slightly different on owned land versus rented land. Rented land tended to receive a greater percentage of moldboard plow use (8.4%) as opposed to that of owned land (5%). On the other hand, chisel plows showed a greater percentage of use on owned land (15.4%) as opposed to rented land (11.2%). Overall, it

seems that part owners had a tendency to substitute moldboard plows for chisel plows for rotated corn following soybeans on their rented land. Field cultivator use and disc use was constant for both owned and rented land, hovering around 40% in both cases. Because of this discrepancy in use of moldboard plows and chisel plows on owned versus rented land, the Chi-squared yielded by the Likelihood Ratio Test was 11.28 with three degrees of freedom showing a slight significant difference in use did exist.

Finally, Figures 18, 19, and 20 summarize the percentage distributions in use of moldboard plows, chisel plows, field cultivators, and discs for soybeans following corn. Figure 18 summarizes the percentage use of primary tillage equipment on all owned land versus all rented land. The distributions shown in the figure are almost identical. This translates to the idea that tillage use on all owned land was essentially the same as that of all rented land. This is backed by the Likelihood Ratio Test which yielded a Chi-squared of only 4.22 with three degrees of freedom.

Figure 19 gives the percentage distributions of use for the four basic primary tillage instruments on fully owned versus fully rented farms. As with all owned land versus all rented land, the distributions for fully owned farms versus fully rented farms were essentially the same. Moldboard plow use hovered around 10%, chisel plow use around 11%, field cultivator use around 34%, and disc use around 46%. This resulted in the Likelihood Ratio Test yielded a relatively low Chi-squared (5.014 with three degrees of freedom) and

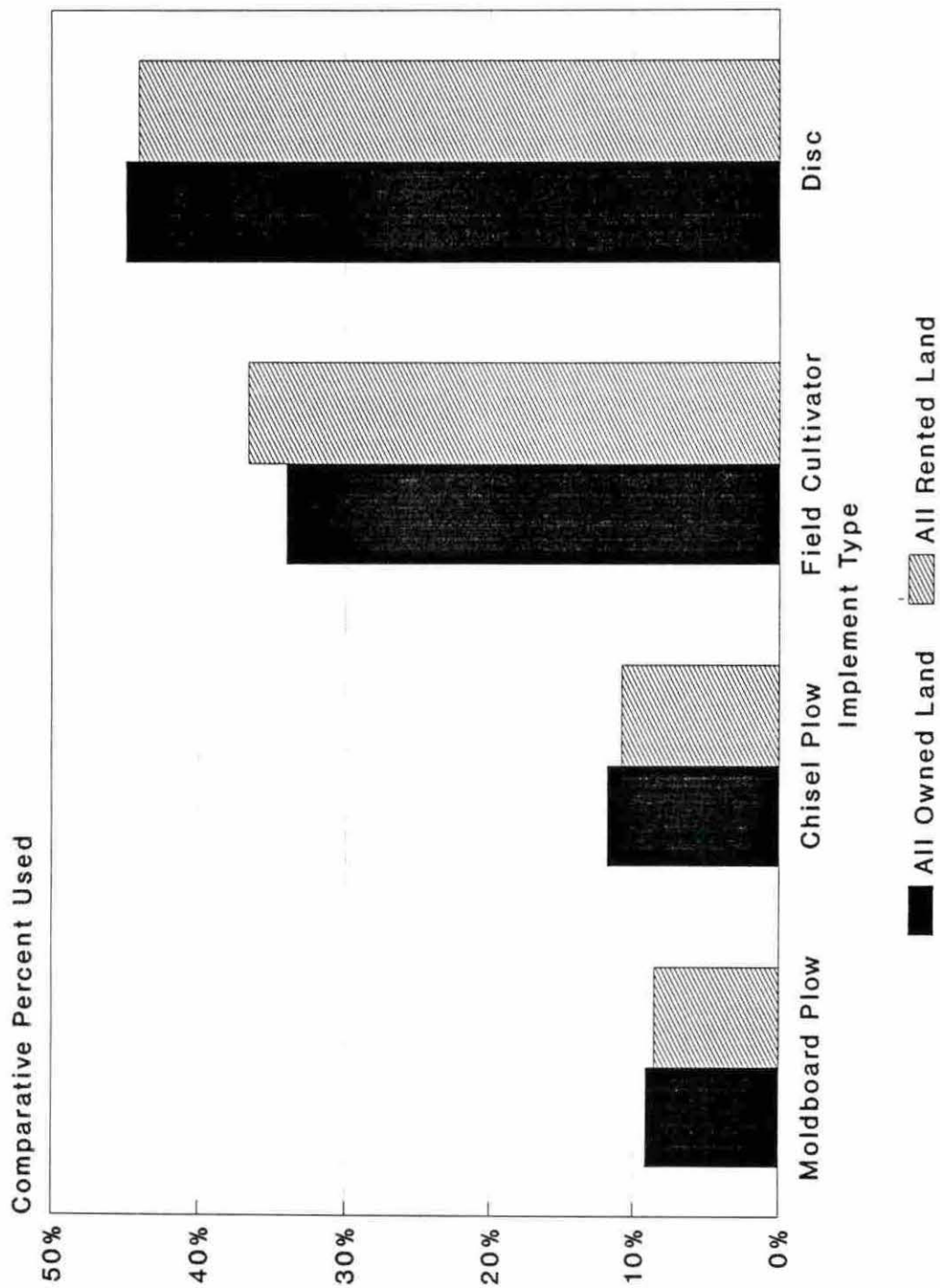


Figure 18. Percentage Distribution of Tillage Equipment Use on Soybeans Following Corn for All Owned Land Versus All Rented Land.

Note: $\chi^2 = 4.22$ with 3 degrees of freedom; no significant difference found

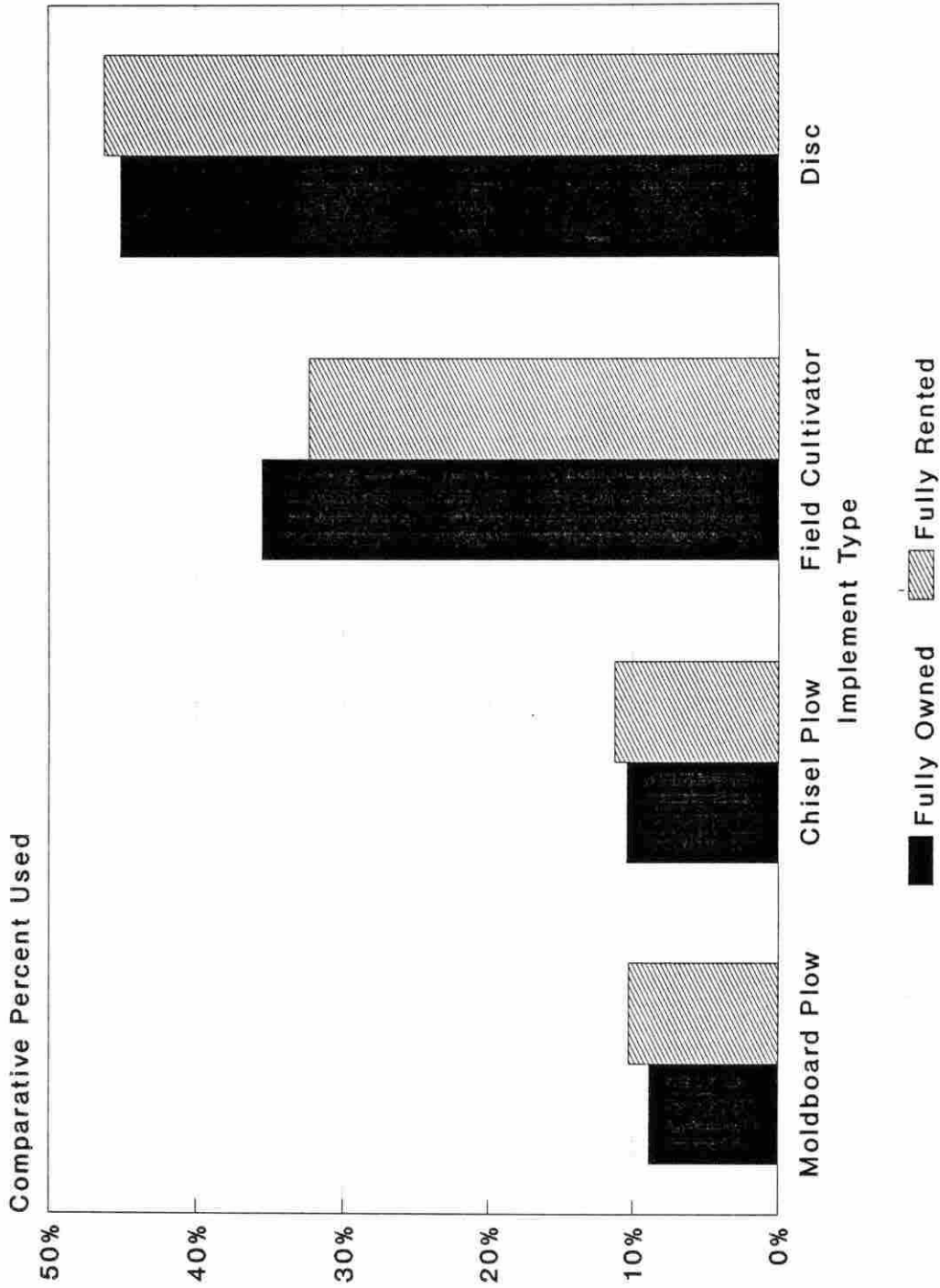


Figure 19. Percentage Distribution of Tillage Equipment Use on Soybeans Following Corn for Fully Owned Versus Fully Rented Farms.

Note: $\chi^2 = 5.014$ with 3 degrees of freedom; no significant difference found

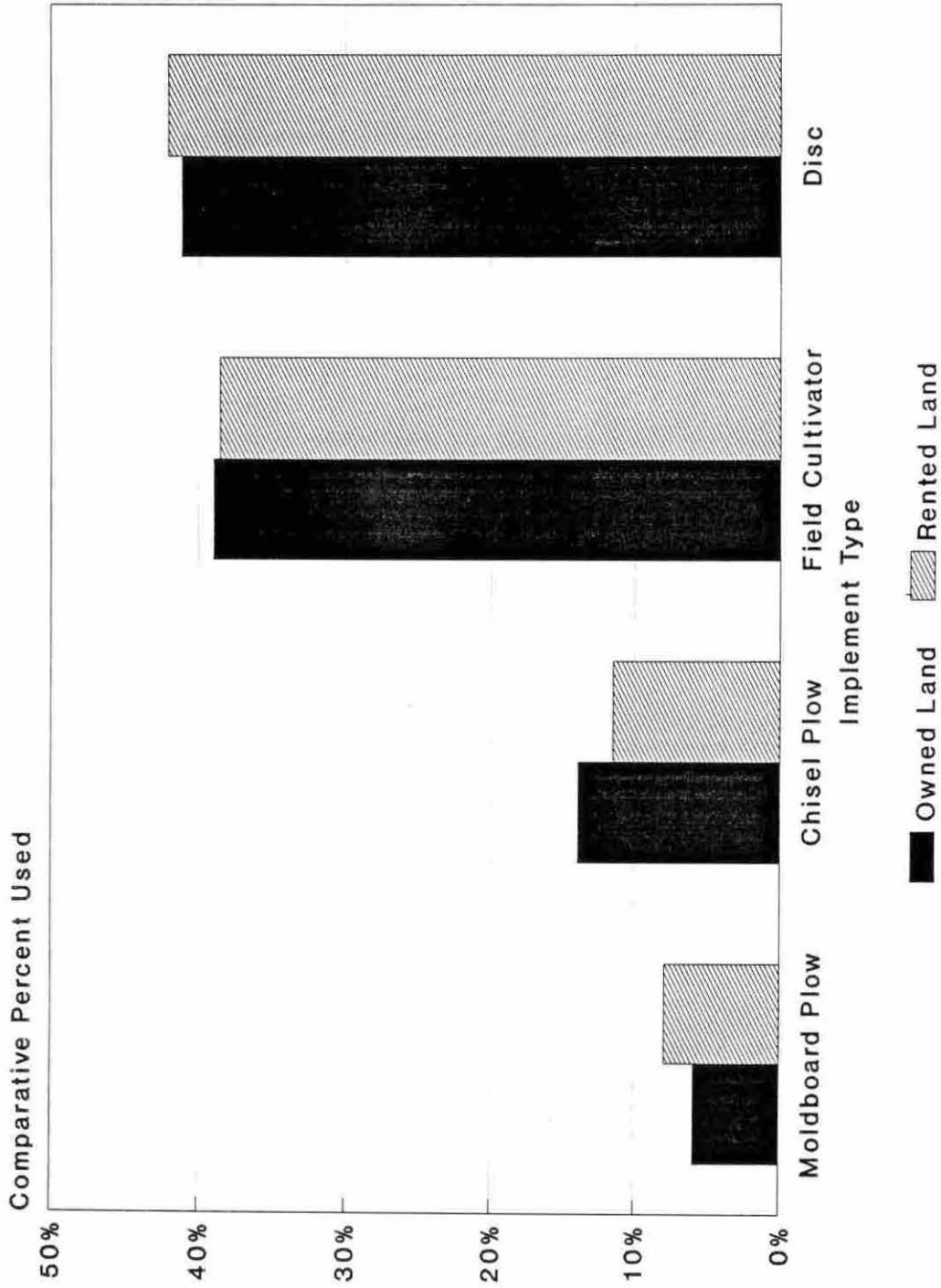


Figure 20. Percentage Distribution of Tillage Equipment Use on Soybeans Following Corn by Part Owners for Owned Versus Rented Land.
 Note: $\chi^2 = 3.931$ with 3 degrees of freedom; no significant difference found

giving no evidence for significant difference in the use distributions of primary tillage equipment on fully owned versus fully rented farms.

Unlike the distributions found for continuous corn and rotated corn following soybeans, Figure 20 shows that the percentage distribution of tillage equipment used by partially owned farms was essentially the same for owned land versus rented land on soybeans following corn. Moldboard plow use hovered around 7%, chisel plow use around 12.5%, field cultivator use around 39%, and disc around 42%. Again, the Likelihood Ratio Test yielded a small Chi-squared (3.931 with three degrees of freedom) and no significant difference in tillage use was found.

Mechanical practices were also compared on the basis of number of trips over a field. Figures 21, 22, and 23 give summaries of the average number of trips by opposing tenure categories for three separate crops in rotation: continuous corn, rotated corn following soybeans (rotated corn - CSb), and soybeans following corn (soybeans - CSb). Figure 21 gives the average number of trips over a field for all owned land versus all rented land. For each rotation listed, a Studentized t-Test for Independent Sample Means was conducted (Appendices A and B). For both the continuous corn rotation and the soybeans - CSb the variances of the two samples were found to be equal using the F-test for Homogeneity of Population Variances (Appendix D). In the case of the rotated corn - CSb, the variances were found to be unequal. The resulting Studentized t-Tests for Independent Sample Means with Equal Variances

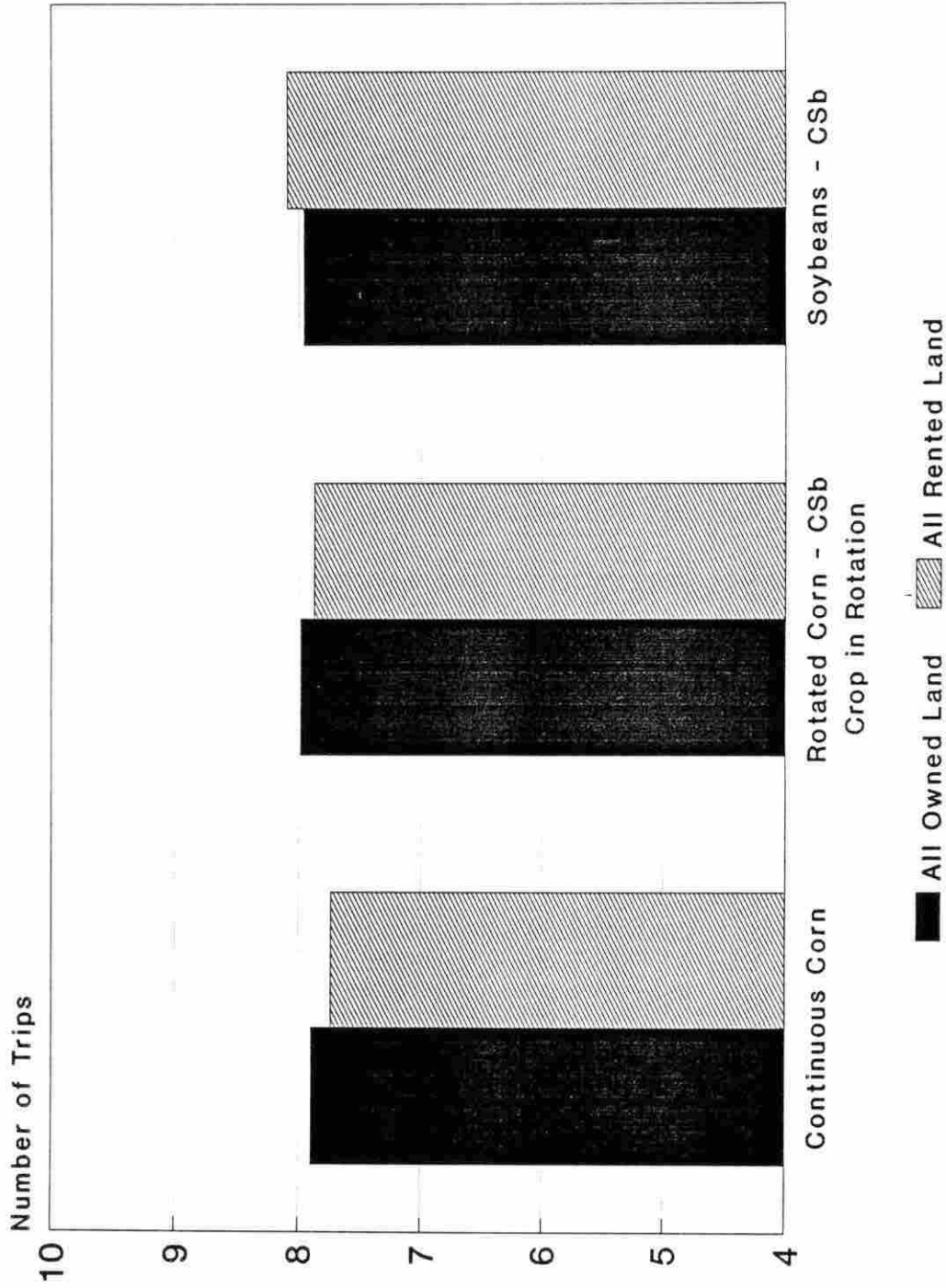


Figure 21. Average Number of Trips Over a Field for All Owned Land Versus All Rented Land
Note: No significant difference found

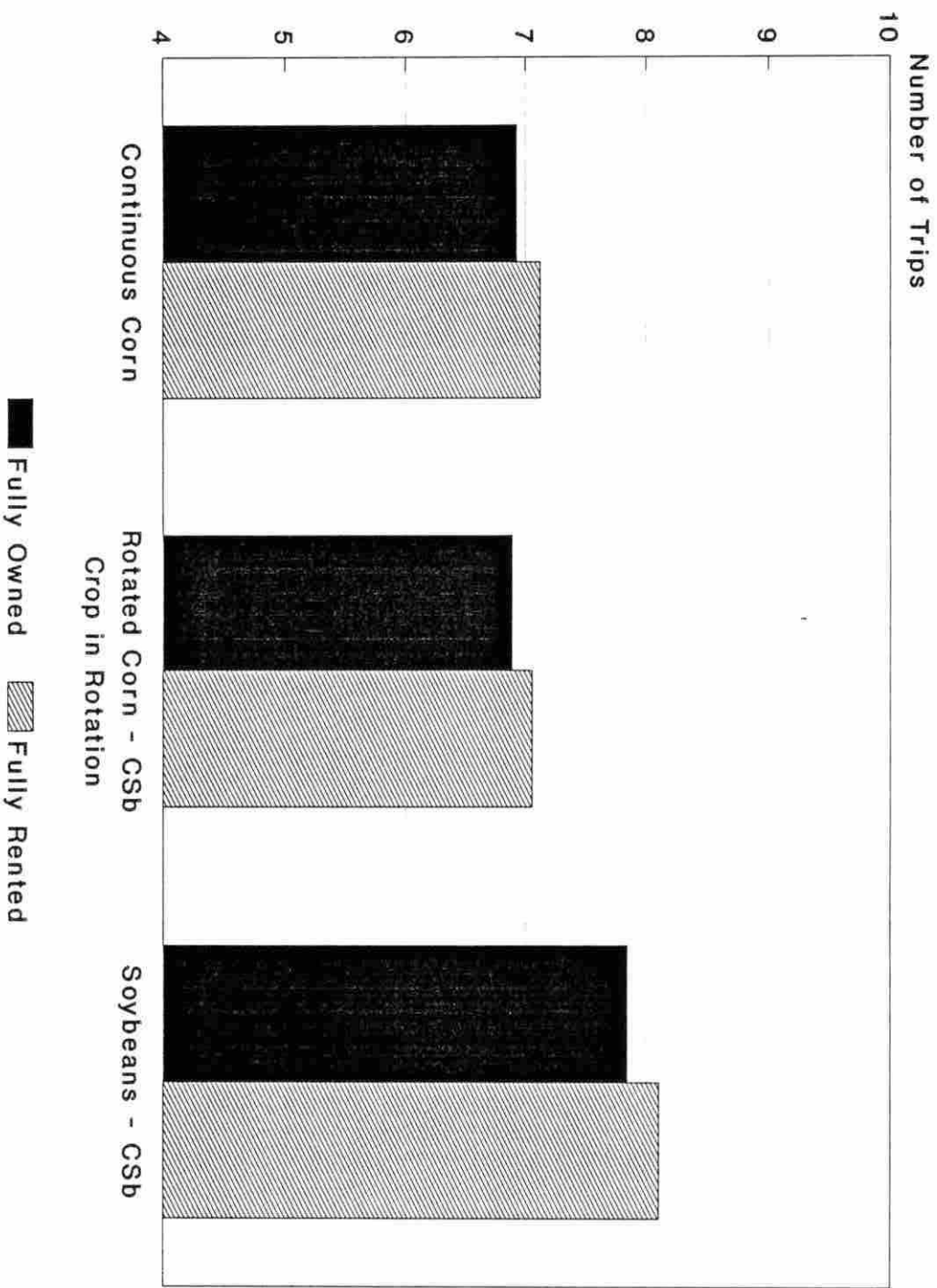


Figure 22. Average Number of Trips Over a Field for Fully Owned Farms Versus Fully Rented Farms
Note: No significant difference found

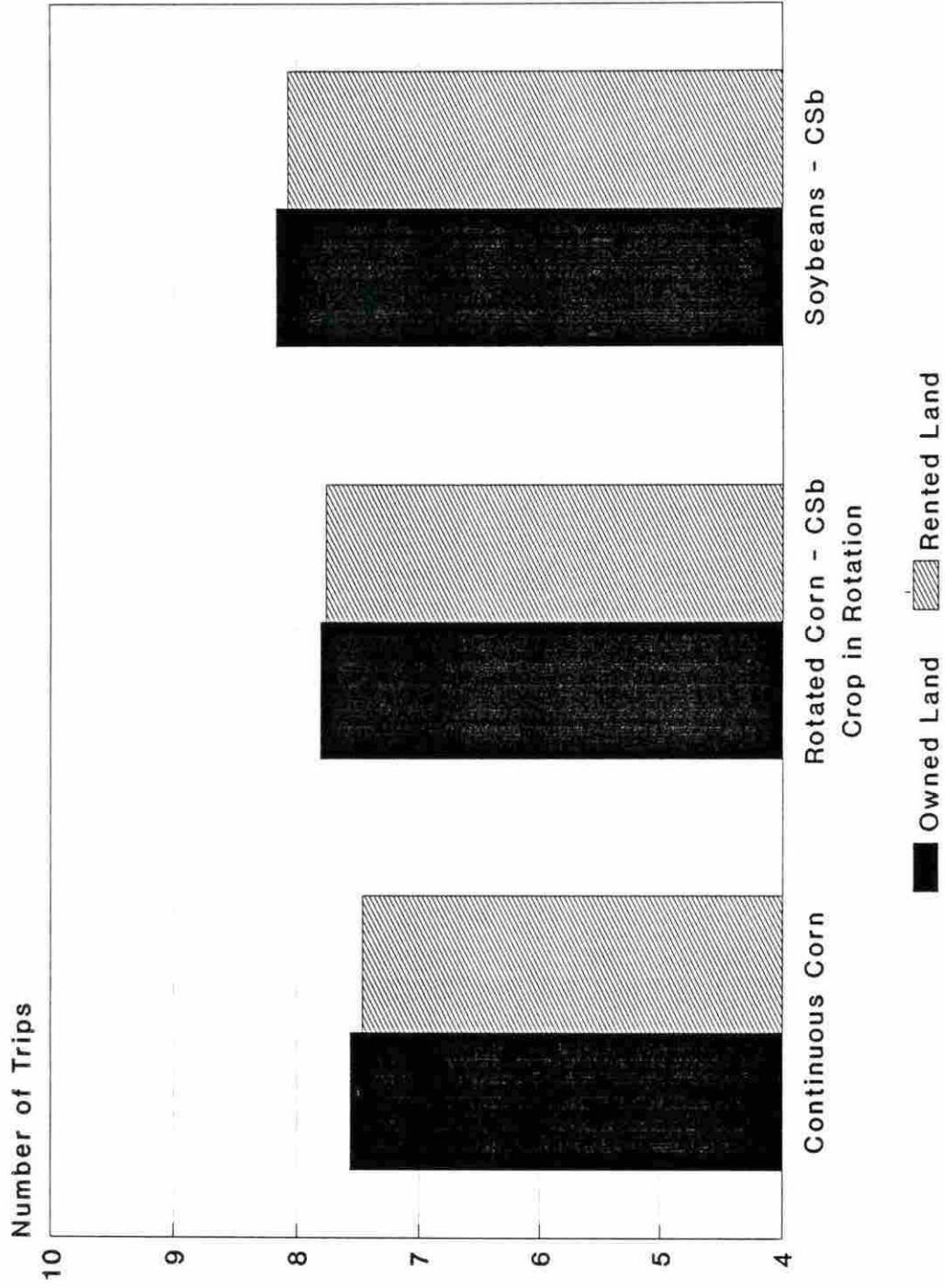


Figure 23. Average Number of Trips Over a Field by Part Owners on Owned Land Versus Rented Land
 Note: No significant difference found

yielded t' test statistics of .6521 with 387 degrees of freedom for continuous corn and -1.01 with 847 degrees of freedom for soybeans - CSb. Because of this, no statistically significant difference in the number of trips was evident in either case for all owned versus all rented land. The Studentized t-Test for Independent Sample Means with Unequal Variances used for the rotated corn - CSb yielded a t' test statistic of .8728 with 908.9 degrees of freedom, also showing no significant difference in the number of field trips for all owned versus all rented land.

Figure 22 gives the average number of field trips for fully owned versus fully rented farms. For each of the crops in rotation listed, the number of trips was greater for the fully rented farms as apposed to the fully owned farms. Yet, the differences were not found to be statistically significant in any case. In the case of continuous corn, the variances were found to be unequal and the resulting t-Test yielded a t' value of only -1.2786 with 1317.7 degrees of freedom. In the cases of the rotated corn - CSb and soybeans - CSb, the variances of both samples were found to be equal and the resulting t-Tests yielded values of -1.408 with 2296 degrees of freedom and -1.5625 with 572 degrees of freedom respectively, showing no significant differences existed.

Finally, Figure 23 shows that in the case of part owners, no real significant difference exists in the average number trips over a field on owned versus rented land. This statement is backed up by the resulting t-Tests for each crop in rotation. The t' test statistics were .2 with 71 degrees of freedom

for continuous corn, .266 with 327 degrees of freedom for rotated corn - CSb, and .4727 with 277 degrees of freedom for Soybeans - CSb. In all cases the variances of the compared samples were found to be equal.

Pesticide Practices

The percentage distribution of methods of pesticide application for the three tenure category comparisons are shown in Figures 24, 25, and 26. In all cases, broadcasting was the predominant method chosen. Method of application distribution for all rented land versus all owned land is presented in Figure 24. As can be seen in the figure, no significant difference existed between the two tenure groups for the methods of application used. This evidence was supported by the relatively low Chi-squared value of 5.2 with four degrees of freedom. For both groups, broadcasting was the chosen method of application 71% of the time. Banding was the second most chosen method of application, but it accounted for only 18% for all owned land and 16% for all rented land.

Figure 25 shows the percentage distribution of application methods used for fully owned farms versus fully rented farms. Even though the Chi-squared value of 12.76 with 4 degrees of freedom showed that a significant difference did exist, this difference was very slight. The differences found seemed to show that fully owned farms had a slight tendency to broadcast more than fully rented farms (73% to 70%), while fully rented farms tended to use more incorporation (5% to 2%). Overall, evidence suggests that the differences

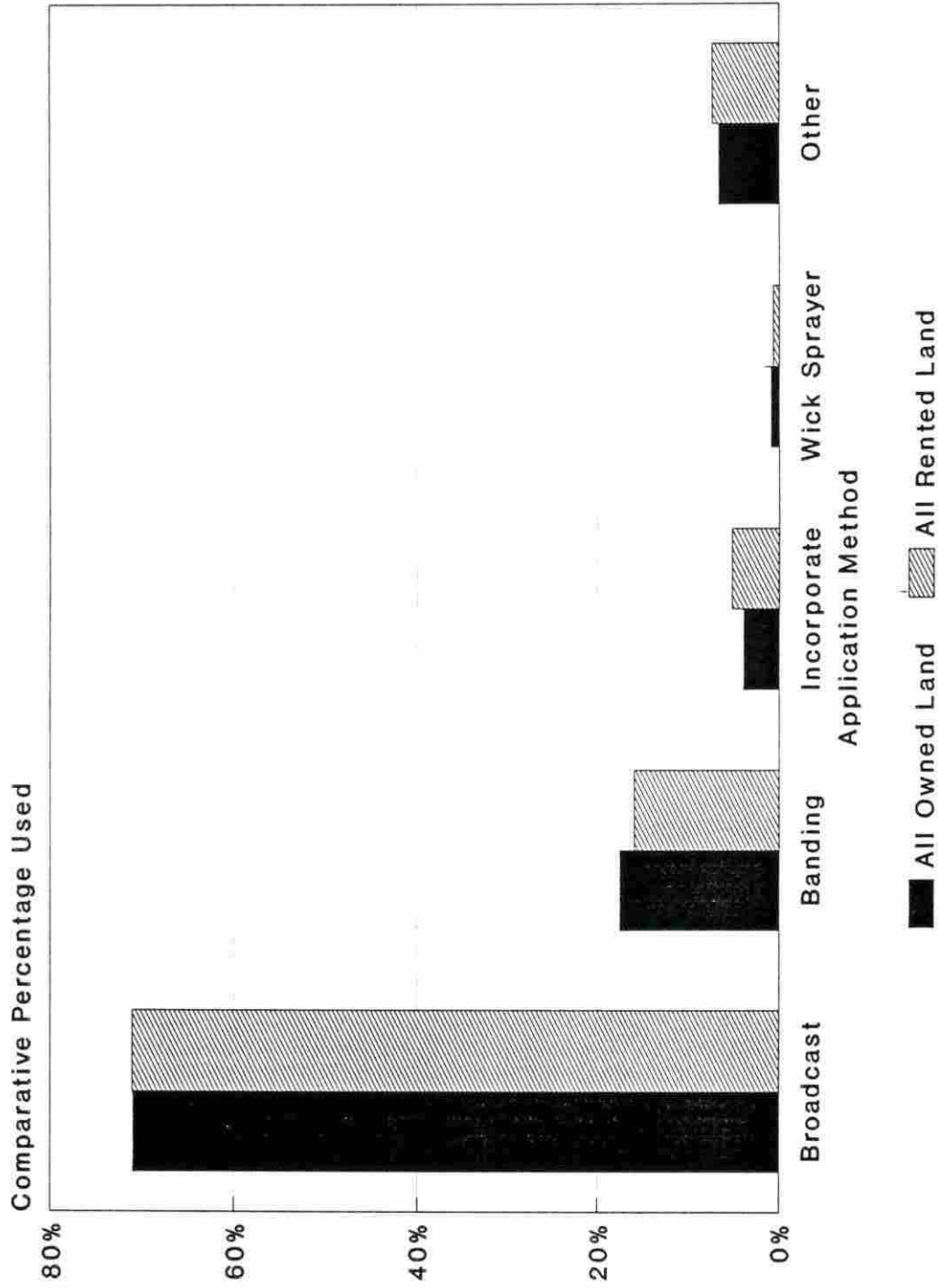


Figure 24. Percentage Use of Selected Pesticide Application Methods on All Owned Land Versus All Rented Land

Note: $\chi^2 = 5.20$ with 4 degrees of freedom; no significant difference found

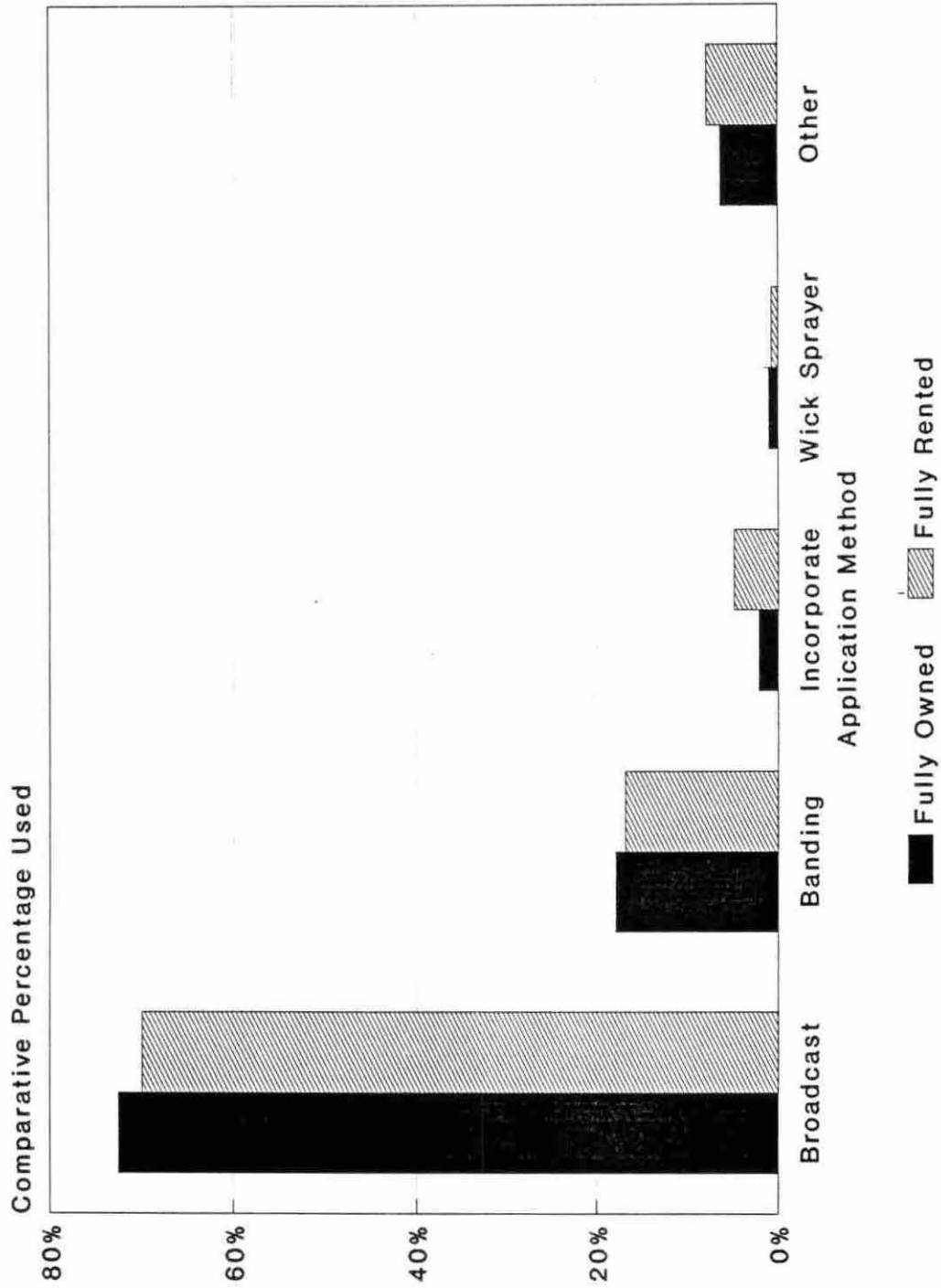


Figure 25. Percentage Use of Selected Pesticide Application Methods on Fully Owned Farms Versus Fully Rented Farms

Note: $\chi^2 = 12.76$ with 4 degrees of freedom; slight significant difference found

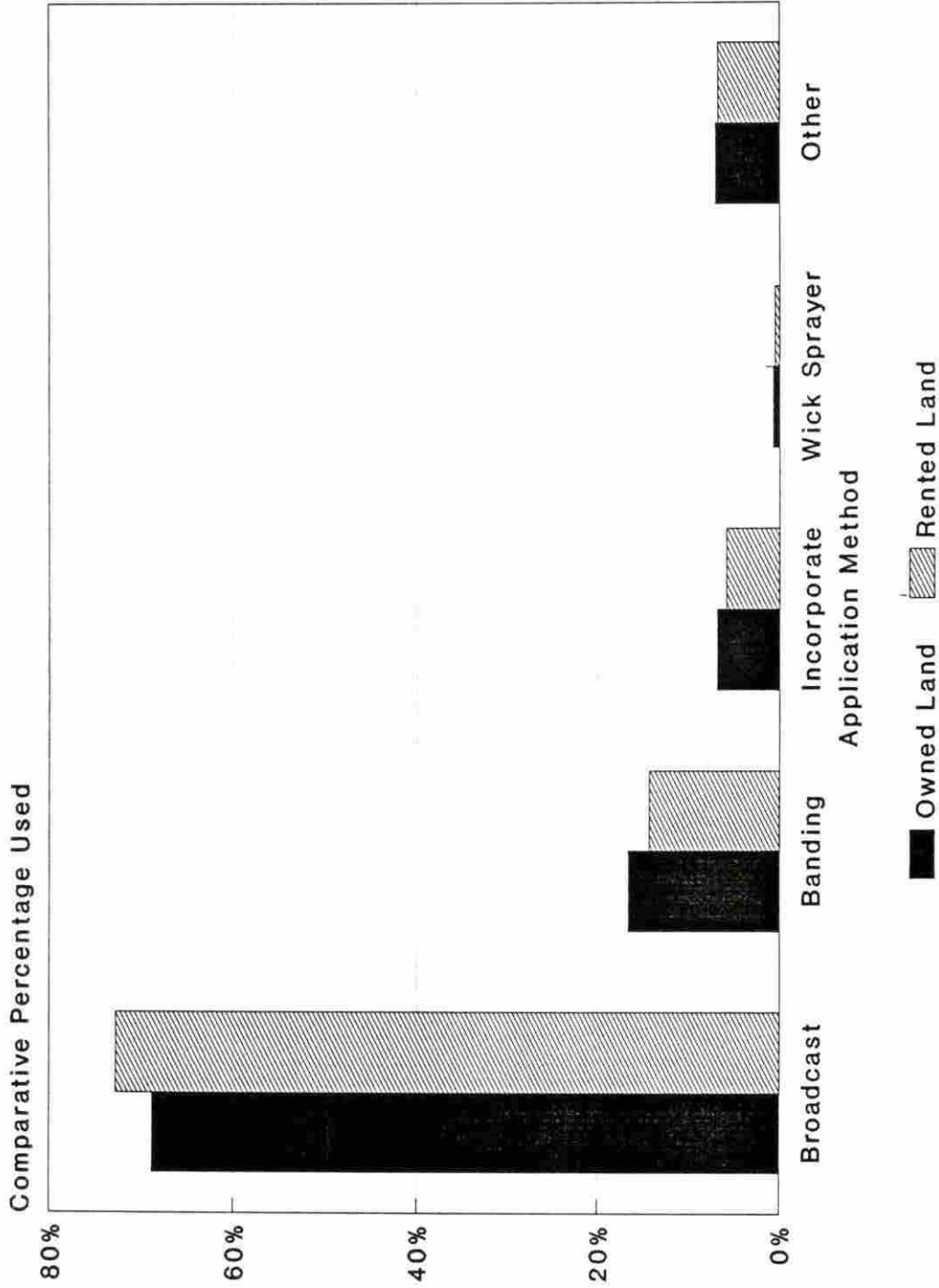


Figure 26. Percentage Use of Selected Pesticide Application Methods for Part Owners on Owned Versus Rented Land

Note: $\chi^2 = 2.29$ with 4 degrees of freedom; no significant difference found

found were not substantial.

The percentage distribution of pesticide application methods used by partially owned farms on owned versus rented land is shown in Figure 26. The differences found suggest that partial owners had a tendency to use more broadcasting on rented land than on owned land (73% to 69%) and more banding on owned land than on rented land (17% to 14%). Yet, the Chi-squared value of 2.29 with 4 degrees of freedom gives evidence that the differences found are not significant.

Figures 27, 28, and 29 give summaries of the percentage distributions of use of pesticide forms for contrasting tenure groups. Figure 27 depicts the percentage distribution of use of pesticide forms for all owned land versus all rented land. Although the Chi-squared value of 11.617 with five degrees of freedom suggests a slight significant difference in these distributions, close examination of the figure shows the difference to be minute. The tendency seemed to be a substitution of liquid pesticides for granular pesticides on rented land, but this only accounted for around 3% of the respondents. In both cases, liquid was the predominant pesticide form chosen, hovering around 78% for all owned land and 81% for all rented land.

The percentage distribution of use of pesticide forms for fully rented farms versus fully owned farms is given in figure 28. A close examination of this figure reveals that no significant difference existed between the use of particular pesticide forms for fully owned versus fully rented farms. This

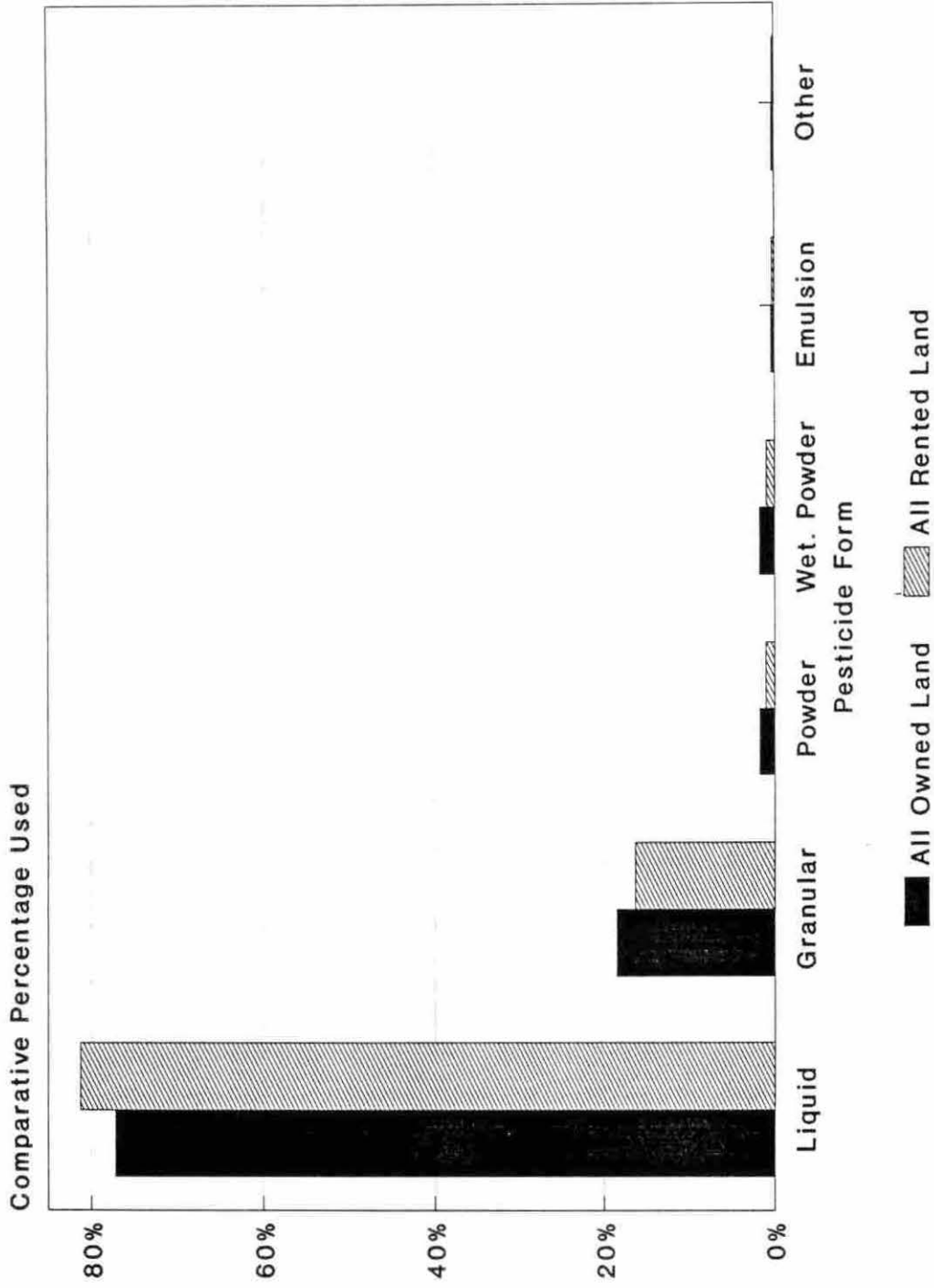


Figure 27. Percentage Use of Selected Pesticide Forms on All Owned Land Versus All Rented Land
 Note: $\chi^2 = 11.617$ with 5 degrees of freedom; slight significant difference found

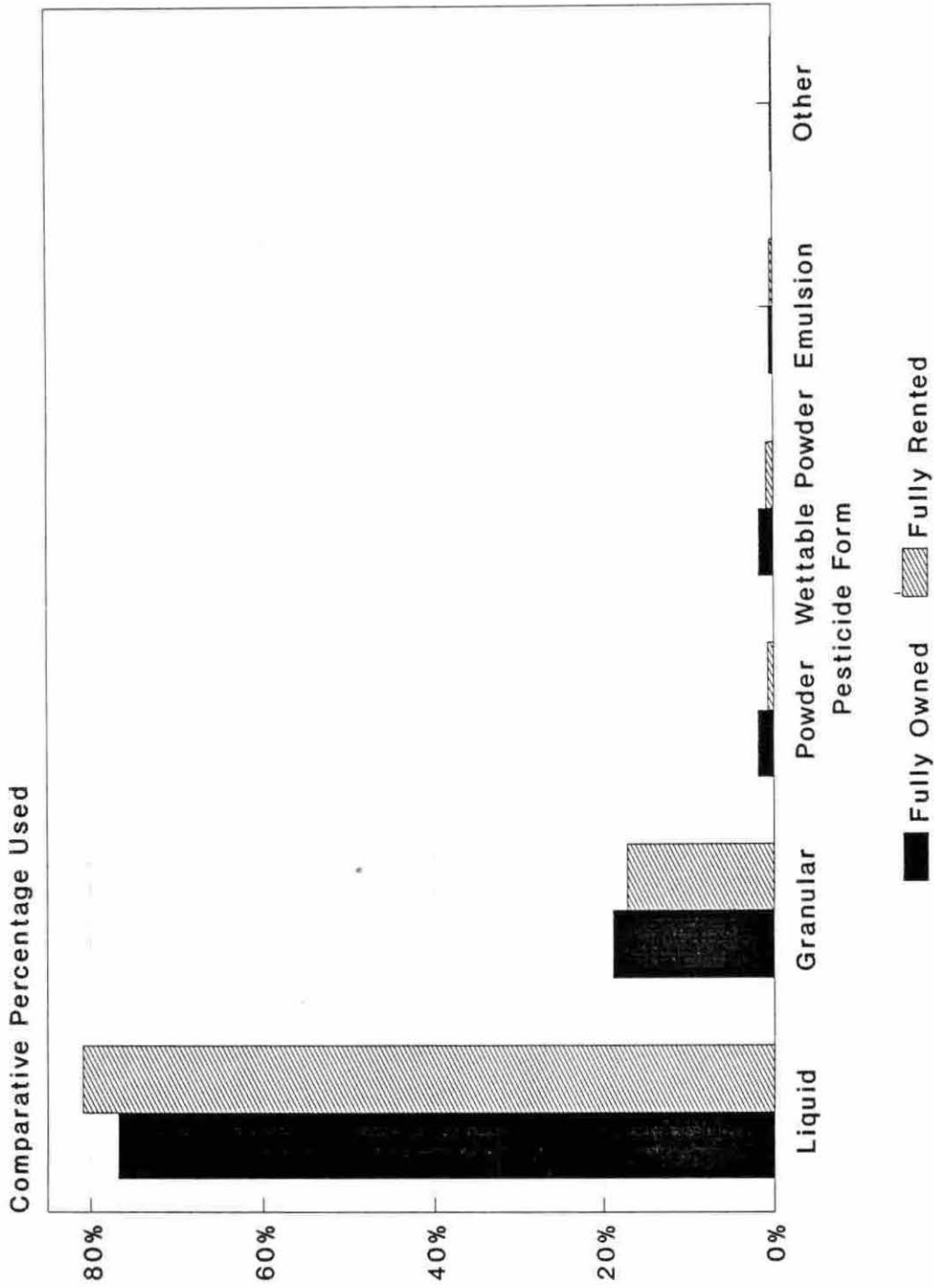


Figure 28. Percentage Use of Selected Pesticide Forms on Fully Owned Farms Versus Fully Rented Farms
 Note: $\chi^2 = 10.317$ with 5 degrees of freedom; no significant difference found

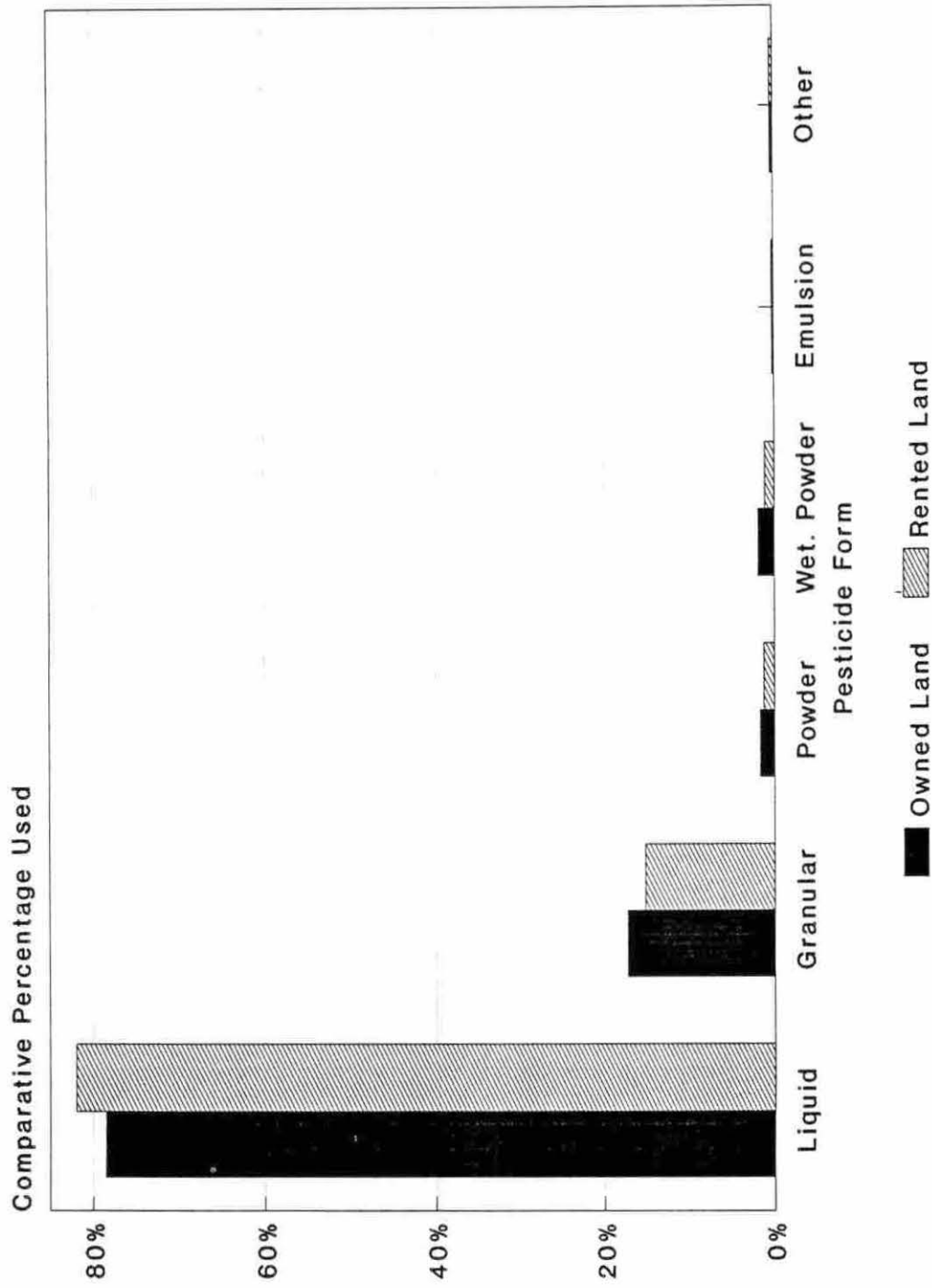


Figure 29. Percentage Use of Selected Pesticide Forms by Part Owners on Owned Land Versus Rented Land
 Note: $\chi^2 = 2.884$ with 5 degrees of freedom; no significant difference found

evidence is backed up by the Likelihood Ratio Test which yielded a Chi-squared of 10.317 with five degrees of freedom. As with all owned land versus all rented land, there was a tendency for use of more liquid by full renters and granular by full owners, but again this only accounted for around 3% of the respondents. For both tenure groups, liquid was the predominant pesticide form chosen, hovering around 78% for all fully owned farms and 81% for fully rented farms.

Figure 29 shows the percentage distribution of use of certain pesticide forms by partially owned farms on owned versus rented land. Partial owners had a tendency to use more liquid forms of pesticides on rented land than on owned land (82% to 79%) and more granular forms on owned land than on rented land (17% to 15%), but these differences were far from significant as the Likelihood Ratio Test yielded a Chi-square statistic of only 2.884 with five degrees of freedom.

Finally, Figures 30, 31, and 32 show the percentage distributions of pesticide timing for the three different contrasting tenure groups. As seen in Figure 30, all owned land had a tendency to have more pesticides applied during planting and pre-emergence. This contrasted with all rented land, which had a greater percentage of pesticides applied at post-emergence. Pesticide application was 2% greater at planting and 5% greater at pre-emergence on all owned land than on all rented land. This contrasted to the fact that pesticide application was 7% greater at post emergence for all rented land than for all

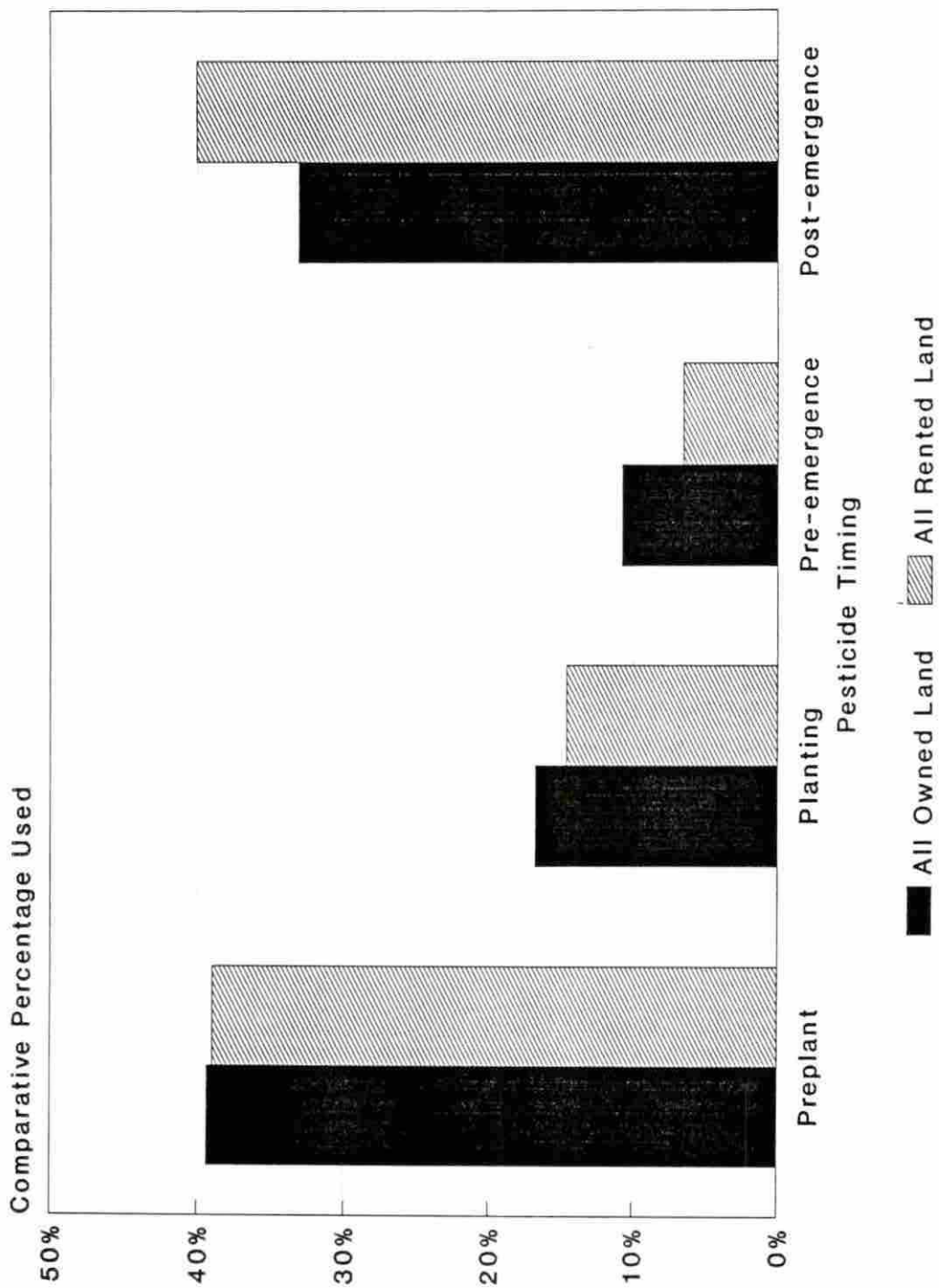


Figure 30. Percentage Use of Selected Pesticide Timing on All Owned Land Versus All Rented Land
 Note: $\chi^2 = 28.381$ with 3 degrees of freedom; significant difference found

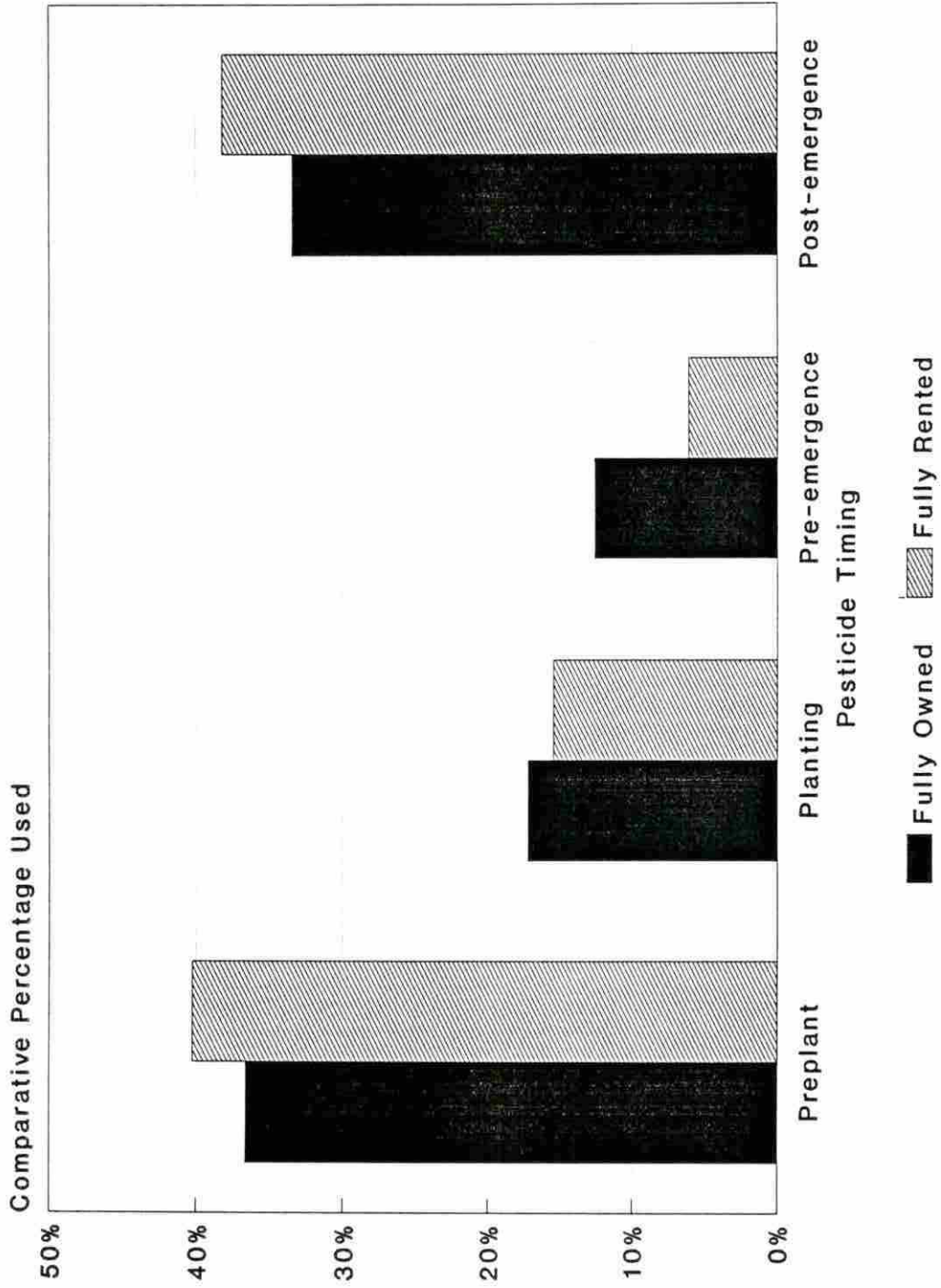


Figure 31. Percentage Use of Selected Pesticide Timing on Fully Owned Farms Versus Fully Rented Farms
 Note: $\chi^2 = 26.869$ with 3 degrees of freedom; significant difference found

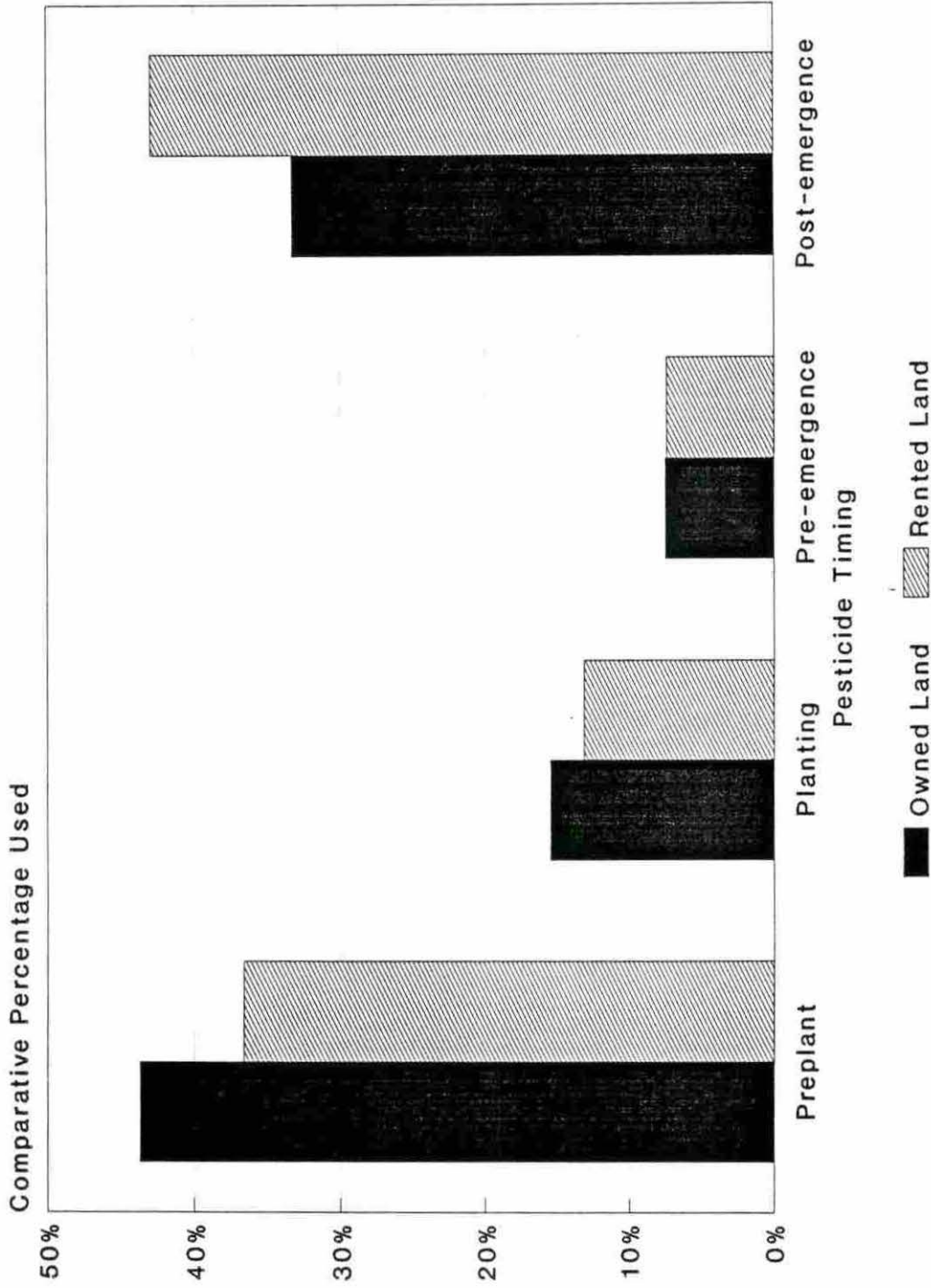


Figure 32. Percentage Use of Selected Pesticide Timing by Part Owners on Owned Land Versus Rented Land
 Note: $\chi^2 = 11.595$ with 3 degrees of freedom; slight significant difference found

owned land. The Likelihood Ratio Test yielded a Chi-squared value of 28.381 with three degrees of freedom, which showed that a slight significant difference did exist.

Figure 31 depicts the percentage distribution of pesticide timing for fully owned versus fully rented farms. As the figure shows, fully rented farms had a tendency to apply more pesticides during preplanting and post-emergence than did fully owned farms. Conversely, fully owned farms showed a greater tendency to apply pesticides more during planting and pre-emergence than did fully rented farms. The difference in use was 3% greater for preplant and 5% greater for post-emergence on fully rented farms and 2% greater for planting and 6% greater for pre-emergence on fully owned farms. Overall, the Likelihood Ratio Test proved the differences to be significant with a Chi-squared value of 26.869 with three degrees of freedom.

Finally, the percentage distribution of pesticide timing for partially owned farms on owned versus rented land is shown in Figure 32. As can be seen in the figure, part owners had a tendency to apply pesticides more during preplanting on owned land than on rented land (44% to 37%) and more during post-emergence on rented land than on owned land (43% to 33%). The difference was found to have a significant difference as the Likelihood Ratio Test yielded a Chi-squared value of 11.595 with three degrees of freedom.

Fertilizer Use

Summaries of the average amounts of fertilizer use per acre by the three tenure category comparisons are given in Figures 33, 34, and 35. Figure 33 shows the average amounts of nitrogen, phosphate, and potash used on all owned land versus all rented land. Nitrogen use was found to be 5 pounds per acre greater on all rented land than on all owned land. This difference was found to be significant using the Studentized t-Test for Independent Sample Means with Equal Variances which yielded a t' value of -3.06 with 3830 degrees freedom. Phosphate use was found to be nearly 4 pounds per acre greater on all rented land than on all owned land. This difference was also found to be significantly different using the Studentized t-Test for-Independent Sample Means with Unequal Variances which yielded a t' value of -4.06 with 2428.1 degrees of freedom. Potash use was found to be nearly 4 pounds per acre greater on all rented land than on all owned land. Again, this difference was found to be statistically significant as the t' value for equal variances equaled -2.34 with 2516 degrees of freedom.

Average fertilizer use for fully owned farms versus fully rented farms is shown in Figure 34. Nitrogen use was found to be nearly 10 pounds per acre greater on fully rented farms than on fully owned farms. The t-Test for equal variances yielded a t' value of -4.93 with 2141 degrees of freedom which showed the difference to be significantly different. Phosphate use was found to be nearly 8 pounds per acre greater on fully rented farms than on fully

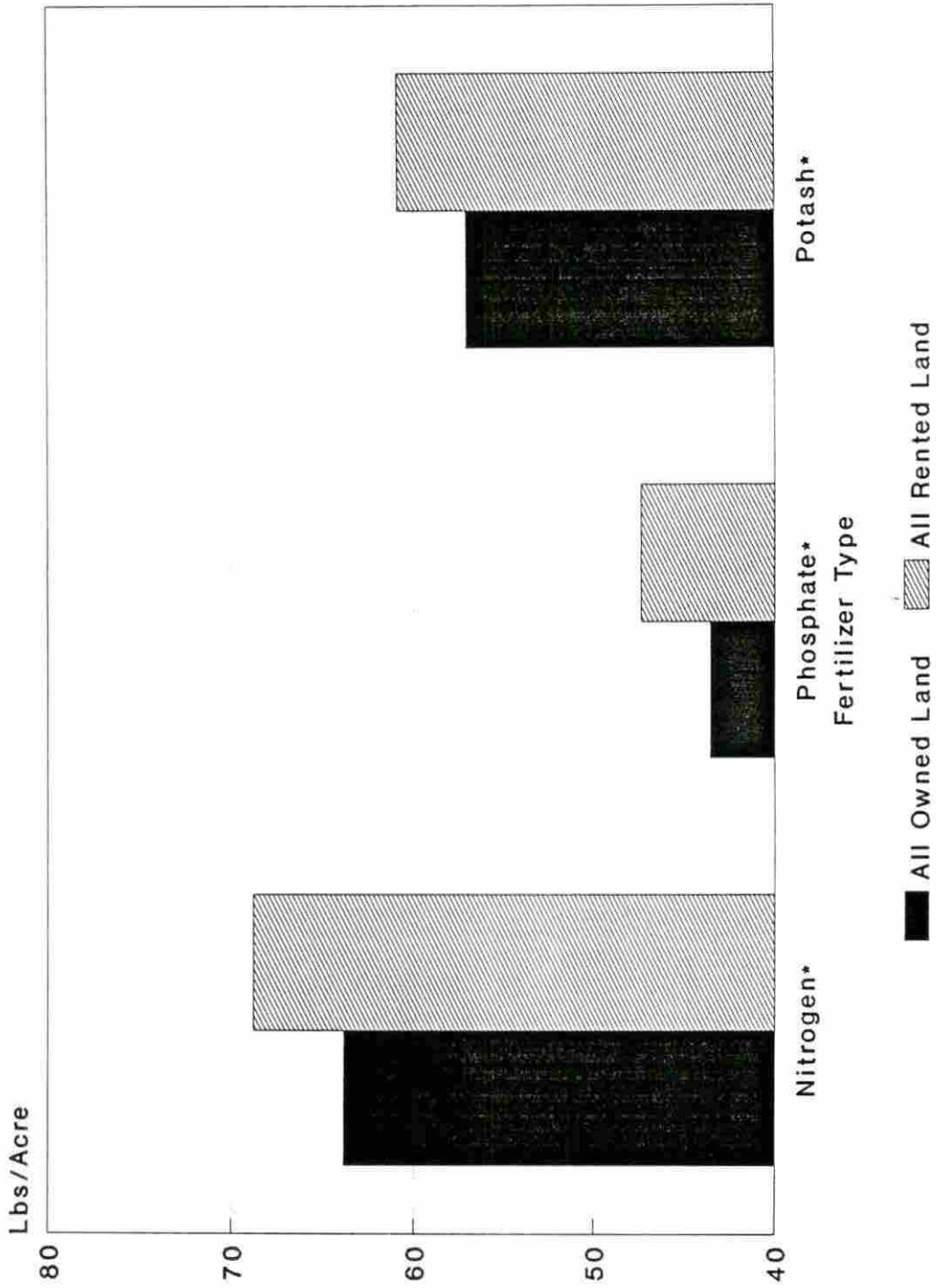


Figure 33. Fertilizer Use for All Owned Land Versus All Rented Land

* Statistically significant difference found

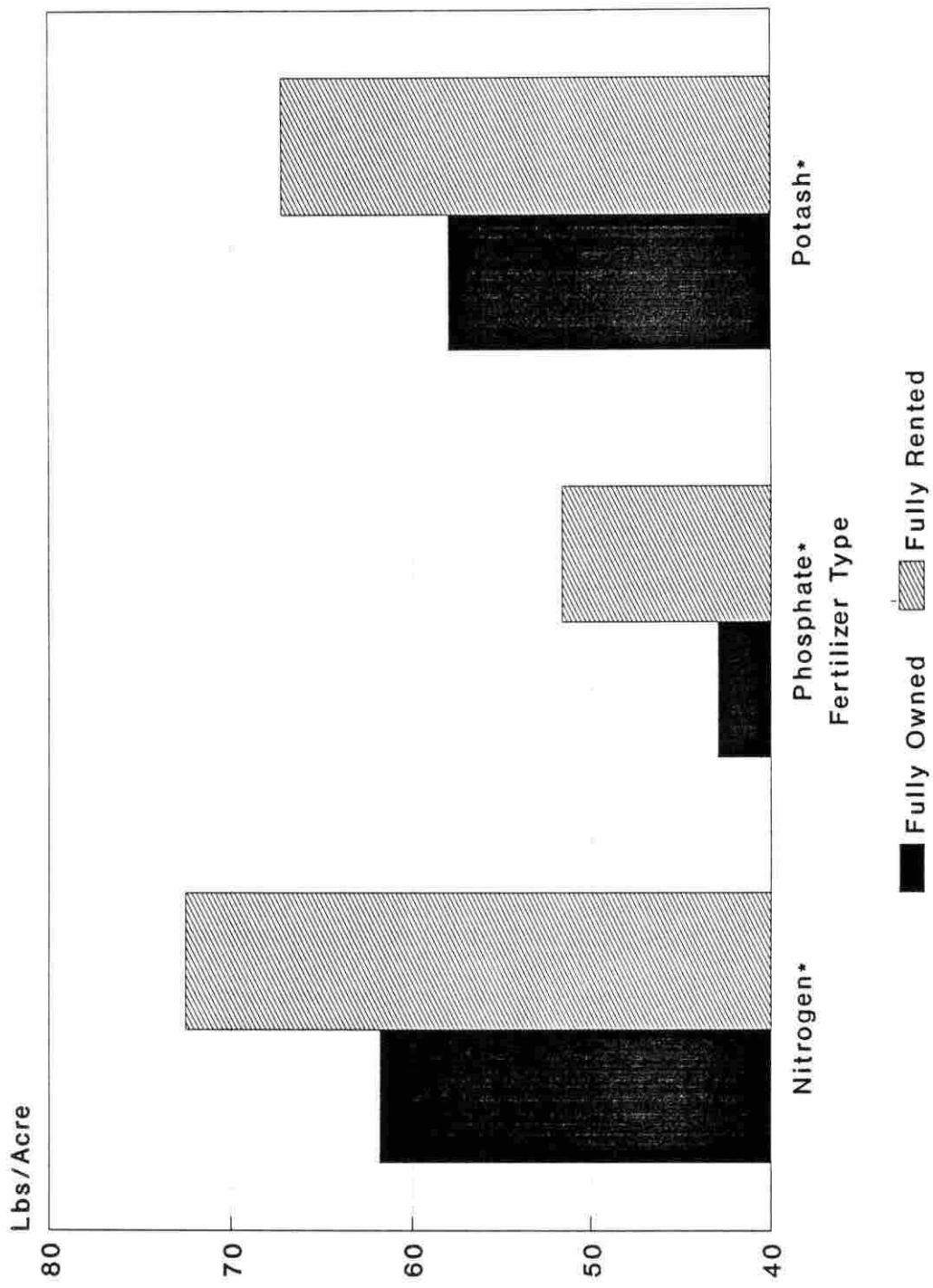


Figure 34. Fertilizer Use for Fully Owned Farms Versus Fully Rented Farms
* Statistically significant difference found

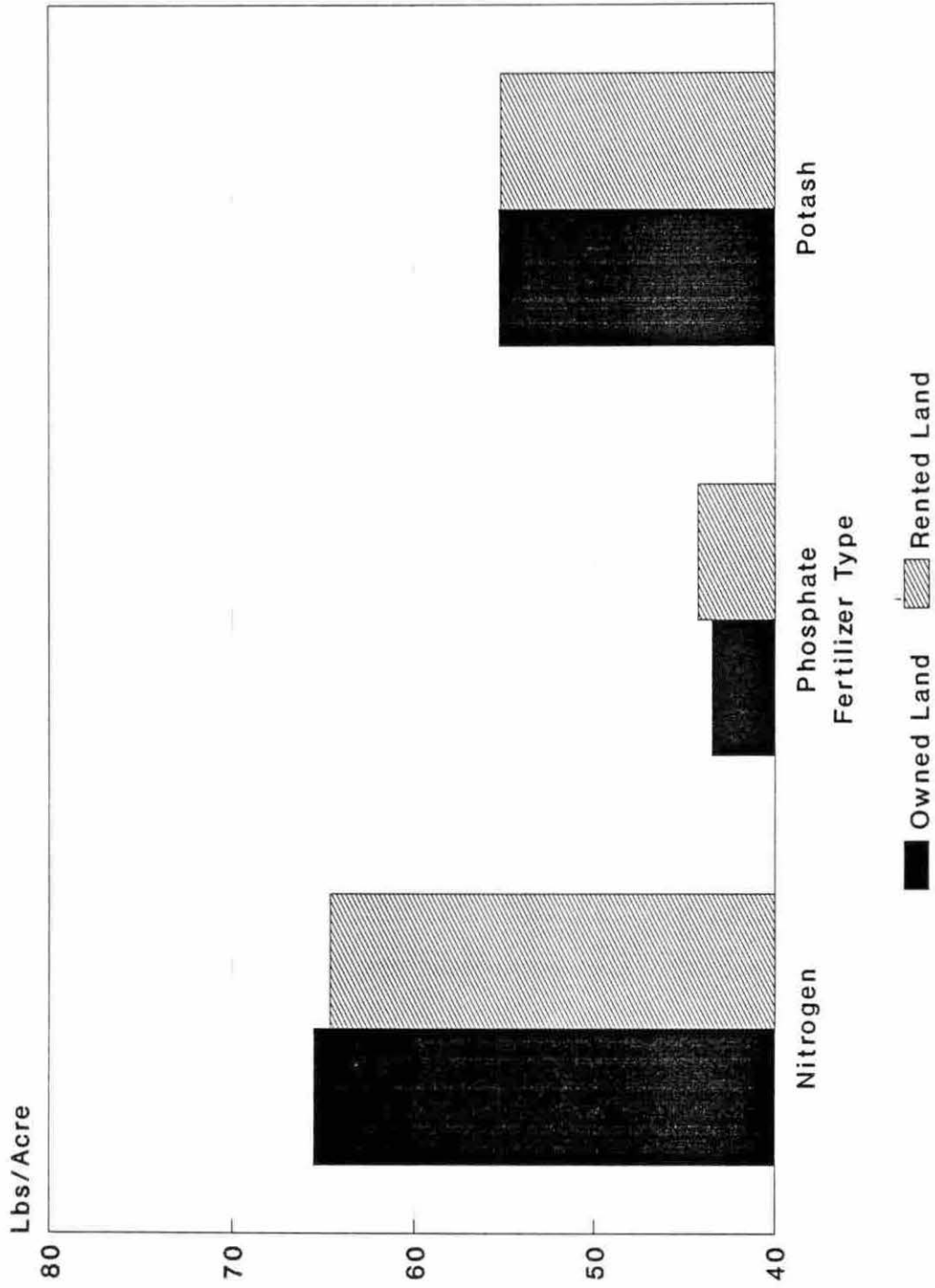


Figure 35. Fertilizer Use for Part-Owners on Owned Land Versus Rented Land

owned farms. This difference was also found to be significantly different by the t-Test for sample means with equal variances which yielded a t' value of -6.79 with 1365 degrees of freedom. Potash use was found to be nearly 9 pounds per acre greater on fully rented farms than on fully owned farms.

Again, the t-Test for sample means with equal variances showed the difference to be statistically significant as a t' value of -3.84 with 1382 degrees of freedom was yielded.

Finally, the summary of fertilizer use by partially owned farms for owned versus rented land is shown in Figure 35. Only a one pound per acre difference was found for both nitrogen and phosphate, and potash use was essentially the same for both owned and rented land. In not one of the three cases was a statistically significant difference found.

Figures 36, 37, and 38 show average nitrogen use for corn on the three most common rotations found in the survey: continuous corn, corn-soybeans, and corn-oats-meadow. Figure 36 gives a summary for nitrogen use on all owned land versus all rented land. Nitrogen use per acre on continuous corn was found to be 5 pounds greater on all rented land than on all owned land. This difference was found to be significantly different using the Studentized t-Test for Independent Sample Means with Equal Variances which yielded a t' value of -3.06 with 3830 degrees of freedom. Nitrogen use on the corn-soybeans rotation was found to be essentially equal for both all owned land and all rented land. A t' value of only -0.44 with 599 degrees of freedom was

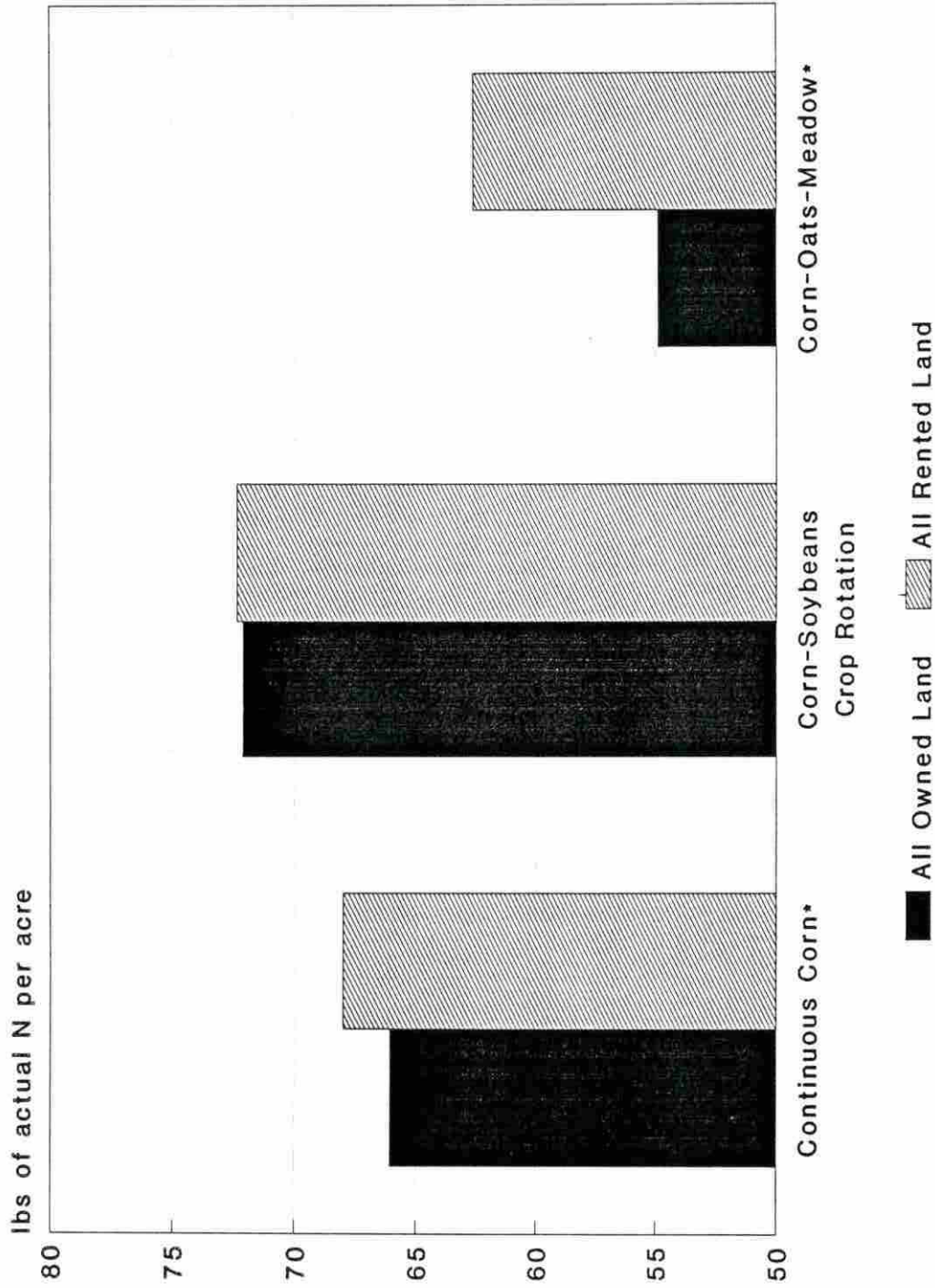


Figure 36. Nitrogen Use by Rotation for All Owned Land Versus All Rented Land
* Statistically significant difference found

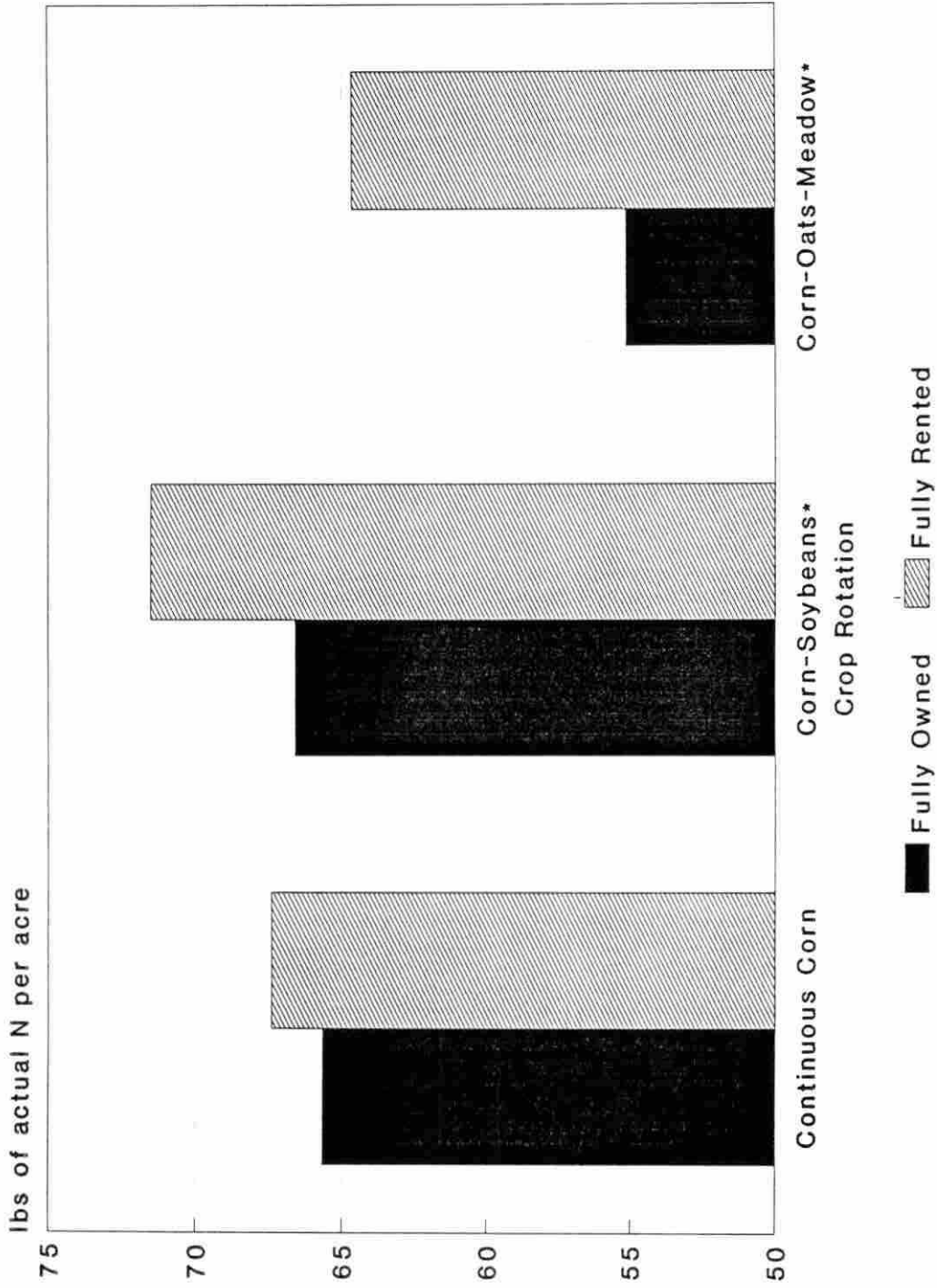


Figure 37. Nitrogen Use by Rotation for Fully Owned Versus Fully Rented Farms
 * Statistically significant difference found

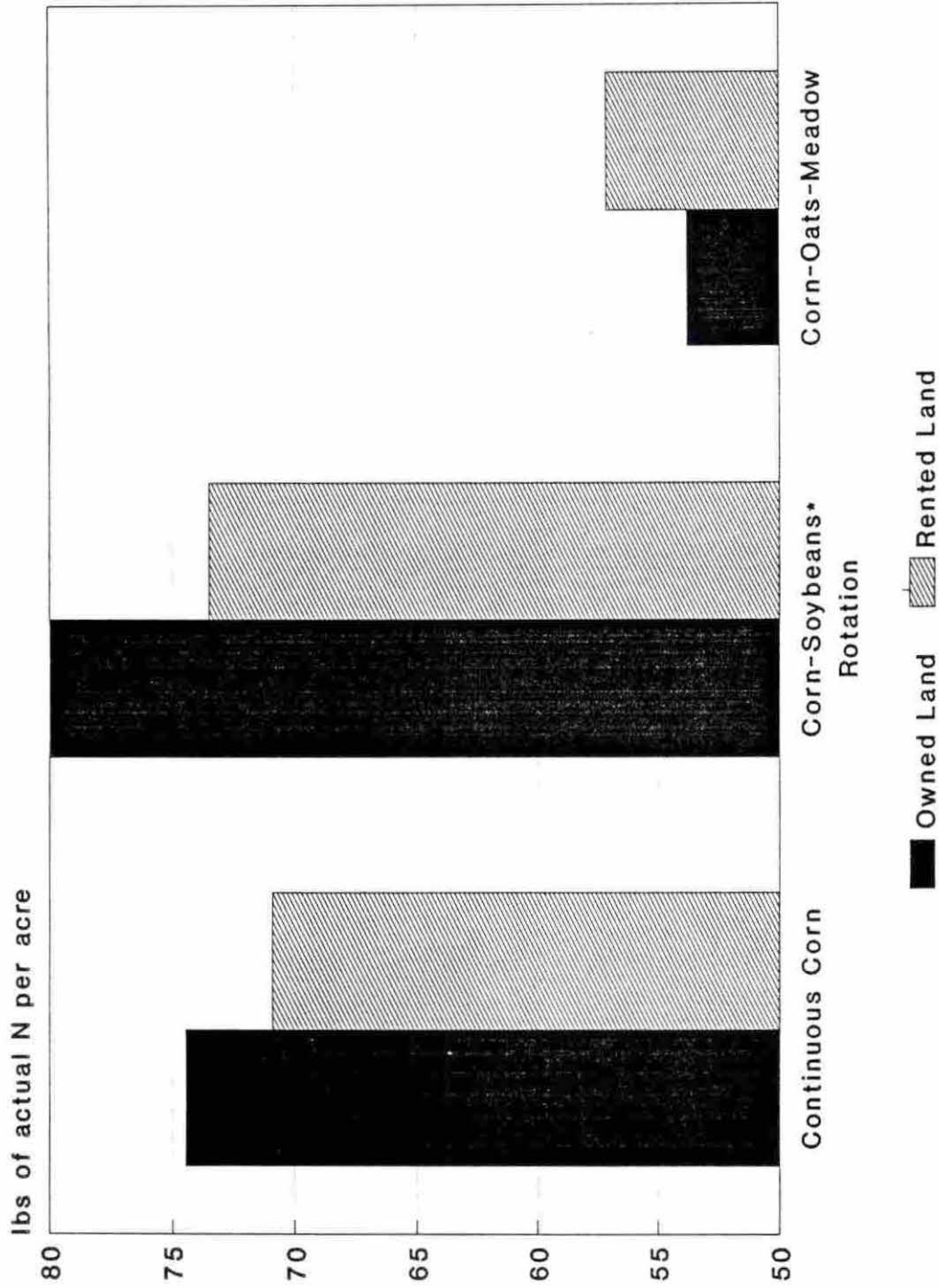


Figure 38. Nitrogen Use by Rotation for Part Owners on Owned Versus Rented Land
* Statistically significant difference found

yielded. Finally, nitrogen use on the corn-oats-meadow rotation was found to be almost 8 pounds per acre higher on all rented land versus all owned land. This difference was indeed found to be significant as the Studentized t-Test for Independent Sample Means with Unequal Variances yielded a t' value of 2.97 with 483.6 degrees of freedom.

Figure 37 gives a summary for nitrogen use on fully owned farms versus fully rented farms. Nitrogen use per acre for continuous corn was found to be only 2 pounds greater for fully rented farms versus fully owned farms. This difference was not found to be significant as the Studentized t-Test for Independent Sample Means with Equal Variances yielded a t' value of only 0.369 with 528 degrees of freedom. Nitrogen Use per acre for the corn-soybeans rotation was found to be nearly 5 pounds greater for fully rented farms than for fully owned farms. This difference was found to be significant as the Studentized t-Test for Independent Sample Means with Equal Variances yielded a t' value of 1.68 with 1157 degrees of freedom. Nitrogen use per acre for the corn-oats-meadow rotation was found to be nearly 10 pounds greater for fully rented farms versus fully owned farms. Again, the Studentized t-Test for Independent Sample Means with Equal Variances showed the difference to be significant as it yielded a t' value of 1.89 with 485 degrees of freedom.

Figure 38 gives a summary for nitrogen use by partially owned farms on owned land versus rented land. Nitrogen use per acre for continuous corn by part owners was found to be around 3.5 pounds greater for owned land than

for rented land. Yet, this difference was not found to be significant by the Studentized t-Test for Independent Sample Means with Equal Variances which yielded a t' value of only .288 with 73 degrees of freedom. Nitrogen use per acre by part owners for the corn-soybeans rotation was found to be over 7 pounds greater for owned land than for rented land. Unlike that of the continuous corn rotation, the t-Test did prove to show the difference to be significant as it yielded a t' value of 1.84 with 658 degrees of freedom. Nitrogen use per acre for part owners on the corn-oats-meadow rotation was found to be around 3 pounds greater for rented land than for owned land. Yet, this difference was not found to be significant as the t' value generated by the Studentized t-Test for Independent Sample Means with Equal Variances was only -0.396 with 125 degrees of freedom.

Crop Rotations Used

Percentage distributions of the crop rotations use by the three tenure categories compared are shown in Figures 39, 40, and 41. Figure 39 shows the percentage distribution of crop rotations used on all owned land versus all rented land. In both cases, the corn-soybeans rotation had the greatest percentage of use, yet this use was substantially higher on all rented versus all owned land (52% to 35%). On the other hand, all owned had a tendency to have more corn-oats-meadow rotations than all rented land (24% to 18%). There was also tendency for all owned land to have more permanent pasture and other rotations. Overall, the Likelihood Ratio Test showed these two

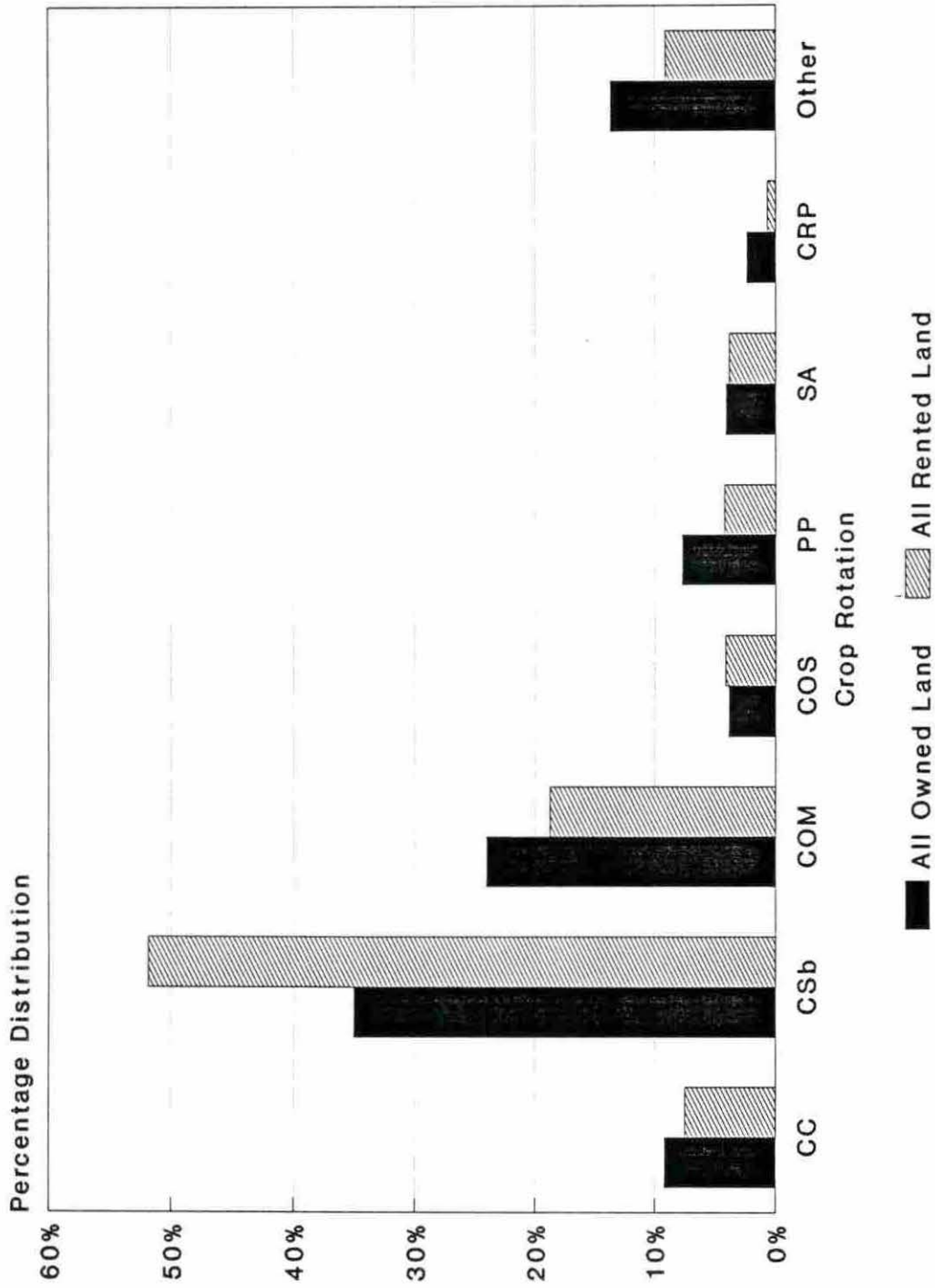


Figure 39. Percentage Distribution of Crop Rotations Used on All Owned Land Versus All Rented Land
 Note: $\chi^2 = 157.276$ with 7 degrees of freedom; significant difference found

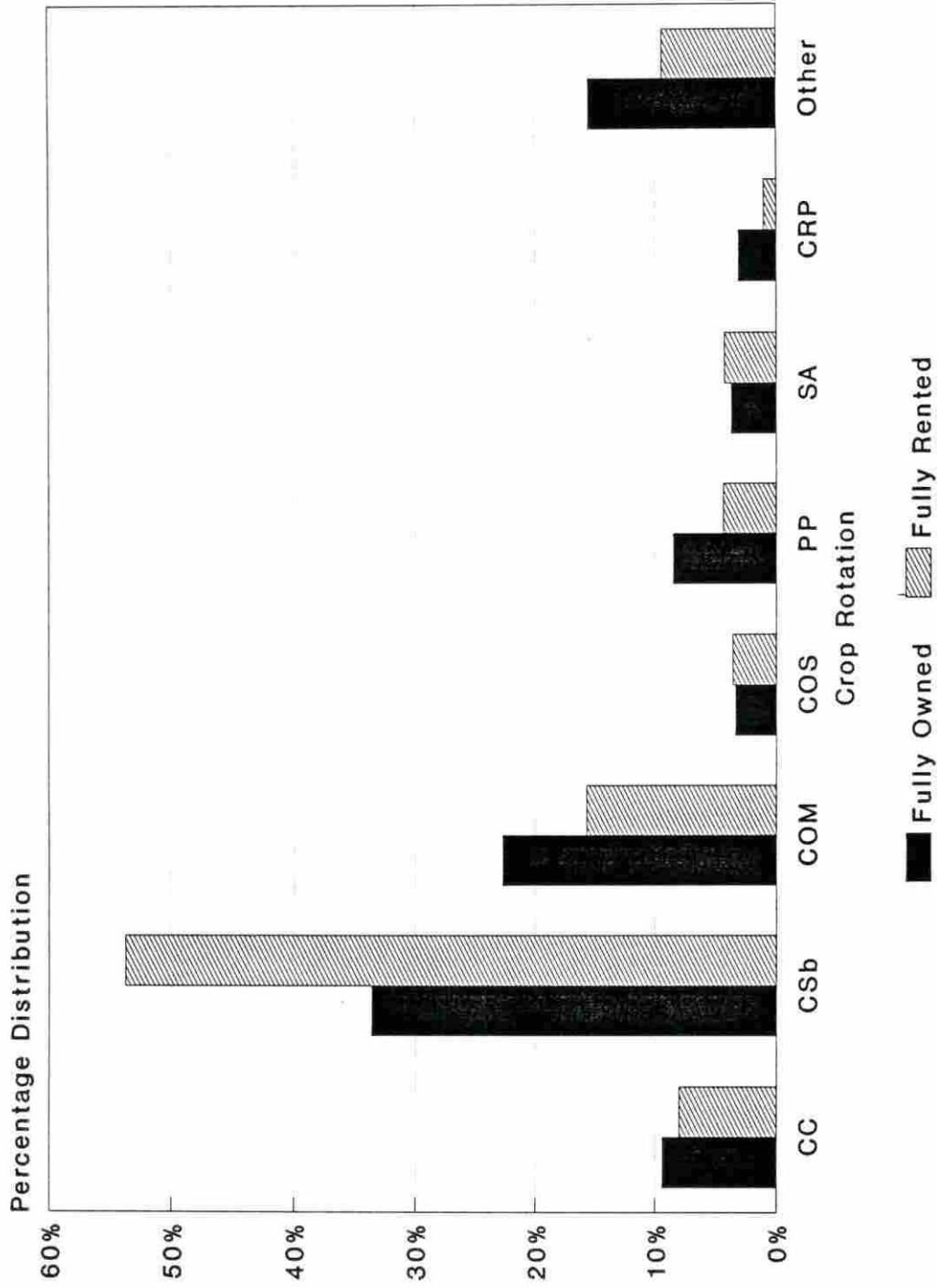


Figure 40. Percentage Distribution of Crop Rotations Used on Fully Owned Farms Versus Fully Rented Farms
 Note: $\chi^2 = 126.997$ with 7 degrees of freedom; significant difference found

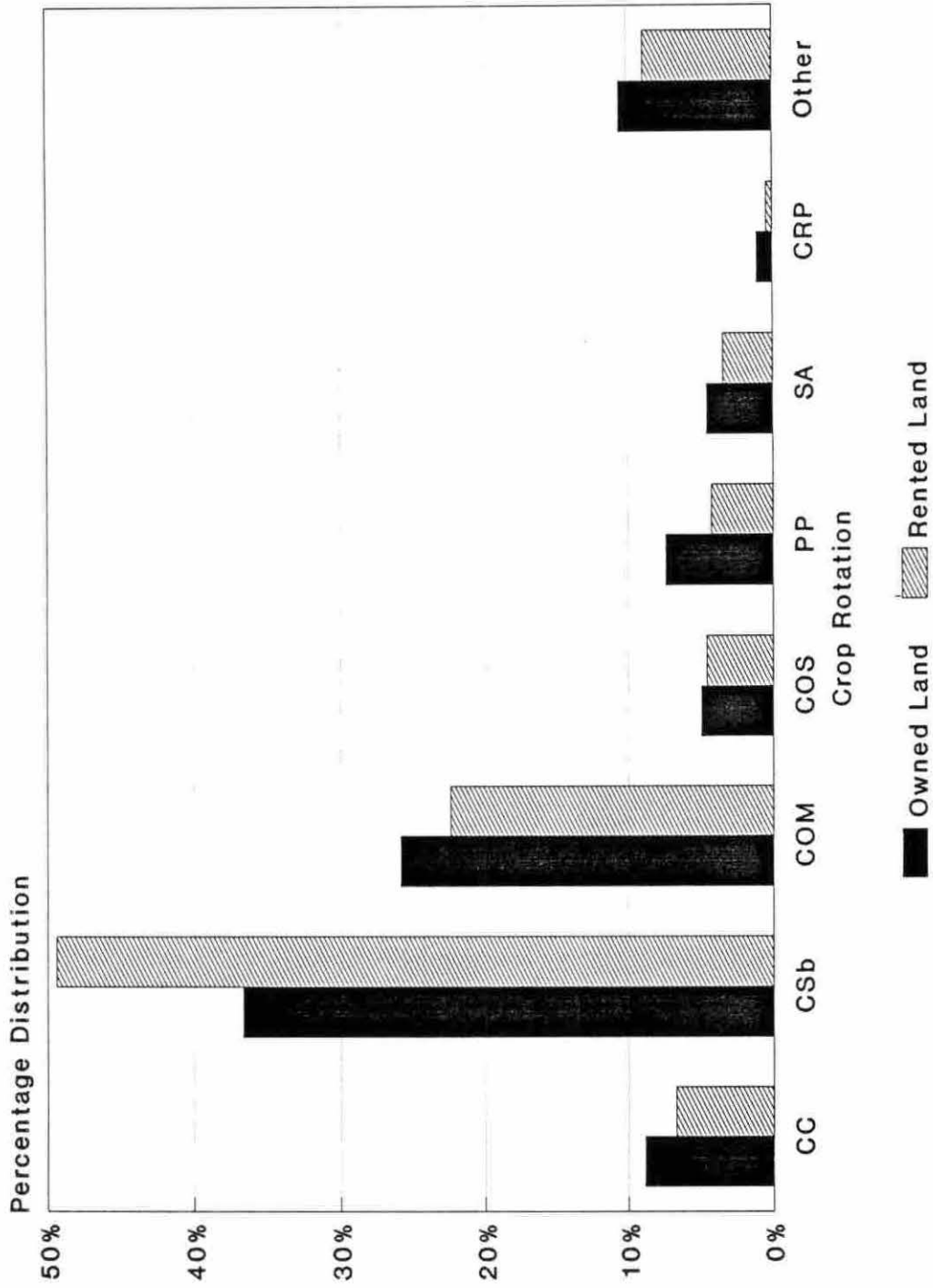


Figure 41. Percentage Distribution of Crop Rotations Used by Part Owners on Owned Land Versus Rented Land
 Note: $\chi^2 = 38.826$ with 7 degrees of freedom; significant difference found

distributions to be significantly different as it yielded a Chi-squared value of 157.28 with 7 degrees of freedom.

Figure 40 displays the percentage distribution of rotations used on fully owned versus fully rented farms. Again, the corn-soybeans rotation tended to be the most popular in both cases, yet its use was substantially higher on fully rented farms versus fully owned farms (54% to 34%). On the other hand, fully owned farms tended to use corn-oats-meadow and other rotations more than the fully rented farms. These differences were 23% to 16% and 16% to 9% respectfully. The Likelihood Ratio Test yielded a Chi-squared value of 127 with 7 degrees of freedom which proved these two distributions to be significantly different.

Finally, Figure 41 shows the percentage distribution of rotations used by partially owned for owned versus rented land. As with both the all owned land versus all rented land and fully owned farms versus fully rented farms, the corn-soybeans rotation appeared to be the rotation of choice. Yet, this percentage is substantially greater for rented land versus owned land (49% to 37%). Owned land, on the other hand, tended to have a greater percentage of use for the corn-oats-meadow, permanent pasture, and other rotations. Overall, the Likelihood Ratio Test showed the two percentage distributions to be significantly different as it yielded a Chi-squared value of 38.83 with 7 degrees of freedom.

CONCLUSIONS AND INTERPRETATION

The results of this research have provided some interesting insights into how different tenure situations may affect the adoption and use of practices which are considered more sustainable. In areas such as fertilizer use and crop rotation use, the survey data revealed significant differences, while in other areas, such as mechanical practices and pesticide use, the differences were subtle or nonexistent. The conclusions will be discussed in the same order as they were presented in the results section and followed by a summary and overall interpretation.

Mechanical Practices

Primary tillage use between contrasting tenure groups showed little to no differences regardless of the rotation. For the continuous corn rotation, the only significant difference found was between owned land and rented land for partially owned farms (Figure 14). In this case there was a slight tendency to substitute field cultivator use for chisel plow use on rented fields versus owned fields. This suggest that partial owners used the less intensive tillage implement on the rented land to off-set some of the rental cost. In all other comparisons for the continuous corn rotation, no significant differences were found.

Primary tillage use on rotated corn following soybeans and soybeans following corn showed little to no significant difference for all owned versus all rented land, fully owned farms versus fully rented farms, or owned land versus

rented for partially owned farms. A slight difference did emerge between owned land versus rented land for partially owned farms (Figure 17). Yet, no real pattern of use emerged suggesting that the differences found were not substantial.

Overall, mechanical practices for all owned land versus all rented land and fully owned farms versus fully rented farms exhibited no significant differences. This was demonstrated by both the percentage distribution of primary tillage equipment summaries and the average number of trips over a field. This same was true for owned land versus rented land for partially owned farms, except in the case of primary tillage use on the continuous corn rotation. All of this suggests that tillage decisions are not influenced by the tenure of the land.

Pesticide Practices

Pesticide use, much like the mechanical practices discussed above, showed little to no difference in use for any of the three tenure comparisons made; all owned land versus all rented land, fully owned farms versus fully rented farms, and owned land versus rented land for partially owned farms. Application methods were dominated by broadcasting for all three tenure comparisons. The same was true for pesticide forms used, which was dominated by the use of liquid pesticides in all three cases. Analyzing the results showed no significant differences because pesticide methods and forms were dominated by one particular category. This evidence suggested that

pesticide application methods used and pesticide forms used were not influenced by the land tenure situation of a particular farmer.

Unlike pesticide application method and pesticide form, timing of pesticide application did show some signs of being a function of the particular tenure situation. In the case of all owned land versus all rented land (Figure 30), there was a slight tendency for more pesticides to be applied post-emergence on land that was rented. The same was true for fully rented farms versus fully owned farms (Figure 31). Yet, where this was most evident was with rented land versus owned land for partially owned farms (Figure 32). In this case, post-emergence application was ten percentage points greater on rented land than on owned land. Overall, this showed there was a tendency to delay pesticide application on land that was rented until a problem arose regardless of the tenure comparison made.

Fertilizer Use

Of all the production areas investigated in this research, fertilizer use showed the most apparent and interesting results. In the cases of fertilizer use for all owned land versus all rented land and fully owned farms versus fully rented farms (Figures 33 and 34), nitrogen, phosphate, and potash use was greater on land which was rented versus land which was owned. In the case of owned land versus rented land for partially owned farms (Figure 35), no significant differences were found for nitrogen, phosphate, and potash use. The difference in use for fully owned versus fully rented farms was nearly ten

pounds per acre for all three fertilizers listed. The difference in use of the three fertilizers listed was only five pounds per acre for all owned land versus all rented land. This difference was much less than fully owned farms versus fully rented farms because the samples for all owned land versus all rented land include data from both partially and fully owned or fully rented farms.

The evidence found in these comparisons suggests that full renters tended to equate higher returns with higher yields and higher yields with higher rates of fertilizer use, while full owners tended to use fertilizers as a way to maximize returns and not necessarily yields. On the other hand, partial owners showed no significant difference in the use of fertilizers, suggesting their tenure relationship to the land held no bearing over the amount of fertilizer used. Fertilizer use for both owned land and rented land tended to be the same for partially owned farms.

As was discussed earlier, because of the increased interest in nitrogen use and its affect on the environment, a separate set of comparisons were made. Nitrogen use for corn in the three most popular rotations found in the survey also revealed some interesting results. As with all fertilizer used, the largest differences existed for fully owned farms versus fully rented farms (Figure 37). For all three rotations, nitrogen use on corn was greater for the fully rented farms than for the fully owned farms. The differences found were significant for both the corn-soybeans and corn-oats-meadow rotations. Evidence here suggests that as the producers switched to rotations which were

more diverse and included crops capable of nitrogen fixation, full owners were more inclined to adjust the amount of nitrogen applied to corn than were full renters. Again this suggest that full renters tended to equate higher returns with higher yields and higher yields with higher rates of fertilizer use.

The most surprising result in the fertilizer use section was the tendency for part owners to use more nitrogen on owned land versus rented land for corn in both the continuous corn and corn-soybeans rotation (Figure 38). Even though the difference was only significant for the corn-soybeans rotation, the evidence suggests that part owners tended to use less nitrogen on the rented land because they wanted to exhaust the nutrient source already available in the soil and to partially off-set the added rental costs.

Crop Rotations Used

In all cases, all owned land versus all rented land, fully owned farms versus fully rented farms, and owned land versus rented land for partially owned farms, the corn-soybeans rotation was the most predominant rotation used. Yet, in the cases where the land was rented, the corn-soybeans rotation made up approximately 50% of the rotations chosen, while only making up 35% of the rotations chosen for land that was owned. The corn-oats-meadow rotation and other rotation tended to be more popular on land which was owned versus land which was rented. These differences tended to be greater for fully owned farms versus fully rented farms than for owned land versus rented land for partially owned farms. Because all owned land versus all rented

land included samples from both the fully owned farms versus fully rented farms and owned land versus rented land for partially owned farms, the percentages tended to land in between those two groups.

Overall, the results found here suggest that there is a greater tendency to use rotations which are more diverse and involve leguminous crops on land that is owned versus land that is rented. This difference is greater and more apparent for fully owned farms versus fully rented farms.

Summary

Table 5 provides a summary of the production areas compared.

Mechanical practices, including primary tillage used and number of trips over a field, showed no strong evidence of differences in use based on the land tenure situation. Differences were found for primary tillage use by part owners on continuous corn and corn following soybeans, but these difference were slight and revealed no true pattern.

In the area of pesticide practices, pesticide application methods and pesticide forms showed no strong significant differences between tenure categories, while pesticide timing was quite different. This difference involved a higher instance of post-emergence application on land that was rented. It is possible that farmers may be more interested in taking care of the weed problems on their owned land first. Another possible reason could be less concern over weed seed development on land that may be rented for a short period of time.

Table 5. Summary of Differences Found for the Three Tenure Category Comparisons

	All Owned vs. All Rented Land	Fully Owned vs. Fully Rented Farms	Owned vs. Rented Land for Part Owners
Mechanical Practices			
Primary Tillage			
Continuous Corn	-	-	+
Rotated Corn	-	-	+
Soybeans	-	-	-
Number of Field Trips	-	-	-
Pesticide Practices			
Application Method	-	+	-
Application Form	+	-	-
Application Timing	✓	✓	+
Fertilizer Use			
Nitrogen	✓	✓	-
Phosphate	✓	✓	-
Potash	✓	✓	-
Nitrogen Use by Rotation			
Continuous Corn	✓	-	-
Corn-Soybeans	-	+	+
Corn-Oats-Meadow	✓	+	-
Crop Rotations Used	✓	✓	✓

- No statistically significant difference found

+ Statistically significant difference found to $\alpha = 0.05$

✓ Statistically significant difference found to $\alpha = 0.01$

Fertilizer use showed strong differences for all owned land versus all rented land and fully owned farms versus fully rented farms. This difference was a tendency for fertilizer use to be greater on land that was rented than on land that was owned. No significant difference in use by part owners on owned versus rented land was found for any of the three fertilizers listed.

Finally, crop rotations used showed strong significant differences for all three tenure comparisons. The evidences suggests a greater tendency for farmers to use diverse rotations that include legumes on owned land and rotations with only one or two grain crops on rented land.

Overall Interpretation

Even though both sides of the tenure spectrum have a tendency to use practices that appear to be more sustainable in different production areas, there is evidence that future adoption and use of practices seen as sustainable will be faster for land that is owned versus land that is rented, especially in the case of fully owned farms versus fully rented farms. Five factors currently exist which will make the transition easier for land that is owned versus land that is rented:

1. Greater investment incentives associated with longer planning horizons for land that is owned.
2. Greater interest in the welfare of the land associated with the stability in the tenure relationship for land that is owned.
3. Greater percentage of farmers are already including diverse crop rotations in their practices for land that is owned.
4. Greater percentage of farmers are already integrating livestock into their production system for land that is owned.

5. Greater percentage of farmers already making adjustments for fertilizer use on corn for land that is owned.

Because the length of stay on land that is owned is much longer than for land that is rented, the planning horizon for that particular farmer is greater. The direct result of this being that investment costs for sustainable practices which have many of their benefits in the long-run are much less for owned land. Stability in the tenure relationship also makes investment into sustainable practices more attractive because people who both own and operate their land know they will be reaping the benefits of this investment directly and indefinitely. Sustainable farming systems are also characterized by lower use of inorganic fertilizers, higher diversity in crop rotations used, and greater integration on livestock into the production system, and these practices are already more prevalent for land that is owned, especially in the case of fully owned farms. Figures 33 through 37 show how inorganic fertilizer use was lower for fully owned farms, Figures 39 through 41 show that more diverse crop rotations were used on land that was owned versus land that was rented, and Figure 10 shows how livestock integration is greater for tenure situations involving owned land.

Table 3 gives a summary of how sustainable agriculture differs from conventional agriculture. Looking at the evidence found in this research, the use of these practices or the potential for use of these practices should be greater for land that is owned than for land that is rented. As the move toward

an agricultural system which is more sustainable in nature increases, changes must be made in current leasing practices to make adopting sustainable practices more attractive for land that is rented. To promote sustainable practices, lease arrangements must be adjusted to use longer terms so that tenants can adopt crop rotations and longer term investments in soil conservation, nutrient management, and livestock integration. Furthermore, ways must be found to encourage the adoption of sustainable practices, such as reduced reliance on chemical controls, by compensating tenants for improving soil fertility through the use of organic and cultural controls and caring for the land. Because so much of the land in Iowa, and the country as a whole, is under some sort of leasing arrangement, continued research must be performed to determine if land tenure continues to be a factor in an agricultural producer's production decisions. This research should include a comparison of how the rental arrangements of crop share versus cash rent effect the production decisions of farmers. This research should also include an analysis of the demographic characteristics of different tenure groups to determine if age, education, and geographic location of a farmer have an effect on production decisions. Overall, as farmland rental continues to be of great importance, further research needs to be done to monitor its effects on the move to a more sustainable agricultural system.

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APPENDIX A. LIKELIHOOD RATIO TEST FOR SIGNIFICANT DIFFERENCE IN FREQUENCY DATA

Frequency Table:

n_{11}	n_{12}	n_{13}	n_{1t}
n_{21}	n_{22}	n_{23}	n_{2t}
n_{t1}	n_{t2}	n_{t3}	n

Where: n_{ij} = the number of respondents for the cell in row i and column j .

n_{it} = the sum of respondents for the cells in row i .

n_{tj} = the sum of respondents for the cells in column j .

n = the total number of respondents.

Hypothesis Test:

$$H_o: \pi_{11} = \pi_{21}, \pi_{12} = \pi_{22}, \pi_{13} = \pi_{23}$$

$$H_a: \pi_{11} \neq \pi_{21}, \pi_{12} \neq \pi_{22}, \pi_{13} \neq \pi_{23}$$

$$\alpha = 0.05$$

Where: π_{ij} = the frequency of responses for the cell in row i and column j .

Model: $\prod \pi_{ij}^{n_{ij}}$

$$\begin{aligned} \text{Maximum likelihood under } H_o: \hat{\pi}_{ij} &= n_{tj} / n \\ \text{Maximum likelihood under } H_a: \hat{\pi}_{ij} &= n_{ij} / n_{it} \end{aligned}$$

Test Statistic:

$$\begin{aligned} & -2 \ln \left(\frac{\text{likelihood under } H_o}{\text{likelihood under } H_a} \right) \\ &= -2 \ln \left\{ \frac{\prod (n_{tj} / n)^{n_{tj}}}{\prod (n_{ij} / n_{it})^{n_{ij}}} \right\} \\ &= -2 \left\{ \sum n_{tj} \ln(n_{tj} / n) - \sum n_{ij} \ln(n_{ij} / n_{it}) \right\} \\ &\sim \chi^2 \text{ with } (k-1)-r \text{ degrees of freedom} \end{aligned}$$

Where: k = number of cells: n_{ij}

r = number of restrictions in $H_o: \pi_{ij} = \pi_{ij}$

Source: Agresti, 1990

**APPENDIX B. STUDENTIZED t-TEST FOR INDEPENDENT SAMPLE MEANS
WITH EQUAL VARIANCES**

Hypothesis Test:

$$H_0: \mu_1 - \mu_2 = D_0$$

$$H_a: \mu_1 - \mu_2 \neq D_0$$

$$\alpha = 0.05$$

Where: μ_1 = Mean value for population 1.
 μ_2 = Mean value for population 2.
 D_0 = Specified value (for this study $D_0 = 0$)

Test Statistic:

$$t' = (y_1 - y_2 - D_0) / s_p \left\{ (1/n_1) + (1/n_2) \right\}^{1/2}$$

Where: y_1 = Mean value for sample 1.
 y_2 = Mean value for sample 2.
 s_p = The mean of the two sample variances.
 n_1 = number of observations in sample 1.
 n_2 = number of observations in sample 2.

Degrees of Freedom:

$$df = n_1 + n_2 - 2$$

Source: Ott, 1988

**APPENDIX C. STUDENTIZED t-TEST FOR INDEPENDENT SAMPLE MEANS
WITH UNEQUAL VARIANCES**

Hypothesis Test:

$$H_0: \mu_1 - \mu_2 = D_0$$

$$H_a: \mu_1 - \mu_2 \neq D_0$$

$$\alpha = 0.05$$

Where: μ_1 = Mean value for population 1.
 μ_2 = Mean value for population 2.
 D_0 = Specified value (for this study $D_0 = 0$)

Test Statistic:

$$t' = (y_1 - y_2 - D_0) / \{(s^2_1/n_1) + (s^2_2/n_2)\}^{1/2}$$

Where: y_1 = Mean value for sample 1.
 y_2 = Mean value for sample 2.
 s^2_1 = Variance for sample 1.
 s^2_2 = Variance for sample 2.
 n_1 = number of observations in sample 1.
 n_2 = number of observations in sample 2.

Degrees of Freedom:

$$df = (n_1 - 1)(n_2 - 1) / [(n_1 - 1)c^2 + (n_2 - 1)(1 - c)^2]$$

$$\text{Where: } c = (s^2_1/n_1) / [(s^2_1/n_1) + (s^2_2/n_2)]$$

Source: Ott, 1988

APPENDIX D. F-TEST FOR HOMOGENEITY OF POPULATION VARIANCES

Hypothesis Test:

$$H_0: \sigma^2_1 = \sigma^2_2$$

$$H_a: \sigma^2_1 \neq \sigma^2_2$$

$$\alpha = 0.05$$

Where: σ^2_1 = variance of population 1.
 σ^2_2 = variance of population 2.

Test Statistic:

$$F = S^2_1/S^2_2$$

Degrees of Freedom:

$$df_1 = n_1 - 1$$

$$df_2 = n_2 - 1$$

Where: S^2_1 = variance of sample 1.
 S^2_2 = variance of sample 2.
 n_1 = number of observations for sample 1.
 n_2 = number of observations for sample 2.

Source: Ott, 1988