ENERGY EFFICIENCY AND AGRICULTURAL PRODUCTION: A CASE STUDY OF LETTUCE FARMS IN THE GREATER VANCOUVER CENSUS DIVISION

by

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Energy Efficiency and Agricultural Production: A Case Study of Vancouver Lettuce Farms

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ABSTRACT

The energy crisis of the 1970s led to a realization of the dependence of agriculture on inputs of non-renewable energy. Since that time, researchers have attempted to find an agricultural production method that would conserve non-renewable energy while maintaining yields. Underlying this search has been the assumption that such a method would be unique and universally applicable. It is suggested that no unique solution has been found because researchers have failed to consider the variability of agricultural communities with regard to their site, situation and culture.

In this study, a questionnaire was used to collect data from 27 lettuce farmers in the Greater Vancouver Census Division. The objectives of the study were to:

1. isolate a production method that minimizes expenditures on non-renewable energy as a percentage of gross sales; and
2. determine the relative importance of site and situation in affecting the combination of inputs that constitutes the production method.

It was hypothesized that a unique production method would be found if site and situation were constant throughout the study area. If either site or situation varied, it was expected that no unique method would be found.

Site was relatively uniform throughout the study area. Situation varied, with farms in Burnaby subject to a higher risk of rural to urban land conversion than those in Surrey. The

cultural background of the farmers also varied. Chinese farmers were found in all parts of the study area, while all of the Caucasian farmers interviewed were located in the Cloverdale area of Surrey.

Two energy efficient strategies were derived: one suited to a small scale and one to a large scale. Geographic distribution of these strategies matched variations in situation and culture. Small efficient farms were concentrated in Burnaby, and were operated by Chinese growers. Large efficient farms were concentrated in Cloverdale, and in all but one case, were operated by Caucasian growers.

ACKNOWLEDGEMENTS

Acknowledging all those who have helped me over the past three years is a somewhat difficult task, as the cast of characters has changed over time. Throughout this period, however, certain figures have remained constant. Dr. J.T. Pierce, my senior supervisor, has shown far more patience and good humour than I have deserved, particularly during the last semester. If I have bothered you more often than you might have wished, John, it is only because I wanted to get it right.

Drs. W.G. Bailey and R.B. Horsfall, the other members of my committee, have dragged me out of mathematical and statistical difficulties on many occasions. Following your advice may not always have been fun, but it has kept me honest.

Simon Fraser University provided the money I needed to complete my thesis, and the support staff necessary to make it possible. Moyna, Rosemarie, Gwen, Mary, Hannele, Ray, Gary and Margaret helped me with the nitty-gritty details more often than I care to admit.

Credit for preservation of my sanity goes almost entirely to my friends. Cathy Boniface has functioned as my alter ego, talking me through the crises arising from life, work and love. She and Jamil Brownson have always been willing to discuss the philosophical implications of lettuce farming. Mike Bronson fulfilled a similar function during my Alaskan hiatus.

As for the rest of you: Tom, Diane, Doris, Simon, Cara, Lori, Lorraine, Ted, Susan, Anne, Jerry, Isabelle, Guy, Gary,

Anna, Ian, John, Simon, Jim, Jim...(if I've left anyone out, it's not deliberate), you've all provided humour, good fellowship and beer when I've needed them.

Finally, I want to thank Marc for the good memories, and my parents for sticking by me, even when they thought I was running away to grow organic vegetables in NWT.

But perhaps I should let you all say it in your own words...

JTP: "You need a more elaborate conceptualization of the production possibility frontier."

WGB: "I see nothing profound about Figure 3."

RBH: "How are the organic rutabagas?"

Chinese farmer: "Aren't you done with that thing yet?"

Extension agent, Ministry of Agriculture: "Are you sure you know how to use the xerox machine?"

Frank Camp: "Your mother thinks you've flunked and are afraid to tell us."

CB: "Let's cycle down to the beach."

MPB: "You're a class act, Camp."

Any number of others: "Bag it, and go for a beer."

After the rain, the vicious dogs and the statistics, I'll never be the same. Thank you all.

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CHAPTER 1: INTRODUCTION

The topic

The energy shortages of the early 1970s brought a sudden recognition of the dependence of agriculture on non-renewable energy. While the shortages of that time have proved transitory, the questions raised are not. Researchers are still searching for an agricultural production method that will conserve non-renewable energy while maintaining yields at their present level (Doering, 1980).

Underlying much of this search has been the assumption that, once found, such a method would prove to be unique and universally applicable (Doering, 1980). What the characteristics of this method would be has been the subject of much debate. Many researchers suggest that this method would closely resemble present capital-intensive agricultural practices, while others maintain that it would be more closely allied with traditional labour-intensive agriculture.

No unique method has been found, and conflicting evidence exists to support proponents of both small and large scale, labour and machinery intensive production (Pimentel and Pimentel, 1979; Johnson et al., 1977). A possible reason for this conflict is that there has been a common failure to consider the variability of agricultural communities with regard to their site, situation, and culture. Thus traditional agriculture may be energy efficient in one location, while mechanized agriculture is efficient in another. An energy efficient production method will not be universally applicable, but will be unique to its site and situation.

It is not necessarily true that the method best suited to achieve energy efficiency in a given area is the most culturally acceptable method for that area. Thus it is further suggested that the final level of energy efficiency will be a function of the cultural acceptability of a production method within a given rural settlement.

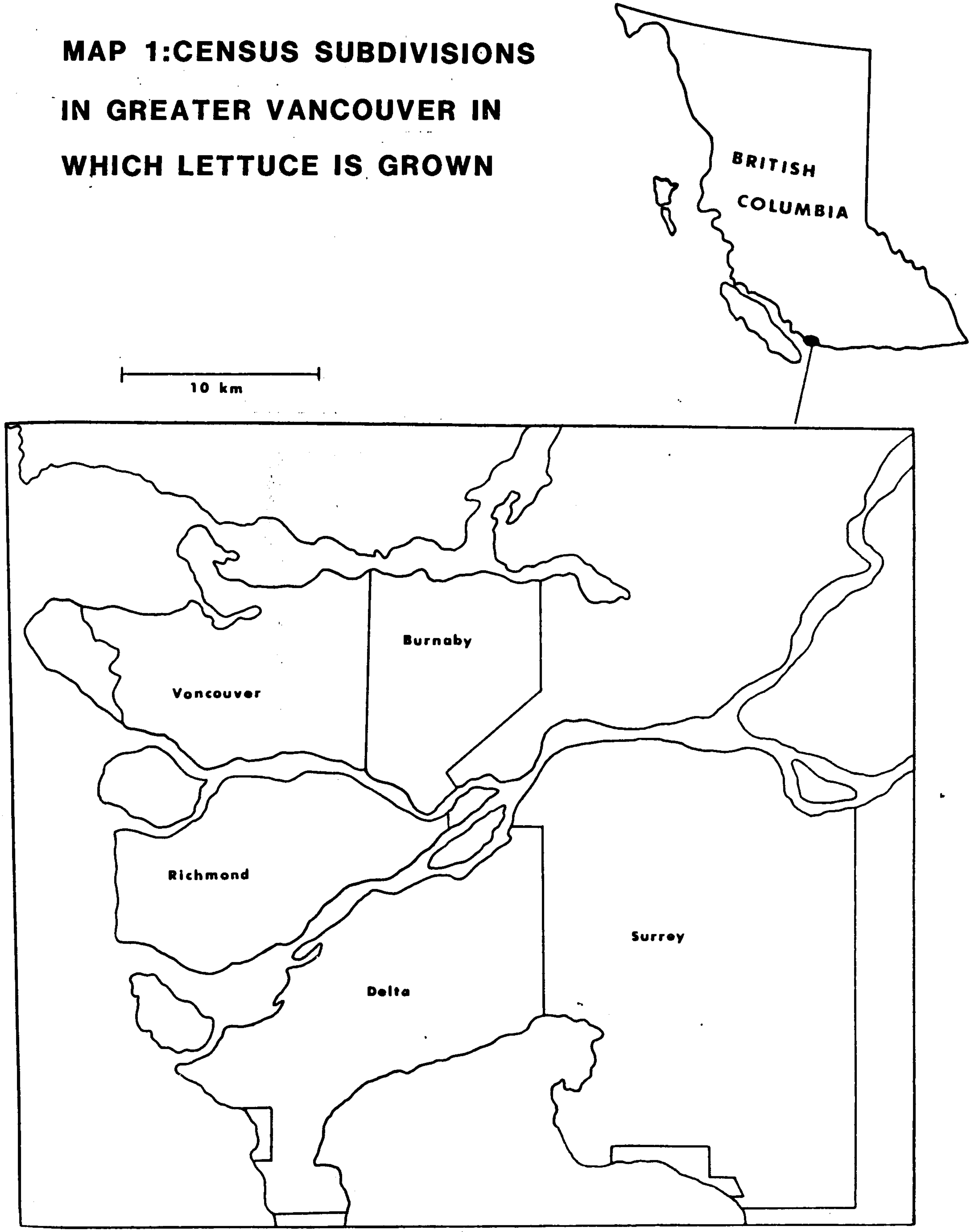
The thesis

The purpose of this thesis is to assess the role played by site and situation in determining an energy efficient production method. To accomplish this purpose a study was undertaken of lettuce production in the Greater Vancouver Census Division (GVCD)(Map 1). The study has two objectives:

1. to isolate a production method that minimizes expenditures on non-renewable energy as a percentage of gross sales.
2. to determine the relative importance of site and situation in affecting the combination of inputs that constitutes the production method.

Gross sales, rather than net sales, were chosen as a measure of yield because the study is concerned with the farmer's ability to produce a crop, rather than with his ability to sell it. It was hypothesized that a unique production method would be found if site and situation were constant within the study area. If either site or situation varied, it was expected that

MAP 1: CENSUS SUBDIVISIONS IN GREATER VANCOUVER IN WHICH LETTUCE IS GROWN



no unique method would be found.

In formulating these objectives, it was assumed that the characteristics of the most efficient farms in the area describe the energy efficient production method best suited to the site and situation. Furthermore, it was expected that the degree to which this method is utilized is a function of local cultural preference and perception. While this expectation is not stated as a testable hypothesis in the thesis, the role of culture in a farmer's choice of production method is discussed qualitatively.

The following chapter details the evolution of the debate over agriculture and energy since the early 1970's. Chapter 3 suggests an alternative way of viewing energy efficiency, emphasizing agricultural production as a function of site, situation and culture, and outlines the variables and analytical techniques used in this study. Chapter 4 describes the study area and method of data collection, and discusses the results of the analysis. Conclusions are found in Chapter 5.

CHAPTER 2: LITERATURE REVIEW

The oil embargo imposed on the West by the Organization of Petroleum Exporting Countries (OPEC) in 1973 raised three major concerns in the agricultural community. The first was the need to assess the extent of the crisis. It was necessary to answer immediate questions about the security of supply, and to determine the extent of Western agriculture's dependence on hydrocarbons. The second concern was to understand how this dependence had come about. The third was to derive an energy efficient method of agricultural production.

As pointed out in Chapter 1, researchers have been divided in their answer to this last question. Most think that either the present system of machinery-intensive agriculture requires only minor adjustments, or that agriculture must cease to rely on large inputs of machinery. Compromise between these views has been hampered for three reasons. First, researchers have been searching for a unique, technical solution to the problem. Second, scientific discourse has been interwoven with philosophical debate over the quality of life. Finally, the fact that certain aspects of the problem are location-specific has been almost universally ignored.

The purpose of this chapter is to review the research on each of these concerns, concentrating particularly upon the debate over the nature of an energy efficient system. The results of studies produced on both sides of the debate are compared, and a new, narrower question formulated: can a unique production method be found when site, situation and culture are uniform?

Dimensions of the energy crisis in agriculture

Early assessments of the crisis faced by Western agriculture were bleak. In the U.S., shortages of liquid petroleum gas (lpg) in the fall of 1972 forced the Department of Agriculture to develop a plan to transport emergency fuel for crop drying (Butz, 1973). While no such emergencies confronted Canadian farmers, the level of energy dependence in Canada was as great as in the U.S. Canada ranked first in the world in energy use per dollar of Gross Domestic Product (Agricultural Economics Research Council of Canada, 1974). Eight percent of the gasoline and twelve percent of the diesel fuel consumed nationwide were used in agricultural production. In Saskatchewan, the figures jumped to 34% and 46% respectively (Brooks, 1981). Brooks argued that high rates of energy consumption were the natural result of more intensive agriculture, and noted that between 1949 and 1971 use of inorganic fertilizers increased tenfold, while farm production only went up 70% (Brooks, 1981).

Immediate security of supply was the most pressing concern for both the U.S. and Canada. In the U.S., Secretary of Agriculture Butz (Butz, 1973) argued for the continuation of energy intensive farming methods, since exports of agricultural products could be used to generate the foreign revenue necessary to continue purchasing petroleum abroad. Canadian concerns for energy security, on the other hand, eventually led to the National Energy Policy of 1980, designed to produce national self-sufficiency in energy. The Ontario Institute of Agrologists suggested that, in the meantime, farming be given priority in the allocation of fuel supplies. In the long term, alternative sources of energy, such as wind and solar power, could be developed (Ontario Institute of Agrologists, 1977).

Interest in alternate sources of energy also led to discussion of what agriculture could do to alleviate the energy crisis in other sectors of the economy through the production of biomass (Hooker et al., 1981). As a result, production of gasohol from corn began in the U.S. in the 1970's , although there has been nothing in North America as ambitious as the Brazilian efforts at gasohol production from sugar cane. Lockeretz argued convincingly that intensive biomass production could make only a small dent in meeting U.S. energy requirements. Furthermore, it would drastically cut the amount of agricultural land available for food production (Lockeretz, 1982).

On-farm production of energy might not be directed to an outside market. It could be used simply to meet energy needs on the farm, thus freeing farmers from dependence on outside sources of supply, saving money and energy. Systems of producing methane from manure and other composts were developed. In practice, such technology proved costly to implement. Solar heating systems were shown to be relatively less expensive energy production projects, and were thus more readily utilized (Blobaum, 1982).

The search for alternative energy sources was paralleled by efforts to conserve energy. The elasticity of agricultural demand for energy, or the degree to which demand would fluctuate with changes in price and supply, was a subject of much debate. Lopez (1982), in a quantitative analysis of Canadian agriculture, stated the elasticity was quite high. Wood (1981), synthesizing the results of several studies, concluded that on the contrary, modern industrialized farmers were addicted to energy, and that demand for energy would remain high. Corroboration of this view was provided by Dvoskin and Heady (1977), who utilized a linear programming model of U.S. agriculture to show that a doubling in energy prices resulted in only a 5% reduction in energy use.

The evolution of energy dependent agriculture

If demand for energy were inelastic, then an obvious way to begin the search for a more efficient production method would be to determine how the dependence on energy had evolved. According to Dahlberg (1979), "in the United States, geographic and historical factors combined to lead farmers to seek to maximize return on labor since land was abundant. Over the decades, the search for labor efficiency led to more and more mechanization and chemical inputs."

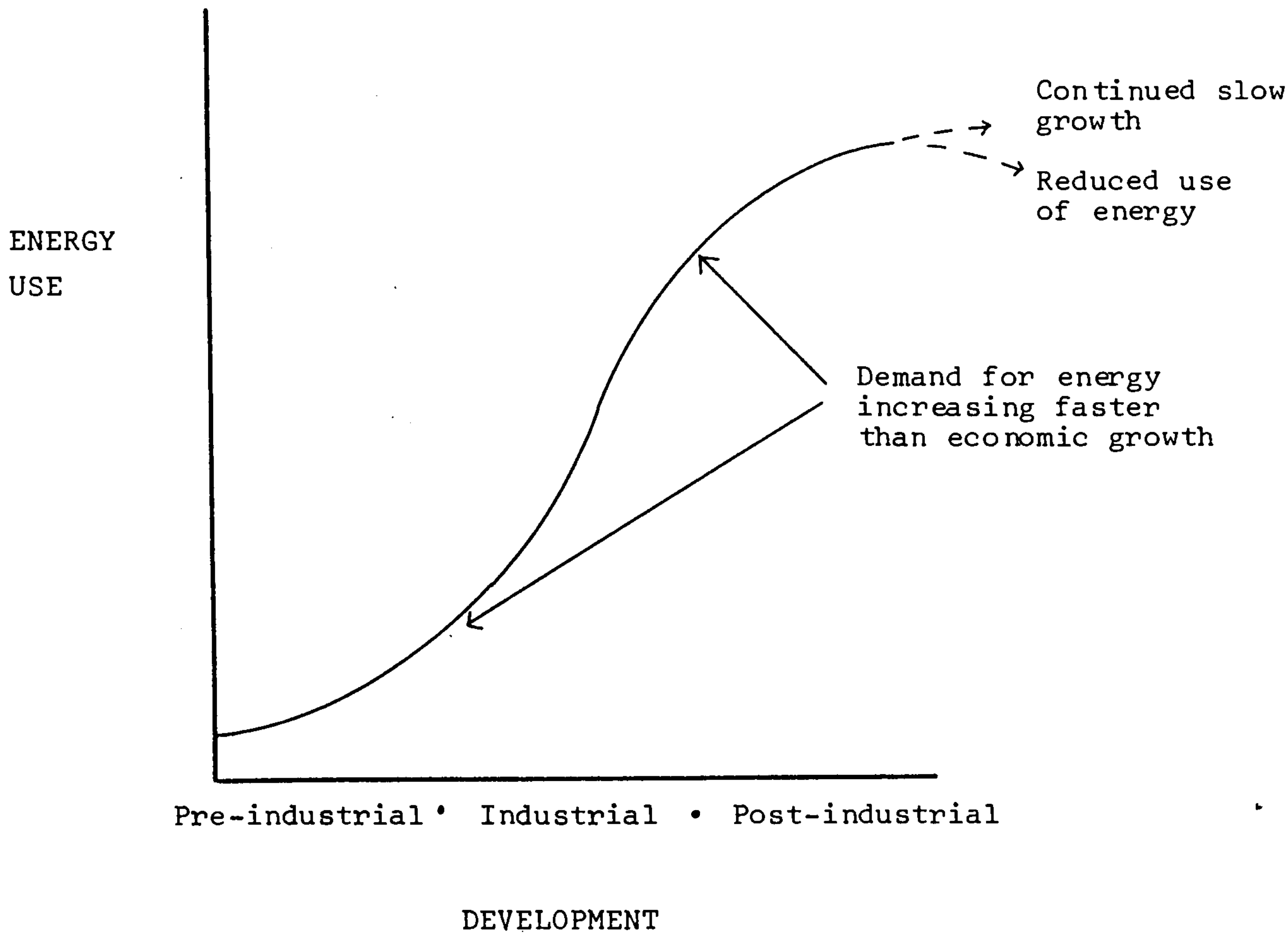
A more detailed explanation is provided by Kislev and Peterson (1981). They argued that technical change in agricultural production might originate in either the agricultural or manufacturing sector: "innovations in manufacturing represent external technical change to agriculture which may or may not show up in the conventional estimates as productivity gains in the latter sector." The authors conclude that farm wages increasing relative to machinery costs after World War II created an upward demand for farm machinery, thus inducing innovation in the manufacturing sector. This process was no doubt reinforced by increasing demand for labour in industry.

Several researchers took a much longer view of the evolution of energy dependency. Pimentel and Pimentel (1979) stated that energy is central to the organization of both our agricultural system and our society as a whole. In traditional hunting and gathering societies, food energy was obtained through labour intensive methods that employed all of the working population. As agriculture developed, a smaller number of individuals produced a greater amount of food energy, thus freeing part of the population to engage in other activities. The result was the division of labour. According to Bayliss-Smith (1982), this increase in productivity was accomplished in part through harnessing solar energy stored in plants, and in part through the use of domestic animals and simple machinery.

Over time, farming itself has changed. Andreae (1981) describes a three stage theory of agricultural development. Originally farming was largely extensive in nature, and extensive use of the land was linked with monocultural production (e.g. grazing.) As land values increased, perhaps due to population pressure, diversification and intensification resulted (e.g. mixed farming.) This diversified use of the land was characterized by labour intensive production. Finally, increased integration of agriculture into national economies resulted in specialized agriculture, depending on intensive use of capital (e.g. grain production on the Canadian Prairies). The changing nature of agriculture outlined by Andreae may be linked to changing uses of energy on the farm. Over time, greater use has been made of energy as a substitute for labour.

At first, energy resources were predominately animate or renewable in nature: draught animals, wood, wind and water. Brooks (1981) points out that it was the location of wood and water resources that influenced the population distribution and settlement of Europe in the Middle Ages. Indeed, it was a shortage of firewood that sparked Europe's first energy crisis in the nineteenth century. Eventually, dependence shifted to inanimate machinery and the concommitant use of non-renewable fossil fuels. Throughout this evolution, the trend has been away from the use of human labour, and toward an increased per capita consumption of energy. The extent of this pattern can be seen in Odell's (1981) diagram showing the relationship between energy

Figure 1: The relationship between energy use and economic development. (After Odell, 1981)



use and economic development (Figure 1).

The concensus among these authors is that over time, high per capita energy consumption has been associated with economic growth. The increased reliance of agriculture on energy inputs made possible the division of labour, and the economic diversification of society. This correlation raises an important question: would decreased dependence on energy necessarily entail a reversal of these other processes as well? Potential changes in agricultural energy use thus raise the spectre of societal transformation, with writers of social commentary, as well as scientific researchers, participating in the debate over agriculture's energy future.

The debate over energy efficient production: barriers to concensus

The effort to derive an energy efficient production method has largely consisted of an attempt to determine whether traditional farming or mechanized farming is more efficient. Since most researchers have been seeking a single form of energy efficient farming, the only options have seemed to be to choose one or the other of these two approaches, or to attempt a compromise between them. The potential for compromise has received relatively little attention, and the tone of the literature has, in some respects, been more political than scientific. Hooker (1981) suggests that the need to derive an appropriate energy future is complicated by the fact that

> "energy policy is deeply connected to social policies, to the style and quality of life we enjoy and hence to our culture, and to the ways in which we think of ourselves as a people. Energy policy is, therefore, a fundamental social policy".

The debate over energy use in agriculture has, therefore, not necessarily been perceived by the participants as a value-free process in which two production methods will be compared, and the more efficient chosen. Rather, it has often been seen as a battle between the political, economic and social status-quo of the industrialized world, and those agitating for a complete overhaul of Western society.

This perception arises from the fact that many of the arguments over mechanized agriculture are not based on comparison of energy efficiencies, but rather on environmental and social considerations. Environmentalists have pointed out that dependence on monocultural production may be depleting the genetic variability of agricultural crops, leaving the world's food supply vulnerable to devestation by insects and disease (Brooks, 1981). Presently, the main defense against such devestation is the wide use of energy-intensive pesticides. This defense, according to Lappe (1971), may prove to be a hazard to both humans and the environment. Pesticide use in the U.S. doubled in the 1966-76 period, to a level close to 270 million kg of active ingredients, while pesticides already introduced into the environment may remain active for up to forty years (Lappe, 1971). A further hazard may be posed by the use of inorganic fertilizers that may have an adverse effect on the ozone layer (Schneider, 1976). Finally, Lovins (1977) states that mechanized agriculture's dependence on intensive irrigation can lead to salinization of crop land.

On the other hand, Just et al. (1979) assert that pollution is not inherent in the technologies associated with machinery intensive agriculture. Given proper environmental policy, the authors state, technology can be used to improve the environment. Tweeten (1983) points out that studies in the Southeastern U.S. have shown that soil conservation practices are more commonly utilized on corporate-run farms than on more traditional family farms.

Opposition to mechanized agriculture on social grounds began even prior to the OPEC embargo. Works such as The Limits to Growth (Meadows et al., 1974) postulated economic, social and ecological collapse if increased energy consumption and economic expansion were pursued ad infinitum. Schumacher (1973) went beyond scientific speculation to condemn the injection of economic motivation into almost every aspect of human life. Modern industrial agriculture did not escape his scrutiny:

> "The crude materialist view sees agriculture as 'essentially directed towards food-production.' A wider view sees agriculture as having to fulfil at least three tasks:
> - to keep man in touch with living nature, of which he is and remains a highly vulnerable part;
> - to humanise and ennoble man's wider habitat; and
> - to bring forth the foodstuffs and other materials which are needed for a becoming life.
>
> I do not believe that a civilization which recognises only the third of these tasks, and which pursues it with such ruthlessness and violence that the other two tasks are not merely neglected but systematically counteracted, has any chance of long term survival" (Schumacher, 1973).

Tweeten (1983) criticizes Schumacher's argument that small scale farming operations provide a higher quality of life to the farmer. He cites evidence that in the U.S. residents of small, low income farms suffer from "feelings of alienation, demoralization and pessimism." Only when the farmer has substantial off-farm income does farming contribute to his quality of life (Tweeten, 1983). Britton (1979) points out that, while Schumacher's arguments are gaining in popularity, there is as yet very little evidence to support them. Before they can gain credence among policy makers, he states, a great deal of research must be conducted.

Compromise has also been made more difficult by economic and political pressures on the agricultural community. Hightower (1972) suggests that agricultural research in North America is biased toward large, technology intensive farming. Just et al. (1979) confirm this point for the U.S., stating that much of the agricultural research in the United States is funded by chemical companies and other private sector organizations. It is these companies that manufacture the energy-intensive pesticides, herbicides and fertilizers upon which improved modern crop varieties are so dependent.The farmer has little choice in what varieties and chemicals are available to him through the market (Just et al., 1979). Lovins (1977) goes further in his assessment, arguing that the importance of crop exports to the balance of payments creates political support for energy-intensive agribusiness.

The situation is somewhat different in Canada, where over half the country's agricultural research is conducted by Agriculture Canada (Agriculture Canada, 1979). Canada does import 95% of its active pesticide ingredients, and much of this trade originates in the U.S. Almost half of these imports requires no formulation but is ready to use (Agriculture Canada, 1977). Thus, while the Canadian research community is not subject to the institutional 'bias' discussed by Just et al., the farmer's choices are limited by the market.

A final barrier to compromise has been a dispute over the definition of the terms "yield" and "energy efficiency." White (1975) argues that the high productivity of modern agriculture is largely a result of its use of energy. In the U.K., four percent of the nation's energy consumption produces over half the unprocessed food (White, 1975). Doering (1980) states that the use of energy intensive technology has made increases in yield possible. Use of large equipment allows more timely harvesting, thus reducing crop loss. The introduction of the tractor has released pasture land for cultivation, while reducing the area needed to grow feed for draught animals (Doering, 1980).

Other authors have raised doubts as to the productive superiority of mechanized farming. Innis (1980) pointed out that in comparing yields on "modern" farms with those of "traditional" farms, past researchers often ignored the fact that the traditional farmers were frequently growing more than one crop in a field, or intercropping. When calculating the yield of the field, the output of crops other than the main cash crop was often not considered. This selective accounting showed that monocropping produced higher yields.

Dahlberg (1979) further argued that many studies define yield in terms of dollar return to dollar input, rather than in terms of food energy produced per unit of land. When the latter definition is used, he suggests, small, intensively cultivated units are the most productive.

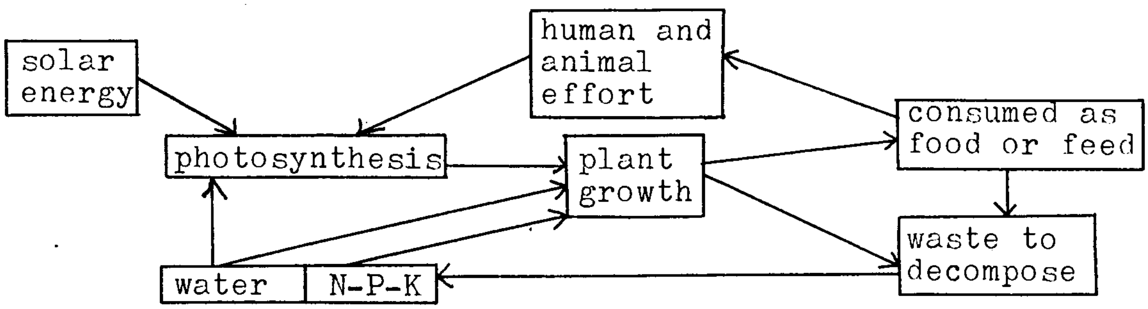
One common approach to providing a value-free definition of energy efficiency has been output-input analysis. This method reduces the outputs and inputs of an agricultural system to their thermodynamic value. Dividing output by input, one arrives at a measure of the energy output produced per unit of energy input.

The output-input approach is closely related to the materials balance approach described by Whitby and Willis (1978). This technique uses physically-based models to build up an accounting system of stocks and flows of matter and energy. Schematic diagrams, illustrating the materials balance approach for traditional (i.e. non-mechanized) and modern (i.e. fossil fuel dependent) agriculture are given in Figure 2.

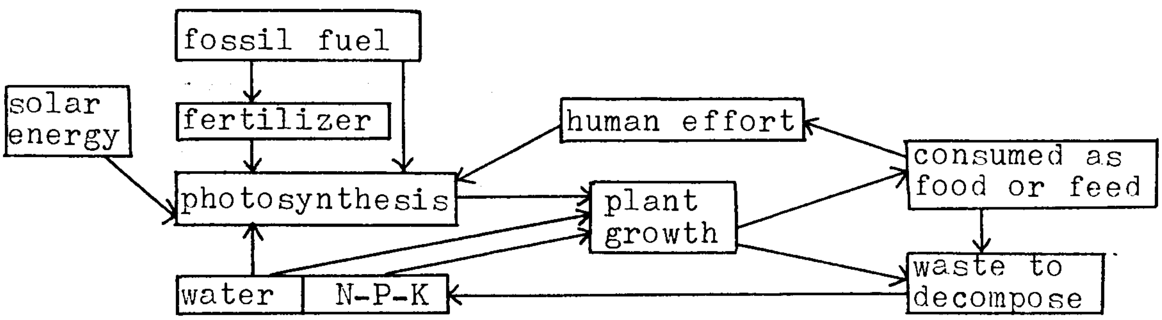
These attempts to produce value-free methods of assessing energy efficiency have often been perceived as value-laden. Many of the output-input studies done (notably those by Pimentel) have shown traditional or non-mechanized agriculture to be more

Figure 2: Material and energy flows in traditional and modern agriculture. (After Whitby and Willis, 1978)

A. Traditional agriculture



B. Modern agriculture



efficient than its modern counterpart. As a result, readers have often considered output-input studies to be attempts to advocate small-scale farming, organic agriculture, or back-to-the-land movements.

There are other problems with accepting output-input and materials balance analyses as the best approach to measuring energy efficiency. As revealing as such thermodynamically based analyses are, they cannot be relied on solely. For one thing, in North America at least, farmers are in the business of raising crops for their cash return, not their caloric value (Wood, 1981). Occasionally, this point is lost in output-input analyses, as in Pimentel and Pimentel's study demonstrating the energy inefficiency of producing diet soda, a product prized for its market value, not its nutritional content (Pimentel, 1979). This point is underlined by Whitby and Willis (1979) who state that materials balance approaches must take financial considerations into account if they are to be used in formulating policy.

In addition, certain crops have high nutritional value in spite of possessing a low caloric value--lettuce is one example. Such crops would be shown to be extremely inefficient by output-input analysis, and it is notable that output-input studies concentrate almost solely on grains, roots, legumes and livestock. Lockeretz (1982) maintains that food may be raised for its nutritive energy value, but since fossil fuels do not have nutritive energy value, output-input ratios are misleading.

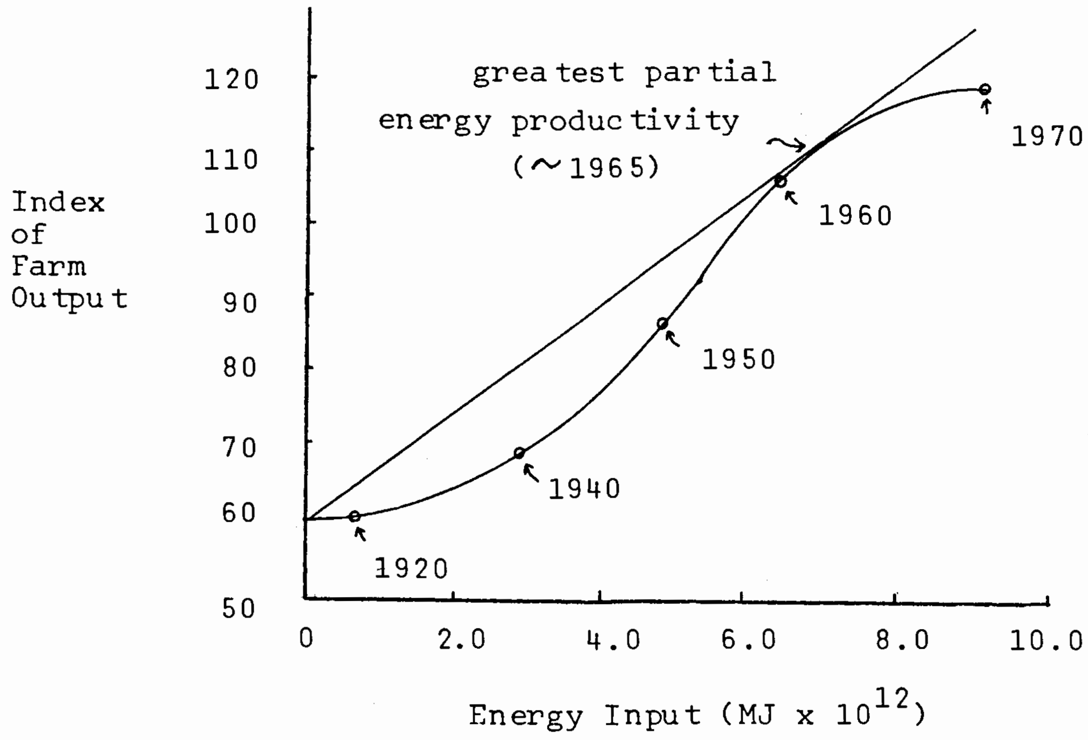
Perhaps Fluck and Baird (1980) have provided the best definition of energy efficiency. They define energy productivity from a curve showing the relationship of energy output to input. Partial energy productivity at any given level of energy use is given by the slope of the line connecting the y-intercept with the given value of x. Applying their principle to a curve showing the index of U.S. farm output as a function of energy input over the period 1920-1970, indicates that greatest partial energy productivity was achieved around 1965, and productivity has been decreasing since then (Figure 3). While utilizing this definition of efficiency does not determine whether traditional or mechanized agriculture is more efficient, it does provide a first indication of the level of inefficiency in the present system.

The debate over energy efficiency: the evidence

Bearing conflicting ideologies and definitions of energy efficiency in mind, it is possible to compare the results of case studies of energy use in both traditional and mechanized farming. Much of this research has concentrated on farm scale; that is, on the question of whether small or large scale farms are more efficient.

The results of these studies indicate the paradoxical nature of energy efficiency. Studies by Pimentel and Pimentel (1979) show that small farms in peasant societies are invariably more efficient than larger ones in the industrialized world.

Figure 3: Farm output as a function of energy input to the U.S. food system, 1920-70. (After Fluck and Baird, 1980)



Small farms in North America, on the other hand, have repeatedly proven less efficient than larger ones (Johnson et al., 1977; Tweeten, 1983; Buttel and Larson, 1979). In part, such discrepancies are the result of comparing output-input studies of peasant agriculture with studies of industrial agriculture measuring efficiency in dollar terms. Such difficulties are complicated by the fact that many of the dollar-based studies do not distinguish between farms, except on the basis of scale, and compare farms growing grain crops with farms on the urban-rural fringe. Work by Heaton and Brown (1982), and Buttel and Larson (1977) are particularly good examples of such inappropriate comparisons. The dangers of ignoring spatial variation in energy efficiency studies will be discussed later.

The work of Johnson et al. (1977) used output-input analysis to demonstrate that larger farms were consistently more efficient than smaller ones. This conclusion held only when all the farms under comparison grew the same crops, in the same geographical area, using machinery intensive technology. Since this study was done using thermodynamic measures, its results can be directly compared with those of Pimentel and Pimentel (1979). Such a comparison indicates that small farms are indeed efficient in one location and society, but not in another. Optimum energy efficiency cannot therefore be obtained at a given scale of operation under all conditions. Rather, efficiency must be a function of either geographic variation, or the technology used on a given scale of operation, or both.

Further insight into the role of these factors is provided by a closer examination of the study by Johnson et al. (1977). This work contrasts energy efficient Amish farms with neighboring non-Amish operations in three areas of the United States. Invariably the small-scale Amish were more efficient (in output-input terms), although the competitiveness of their yields differed over the three study sites. Small scale non-Amish farms in the study consistently proved less efficient than larger non-Amish farms. The non-Amish farms, regardless of size, shared a highly industrialized technology. The Amish, on the other hand, utilized a great deal of animate energy in the form of draught animals, which were fed by grazing on the farm. Home heating needs, particularly among the Pennsylvania Amish, were fulfilled largely by wood heat, with the fuel taken from wood lots that were, again, located on the farm. Reliance on these renewable resources dictated a diversified, small-scale farm structure that was not only energy efficient, but cushioned these farmers from many of the economic pressures that afflicted their equally small-scale non-Amish neighbors. The authors note:

> "Amish conservation and its economic consequences also account for the prosperity and expansion of Amish agriculture, a striking factor in itself in this era of poverty-stricken small farms and larger commercial agriculture...Their simple technology has enabled the Amish to avoid the major causes of small farm poverty and bankruptcy, the difficulty of obtaining the capital to purchase modern agricultural machinery or the heavy debt payments required if it is obtained" (Johnson et al., 1977).

The efficacy of a diversified farming structure for conserving energy is confirmed elsewhere. Blobaum (1982), in a study of the Small Farm Energy Project, an attempt at increasing energy self-sufficiency, noted that mixed farms proved capable of saving much more energy than did monocultural operations.

A second point arising from Johnson et al. (1977) concerns the ability of diversified Amish operations to maintain yields. The suitability of their technology to local physical conditions is of paramount importance. The Pennsylvania Amish achieve higher yields than their non-Amish counterparts, while the Illinois Amish do not:

> "The differences between the two sets of results probably stem from the differences between the two environments. The diversity of Central Pennsylvania, with its long narrow valleys, steep wooded hills, and marginal pasture, can be used efficiently by the Amish while the uniformly good soil of Illinois is ideal for modern technology" (Johnson et al., 1977).

Lockeretz et al. (1981) in a study of organic farmers in the Corn Belt, confirmed the ability of energy saving operations to thrive under adverse conditions. This study demonstrated that energy efficient organic farms on the excellent soils of the mid-West achieved higher yields than conventional farms in years of bad weather, and lower yields when good weather prevailed. These site and weather dependent yield variations are in part explained by the nature of the high-yielding plant varieties generally used by mechanized farmers in North America. Schneider (1976) pointed out that while under good conditions these varieties generally produced higher yields, conventional varieties, on average, suffered less variability when subjected to environmental stress.

The energy efficient farms studied by Blobaum (1982), Lockeretz et al. (1981) and Johnson et al. (1977) have several features in common. They share a diversified, highly self-sufficient structure, and an ability to achieve above average yields on relatively poor soil or under poor conditions. These characteristics indicate that energy efficiency can be most successively practiced when the economic emphasis is on risk-aversion. Dependence on expensive inputs, such as fertilizer, pesticides and machinery, increases the risk of small farm bankruptcy. At the same time, the success of energy intensive operations is reliant upon good climatic and soil conditions to optimize yields. At the margin of production, a diversified, non-energy intensive farming structure minimizes the risks of crop failure and bankruptcy.

Traditional peasant farming, which possesses these same attributes of diversity and self-sufficiency, similarly avoids the dangers of crop failure and bankruptcy. Peasant farms, too, experience a relatively high average yield, but a relatively low maximum yield. Indeed, it was this risk-averting outlook that made many farmers averse to adopting the expensive, energy-intensive techniques of the Green Revolution (Dahlberg, 1979). Thus a connecting link exists between energy efficient operations in various cultures, in the form of a shared economic perspective on the optimum use of the land. For farmers on the margin of production, the perceived risks of crop failure and bankruptcy may be greater than the benefits of increased yields and labour productivity resulting from reliance on fertilizers, pesticides and machinery.

Risk-aversion may well represent an appropriate framework for research on energy efficient farming technology in a North American context. One possible application of a risk aversion perspective could be the use of game theory to derive energy efficient strategies. Qualitatively, awareness of risk aversion strategies could be useful in formulating research questions or might aid in the interpretation of data.

Care should be taken that risk-aversion is not associated with a set of specific production techniques that can be rigidly applied to any and all situations, regardless of their suitablity. Johnson et al.'s (1977) study of the Amish illustrates the marginal nature of profit-maximizing techniques when they are applied to the rugged landscape of central Pennsylvania. Equally, it demonstrates the disadvantages of using diversified Amish techniques on the level, uniform soils of the Midwest.

Clearly, if they are to be successful, energy efficient farming methods must be suited to the environment to which they are applied. This environment is not simply physical in nature. DeSouza and Foust postulate that the pattern of rural land use is a function of four considerations: site, situation, cultural preferences and perception, and the system of agricultural production (deSouza and Foust, 1979). The compatability of the last with the first three is crucial. Site, as mentioned above, and situation are both important determinants of the competitiveness of differing agricultural techniques. Cultural preferences and perception, which have received little attention in the literature, are the key to whether agricultural innovations are adopted or rejected. As Blobaum (1982) points out, the important question is not to determine the level of energy efficiency that can be achieved under ideal conditions, but rather to discover what actual farmers will do to save energy when offered technical assistance.

Searching for an efficient method on a local scale: the subject of the thesis

Conflicting evidence within the literature indicates that there is no uniquely efficient production method that is universally applicable. Efficiency is a function of the farmer's strategy for dealing with his environment. If that strategy is appropriate to the site and situation, then the farm will probably be efficient. Generally speaking, a strategy of risk aversion appears to be more efficient on the margin of production.

The framework of the thesis is derived from these observations. It is hypothesized that when site and situation are uniform, there is a unique, energy efficient production method which is most appropriate to that environment. That method may not necessarily be appropriate to any other site, situation, or culture. Research methodology of the thesis is outlined in the next chapter.

CHAPTER 3: RESEARCH METHODOLOGY

The nature of agricultural production

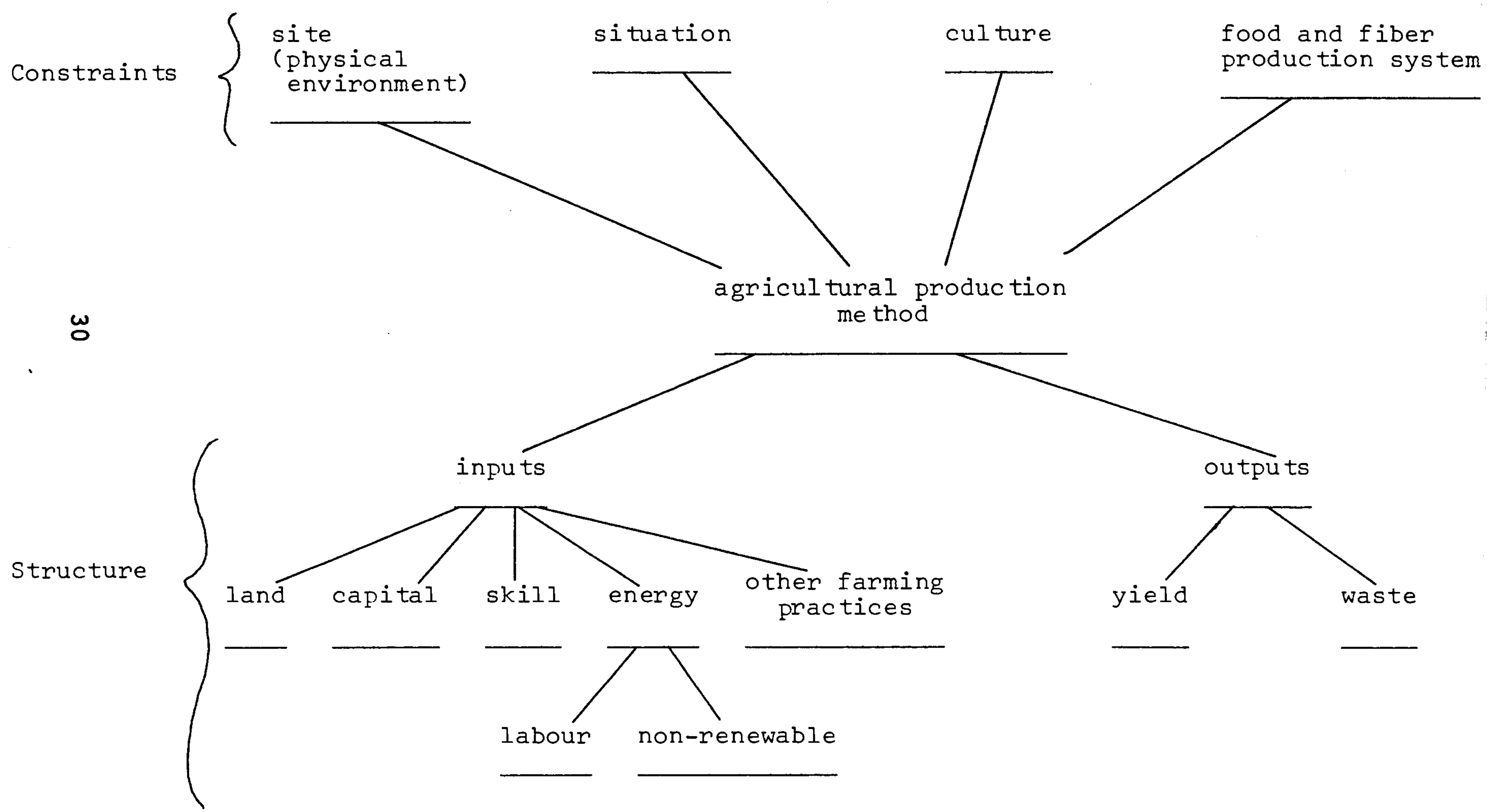
Research on the role of energy in agriculture has been characterized by a failure to consider the impact of geographic variation on the nature of agricultural production methods. This failure can be traced back to the definition of agricultural production. By expanding on the conventional conceptualization of production, it will be possible to restate the problem of deriving energy efficient strategies in a way that will take geographic variation into account.

The production method is a strategy chosen by the farmer. This strategy comprises certain combinations of inputs which are chosen by the farmer, and are used to produce a yield of food or fiber and a certain amount of waste. These inputs are land, energy, capital, skill and other farming practices (Figure 4). Energy can be subdivided into labour and non-renewable energy. Radiant energy is not included, as it is assumed that the farmer has little or no control over this input. The farmer can choose to maximize or minimize returns on any of these inputs.

In choosing his production strategy, the farmer is constrained by four factors:

1. the physical environment, or site;
2. the relative location of the farm, or situation;
3. his culture, or those methods of agricultural production which have been acquired through contact with peer groups; and

Figure 4: Constraints upon and structure of the agricultural production method



4. his role as a provider of raw materials for the system of food and fiber production (Figure 4).

Each of these factors places limitations upon the farmer. The physical environment limits his choice of crop to what will grow upon the land. His relative location restricts him to crops that can be profitably produced and transported to market. His culture limits both his choice of crops and the means he will use to produce those crops. His role as the first link in the food and fiber production system encourages him to produce cheap, abundant food for the urban market.

These constraints are not mutually exclusive. The need to produce competitively priced food can lead to specialized production of those crops best suited to the physical environment. A farm's relative location is a function of the pattern of food and fiber processing, distribution and consumption. Changing systems of food and fiber processing can, over time, affect the cultural perceptions of the farmer. And culture influences not only the farmer, but the consumer as well, thus influencing the demand for certain types of produce.

The farmer's choice of production method is a compromise among the constraints placed upon him by these four factors. The conventional North American production strategy emphasizes specialized, capital-intensive crop production for national and world markets. In a time of low petroleum prices, such a production method is economically rational. Areas can specialize in crops well suited to the local environment, and labour costs are minimized. Transport costs are low, and soil nutrient depletion and crop damage can be minimized through the use of hydrocarbon based fertilizers and pesticides.

The higher cost of non-renewable energy, however, coupled with the increasing awareness of environmental and social costs outlined in the last chapter, suggests the need for an alternative approach. This implies a strategy of maximizing returns on non-renewable energy, and concommitantly, a change in the use of other inputs to the agricultural production system. In making such a change, the farmer is engaged in establishing a new compromise among the constraints placed upon him by site, situation, culture and the food and fiber production system.

Most researchers have recognized only the last of these constraints on the decision making process. For example, a comparison of energy efficiency in corn production in Colombia and in the midwestern United States ignores variation in site, situation and culture (Pimentel and Pimentel, 1979). Only the role of the farmer as a producer of corn is the same for both locations. The result of such research is that the influence of site, situation and culture upon the characteristics of an energy efficient production method is poorly understood.

This thesis is a preliminary assessment of the role played by these factors. Evidence for this assessment is drawn from a study of lettuce production in the Greater Vancouver Census Division. The study seeks to identify efficient farming operations, and to determine combinations of factor inputs that are characteristic of those operations. It is hypothesized that a unique energy efficient strategy will be found if, and only if, site and situation are constant throughout the study area. It is further suggested that farmers in the area will practice a given production method only if it is culturally acceptable to them.

Defining the variables

The study has two objectives. The first is to isolate an energy efficient production method, and the second is to determine the relative importance of site and situation in affecting the combination of inputs to that method. To accomplish these objectives it is necessary to define energy efficiency, as well as the inputs to the production method.

The inputs to the production method have already been listed. They are land, capital, labour, non-renewable energy, skill and other farming practices. Energy efficiency is defined as:

$$\text{energy efficiency} = \text{yield} / \text{non-renewable energy input} \quad (1)$$

There are by definition three ways to maximize energy efficiency: to minimize energy use, to maximize yield, or to do both.

Quantifying the variables

The variables defined in the preceding section can be used to describe the production of any crop, in any location. In quantifying these variables, however, it is necessary to take into account the specific nature of lettuce production in the GVCD. The quantified variables, therefore, are unique to the crop under discussion (Table 1). Non-renewable energy is here defined as dollars expended on non-renewable energy inputs, while yield is quantified as cartons harvested per crop per hectare (hitherto referred to as crop hectare) multiplied by the price per carton. Energy efficiency is, therefore, dimensionless, but with a bias toward economic, rather than energetic or output-input, definitions of efficiency. This bias reflects two facts. First, farmers in this area produce for profit, not subsistence. Second, lettuce is a crop having both nutritional and economic value, in spite of its low energy content.

Non-renewable energy inputs are defined as fertilizer, fuel, pesticides and herbicides, other chemicals and electricity. The majority of electricity in British Columbia is produced by hydroelectric projects, and electricity is actually a renewable energy input. For the purposes of this study, however, energy use is calculated by adding expenditures on both hydrocarbons and hydroelectricity. Total expenditures on non-renewable energy are calculated by adding expenditures on these inputs. These variables are also considered as independent

Table 1: Relationships between the inputs and outputs of the agricultural production method and the variables used in the thesis.

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energy efficiency = (yield x price) / $ expended on non-renewable energy

yield = cartons crop ha^{-1}

non-renewable energy inputs	[a]fertilizer = kg N crop ha^{-1}
	fuel = $ crop ha^{-1}
	electricity = $ crop ha^{-1}
	[b]machinery = MJ crop ha^{-1}
	pesticides and herbicides = $ crop ha^{-1}
	other chemicals = $ crop ha^{-1}
land	farm size = ha of cropland
	lettuce area = crop ha

labour = person-hours crop ha^{-1}

skill	age = years
	experience = years
	education = (1)none; (2)primary; (3)secondary; (4)technical; (5)university
other farming practices	greenhouse = (1)yes; (2)no
	irrigation = % lettuce area
	crops = # $year^{-1}$
	managerial hours = hours crop ha^{-1}
	bedwidth or cultivation pattern = (1)continuous; (2) 0.75-1.4 m; (3)1.5-1.85 m

[a]measured in $ crop ha^{-1} in determining $ expended on non-renewable energy.

[b]not used in determination of $ expended on non-renewable energy. Equal to the sum of fuel and electricity.

inputs to the production process. Fuel, electricity, pesticides and herbicides and other chemical inputs are all quantified in terms of dollars expended per crop ha, while fertilizer use is evaluated as kilograms of nitrogen per crop ha. Fertilizer is quantified as kilograms of nitrogen because the price of fertilizer varies, depending upon the quantity of potassium, phosphate and fillers it contains. In addition, the variable machinery aggregates fuel and electricity use in terms of MJ per crop ha. This variable is useful in that it summarizes the amount of energy which is used as a substitute for labour, as opposed to energy such as fertilizer and chemicals which is used to overcome limitations posed by the physical environment.

Input of land is subdivided into two variables: total farm size in hectares of cropland, and crop hectares in lettuce. This division emphasizes that not all farmers maintain the same portion of their land in lettuce. Quantifying lettuce area in terms of crop hectares indicates the intensity of production. A farmer growing two crops per hectare per year has twice as many crop hectares as a grower producing only one crop on the same land area. Labour is evaluated as person-hours per crop hectare, both paid and unpaid. Skill is subdivided into three variables: the age of the farmer, years engaged in farming and education. Education is rated on a scale of 1 to 5, 1 indicating none; 2, primary; 3, secondary; 4, technical school; 5, university. Other farming practices is an umbrella term for five variables: presence or absence of a greenhouse, percentage of lettuce area irrigated, number of crops per year, manager hours per crop hectare, and bedwidth or cultivation pattern. The variable manager hours duplicates some information included in the labour variable, but allows insight into the ratio of management to labour and of management to land. The variable bedwidth or cultivation pattern takes one of three values: 1, no division into beds or a continuous cultivation pattern; 2, a bedwidth of 0.75-1.40 m, or a narrow cultivation pattern; 3, a bedwidth of 1.5-1.85 m, or a wide cultivation pattern.

Capital is not included as a quantified variable in the study. This omission is a function of the reluctance of farmers to discuss financial issues. While it is understood that this omission imparts an obvious limitation to the study, the levels of energy investment present in fixed capital on any given farm are reflected in variables such as use of greenhouse, bedwidth, farm size, lettuce area, fuel and machinery. These variables do not take interest rates or depreciation into account. Thus it should be noted that the results of this research are concerned with production efficiency, rather than overall operating efficiency.

Analytical techniques

Initial attempts at multivariate analysis failed, due to the small size of the sample. Subsequent attempts relied on bivariate analysis. Qualitative assessment of the data indicated the presence of two differing production methods, one large scale and one small. The sample was then stratified according to size and energy efficiency, and comparisons were made of the levels and combinations of inputs associated with the resulting subgroups. The details of this process, along with a description of the study area and the results of the analysis, are found in the next chapter.

CHAPTER 4: ANALYSIS

Study area and data collection

The Greater Vancouver Census Division is located in the Lower Mainland of British Columbia. It consists of six census subdivisions, Burnaby, Delta, North Vancouver, Richmond, Surrey and Vancouver. Of 1407 farms in the GVCD, there were 82 producing lettuce in 1981 (Statistics Canada, 1982). Table 2 illustrates the diverse scale of market gardening in the GVCD.

On average, vegetable growers in Burnaby and Vancouver produce less than 2 ha of vegetables, those in Richmond and Surrey between 5 and 10 ha, and those in Delta grow just under 25 ha. The distribution of lettuce production is heterogeneous, and bears little resemblance to the overall distribution of market gardening. The greatest concentrations of lettuce farms are found in Surrey and Burnaby, with little production taking place in the other three census subdivisions. This distribution was reflected in the pattern of response to the questionnaire used to collect data for the study. Data were collected for the 1983 growing season. A copy of the questionnaire may be found in Appendix I.

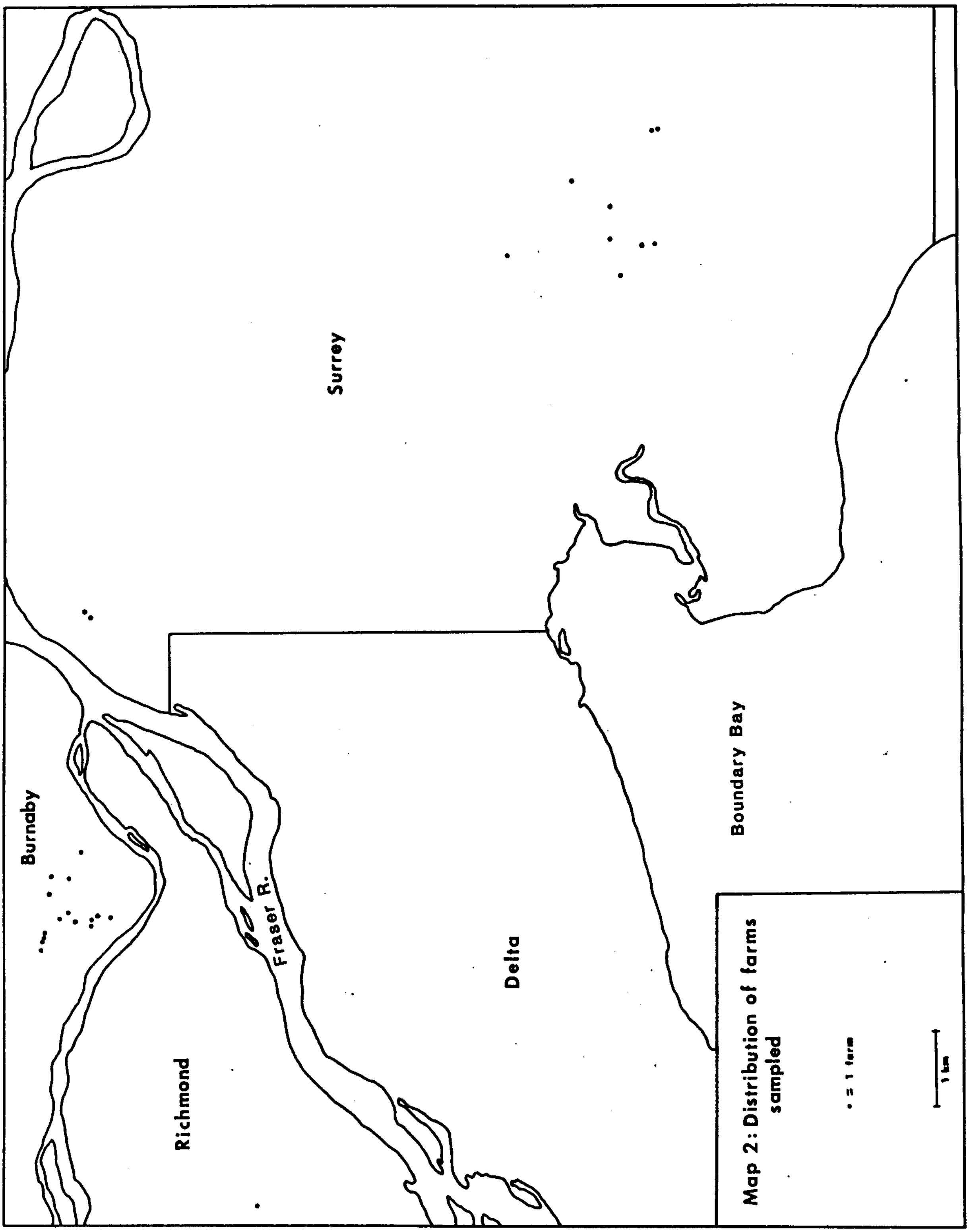
Of the 82 growers listed in the census, it was only possible to obtain the names of 61, as the Ministry of Agriculture considered this information confidential. None of the 61 was located in Delta. Although Delta farms account for over half the entire area in vegetables in the GVCD, lettuce accounts for only 3.5 ha of the 1374 ha in vegetables there. The

Table 2: Distribution of lettuce production and total vegetable production in the GVCD, 1981. (Source: Statistics Canada, 1982)

Area	Number of farms	Number of farms with vegetables	Vegetable area (ha)	Number of farms with lettuce	Lettuce area (ha)
Greater Vancouver	1407	225	2376.1	82	235.0
Surrey	842	84	676.2	36	212.9
Delta	209	57	1374.0	4	3.5
Richmond	273	44	251.0	10	4.3
Burnaby	46	35	66.9	28	12.6
North Vancouver	13	0	0.0	0	0.0

absence of data from Delta, therefore, was not considered a limitation. Names were provided by the Cloverdale Lettuce Cooperative and the B.C. Lower Mainland Farmers Cooperative Association. The 61 farmers were all contacted, but questionnaires were completed by only 31. The remaining 30 refused to be interviewed, had gone out of business, were unable to answer the questions, or did not speak English. Four of the 31 farms surveyed were removed from the sample due to inconsistencies between the farmer's stated pesticide costs and his stated rate of application. Farmers generally were aware of the amount of pesticide they utilized on a crop by crop basis, while their knowledge of other input levels often was restricted to the scale of the farm as a whole. Estimates of pesticide costs and rates of application, therefore, functioned as an internal check on the consistency of a farmer's response. Thus, the final sample consisted of 27 cases, 15 located in Burnaby, 11 in Surrey, and 1 in Richmond (Map 2). While this sample represents only one-third of the total population, its distribution is geographically representative of the entire population of lettuce growing operations.

Atmospheric and site data indicate that, with the exception of the farm in Richmond, the site characteristics of the farms sampled are sufficiently similar to be considered uniform within the framework of this study. The average number of frost free days over the period 1951-1980 varied from approximately 200 in the Surrey and Richmond areas, to 235 in South Burnaby. There



Map 2: Distribution of farms sampled

were approximately 1950 degree days, measured on a base of 5 degrees centigrade, in Richmond and Surrey, and 2100 in Burnaby. Annual precipitation ranged from roughly 1400 mm in Surrey to 1600 mm in Burnaby, with a lower rate of approximately 1000 mm in Richmond. In all areas, the greatest amounts of precipitation were received during the winter, before and after the growing season (Atmospheric Environment Service, 1981).

None of the farms was located on land higher than five to ten meters, and slope was less than 4% on all of the farms. Canada Land Inventory (CLI) classifications were similarly homogeneous, with all farms falling into class 4 or 5, indicating a low capability for agriculture (Ministry of the Environment, 1984). The low rating is attributable to high levels of undecomposed organic matter. There are obviously greater micro-scale variations in soil capability than are indicated by the CLI ratings, but it should be remembered that the CLI was developed for regional planning purposes, and is not accurate below a scale of 1:125,000 (Mitchell and Sewell, 1981). In the sense that they differentiate the agricultural capability of the study area from that of land elsewhere in Canada, these ratings are suitable for present purposes.

Differences in ethnic makeup and the level of urban anticipation indicate that situation is not constant within the study area. Almost all of the farmers in Burnaby are first-generation Chinese immigrants, and many speak little or no English. This language difficulty severely limits communication between growers and extension agents from the Ministry of Agriculture. Communication is also limited because some extension agents do not really consider the Burnaby operations to be farms, since they generally produce less than one ha of lettuce, and are characterized by labour intensive production methods. While there are a number of Chinese producers in Surrey, most of these farm on a relatively large scale, and are in more frequent contact with extension agents.

Farming in Burnaby may have a relatively limited future. Twenty-eight of the thirty-five vegetable operations there are located in the Big Bend area of South Burnaby. Of these, eighteen are in Agricultural Land Reserve (ALR). While the majority of these are freehold, one farm is located on a municipal lease, and farmers hold 2 1/2 additional ha in municipal lease and just over 3 ha in municipal allotment gardens. One farm is located on land zoned for heavy industry. McSkimming and Jones (1981), in a study of the area, state that the municipality seems to be holding land in the ALR only to keep assessment values down and to prevent piecemeal development. Thus the ALR designation is not intended to prevent development in Big Bend, but rather to give the municipality control over the development process. In the future an area which includes thirteen of the twenty-eight Big Bend farms will likely be developed for industry.

The transitional nature of agriculture in this heavily Chinese area was further confirmed in conversation with Doug Mah (personal communication), whose father grows lettuce in Surrey. In an interview he stated that many Chinese growers, in Surrey as well as Burnaby, came to Canada principally for the purpose of sending their children through the school system, including university. A university degree, they feel, will greatly increase their childrens' chances for social mobility if they return home to Hong Kong or Taiwan.

These differences in situation are reflected in variations in scale, choice of crop varieties, and marketing patterns between Burnaby and Surrey. There is an enormous disparity in scale between Burnaby and Surrey. Lettuce farms in Burnaby produce on less than one ha on average, a proportion shared by operations in Richmond, Delta and Vancouver. In Surrey, on the other hand, the average is over 5 ha. The farms in Burnaby can best be described as market gardens, with lettuce as one of the principle crops. Agriculture in Surrey is more appropriately described as mixed farming; several farmers interviewed grow potatoes as the primary crop, with smaller areas in green vegetables.

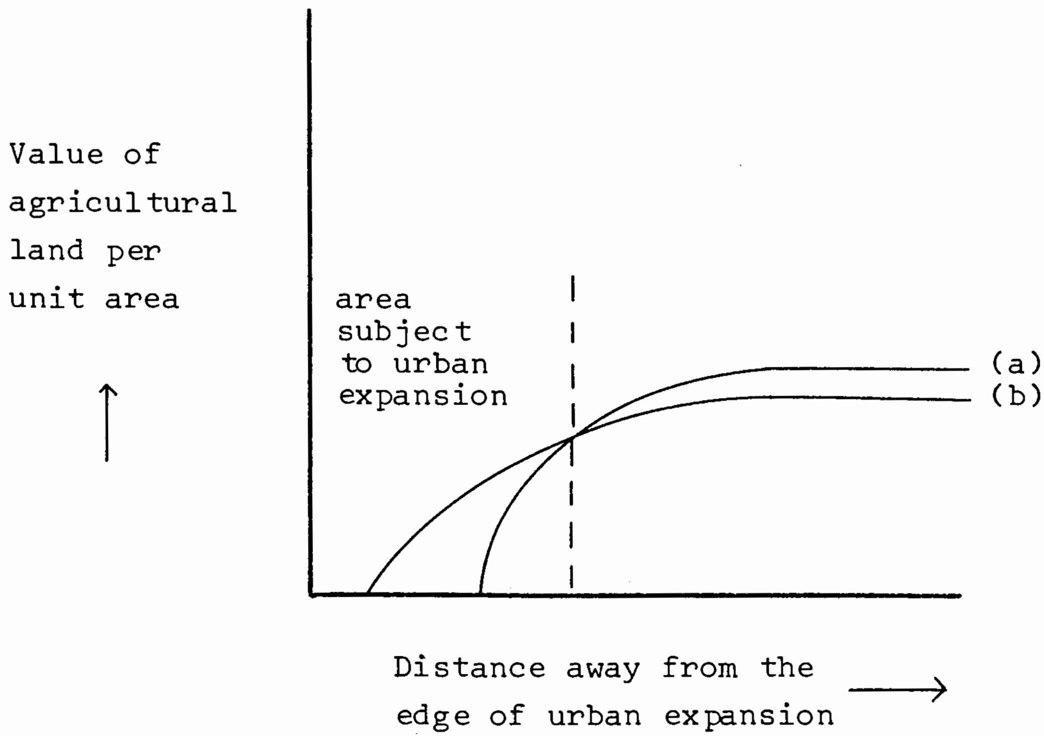
The dichotomy between Burnaby and Surrey is not simply restricted to differences in scale of production. Farms in Surrey primarily produce head lettuce, such as Iceberg. Those in Burnaby produce mostly leaf lettuce, such as Buttercrunch, Red and Romaine. This places farmers in Surrey in direct competition with California growers for the Vancouver market. Growers in Burnaby, however, face relatively little competition, except from one another. This difference is reflected in the marketing patterns of the two census subdivisions. Farmers in Surrey sell their product through the Cloverdale Lettuce Cooperative. Those in Burnaby depend largely on road-side stands and direct sales to Vancouver stores or to consumers through the Granville Island Public Market.

The marketing patterns of Burnaby growers cannot be imitated by the larger Surrey farmers. Legally, farmers are required to sell lettuce through the Cooperative, or directly to consumers. An exception is made in the case of of the Burnaby market gardeners, ostensibly because their marketing pattern predates creation of the Cooperative. This exception may be further attributed to two factors. First, only 5% of the area in lettuce in the GVCD is located in Burnaby, although 25% of the farms producing lettuce are there. A second factor may be the limited communication between Burnaby farmers and extension agents mentioned above.

The dichotomy between small scale market gardening in an area subject to urban expansion, and large scale mixed farming in a stable agricultural environment is not unusual. Sinclair (1967) and Bryant (1974) have both advanced the theory that the level of fixed costs or improvements in agricultural land diminishes with anticipation of urban expansion. This theory is a modification of Von Thunen's model of increasing improvements to agricultural land with increasing proximity to the market. Bryant and Sinclair both suggest that under the conditions described by Von Thunen, the expected pattern will prevail. With encroaching urbanization, and increasing uncertainty about the length of time left for agriculture, the pattern is broken. Figure 5 shows two types of land use, (a) and (b). Type (a) requires a higher level of fixed investment, and will normally provide a higher return than type (b). Under conditions of urban expansion, (b) will provide a lower annual return, but will avoid capital loss through urban conversion. This model provides an explanation of the structural differences between lettuce operations in Burnaby and in Surrey. The farmers of the Big Bend area can utilize labour intensive methods requiring minimal capital investment. Larger farmers in Surrey can substitute capital for labour without risking the loss of their investment to the process of urban conversion. Whether farmers in either area are actually conscious of the prospect of urbanization is not known, however. The farmers interviewed were not asked whether they anticipated urbanization of their property.

The major difficulty with the study was the quality of the raw data. Many farmers did not know the amount of energy they use on their lettuce crop, and estimates were made, based on the amount of on-farm energy use and the amount of land in lettuce. In some cases, fuel expenditures were estimated from the amount of fuel used and from the cost per litre of gas, as quoted from Central Oil Sales, Ltd., in Surrey. Fertilizer and pesticide costs were similarly approximated with price quotes from Coast Agri-Fertilizers, Agro-Chemical and Equipment, and Green Valley

Figure 5: Values of agricultural land under two land uses. Use (a) requires a higher fixed investment and under normal conditions yields a higher return per unit area than use (b). Use (b) provides a lower annual return, but minimizes the amount of fixed capital that could be lost through rural to urban land conversion. In areas subject to urban expansion, therefore, the value of agricultural land in use (b) is greater than that of land in use (a). (After Bryant, 1974)



Fertilizer and Chemical. Electricity costs were estimated with prices from B.C. Hydro. Rates of machinery use were calculated by converting rates of electricity and fuel use to megajoules, and adding them.

In some cases pesticide use was estimated by taking the number of applications stated by the farmer and multiplying it by the recommended rate of use, as provided by the companies named above and by the Ministry of Agriculture. This computation was made whenever a farmer did not know or failed to provide his rate of use. Additionally, this calculation was performed for every farm in order to provide an internal check between the farmer's statement of pesticide costs and his stated rate of application. While this provided a check on only one small component of the farmer's statement, it was the only check available on the accuracy of respondents' energy estimates. It was assumed that if this statement were inaccurate, then there might exist other errors. In all but four cases, the farmer's statement was confirmed. These four cases were those which were dropped from the original sample of 31 farmers. Other cases, with admittedly weak data, were retained because the data were consistent. No amount of manipulation could make inconsistent data usable, however, and these four cases each contained internal contradictions.

Relationships within the sample

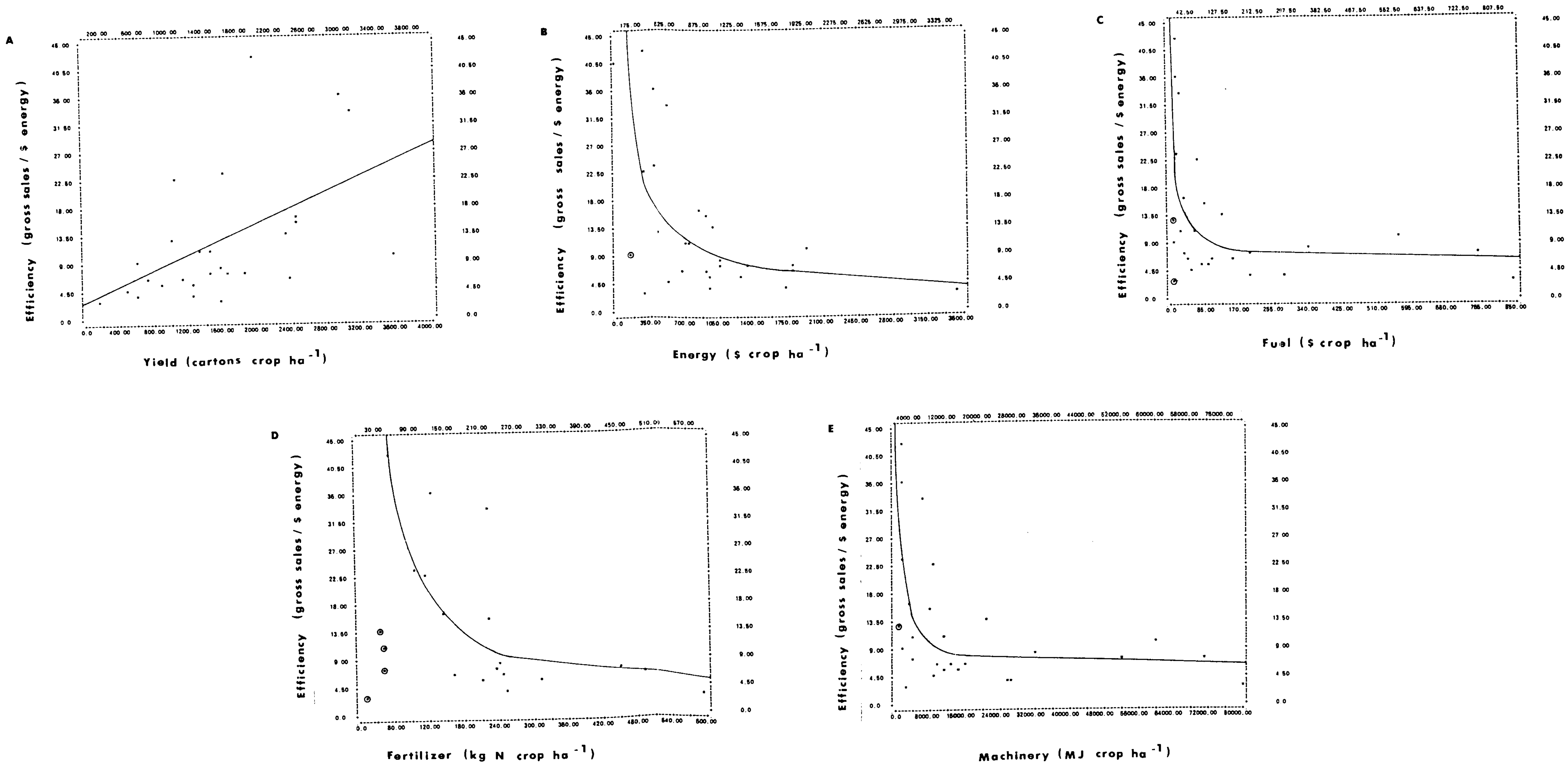
As stated in Chapter 3, energy efficiency is defined as energy expenditures divided by gross sales, and is assumed to be a function of the input variables. It is assumed that certain combinations of these inputs will be associated with certain levels of energy efficiency. Therefore the data analysis sought to answer two questions:

1. what relationships, if any, exist between energy efficiency, energy use and yield and the other inputs?
2. which inputs are substitutable and which are complementary? A substitutable input is one which can serve in place of another, while a complementary input is one which is utilized in conjunction with another. Inputs are considered to be substitutable if they have an inverse relationship, and complementary if they have a positive relationship.

Answers to these questions are based on simple regression of every variable against every other variable, and on examinations of input levels, their means, ranges and extremes. The results of the regressions are found in Appendix II, while information on input levels is contained in Appendix III.

Figure 6 shows scatter plots of energy efficiency against yield and energy inputs. These variables are related to efficiency by definition, and are the only variables that show any consistent relationship with efficiency. Efficiency is directly related to yield, and to the reciprocal of energy, i.e. it is inversely related to energy. The latter relationship is

Figure 6: Regression of energy efficiency on yield, energy use, fuel, fertilizer and machinery. These variables are related to efficiency by definition, and are the only variables that show any consistent relationship with efficiency. If the observations circled in Figures B-F are excluded, the relationships shown in those figures may be described by curves of the form $y = a + bx^{-1}$. Intercepts, beta values, correlation coefficients, error estimates and significance levels for these curves may be found in Appendix IV.



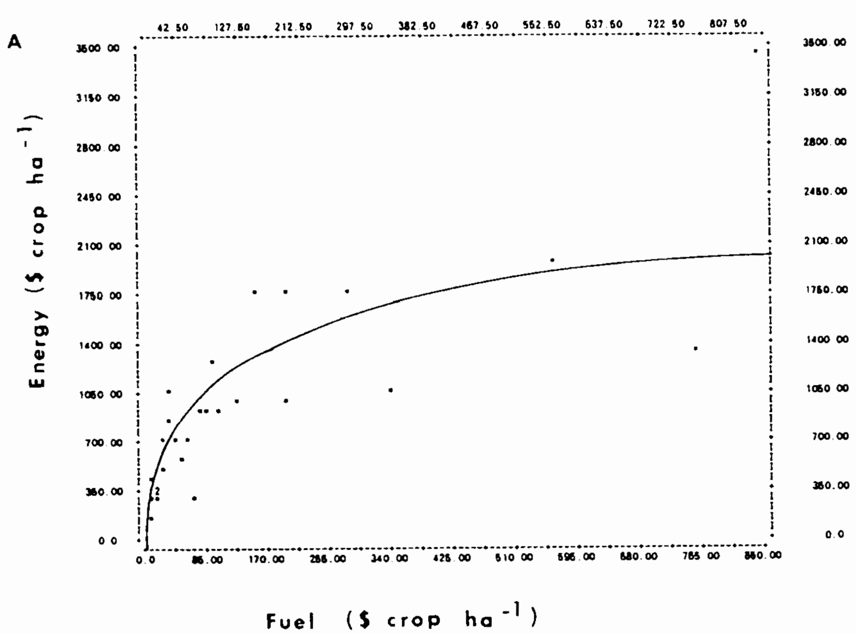
significant at the .05 confidence level only if certain observations (circled in Figures 6b-f) are excluded. These observations represent those few farms which are inefficient even while using a low level of energy inputs.

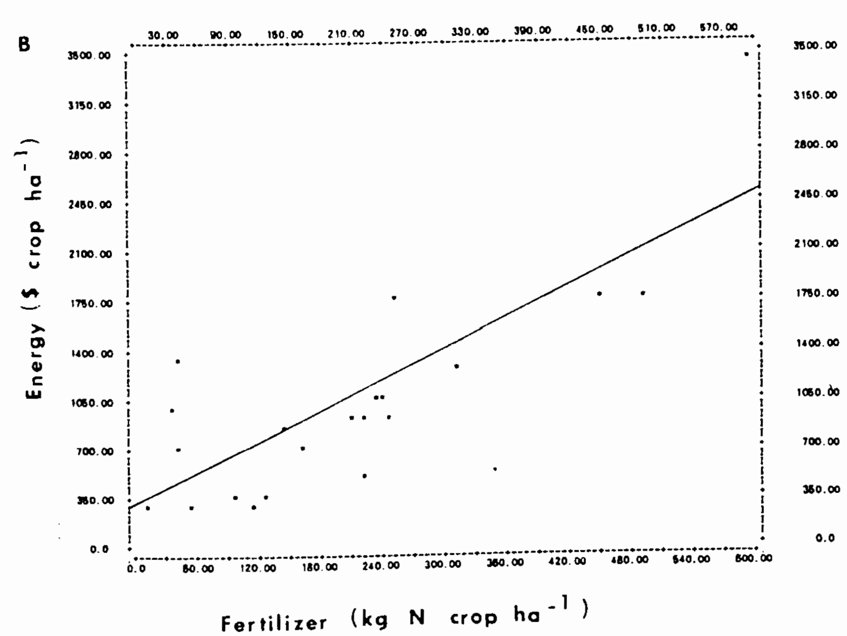
Energy use increases with increasing applications of fuel, fertilizer and machinery (Figure 7). Again, these relationships are not unexpected, as the inputs are related to energy by definition. What is significant is that these are the only variables which correlate with energy use at the .05 confidence level.

Table 3 shows differing proportions spent on fuel, fertilizer and pesticides for the total sample, and for subgroups which will be defined later in the chapter. For the total sample, fertilizer accounts for the majority of energy expenditures, with fuel and pesticide use making up most of the remainder.

Figure 8 shows the relationship of land, defined by the two variables farm size and lettuce area, to labour, management and number of crops per year. When the area under cultivation is small, farmers appear to have a great deal of choice in their level of inputs. On larger operations, farmers seem constrained to extensive use of both land and labour. As the amount of land under cultivation increases, fewer crops per year are grown, and the amount of time put in by both labourers and managers decreases rapidly. It can be concluded that after a certain size is achieved, large inputs of land act as a substitute for

Figure 7: Regression of energy use on fuel, fertilizer and machinery. These variables are related to energy by definition, and are the only variables that show any consistent relationship with energy. The curves superimposed on Figures A and C are of the form y = a + b(ln x). Intercepts, beta values, correlation coefficients, error estimates and significance levels for these curves may be found in Appendix IV.





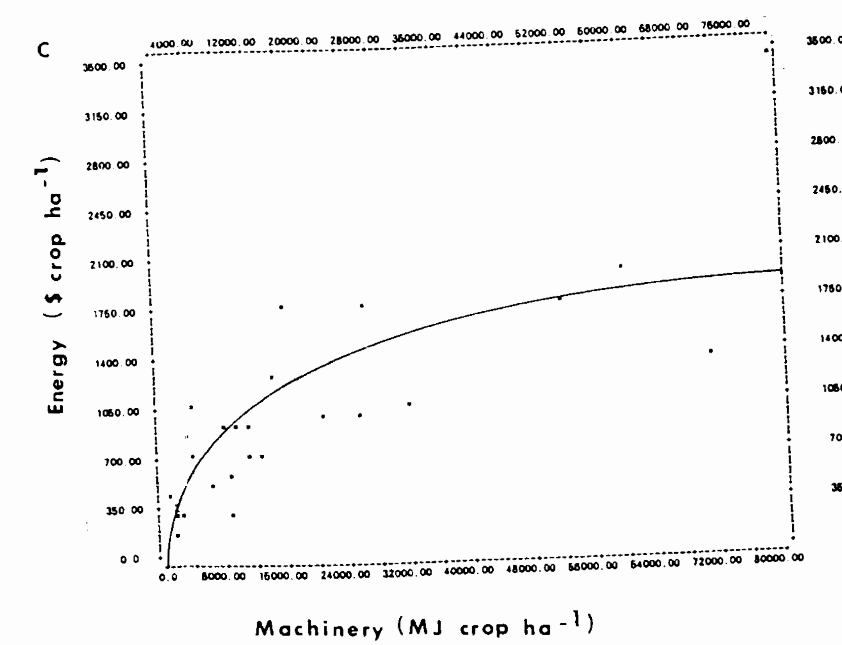


Table 3: Mean fuel, fertilizer and pesticide expenditures as a percentage of mean total energy expenditures

	Total sample	Group A	Group B	Group 1	Group 2	Group 2a	Group 3
Fuel	16%	18%	5%	8%	15%	21%	18%
Fertilizer	64%	67%	49%	74%	61%	69%	65%
Pesticide	16%	12%	44%	12%	24%	10%	13%

Figure 8: Regressions of farm size and lettuce area on labour, managerial hours and crops per year. This figure shows that large inputs of land act as a substitute for intensive use of labour and land. The curves superimposed on Figures A-B and D-E are of the form $y = ae^{b/x}$. Intercepts, beta values, correlation coefficients, error estimates and significance levels for these curves may be found in Appendix IV.

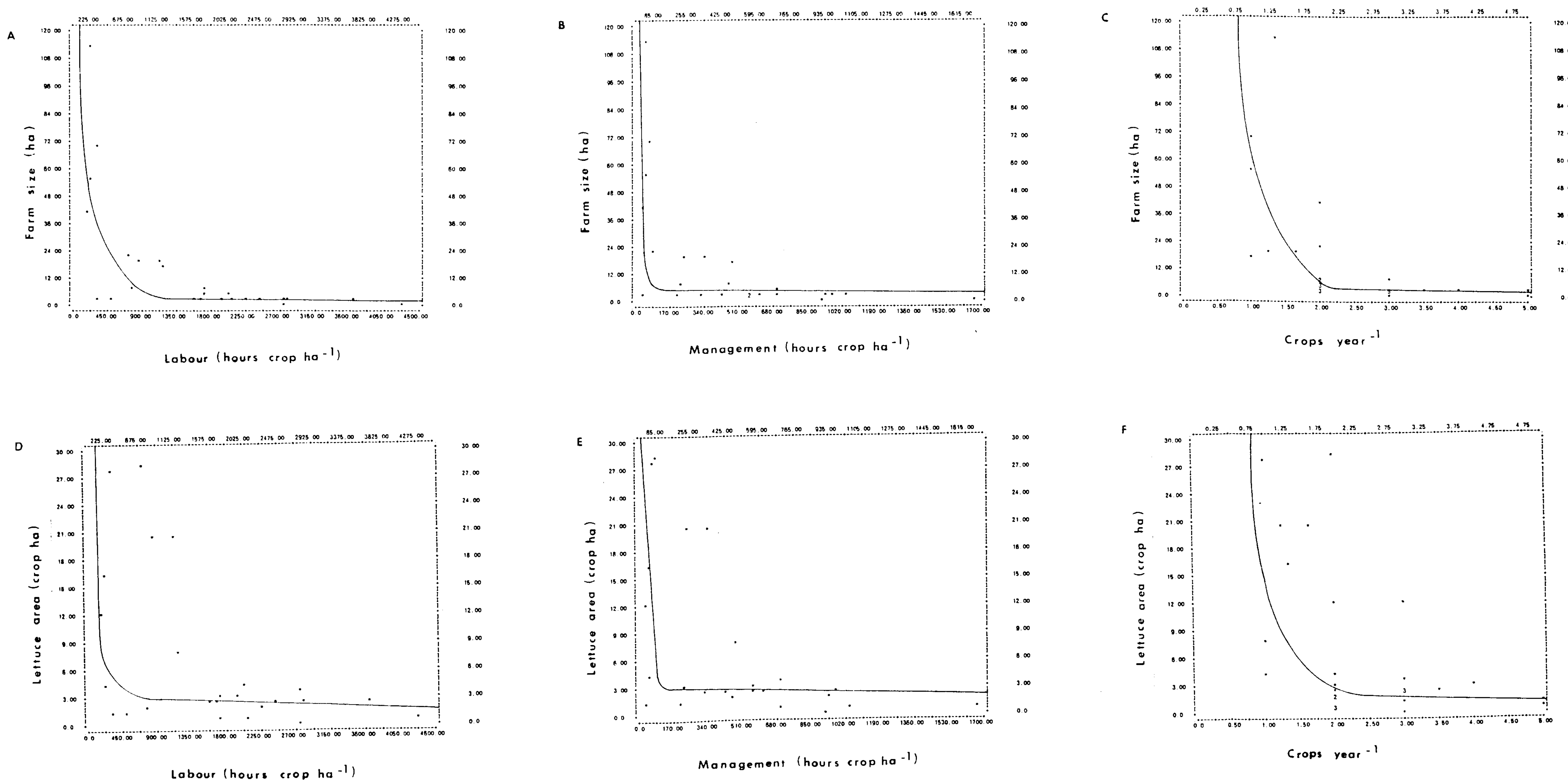
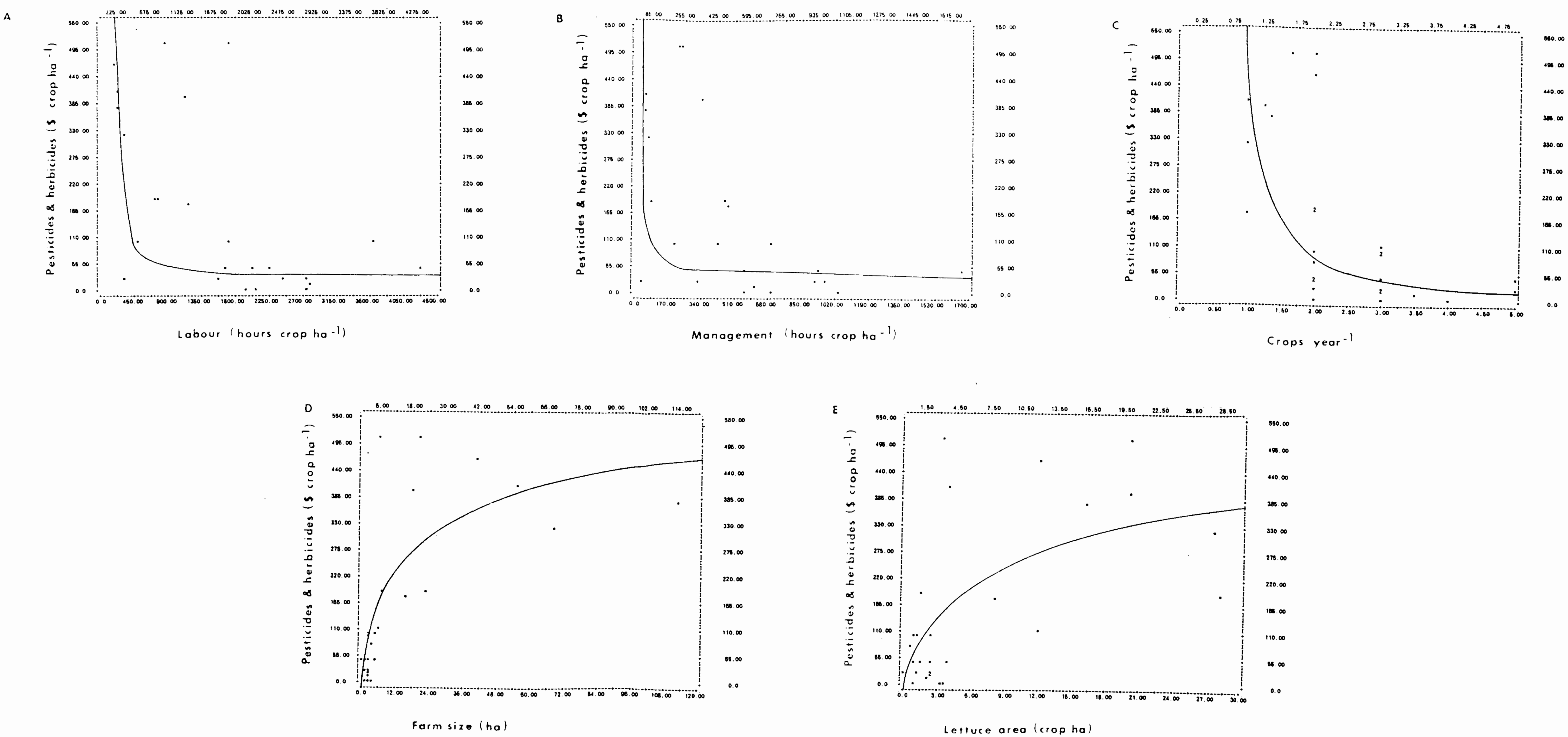


Figure 9: Regression of pesticide and herbicide use on labour, managerial hours, crops per year, farm size and lettuce area. This figure shows that intensive use of pesticides and herbicides acts as a substitute for intensive use of labour and land; and as a complement for large inputs of land. The curves superimposed on Figures A-C are of the form $y = ae^{b/x}$; the curves superimposed on Figures A-C are of the form $y = a + b(\ln x)$. Intercepts, beta values, correlation coefficients, error estimates and significance levels for these curves may be found in Appendix IV.



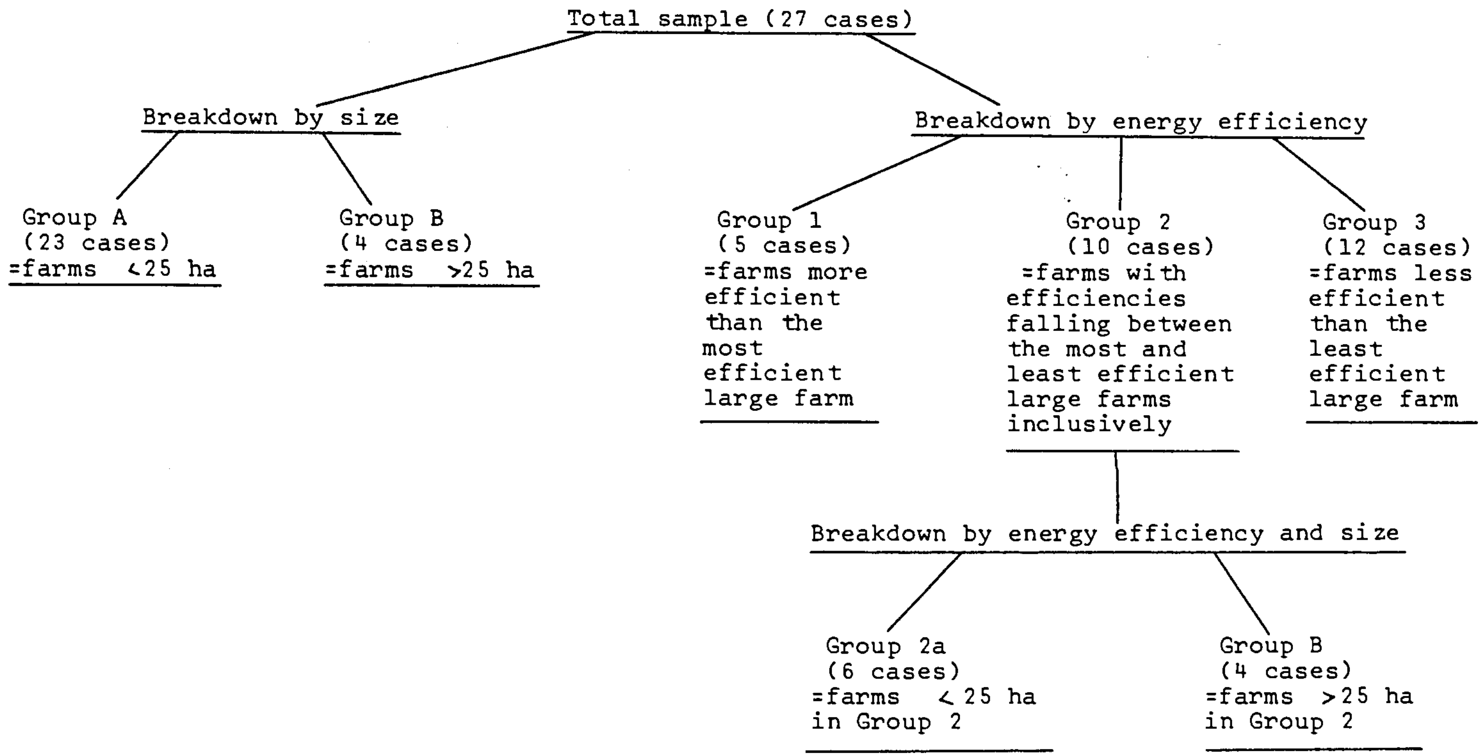
intensive use of both labour and land. Figures 9a-c show that past a certain threshold, pesticide also functions as a substitute for intensive use of land and labour. Intensive use of pesticides thus acts as a complement to extensive use of the land (Figures 9d-e)

The sample stratified by size

Since analysis of the sample as a whole provides no information about the nature of an energy efficient production method, it is necessary to break the sample into subgroups for further analysis. Figure 10 presents a schematic breakdown of the sample into subgroups. Results of the regressions for these subgroups, and information on input levels, are contained in Appendix II and Appendix III respectively. An initial stratification is based on size. Of the 27 farms sampled, 23 consist of 25 ha or less (Group A). The remaining four have a land base of 40 ha or more (Group B). The magnitude of this size difference indicates that the two groups constitute two distinct populations. Low labour and managerial inputs, a small number of crops per year, and high levels of pesticide use all confirm that the larger farmers utilize a different production method than do the remainder of those sampled.

A comparison of Groups A and B reveals these differences in production method. Mean levels of all energy inputs, except pesticides, are higher in Group A than in Group B, while yields are lower. Group B farms are therefore more energy efficient on

Figure 10: Schematic breakdown of the sample into subgroups



average than are the smaller farms (Appendix III).

Figures 11 and 12 show the same relationships illustrated in Figures 8 and 9, but with the data stratified by farm size. Figures 11d-f show that the majority of Group A farmers grow less than 10 ha of lettuce. The few farms that do grow more follow the general pattern of substitution described in Figures 8d-f. However, the distribution of Group A farms in the upper portions of Figures 11d-f falls to the right of the distribution of Group B farms. This indicates that the smaller farmers are slightly more intensive in their use of labour and land, even when the area in lettuce production is fairly large. Figures 12a-c show that the majority of small farmers spend less than $200 per crop ha on pesticides. Those few that do are, again, distributed slightly to the right of the larger farmers, and are thus more intensive in their use of labour and land. Figures 12d-e reiterate the tendency of small farmers to utilize small amounts of pesticide.

Figures 11 and 12 confirm that smaller farmers vary in the intensity with which they use labour and land, but are more likely to use these inputs intensively than are their larger neighbours. Larger farmers substitute land and pesticide for the more intensive methods of the market gardener. These farmers do not, therefore, obtain the highest yield per ha, but they do minimize expenditures on labour.

Figure 11: Regressions of farm size and lettuce area on labour, managerial hours and crops per year, showing the results of stratifying the sample by size. Large farms are those denoted by x.

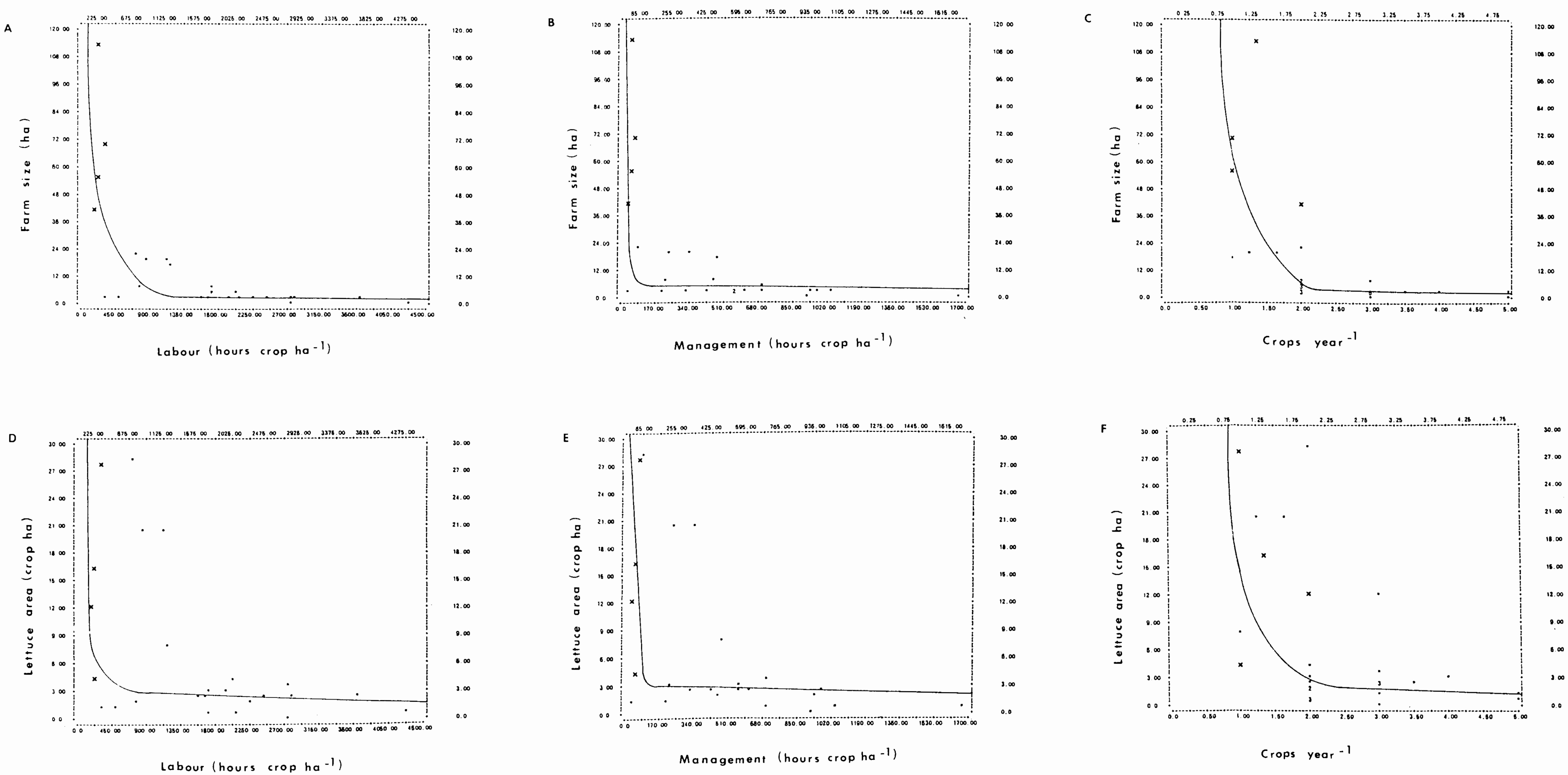
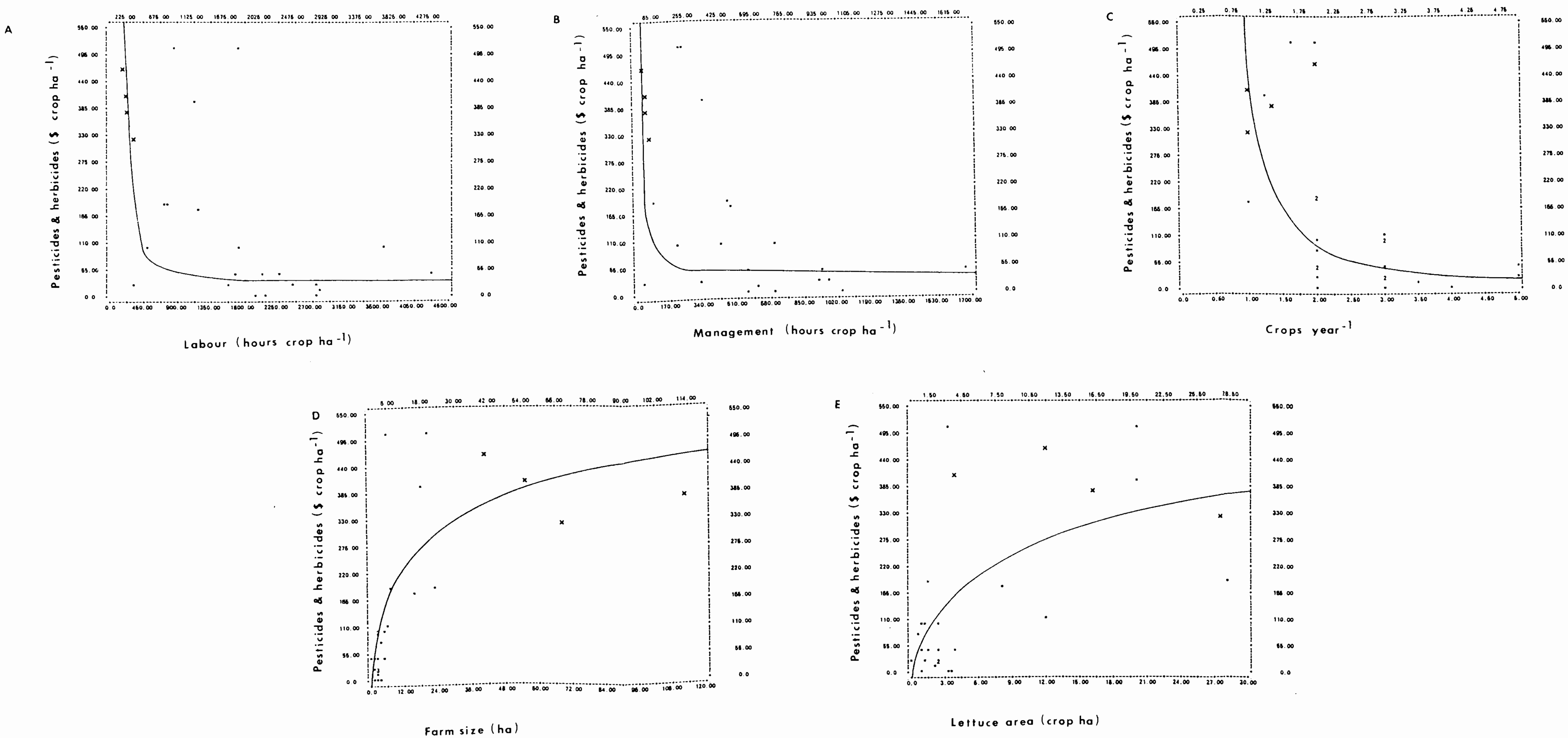


Figure 12: Regression of pesticide and herbicide use on labour, managerial hours, crops per year, farm size and lettuce area, showing the results of stratifying the sample by size. Large farms are those denoted by x.



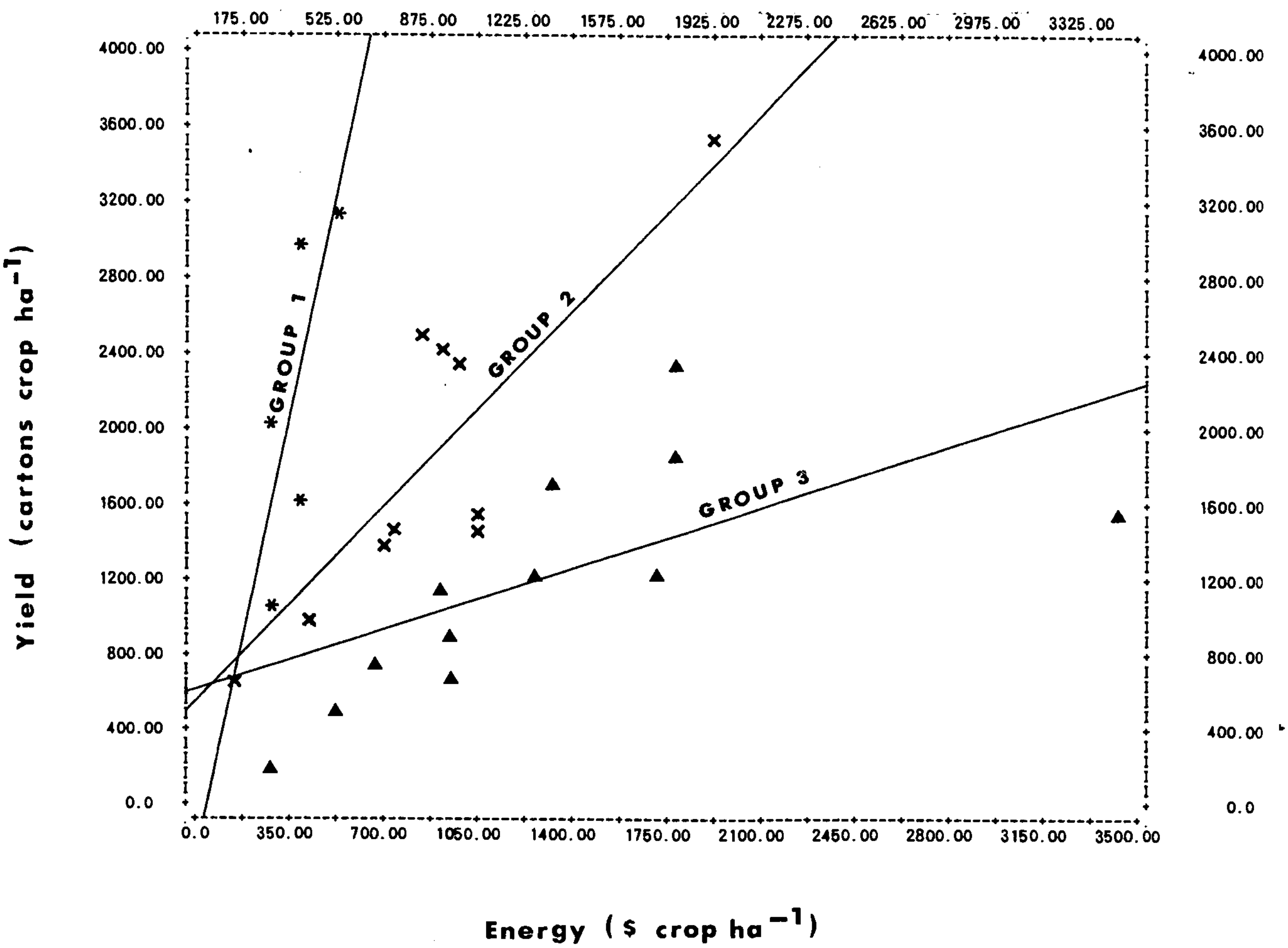
The sample stratified by energy use

Although Group A farms are less efficient on average than Group B farms, it does not necessarily follow that small farms are less efficient than larger ones. The difference in means is attributable to the fact that the four large farms of 40 ha or more are remarkably homogeneous in terms of their levels of energy efficiency: all four rank above average for the total sample. Among the smaller farms there was no consistency in efficiency ranking: the most and least efficient farms sampled were both less than 5 ha in size. Mean efficiency for Group A was 14.5%, with a standard deviation of 9.7%.

To understand the reason for the wide variation in small farm efficiencies, three subgroups were identified for further analysis. Group 1 consisted of those farms that were more efficient than the most efficient large farm; Group 2 consisted of those farms with efficiencies falling between the most and least efficient large farms, inclusively; Group 3 consisted of those farms less efficient than the least efficient large farm. These groups contained 5, 10 and 12 cases, respectively. This subdivision facilitates an understanding of any structural differences that might exist between efficient (Group 1) and inefficient (Group 3) small farms. Group 2, bounded by the relatively homogeneous large farms, contains those small farms which are neither very efficient nor very inefficient. Structural differences between large and small farms within Group 2 are discussed later in the chapter.

There are three ways to maximize energy efficiency: by maximizing yield, by minimizing energy use or both. A comparison of mean input levels for Groups 1,2 and 3 shows that efficient farmers both maximize yield and minimize energy use (Appendix III). The more efficient the group, the lower its use of all energy inputs. The only exception is inputs of pesticide and chemicals, where Group 2 consistently utilizes more than Groups 1 and 3. The more efficient groups also have higher yields. The efficient farmers are doing more with less. This pattern of energy use is illustrated in Figure 13, which shows the regression of yield on energy for each of Groups 1, 2 and 3. In each of the three groups there is a positive, linear relationship between energy use and yield. The intercept terms for all three groups indicate that the use of little or no energy would produce yields close to zero. The slope of the regression line is greater than 1.0 in Group 1, approximates unity in Group 2, and is less than 1.0 in Group 3. This means that for every additional dollar invested in energy, yields increase by more than a dollar in Group 1, approximately a dollar in Group 2, and less than a dollar in Group 3. It should be noted, however, that removal of the observation farthest to the right increases the slope of the regression line to approximately unity (1.13) for Group 3. Thus the difference between Groups 2 and 3 is far less than that separating Groups 1 and 2.

Figure 13: The relationship of energy to yield for Groups 1,2 and 3.

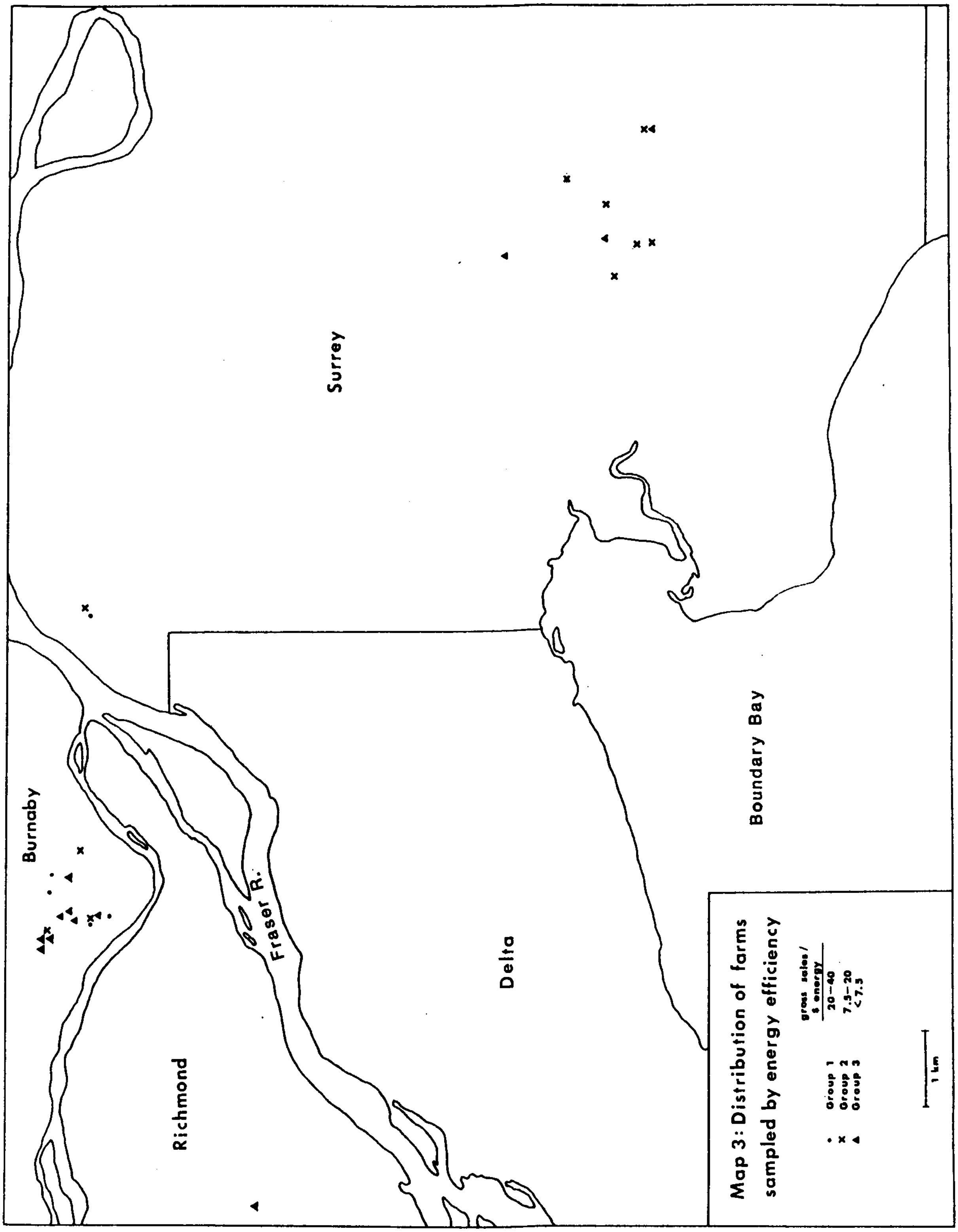


* = Group 1	B =6.33	y-intercept= -141.5
× = Group 2	B =1.57	y-intercept= 426.4
▲ = Group 3	B =0.52	y-intercept= 482.7

Possible explanations: structural differences between Groups 1 and 3

If it is possible to derive characteristic and distinct combinations of inputs for Groups 1 and 3, it will be possible to identify a small scale energy efficient production method. An initial examination of these groups shows that they are actually quite similar. All of these farmers are Chinese, while all four of the non-Chinese farmers sampled are in Group 2. Additionally, 80% of the farms in Group 1, and 66% of those in Group 3 are located in Burnaby, while 70% of the farms in Group 2 are in Surrey (Map 3). By definition, farms in Groups 1 and 3 all have a land base of under 25 ha. These two groups are therefore considered to be efficient (Group 1) and inefficient (Group 3) forms of small scale Chinese market gardening. It is thus important to determine those characteristics which distinguish Group 1 from Group 3.

A comparison of mean input levels indicates that farmers in Group 1 tend to be in their late thirties with approximately ten years farming experience, while those in Group 3 are in their late forties with twenty years experience (Appendix III). Group 3 farmers are distinguished primarily by the magnitude of their energy use. Appendix III shows that mean inputs of land, labour, management and number of crops are similar for both groups. Given the relationship between these inputs and pesticide use, as illustrated in Figures 8 and 9, pesticide inputs for these groups should also be similar. Yet on average Group 3 farmers



Map 3: Distribution of farms sampled by energy efficiency

spend four times as much on pesticides as do Group 1 farmers.

Group 3 growers also spend eight times as much on fuel as do Group 1 farmers. Twice as much fertilizer is used on the average Group 3 farm, and almost four times as much is spent on it (Appendix III). This last point undoubtedly reflects the inefficiency of buying fertilizer by the 20 kg bag, a practice common among many of the small farmers in Burnaby.

Table 3 shows differing proportions spent on fuel, fertilizer and pesticide. Group 3 farmers spend 10% more of their energy dollar on fuel, and 9% less on fertilizer than do Group 1 growers. Given that labour inputs are similar for both groups, this means that Group 3 farmers are using fuel for field operations that could be done by hand. Reading of individual questionnaires shows that none of the Group 1 farmers owns more than one tractor, and none uses a tractor more powerful than 40 horsepower. Half of the Group 3 farmers use more than one tractor, and one grower uses tractors as powerful as 80 horsepower. Appendix III shows that machinery use by Group 3 farmers is in fact seven times that of Group 1 farmers. They are therefore spending additional money on energy while reducing the productivity of their labour force. Group 1, on the other hand, spends a higher proportion of its energy expenditures on fertilizer than does any other group. Fertilizer, unlike fuel or pesticide, is a hydrocarbon input used to overcome site limitations, not to replace human energy.

Another major feature distinguishing Groups 1 and 3 is that the range of values for almost every input is much smaller for Group 1 (Appendix III). Group 1 farms employ a homogeneous production method characterized by the use of techniques suitable to a small scale. All of these farms use a greenhouse, and none of them use wide wheel base cultivation equipment. The emphasis is on labour and fertilizer, not fuel, pesticide and machinery.

Group 3, on the other hand, is a heterogeneous collection of farms tied together by the inefficiency of their energy use. An examination of individual cases (Appendix V) shows that some farmers use rototillers, while others have a wide cultivation pattern; some spend nothing on pesticides, while others spend as much as the four largest farmers sampled; some have a greenhouse, while others do not. But in the majority of cases there is either a relatively inefficient use of energy, or the use of some input at a level characteristic of the larger scale operations.

The reliance of Group 3 farmers upon machinery and fuel, rather than upon ferilizer and labour, may be a function of their greater age and experience. Being older, these farmers may be more willing to accept higher energy expenditures in exchange for a reduction in their workload. Being more established, they may be better equipped to accept the risk entailed by such an increase in expenditures. While such a hypothesis is purely speculative, it may serve to explain the differing energy expenditures of two groups that are otherwise quite similar.

Group 2: the sample stratified by energy use and size

Having examined structural differences between Groups 1 and 3, it is now necessary to examine Group 2. Group 2, it will be remembered, is a heterogeneous group, containing both large and small farms. To understand the pattern of energy use within Group 2, it must be stratified according to size. Group 2a is thus defined as the group containing those farms of 25 ha or less which are contained within Group 2. Group B, as stated above, is defined as farms of 25 ha or more.

The most important differences between these groups are caused by the higher yields and energy efficiencies of the larger farmers. Like farmers in Group 1, the large farmers in Group B maximize returns to non-renewable energy. There are only eight farms in the total sample of 27 that have both below average energy costs and above average yields (Appendix V). Four of these are in Group 1, while three are in Group B. (The eighth is a small farm in Group 2a).

The production method practiced by Group B growers is quite different from that used by Group 1 growers, however. They use more pesticides, less labour and management, and grow fewer crops on average than do any of the 24 small farms sampled (Appendix III). None of these farmers uses a greenhouse, and all use wide wheel base cultivators (Appendix III). These characteristics describe a strategy of energy efficiency that emphasizes substitution of energy for labour. Indeed, these farms use almost three times as much energy on average as do those in Group 1. Table 3 shows that fertilizer makes up a smaller percentage of the total energy package for farms in Group B than for those in any other group. An increasing proportion of energy use is accounted for by pesticides, an input that is substituted for labour. The energy efficient strategy adopted by these growers is one suited to a large scale.

Group 2a, on the other hand, appears to represent a transitional stage between Groups 1 and 3. Like Group 1 growers, these farmers all start their crop in a greenhouse, and none of them utilizes wide wheel base cultivation equipment (Appendix III). However, Group 2a farmers use almost as much energy and machinery as do those in Group 3 (Appendix III).

It should be noted that the wide range of input levels for Group 2 is almost entirely accounted for by Group 2a (Appendix III). The large efficient farms are, like the small efficient ones, a homogeneous group.

Discussion

The above analysis indicates that there are two energy efficient strategies employed within the study area. One is suited to a large scale, and the other to a small scale. To understand why each of these strategies is successful it is necessary to determine

1. what it is they have in common? and
2. why there are two strategies being utilized rather than one?

The answer to the first question is that each strategy is appropriate to the scale at which it is practiced. Small farmers in Group 1 substitute labour for energy wherever possible, and their largest energy input, fertilizer, is one for which labour cannot be substituted. Large farmers in Group B spend 25% less of their energy dollar on fertilizer than do Group 1 growers, and 32% more on pesticide, an input which complements the use of large land areas (Table 3). Farmers in both groups are utilizing principles of substitution and complementarity to determine the mix of inputs best suited to their scale of operation.

Farmers in Groups 2a and 3 do not utilize these principles effectively. Group 3 farmers in particular attempt to use substitutes as complements, by spending such large sums on pesticides when they already employ a large labour force. They incur the costs of both inputs, and minimize returns to both. The high proportion of energy expenditures spent on fuel by both Groups 2a and 3 similarly reduces the productivity of the labour force. These examples bear out the suggestion that failure to recognize the substitutable nature of inputs leads to increased inefficiency. It is this failure which sets Groups 2a and 3 apart from their more energy efficient counterparts.

The answer to the second question, concerning the presence of two efficient strategies within the study area, can be found in the fact that situation is not constant throughout the GVCD.

The small scale efficient strategy is almost entirely confined to South Burnaby, while the large scale efficient farms are all located in Surrey. It is inferred that small scale farms are better adapted to environmental conditions in Burnaby, while large scale operations are better suited to conditions in Surrey. One possible reason for the absence of large scale farms in South Burnaby is provided by Sinclair and Bryant's model, which was discussed earlier. It is speculated that anticipation of urban expansion in the Big Bend area discourages large investments in land improvements and equipment, thus leaving the area to small scale intensive operations. Large operations, on the other hand, are well adapted to the Cloverdale area of Surrey, where economies of scale can be achieved.

It is possible to draw parallels between this distribution, and those discovered by Johnson et al. (1977) in their study of the Amish, and by Lockeretz et al. (1981) in their study of organic farmers in the Corn Belt. As stated in Chapter 2, both the Amish and the organic farmers are risk-averters. On rough terrain, or in years of bad weather, these growers have better yields than do their neighbours who utilize energy intensive production methods. On good soil, or in years of good weather, their yields are not as high as those of their neighbours.

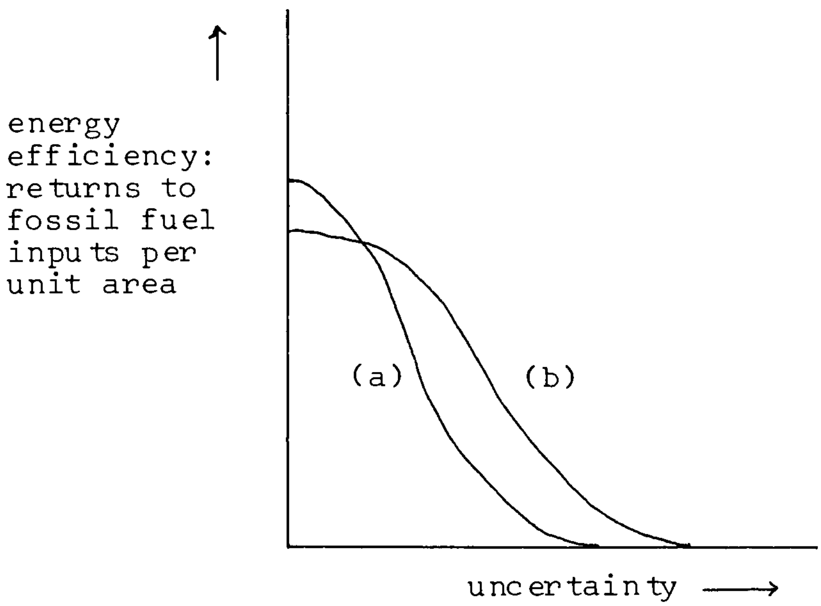
Like these farmers, the small scale, efficient growers in Burnaby do well in an uncertain environment. Uncertainty in Burnaby is the risk of rural to urban land conversion. By minimizing the amount of fixed capital that could be lost through such a conversion, the small scale Chinese gardener functions as a risk-averter. In this context, a risk-averter is defined as a farmer whose production techniques may not allow him to attain the maximum possible yield or efficiency under optimal conditions, but which allow him to remain in business or reduce his losses under sub-optimal conditions. The low level of fixed costs on a small farm allows the farmer to vary his combination of inputs to cope with unexpected changes in the environment. These lower costs also mean that he has a wider profit-margin than does his larger neighbour. The ease with which he can vary his inputs gives him a high degree of flexibility, but also means that his success relies on the quality of his decisions. The wider profit margin, on the other hand, means that the penalty for faulty decision-making is not as high as it might be on a larger farm.

In the relatively stable agricultural environment of Cloverdale, the efficient farm is larger, and uses three times the energy of the efficient Burnaby farm. These farmers, like the non-Amish and the non-organic operators, are profit-maximizers. A profit maximizer, in this context, uses techniques that provide a high yield and high efficiency under optimal conditions, but may lead to poor yields and efficiencies under sub-optimal conditions. When the soil and the weather are good, when the risk of rural to urban land conversion is low, these growers maximize returns to inputs of machinery and pesticides.

Based on these parallels, it is possible to propose a model to explain why small scale operations are more energy efficient in some locations, while large scale farms are more efficient in others. It is not suggested that the results of this thesis constitute proof of the model. Rather, the model is offered as a working hypothesis for future research. Figure 14 shows two types of agricultural production, one small scale and labour intensive, the other large scale and capital intensive. Under conditions of absolute certainty, the large scale farmer can use energy intensive machinery to achieve economies of scale, and energy intensive chemicals to enhance yields and reduce crop damage. Uncertainty, in the form of variable weather and soil conditions, urban anticipation, or simply fluctuating petroleum prices, can reduce the efficacy of this strategy. In this case, the smaller farmer who can vary his inputs is at an advantage. Thus a small scale, risk-averting strategy is more likely to be energy efficient in uncertain environments, or on the margin of production, while a large scale, risk-taking strategy is more energy efficient in a stable environment.

The presence of small farms in Surrey suggests that the farmer's choice of production method is not solely determined by this need for environmental adaptation. Culture also plays an important role. There are no non-Chinese farmers in Burnaby, and all but one of the smaller farms in Surrey are owned by Chinese. Among the large scale farmers interviewed, only one was Chinese. It can be speculated that the Chinese hesitate to abandon small

Figure 14: Changing energy efficiencies under conditions of uncertainty for two land uses, one of which (a) is large scale, capital intensive, and the other of which (b) is small scale, labour intensive.



scale farming techniques, while the non-Chinese hesitate to adopt them.

An interesting corollary to this point is provided by the example of the small, inefficient farmers sampled. These growers, it will be remembered, were inefficient because they were trying to use both large and small scale technology at the same time. The Chinese farmers in the GVCD are in an unusual situation: they have a choice of two culturally acceptable production methods. This broader range of choices can be of great benefit. The use of a rototiller, for example, is a means of utilizing machinery to improve yields in an otherwise traditional farming operation. More choices can, however, also provide a wider latitude for failure, as the example of a farmer using a wide wheel base cultivator on 5 ha of land suggests.

In summary, there are two energy efficient strategies utilized in the GVCD, one large scale and one small. Both recognize the substitutability of certain inputs. Clustering of the small scale strategy in Burnaby, and of the large scale strategy in Surrey can be interpreted as an adaptation to the level of uncertainty in the environment. Since uncertainty varies over space, the nature of an energy efficient production method also varies over space. In general, increased uncertainty favours the small scale producer. The degree to which farmers choose a strategy adapted to their environment seems to be a function of their cultural perceptions.

CHAPTER 5: CONCLUSIONS AND SUGGESTIONS FOR FUTURE RESEARCH

Conclusions

Two energy efficient production methods are found in the GVCD. One is practiced on a large scale, the other on a small scale. Large scale efficient farms are confined to the Cloverdale area of Surrey, while all but one of the small efficient farms are located in Burnaby.

Site is relatively constant throughout the study area. Measures of precipitation, frost free days and degree days show little variation for Burnaby, Surrey and Richmond. Soil capability, slope and elevation are also relatively uniform for the farms studied. Situation is not constant throughout the GVCD. Farms in Burnaby are smaller, grow different varieties of lettuce, and have different marketing patterns than those in Cloverdale. In addition, no non-Chinese farmers are found in Burnaby, while four are in business in Surrey. These variations in situation and culture correspond to the distribution of the two types of energy efficient production method.

The large scale efficient farms are characterized by large inputs of pesticide, and small inputs of labour and managerial time. None of these farmers starts his crop in a greenhouse, and all grow one to two crops per year. These growers all utilize a wide wheel base cultivation pattern. All of these techniques are well suited to a large scale. They minimize labour costs, and make it possible to achieve economies of scale.

The small scale efficient farmers substitute labour and managerial time for pesticide use, and all start their crops in greenhouses. Their yields per crop are about the same as those achieved by the larger growers, but they grow two to three crops per year. The larger number of crops is made possible by the use of greenhouses. These farmers tend to utilize a narrow wheel base cultivation pattern. These are techniques which work on a small scale, allowing the farmer to maximize his yield per hectare. He is able to do this through the use of large inputs of labour, both his own and that of his family and hired workers. Such reliance on human labour might prove problematic on a larger scale; one possible limitation is the availability of labour at critical times in the growing season.

All of the large farms sampled were of above average efficiency for the total sample. The conspicuous absence of inefficient large farms suggests that such operations do not remain in business very long. Fully half the sample consisted of relatively inefficient small farms, most of which were located in Burnaby. On average, these farmers are ten years older and have ten years more experience than their more efficient neighbours. These characteristics may indicate a willingness to substitute non-renewable energy for their own labour as farmers get older.

It is concluded that, in the GVCD, the type of production method that is energy efficient varies with scale, and the scale of operation varies with situation and culture. Large scale operations are not well adapted to South Burnaby, where anticipation of urbanization may inhibit the investment in land and equipment characteristic of large operations. Small scale farmers, on the other hand, may find it difficult to compete with larger operators in Surrey. There, larger available land areas and increased distance from the edge of urban expansion make it possible to take advantage of economies of scale.

Cultural preferences and perceptions, as defined by methods of production that farmers have learnt, appear to limit the degree to which individual farmers adopt the scalle of operation suited to their situation. All but one of the Chinese farmers in Surrey operate small scale, labour intensive operations, even though their farms are less efficient than those of their larger neighbours. No non-Chinese operate in Burnaby, nor do any Caucasian growers operate labour intensive farms. This dichotomy may reflect culturally-defined valuations of labour. For the Chinese growers, labour intensive farming may constitute a way of life. Long hours in the field reinforce social bonding. Furthermore, use of labour intensive techniques allows first generation immigrants to establish businesses with a minimum of capital investment. For the Caucasian growers, farming may be perceived as a way of making a living. Long hours serve only to increase the opportunity cost of farming vis-a-vis other, less strenuous jobs. Thus farmers appear hesitant to abandon the production methods they have learnt, as those methods are associated with cultural values.

Thus, in the GVCD, situation appears to influence the characteristics of an energy efficient production method through its effect on the scale of the farm operation. This influence is modified by the cultural perceptions of the farmer. It is not possible to assess what effect variations in site within the study area might have had upon the characteristics of efficient systems. Nonetheless, it can be stated that an energy efficient production method is not universally applicable, but, at the very least, it is unique to situation and culture.

Suggestions for future research

This thesis constitutes a preliminary investigation into the role of site, situation and culture in determining an energy efficient production method. It is intended to identify patterns of energy efficient farming on the landscape, but not to describe those patterns in detail. As a result, possible applications of its conclusions are somewhat limited.

In the GVCD certain questions must be answered before there is any attempt to define energy efficient production methods in practical terms. Most importantly, there must be a better understanding of how much energy is used than was derived through questionnaire sampling. Direct measurement of inputs over several years would be necessary to describe relationships of substitution and complementarity in detail. Longitudinal study would also determine whether the distribution of efficient farms changes over time.

Understanding the role of crop rotations in determining overall farm efficiency is also important. Past research has indicated that mixed farms tend to be more energy efficient than monocultural operations (Blobaum, 1982). No attempt was made in this study to assess crop-mix, beyond the determination that all of the farms sampled are mixed farms. More detailed studies over a longer period of time may determine that the choice of crop-mix affects the pattern of energy efficiency.

Studies of managerial behavior are necessary to assess the farmer's decision-making process. It is not clear whether farmers in Big Bend have a conscious sense of urban anticipation. Nor is it known whether they trade higher energy expenditures for a lighter workload as they get older. The role of culture, too, needs to be better understood. Will subsequent generations of Chinese farmers cling to small scale methods, will they adopt methods suited to their situation, or will they adopt large scale methods regardless of their situation?

All of these are questions which must be addressed before the parameters of energy efficient, location-specific production methods can be defined in practical terms. Such a definition is beyond the scope of this thesis. The purpose here simply has been to demonstrate that such research must be conducted on a location-specific, rather than on a global basis.

APPENDIX I: STUDY QUESTIONNAIRE

Name:

Address:

Phone:

<u>Personal Data</u>:

1. Date of birth:

2. Number of years engaged in farming:

3. Highest education level completed:

   [ ] primary school [ ] college [ ] technical school

   [ ] high school [ ] university

<u>Farm Size</u>:

1. How much land do you own?

   [ ] <1 acre

   If >1 acre, give exact amount: ________ acres.

2. How much land do you rent or lease to others?

   [ ] <1 acre [ ] none

   If >1 acre, give exact amount: ________ acres.

3. How much land do you rent or lease from others?

   [ ] <1 acre [ ] none

   If >1 acre, give exact amount: ________ acres.

4. How much of the land you work is in cropland, excluding pasture and hayfields?

   [ ] <1 acre

   If >1 acre, give exact amount: ________ acres.

5. How much of the land you work is planted in lettuce?

☐ <1/4 acre ☐ 1/2-3/4 acre

☐ 1/4-1/2 acre ☐ 3/4-1 acre

If >1 acre, give exact amount: ______ acres.

<u>Energy Use</u>:

1. What was the gross value of your total crop sales for the year 1983 as of September 1? : ______$

(If exact amount unavailable, check one below.)

☐ <$1,000 ☐ $10,000-15,000 ☐ $100,000-500,000

☐ $1,000-2,500 ☐ $15,000-25,000 ☐ >$500,000

☐ $2,500-5,000 ☐ $25,000-50,000

☐ $5,000-10,000 ☐ $50,000-100,000

2. What was the gross value of your lettuce sales for the year 1983 as of September 1? : ______$

(If exact amount unavailable, check one below.)

☐ <$1,000 ☐ $10,000-15,000 ☐ $100,000-200,000

☐ $1,000-2,500 ☐ $15,000-25,000 ☐ >$200,000

☐ $2,500-5,000 ☐ $25,000-50,000

☐ $5,000-10,000 ☐ $50,000-100,000

3. What was your total yield of lettuce for the year 1983 as of September 1? : ______ cartons

(If exact amount unavailable, check one below.)

☐ <500 cartons ☐ 5,000-10,000 ☐ 50,000-100,000

☐ 500-1,000 ☐ 10,000-15,000 ☐ >100,000

☐ 1,000-2,500 ☐ 15,000-25,000

☐ 2,500-5,000 ☐ 25,000-50,000

4. For one acre of lettuce what are your approximate expenditures on the following energy inputs (if less than 1 acre is grown, give approximate expenditures for a single crop):

pesticides & herbicides: $__________

fertilizer: $__________

other chemicals: $__________

gasoline, diesel fuel, & oil: $__________

electricity for irrigation, greenhouse, storage (do not include household electricity:) $__________

Production Techniques:

1. From your experience, how many crops of lettuce can you get off your land in a year?

☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6

2. How much nitrogen do you apply per acre of lettuce? (If less than 1 acre grown, give approximate amount for a single crop.)

_______ lbs.

3. How much of total field time is spent on the lettuce crop?

☐ <5%
☐ 5-10%
☐ 10-20%
☐ 20-30%
☐ 30-40%
☐ 40-50%
☐ >50%

4. Because pesticides often require a great deal of energy to manufacture, it is necessary to gain some idea of the level of pesticide use. Please check kinds of pesticides used, and give the number of applications per crop. (For lettuce.)

	#		#
☐ CIPC		☐ Diazinon 50EC	
☐ Gramoxone		☐ Basudine 50EC	
☐ Parathione		☐ Malathion 50EC	
☐ Thioden 4EC		☐ Lannate L	
☐ Monitor		☐ Rotenone	
☐ This		☐ Dithane M-22	
☐ Rovral		☐ Dithane Z-78	
☐ Reglone		☐ Manzate D	
☐ Systox		☐ Zineb	
☐ Cygon		☐ Captan	
☐ Phosdin			

Other:

5. Number of rows per bed of lettuce? ________

6. What is the width of your lettuce beds? ________ inches.

7. What is the distance between your rows of lettuce? ________inches

8. Do you begin your lettuce crop in a greenhouse or use greenhouse started lettuce?

☐ Yes ☐ No

9. How is your manpower organized? (Number of full time and seasonal laborers, number of lead hands or managers, and time worked by each. Please include family members, both paid and unpaid.)

Paid	# hours/week	# months/year

Unpaid	# hours/week	# months/year

10. What equipment do you use for lettuce? Please check type equipment and give number used. (Irrigation equipment is dealt with in Questions 11-14.)

	#
a. seeders	
☐ stanhay	
☐ planet junior	
b. tractors	
☐ 40 hp.	
☐ 60 hp.	
☐ 80 hp.	
other: ________	
________	
________	
c. ☐ rototiller	
d. ☐ rotovator	
e. ☐ roto-spike	
size? ________	
f. pumps	
☐ tractor powered	
size? ________	
☐ motor powered	
size? ________	
☐ electric	
size? ________	

	#
g. sprayers	
type? ________	
size? ________	
h. ☐ wheel hoes	
i. ☐ basket weeders	
j. trucks	
☐ 1/4 ton	
☐ 1/2 ton	
☐ 3/4 ton	
☐ 1 ton	
☐ 5 ton	
other: ________	
________	
________	

Any other equipment used (include size & type, and number used.)

____

11. Have you irrigated your lettuce in 1982 or 1983?

☐ yes ☐ no

12. What type of irrigation equipment do you use?

☐ solid set ☐ Ira-France

☐ wheel system ☐ other: ____________

13. What was the approximate operating cost of irrigation (excluding labor)?

$________ 1982

$________ 1983

14. What proportion of your lettuce was irrigate?

________% 1982

________% 1983

APPENDIX II: CORRELATION MATRICES

A. TOTAL SAMPLE (27 cases)

	Yield	Farm size	Lettuce area	Fuel	Fertilizer	Pesticide	Labour	Machinery	Chemicals	Electricity
Yield	1.0000 (0) P=*****									
Farm size	0.1975 (27) P=0.324	1.0000 (0) P=*****								
Lettuce area	-0.0524 (27) P=0.795	0.5877 (27) P=0.001	1.0000 (0) P=*****							
Fuel	0.1989 (27) P=0.320	-0.1825 (27) P=0.362	-0.1630 (27) P=0.417	1.0000 (0) P=*****						
Fertilizer	0.1115 (21) P=0.631	-0.0086 (21) P=0.970	0.2053 (21) P=0.372	0.4137 (21) P=0.062	1.0000 (0) P=*****					
Pesticide	-0.0157 (27) P=0.938	0.6143 (27) P=0.001	0.5899 (27) P=0.001	-0.1185 (27) P=0.556	0.1183 (21) P=0.609	1.0000 (0) P=*****				
Labour	-0.0337 (25) P=0.873	-0.5832 (25) P=0.002	-0.5052 (25) P=0.010	0.1643 (25) P=0.432	0.3682 (20) P=0.110	-0.5759 (25) P=0.003	1.0000 (0) P=*****			
Machinery	0.2043 (27) P=0.307	-0.1916 (27) P=0.338	-0.0509 (27) P=0.801	0.9540 (27) P=0.000	0.4951 (21) P=0.022	-0.0347 (27) P=0.864	0.1310 (25) P=0.533	1.0000 (0) P=*****		
Chemicals	-0.3145 (27) P=0.110	-0.0894 (27) P=0.658	-0.1780 (27) P=0.375	-0.1980 (27) P=0.322	-0.2797 (21) P=0.220	0.0012 (27) P=0.995	0.1654 (25) P=0.430	-0.2158 (27) P=0.280	1.0000 (0) P=*****	
Electricity	0.0245 (27) P=0.904	-0.0463 (27) P=0.819	0.3926 (27) P=0.043	-0.0080 (27) P=0.968	0.2691 (21) P=0.238	0.3124 (27) P=0.113	-0.1356 (25) P=0.518	0.2884 (27) P=0.145	-0.0651 (27) P=0.747	1.0000 (0) P=*****
Crops year^{-1}	-0.1397 (27) P=0.487	-0.5209 (27) P=0.005	-0.4745 (27) P=0.012	0.0403 (27) P=0.842	-0.1069 (21) P=0.645	-0.5945 (27) P=0.001	0.4892 (25) P=0.013	-0.0271 (27) P=0.893	0.2358 (27) P=0.236	-0.2145 (27) P=0.283
Energy	0.2460 (27) P=0.216	-0.0132 (27) P=0.948	0.0685 (27) P=0.734	0.7947 (27) P=0.000	0.8215 (21) P=0.000	0.1073 (27) P=0.594	0.2669 (25) P=0.197	0.8214 (27) P=0.000	-0.2391 (27) P=0.230	0.1952 (27) P=0.329
Management	-0.1359 (24) P=0.527	-0.5260 (24) P=0.008	-0.5169 (24) P=0.010	-0.0695 (24) P=0.747	-0.0410 (19) P=0.868	-0.5979 (24) P=0.002	0.8272 (24) P=0.000	-0.0853 (24) P=0.692	0.3588 (24) P=0.085	-0.1225 (24) P=0.569
Irrigation	0.0506 (23) P=0.819	0.2755 (23) P=0.203	0.1673 (23) P=0.445	-0.2903 (23) P=0.179	-0.0025 (18) P=0.992	0.1359 (23) P=0.536	-0.1602 (21) P=0.488	-0.3577 (23) P=0.094	-0.4509 (23) P=0.031	-0.2352 (23) P=0.280
Efficiency	0.5179 (27) P=0.006	-0.0351 (27) P=0.862	-0.2136 (27) P=0.285	-0.3422 (27) P=0.081	-0.3885 (21) P=0.082	-0.2273 (27) P=0.254	0.0787 (25) P=0.709	-0.3822 (27) P=0.049	-0.0770 (27) P=0.702	-0.1912 (27) P=0.339
Age	-0.1337 (26) P=0.515	0.2593 (26) P=0.201	0.2180 (26) P=0.285	-0.2386 (26) P=0.240	-0.0439 (20) P=0.854	0.2703 (26) P=0.182	-0.2420 (25) P=0.244	-0.2381 (26) P=0.242	0.1521 (26) P=0.458	-0.0446 (26) P=0.829
Education	0.1970 (25) P=0.345	0.5638 (25) P=0.003	0.2672 (25) P=0.197	-0.0998 (25) P=0.635	-0.1487 (19) P=0.543	0.3574 (25) P=0.079	-0.3999 (23) P=0.059	-0.1074 (25) P=0.609	-0.3272 (25) P=0.110	-0.0407 (25) P=0.847
Experience	0.0069 (26) P=0.973	0.0988 (26) P=0.631	0.0478 (26) P=0.817	-0.0677 (26) P=0.742	0.3886 (20) P=0.090	0.2141 (26) P=0.294	0.0987 (24) P=0.646	-0.0246 (26) P=0.905	0.0535 (26) P=0.795	0.0854 (26) P=0.678
Cultivation	-0.1449 (24) P=0.499	0.5746 (24) P=0.003	0.4743 (24) P=0.019	-0.3853 (24) P=0.063	0.4001 (18) P=0.100	0.7024 (24) P=0.000	-0.3137 (22) P=0.155	-0.4114 (24) P=0.046	0.0016 (24) P=0.994	-0.1709 (24) P=0.424
Greenhouse	0.0100 (27) P=0.961	0.5954 (27) P=0.001	0.2689 (27) P=0.175	0.0505 (27) P=0.803	-0.2043 (21) P=0.374	0.3307 (27) P=0.092	-0.5226 (25) P=0.007	-0.0080 (27) P=0.968	-0.1046 (27) P=0.504	-0.1713 (27) P=0.393

	Crops year^{-1}	Energy	Management	Irrigation	Efficiency	Age	Education	Experience	Cultivation	Greenhouse
Crops year^{-1}	1.0000 (0) P=*****									
Energy	-0.0976 (27) P=0.628	1.0000 (0) P=*****								
Management	0.3825 (24) P=0.065	-0.0985 (24) P=0.647	1.0000 (0) P=*****							
Irrigation	-0.2914 (23) P=0.177	-0.1461 (23) P=0.506	-0.1526 (20) P=0.521	1.0000 (0) P=*****						
Efficiency	0.0860 (27) P=0.670	-0.4691 (27) P=0.014	0.0989 (24) P=0.646	0.0839 (23) P=0.704	1.0000 (0) P=*****					
Age	-0.0924 (26) P=0.653	-0.1087 (26) P=0.597	-0.1108 (24) P=0.606	0.0075 (22) P=0.974	-0.2447 (26) P=0.228	1.0000 (0) P=*****				
Education	-0.4070 (25) P=0.043	-0.0617 (25) P=0.769	-0.3998 (22) P=0.065	0.1655 (21) P=0.473	0.1687 (25) P=0.420	-0.2857 (24) P=0.176	1.0000 (0) P=*****			
Experience	0.0717 (26) P=0.728	0.3269 (26) P=0.103	-0.0493 (23) P=0.823	0.0062 (22) P=0.978	-0.3067 (26) P=0.128	0.7545 (25) P=0.000	-0.2760 (24) P=0.192	1.0000 (0) P=*****		
Cultivation	-0.4610 (24) P=0.023	0.0209 (24) P=0.923	-0.3977 (21) P=0.074	0.5014 (20) P=0.024	-0.2631 (24) P=0.214	0.2411 (23) P=0.268	0.2183 (23) P=0.317	0.2649 (23) P=0.222	1.0000 (0) P=*****	
Greenhouse	-0.2964 (27) P=0.133	-0.0033 (27) P=0.987	-0.3537 (24) P=0.090	0.2967 (23) P=0.169	-0.1602 (27) P=0.425	0.1134 (26) P=0.581	0.4006 (25) P=0.047	-0.1101 (26) P=0.592	0.3254 (24) P=0.121	1.0000 (0) P=*****

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B. GROUP A
(23 cases)

	Yield	Farm size	Lettuce area	Fuel	Fertilizer	Pesticide	Labour	Machinery	Chemicals	Electricity	Crops year^{-1}	Energy	Management	Irrigation	Efficiency	Age	Education	Experience	Cultivation	Greenhouse
Yield	1.0000 (0) P=*****																			
Farm size	-0.0680 (23) P=0.758	1.0000 (0) P=*****																		
Lettuce area	-0.0951 (23) P=0.666	0.9127 (23) P=0.000	1.0000 (0) P=*****																	
Fuel	0.2487 (23) P=0.252	-0.0469 (23) P=0.832	-0.0949 (23) P=0.667	1.0000 (0) P=*****																
Fertilizer	0.1309 (17) P=0.617	0.2489 (17) P=0.335	0.3245 (17) P=0.204	0.4004 (17) P=0.111	1.0000 (0) P=*****															
Pesticide	-0.1566 (23) P=0.476	0.7021 (23) P=0.000	0.5817 (23) P=0.004	0.0063 (23) P=0.977	0.2852 (17) P=0.267	1.0000 (0) P=*****														
Labour	0.0692 (21) P=0.766	-0.5267 (21) P=0.014	-0.4123 (21) P=0.063	0.0552 (21) P=0.812	0.3690 (16) P=0.160	-0.3840 (21) P=0.086	1.0000 (0) P=*****													
Machinery	0.2692 (23) P=0.214	0.0990 (23) P=0.653	0.0653 (23) P=0.767	0.9524 (23) P=0.000	0.4881 (17) P=0.047	0.1461 (23) P=0.506	-0.0150 (21) P=0.949	1.0000 (0) P=*****												
Chemicals	-0.3034 (23) P=0.159	-0.0946 (23) P=0.668	-0.1919 (23) P=0.380	-0.2079 (23) P=0.341	-0.1590 (17) P=0.542	-0.0087 (23) P=0.968	0.1912 (21) P=0.406	-0.2316 (23) P=0.288	1.0000 (0) P=*****											
Electricity	0.0733 (23) P=0.740	0.5244 (23) P=0.010	0.5628 (23) P=0.005	-0.0459 (23) P=0.835	0.2629 (17) P=0.308	0.5201 (23) P=0.011	-0.2774 (21) P=0.223	0.2568 (23) P=0.237	-0.0785 (23) P=0.722	1.0000 (0) P=*****										
Crops year^{-1}	-0.0537 (23) P=0.808	-0.5751 (23) P=0.004	-0.3908 (23) P=0.065	-0.0589 (23) P=0.790	-0.1762 (17) P=0.499	-0.4990 (23) P=0.015	0.3387 (21) P=0.133	-0.1615 (23) P=0.462	0.2287 (23) P=0.294	-0.3376 (23) P=0.115	1.0000 (0) P=*****									
Energy	0.2691 (23) P=0.214	0.0715 (23) P=0.746	0.0829 (23) P=0.707	0.8058 (23) P=0.000	0.8279 (17) P=0.000	0.1772 (23) P=0.419	0.2752 (21) P=0.227	0.8401 (23) P=0.000	-0.2356 (23) P=0.279	0.1908 (23) P=0.383	-0.1250 (23) P=0.570	1.0000 (0) P=*****								
Management	-0.0422 (20) P=0.860	-0.4822 (20) P=0.031	-0.4462 (20) P=0.049	-0.2152 (20) P=0.362	-0.2004 (15) P=0.474	-0.4487 (20) P=0.047	0.7667 (20) P=0.000	-0.2614 (20) P=0.266	0.4081 (20) P=0.074	-0.2384 (20) P=0.311	0.2151 (20) P=0.362	-0.1601 (20) P=0.500	1.0000 (0) P=*****							
Irrigation	-0.0217 (19) P=0.930	-0.0699 (19) P=0.776	0.0486 (19) P=0.843	-0.2608 (19) P=0.281	-0.0189 (14) P=0.949	0.0033 (19) P=0.989	0.0312 (17) P=0.905	-0.3231 (19) P=0.177	-0.4315 (19) P=0.065	-0.1929 (19) P=0.429	-0.1881 (19) P=0.441	-0.1473 (19) P=0.547	0.0122 (16) P=0.964	1.0000 (0) P=*****						
Efficiency	0.5175 (23) P=0.011	-0.2219 (23) P=0.309	-0.2126 (23) P=0.330	-0.3554 (23) P=0.096	-0.4099 (17) P=0.102	-0.2916 (23) P=0.177	0.0994 (21) P=0.668	-0.3994 (23) P=0.059	-0.0729 (23) P=0.741	-0.1897 (23) P=0.386	0.1008 (23) P=0.647	-0.4705 (23) P=0.023	0.1417 (20) P=0.651	0.0723 (19) P=0.769	1.0000 (0) P=*****					
Age	-0.1385 (22) P=0.539	0.0882 (22) P=0.696	-0.0111 (22) P=0.961	-0.2163 (22) P=0.334	-0.0472 (16) P=0.862	0.2281 (22) P=0.307	-0.1768 (21) P=0.443	-0.2095 (22) P=0.349	0.1756 (22) P=0.434	-0.0181 (22) P=0.936	0.0033 (22) P=0.988	-0.1205 (22) P=0.593	-0.0242 (20) P=0.919	-0.0911 (18) P=0.719	-0.2348 (22) P=0.293	1.0000 (0) P=*****				
Education	0.0148 (21) P=0.949	0.2862 (21) P=0.209	0.3034 (21) P=0.181	0.0316 (21) P=0.892	-0.1211 (15) P=0.667	0.0675 (21) P=0.771	-0.1677 (19) P=0.493	0.0629 (21) P=0.787	-0.3809 (21) P=0.088	0.1207 (21) P=0.602	-0.1984 (21) P=0.389	-0.0367 (21) P=0.875	-0.2149 (18) P=0.392	-0.0392 (17) P=0.881	0.1829 (21) P=0.427	-0.4703 (20) P=0.036	1.0000 (0) P=*****			
Experience	0.0611 (22) P=0.787	-0.1079 (22) P=0.633	-0.1778 (22) P=0.429	-0.0296 (22) P=0.896	0.4761 (15) P=0.062	0.1671 (22) P=0.457	0.2370 (20) P=0.314	0.0220 (22) P=0.923	0.0305 (22) P=0.893	0.1106 (22) P=0.624	0.1531 (22) P=0.496	0.3451 (22) P=0.116	0.0276 (19) P=0.911	-0.0070 (18) P=0.978	-0.2861 (22) P=0.197	0.7283 (21) P=0.000	-0.3478 (20) P=0.133	1.0000 (0) P=*****		
Cultivation	-0.3267 (20) P=0.160	0.3273 (20) P=0.159	0.3199 (20) P=0.169	-0.3354 (20) P=0.148	0.5776 (14) P=0.031	0.5365 (20) P=0.015	0.0301 (18) P=0.906	-0.3429 (20) P=0.139	0.0309 (20) P=0.897	-0.0250 (20) P=0.917	-0.2245 (20) P=0.341	0.0459 (20) P=0.848	-0.1520 (17) P=0.560	0.4766 (16) P=0.062	-0.3107 (20) P=0.182	0.1581 (19) P=0.518	-0.2094 (19) P=0.390	0.2270 (19) P=0.350	1.0000 (0) P=*****	
Greenhouse	-0.1765 (23) P=0.421	-0.1578 (23) P=0.472	-0.0372 (23) P=0.866	0.2887 (23) P=0.182	-0.1564 (17) P=0.549	-0.1328 (23) P=0.546	-0.1849 (21) P=0.422	0.2519 (23) P=0.246	-0.1303 (23) P=0.553	-0.0680 (23) P=0.758	0.0153 (23) P=0.945	0.0428 (23) P=0.846	0.0447 (20) P=0.852	0.1946 (19) P=0.425	-0.2298 (23) P=0.292	-0.0630 (22) P=0.781	-0.0671 (21) P=0.772	-0.3505 (22) P=0.110	-0.2545 (20) P=0.279	1.0000 (0) P=*****

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C. GROUP B
(4 cases)

	Yield	Farm size	Lettuce area	Fuel	Fertilizer	Pesticide	Labour	Machinery	Chemicals	Electricity	Crops $year^{-1}$	Energy	Management	Irrigation	Efficiency	Age	Education	Experience	Cultivation	Greenhouse
Yield	1.0000 (0) P=*****																			
Farm size	0.5271 (4) P=0.473	1.0000 (0) P=*****																		
Lettuce area	-0.5807 (4) P=0.419	0.3099 (4) P=0.690	1.0000 (0) P=*****																	
Fuel	0.6576 (4) P=0.342	0.9442 (4) P=0.056	0.0278 (4) P=0.972	1.0000 (0) P=*****																
Fertilizer	0.2895 (4) P=0.710	0.7537 (4) P=0.246	0.5835 (4) P=0.416	0.5135 (4) P=0.486	1.0000 (0) P=*****															
Pesticide	-0.0311 (4) P=0.969	-0.5315 (4) P=0.469	-0.7157 (4) P=0.284	-0.2319 (4) P=0.768	-0.9503 (4) P=0.050	1.0000 (0) P=*****														
Labour	-0.2604 (4) P=0.740	0.1510 (4) P=0.849	0.7321 (4) P=0.268	-0.1770 (4) P=0.823	0.7475 (4) P=0.253	-0.9159 (4) P=0.084	1.0000 (0) P=*****													
Machinery	0.4104 (4) P=0.590	0.9252 (4) P=0.075	0.2298 (4) P=0.770	0.9561 (4) P=0.044	0.4713 (4) P=0.529	-0.2265 (4) P=0.774	-0.1569 (4) P=0.843	1.0000 (0) P=*****												
Chemicals	-0.5787 (4) P=0.421	-0.6095 (4) P=0.390	-0.1950 (4) P=0.805	-0.4345 (4) P=0.565	-0.8934 (4) P=0.107	0.8174 (4) P=0.183	-0.6331 (4) P=0.367	-0.2664 (4) P=0.734	1.0000 (0) P=*****											
Electricity	-0.9918 (4) P=0.008	-0.5205 (4) P=0.479	0.5304 (4) P=0.470	-0.6157 (4) P=0.384	-0.3678 (4) P=0.632	0.1311 (4) P=0.869	0.1434 (4) P=0.857	-0.3576 (4) P=0.642	0.6668 (4) P=0.333	1.0000 (0) P=*****										
Crops $year^{-1}$	-0.4157 (4) P=0.584	-0.3209 (4) P=0.679	-0.1793 (4) P=0.821	-0.1139 (4) P=0.886	-0.7864 (4) P=0.214	0.8020 (4) P=0.198	-0.7473 (4) P=0.253	0.0617 (4) P=0.938	0.9440 (4) P=0.056	0.5275 (4) P=0.473	1.0000 (0) P=*****									
Energy	-0.0857 (4) P=0.914	0.4484 (4) P=0.552	0.7707 (4) P=0.229	0.1333 (4) P=0.867	0.9080 (4) P=0.092	-0.9927 (4) P=0.007	0.9511 (4) P=0.049	0.1510 (4) P=0.849	-0.7516 (4) P=0.248	-0.0172 (4) P=0.983	-0.7638 (4) P=0.236	1.0000 (0) P=*****								
Management	-0.0180 (4) P=0.982	0.2541 (4) P=0.746	0.5874 (4) P=0.413	-0.0506 (4) P=0.949	0.8271 (4) P=0.173	-0.9429 (4) P=0.057	0.9691 (4) P=0.031	-0.0989 (4) P=0.901	-0.7971 (4) P=0.203	-0.1031 (4) P=0.897	-0.8866 (4) P=0.113	0.9512 (4) P=0.049	1.0000 (0) P=*****							
Irrigation	0.6153 (4) P=0.385	0.8785 (4) P=0.121	0.2795 (4) P=0.721	0.7435 (4) P=0.256	0.9250 (4) P=0.075	-0.7664 (4) P=0.234	0.4613 (4) P=0.539	0.6334 (4) P=0.367	-0.9142 (4) P=0.086	-0.6652 (4) P=0.336	-0.7331 (4) P=0.267	0.6845 (4) P=0.315	0.6121 (4) P=0.388	1.0000 (0) P=*****						
Efficiency	0.9272 (4) P=0.073	0.2734 (4) P=0.727	-0.8243 (4) P=0.176	0.5060 (4) P=0.494	-0.0886 (4) P=0.911	0.3438 (4) P=0.656	-0.5767 (4) P=0.423	0.2707 (4) P=0.729	-0.2439 (4) P=0.756	-0.8850 (4) P=0.115	-0.1066 (4) P=0.893	-0.4498 (4) P=0.550	-0.3573 (4) P=0.643	0.2831 (4) P=0.717	1.0000 (0) P=*****					
Age	-0.6239 (4) P=0.376	0.3248 (4) P=0.675	0.9710 (4) P=0.029	0.0934 (4) P=0.907	0.4523 (4) P=0.548	-0.5563 (4) P=0.444	0.5480 (4) P=0.452	0.3349 (4) P=0.665	-0.0155 (4) P=0.985	0.6032 (4) P=0.397	0.0431 (4) P=0.957	0.6117 (4) P=0.388	0.3807 (4) P=0.619	0.1788 (4) P=0.821	-0.8115 (4) P=0.189	1.0000 (0) P=*****				
Education	0.9104 (4) P=0.090	0.1620 (4) P=0.838	-0.7345 (4) P=0.266	0.2878 (4) P=0.712	0.1129 (4) P=0.887	0.0580 (4) P=0.942	-0.2043 (4) P=0.796	-0.0036 (4) P=0.996	-0.5222 (4) P=0.478	-0.9265 (4) P=0.073	-0.4930 (4) P=0.507	-0.1523 (4) P=0.848	0.0355 (4) P=0.964	0.3944 (4) P=0.606	0.8903 (4) P=0.110	-0.8315 (4) P=0.169	1.0000 (0) P=*****			
Experience	-0.9327 (4) P=0.067	-0.1855 (4) P=0.815	0.7965 (4) P=0.203	-0.3554 (4) P=0.645	-0.0261 (4) P=0.974	-0.1759 (4) P=0.824	0.3498 (4) P=0.650	-0.0760 (4) P=0.924	0.4231 (4) P=0.577	0.9281 (4) P=0.072	0.3599 (4) P=0.640	0.2755 (4) P=0.726	0.1124 (4) P=0.888	-0.3464 (4) P=0.654	-0.9515 (4) P=0.049	0.8567 (4) P=0.143	-0.9869 (4) P=0.013	1.0000 (0) P=*****		
Cultivation	99.0000 (4) P=*****	99.0000 (4) P=*****	99.0000 (4) P=*****	99.0000 (4) P=*****	99.0000 (4) P=*****	99.0000 (4) P=*****	99.0000 (4) P=*****	99.0000 (4) P=*****	99.0000 (4) P=*****	99.0000 (4) P=*****	99.0000 (4) P=*****	99.0000 (4) P=*****	99.0000 (4) P=*****	99.0000 (4) P=*****	99.0000 (4) P=*****	99.0000 (4) P=*****	99.0000 (4) P=*****	99.0000 (4) P=*****	1.0000 (0) P=*****	
Greenhouse	99.0000 (4) P=*****	99.0000 (4) P=*****	99.0000 (4) P=*****	99.0000 (4) P=*****	99.0000 (4) P=*****	99.0000 (4) P=*****	99.0000 (4) P=*****	99.0000 (4) P=*****	99.0000 (4) P=*****	99.0000 (4) P=*****	99.0000 (4) P=*****	99.0000 (4) P=*****	99.0000 (4) P=*****	99.0000 (4) P=*****	99.0000 (4) P=*****	99.0000 (4) P=*****	99.0000 (4) P=*****	99.0000 (4) P=*****	99.0000 (4) P=*****	1.0000 (0) P=*****

(COEFFICIENT / (CASES) / SIGNIFICANCE)   (A VALUE OF 99.0000 IS PRINTED IF A COEFFICIENT CANNOT BE COMPUTED)

D. GROUP 1
(5 cases)

	Yield	Farm size	Lettuce area	Fuel	Fertilizer	Pesticide	Labour	Machinery	Chemicals	Electricity
Yield	1.0000 (0) P=*****									
Farm size	0.1753 (5) P=0.778	1.0000 (0) P=*****								
Lettuce area	0.6870 (5) P=0.200	0.6476 (5) P=0.237	1.0000 (0) P=*****							
Fuel	-0.6255 (5) P=0.259	0.4365 (5) P=0.462	-0.3145 (5) P=0.606	1.0000 (0) P=*****						
Fertilizer	0.6042 (5) P=0.281	0.8878 (5) P=0.044	0.8725 (5) P=0.054	0.0377 (5) P=0.952	1.0000 (0) P=*****					
Pesticide	-0.2947 (5) P=0.630	0.5131 (5) P=0.377	-0.1410 (5) P=0.821	0.9217 (5) P=0.026	0.2437 (5) P=0.693	1.0000 (0) P=*****				
Labour	-0.1500 (4) P=0.850	-0.3468 (4) P=0.653	-0.6713 (4) P=0.329	-0.5551 (4) P=0.445	-0.3637 (4) P=0.636	-0.2676 (4) P=0.732	1.0000 (0) P=*****			
Machinery	-0.2458 (5) P=0.690	0.8173 (5) P=0.091	0.1058 (5) P=0.866	0.8428 (5) P=0.073	0.5195 (5) P=0.370	0.8543 (5) P=0.065	-0.0697 (4) P=0.930	1.0000 (0) P=*****		
Chemicals	-0.6912 (5) P=0.196	0.3189 (5) P=0.601	-0.4352 (5) P=0.464	0.9913 (5) P=0.001	-0.0900 (5) P=0.886	0.8925 (5) P=0.042	99.0000 (4) P=*****	0.7779 (5) P=0.121	1.0000 (0) P=*****	
Electricity	0.2140 (5) P=0.730	0.9378 (5) P=0.018	0.4900 (5) P=0.402	0.4154 (5) P=0.487	0.8363 (5) P=0.078	0.5131 (5) P=0.377	0.0095 (4) P=0.990	0.8396 (5) P=0.075	0.3151 (5) P=0.606	1.0000 (0) P=*****
Crops year^{-1}	0.0636 (5) P=0.919	-0.8928 (5) P=0.041	-0.2559 (5) P=0.678	-0.6928 (5) P=0.195	-0.6652 (5) P=0.221	-0.7397 (5) P=0.153	-0.0095 (4) P=0.990	-0.9716 (5) P=0.006	-0.6124 (5) P=0.272	-0.9433 (5) P=0.016
Energy	0.7546 (5) P=0.140	0.6312 (5) P=0.253	0.9815 (5) P=0.003	-0.3947 (5) P=0.511	0.8842 (5) P=0.046	-0.2116 (5) P=0.733	-0.5144 (4) P=0.486	0.0826 (5) P=0.895	-0.5119 (5) P=0.378	0.5332 (5) P=0.355
Management	0.1434 (3) P=0.908	-0.9934 (3) P=0.073	-0.9228 (3) P=0.252	-0.9228 (3) P=0.252	-0.7361 (3) P=0.473	0.0155 (3) P=0.990	0.9407 (3) P=0.220	-0.9228 (3) P=0.252	99.0000 (3) P=*****	99.0000 (3) P=*****
Irrigation	0.0120 (4) P=0.988	-0.0881 (4) P=0.912	-0.5066 (4) P=0.493	0.5348 (4) P=0.465	-0.1212 (4) P=0.879	0.7941 (4) P=0.206	0.0263 (3) P=0.983	0.3557 (4) P=0.644	0.5448 (4) P=0.455	0.0380 (4) P=0.962
Efficiency	0.6000 (5) P=0.285	-0.4662 (5) P=0.429	-0.1215 (5) P=0.846	-0.6556 (5) P=0.230	-0.1275 (5) P=0.838	-0.4629 (5) P=0.432	0.8045 (4) P=0.196	-0.5212 (5) P=0.368	-0.6133 (5) P=0.271	-0.2139 (5) P=0.730
Age	-0.4998 (4) P=0.500	-0.1896 (4) P=0.810	-0.5370 (4) P=0.463	-0.4310 (4) P=0.569	-0.3347 (4) P=0.665	-0.6221 (4) P=0.378	0.8388 (4) P=0.161	-0.0008 (4) P=0.999	99.0000 (4) P=*****	0.0679 (4) P=0.932
Education	0.6912 (5) P=0.196	-0.3189 (5) P=0.601	0.4352 (5) P=0.464	-0.9913 (5) P=0.001	0.0900 (5) P=0.886	-0.8925 (5) P=0.042	99.0000 (4) P=*****	-0.7779 (5) P=0.121	-1.0000 (5) P=0.000	-0.3151 (5) P=0.606
Experience	-0.3673 (6) P=0.543	0.7424 (5) P=0.151	0.0270 (5) P=0.966	0.6844 (5) P=0.202	0.4082 (5) P=0.495	0.5695 (5) P=0.316	0.2537 (4) P=0.746	0.8913 (5) P=0.042	0.6347 (5) P=0.250	0.8181 (5) P=0.091
Cultivation	0.1017 (5) P=0.871	0.6682 (5) P=0.218	0.6627 (5) P=0.223	0.3504 (5) P=0.563	0.6158 (5) P=0.268	0.4304 (5) P=0.469	-0.9384 (4) P=0.062	0.4421 (5) P=0.456	0.2500 (5) P=0.685	0.3851 (5) P=0.522
Greenhouse	99.0000 (5) P=*****	99.0000 (5) P=*****	99.0000 (5) P=*****	99.0000 (5) P=*****	99.0000 (5) P=*****	99.0000 (5) P=*****	99.0000 (4) P=*****	99.0000 (5) P=*****	99.0000 (5) P=*****	99.0000 (5) P=*****

	Crops year^{-1}	Energy	Management	Irrigation	Efficiency	Age	Education	Experience	Cultivation	Greenhouse
Crops year^{-1}	1.0000 (0) P=*****									
Energy	-0.2651 (5) P=0.666	1.0000 (0) P=*****								
Management	99.0000 (3) P=*****	-0.9149 (3) P=0.266	1.0000 (0) P=*****							
Irrigation	-0.2341 (4) P=0.766	-0.4757 (4) P=0.524	1.0000 (2) P=*****	1.0000 (0) P=*****						
Efficiency	0.3928 (5) P=0.513	0.0273 (5) P=0.965	0.9585 (3) P=0.184	0.2211 (4) P=0.779	1.0000 (0) P=*****					
Age	-0.0679 (4) P=0.932	-0.3999 (4) P=0.600	0.6065 (3) P=0.585	-0.8791 (3) P=0.316	0.3519 (4) P=0.648	1.0000 (0) P=*****				
Education	0.6124 (5) P=0.272	0.5119 (5) P=0.378	99.0000 (3) P=*****	-0.5448 (4) P=0.455	0.6133 (5) P=0.271	99.0000 (4) P=*****	1.0000 (0) P=*****			
Experience	-0.9035 (5) P=0.035	0.0549 (5) P=0.930	0.1276 (3) P=0.919	-0.0359 (4) P=0.964	-0.4560 (5) P=0.440	0.5223 (4) P=0.478	-0.6347 (5) P=0.250	1.0000 (0) P=*****		
Cultivation	-0.4082 (5) P=0.495	0.5189 (5) P=0.370	-0.9228 (3) P=0.252	99.0000 (4) P=*****	-0.7187 (5) P=0.171	-0.7920 (4) P=0.208	-0.2500 (5) P=0.685	0.1790 (5) P=0.773	1.0000 (0) P=*****	
Greenhouse	99.0000 (5) P=*****	99.0000 (5) P=*****	99.0000 (3) P=*****	99.0000 (4) P=*****	99.0000 (5) P=*****	99.0000 (4) P=*****	99.0000 (5) P=*****	99.0000 (5) P=*****	99.0000 (5) P=*****	1.0000 (0) P=*****

(COEFFICIENT / (CASES) / SIGNIFICANCE) (A VALUE OF 99.0000 IS PRINTED IF A COEFFICIENT CANNOT BE COMPUTED)

E. GROUP 2
(10 cases)

	Yield	Farm size	Lettuce area	Fuel	Fertilizer	Pesticide	Labour	Machinery	Chemicals
Yield	1.0000 (0) P=*****								
Farm size	0.1979 (10) P=0.584	1.0000 (0) P=*****							
Lettuce area	-0.2057 (10) P=0.569	0.5306 (10) P=0.115	1.0000 (0) P=*****						
Fuel	0.6742 (10) P=0.033	-0.2846 (10) P=0.425	-0.2936 (10) P=0.410	1.0000 (0) P=*****					
Fertilizer	-0.1458 (6) P=0.783	0.5038 (6) P=0.308	0.5300 (6) P=0.279	0.3503 (6) P=0.496	1.0000 (0) P=*****				
Pesticide	0.1275 (10) P=0.726	0.7853 (10) P=0.007	0.4626 (10) P=0.178	-0.2654 (10) P=0.459	0.1480 (6) P=0.780	1.0000 (0) P=*****			
Labour	-0.0549 (10) P=0.880	-0.5679 (10) P=0.087	-0.4584 (10) P=0.183	0.1388 (10) P=0.702	-0.3109 (6) P=0.549	-0.6349 (10) P=0.049	1.0000 (0) P=*****		
Machinery	0.6993 (10) P=0.024	-0.3334 (10) P=0.346	-0.2719 (10) P=0.447	0.9866 (10) P=0.000	0.1385 (6) P=0.794	-0.3236 (10) P=0.362	0.1545 (10) P=0.670	1.0000 (0) P=*****	
Chemicals	-0.3765 (10) P=0.284	-0.2756 (10) P=0.441	-0.2871 (10) P=0.421	-0.2947 (10) P=0.408	-0.5661 (6) P=0.242	-0.1596 (10) P=0.660	0.7672 (10) P=0.010	-0.3232 (10) P=0.362	1.0000 (0) P=*****
Electricity	0.3599 (10) P=0.307	-0.3918 (10) P=0.263	0.0688 (10) P=0.850	0.2840 (10) P=0.427	-0.6846 (6) P=0.134	-0.4285 (10) P=0.217	0.1194 (10) P=0.743	0.4361 (10) P=0.208	-0.2986 (10) P=0.402
Crops $year^{-1}$	-0.4321 (10) P=0.212	-0.6357 (10) P=0.048	-0.5317 (10) P=0.114	-0.2711 (10) P=0.449	-0.7902 (6) P=0.061	-0.7413 (10) P=0.014	0.5875 (10) P=0.074	-0.2201 (10) P=0.541	0.5165 (10) P=0.126
Energy	0.8623 (10) P=0.001	0.0731 (10) P=0.841	0.0036 (10) P=0.992	0.8382 (10) P=0.002	0.5902 (6) P=0.217	0.0753 (10) P=0.836	-0.0141 (10) P=0.969	0.8512 (10) P=0.002	-0.3670 (10) P=0.297
Management	-0.0141 (10) P=0.969	-0.5244 (10) P=0.120	-0.4981 (10) P=0.143	0.2006 (10) P=0.578	-0.1631 (6) P=0.758	-0.5736 (10) P=0.083	0.9879 (10) P=0.000	0.1946 (10) P=0.590	0.7827 (10) P=0.007
Irrigation	0.1839 (9) P=0.636	0.8601 (9) P=0.003	0.6557 (9) P=0.055	-0.1661 (9) P=0.669	0.6647 (6) P=0.150	0.6943 (9) P=0.038	-0.8257 (9) P=0.006	-0.2023 (9) P=0.602	-0.6390 (9) P=0.064
Efficiency	0.3803 (10) P=0.278	0.3272 (10) P=0.356	-0.2908 (10) P=0.415	-0.2636 (10) P=0.462	-0.3268 (6) P=0.527	0.2405 (10) P=0.503	0.1243 (10) P=0.732	-0.2477 (10) P=0.490	0.1898 (10) P=0.599
Age	-0.1149 (10) P=0.752	0.3155 (10) P=0.375	0.5994 (10) P=0.067	-0.2032 (10) P=0.573	0.0780 (6) P=0.883	0.0607 (10) P=0.868	-0.1679 (10) P=0.643	-0.1473 (10) P=0.685	-0.0815 (10) P=0.823
Education	0.3250 (10) P=0.360	0.6382 (10) P=0.047	0.1193 (10) P=0.743	-0.0724 (10) P=0.843	0.3479 (6) P=0.499	0.6910 (10) P=0.027	-0.6554 (10) P=0.040	-0.1420 (10) P=0.696	-0.4456 (10) P=0.196
Experience	-0.1634 (10) P=0.652	-0.1750 (10) P=0.629	0.0394 (10) P=0.914	-0.0340 (10) P=0.926	-0.2756 (6) P=0.597	-0.2044 (10) P=0.571	0.1268 (10) P=0.727	0.0105 (10) P=0.977	0.2006 (10) P=0.578
Cultivation	-0.2926 (9) P=0.445	0.7738 (9) P=0.014	0.4661 (9) P=0.206	-0.5127 (9) P=0.079	0.5975 (5) P=0.287	0.8641 (9) P=0.003	-0.5384 (9) P=0.135	-0.6884 (9) P=0.040	0.0164 (9) P=0.967
Greenhouse	0.1297 (10) P=0.721	0.8523 (10) P=0.002	0.3847 (10) P=0.272	-0.3974 (10) P=0.256	0.1273 (6) P=0.810	0.9186 (10) P=0.000	-0.5855 (10) P=0.075	-0.4444 (10) P=0.198	-0.1336 (10) P=0.713

	Electricity	Crops $year^{-1}$	Energy	Management	Irrigation	Efficiency	Age	Education	Experience	Cultivation	Greenhouse
Electricity	1.0000 (0) P=*****										
Crops $year^{-1}$	0.1685 (10) P=0.642	1.0000 (0) P=*****									
Energy	0.3705 (10) P=0.292	-0.5461 (10) P=0.102	1.0000 (0) P=*****								
Management	0.0109 (10) P=0.976	0.5232 (10) P=0.121	0.0407 (10) P=0.911	1.0000 (0) P=*****							
Irrigation	-0.2508 (9) P=0.515	-0.8151 (9) P=0.007	0.1028 (9) P=0.792	-0.8072 (9) P=0.009	1.0000 (0) P=*****						
Efficiency	-0.0411 (10) P=0.910	0.0293 (10) P=0.936	-0.0856 (10) P=0.814	0.1119 (10) P=0.758	0.0777 (9) P=0.842	1.0000 (0) P=*****					
Age	0.2455 (10) P=0.494	0.0220 (10) P=0.952	0.0581 (10) P=0.873	-0.2033 (10) P=0.573	0.2837 (9) P=0.459	-0.3629 (10) P=0.303	1.0000 (0) P=*****				
Education	-0.4391 (10) P=0.204	-0.6353 (10) P=0.048	0.0856 (10) P=0.814	-0.5949 (10) P=0.070	0.7606 (9) P=0.017	0.4261 (10) P=0.219	-0.3166 (10) P=0.373	1.0000 (0) P=*****			
Experience	0.2170 (10) P=0.547	0.3780 (10) P=0.281	0.0469 (10) P=0.898	0.1218 (10) P=0.737	-0.2808 (9) P=0.464	-0.4840 (10) P=0.156	0.7462 (10) P=0.013	-0.6004 (10) P=0.066	1.0000 (0) P=*****		
Cultivation	-0.7559 (9) P=0.018	-0.5383 (9) P=0.135	-0.3254 (9) P=0.393	-0.4813 (9) P=0.190	0.6276 (8) P=0.096	0.1498 (9) P=0.700	0.0911 (9) P=0.816	0.6107 (9) P=0.081	-0.2093 (9) P=0.589	1.0000 (0) P=*****	
Greenhouse	-0.4346 (10) P=0.209	-0.5852 (10) P=0.076	0.0193 (10) P=0.958	-0.5291 (10) P=0.116	0.6648 (9) P=0.061	0.3106 (10) P=0.382	0.2288 (10) P=0.525	0.6389 (10) P=0.047	-0.0103 (10) P=0.978	0.8854 (9) P=0.001	1.0000 (0) P=*****

(COEFFICIENT / (CASES) / SIGNIFICANCE) (A VALUE OF 99.0000 IS PRINTED IF A COEFFICIENT CANNOT BE COMPUTED)

F. GROUP 2a
(6 cases)

	Yield	Farm size	Lettuce area	Fuel	Fertilizer	Pesticide	Labour	Machinery	Chemicals
Yield	1.0000 (0) P=*****								
Farm size	-0.0751 (6) P=0.888	1.0000 (0) P=*****							
Lettuce area	-0.1981 (6) P=0.707	0.9010 (6) P=0.014	1.0000 (0) P=*****						
Fuel	0.8443 (6) P=0.034	0.1007 (6) P=0.850	-0.2061 (6) P=0.695	1.0000 (0) P=*****					
Fertilizer	-1.0000 (2) P=*****	1.0000 (2) P=*****	1.0000 (2) P=*****	1.0000 (2) P=*****	1.0000 (0) P=*****				
Pesticide	0.0349 (6) P=0.948	0.9160 (6) P=0.010	0.7330 (6) P=0.097	0.3340 (6) P=0.518	1.0000 (2) P=*****	1.0000 (0) P=*****			
Labour	0.0321 (6) P=0.952	-0.4889 (6) P=0.325	-0.3996 (6) P=0.433	-0.1263 (6) P=0.812	-1.0000 (2) P=*****	-0.3352 (6) P=0.516	1.0000 (0) P=*****		
Machinery	0.9146 (6) P=0.011	0.1025 (6) P=0.847	-0.1616 (6) P=0.760	0.9856 (6) P=0.000	1.0000 (2) P=*****	0.2892 (6) P=0.578	-0.1455 (6) P=0.783	1.0000 (0) P=*****	
Chemicals	-0.3389 (6) P=0.511	-0.4269 (6) P=0.399	-0.2875 (6) P=0.581	-0.3906 (6) P=0.444	99.0000 (2) P=*****	-0.2705 (6) P=0.604	0.9066 (6) P=0.013	-0.4472 (6) P=0.374	1.0000 (0) P=*****
Electricity	0.5885 (6) P=0.219	0.1206 (6) P=0.820	0.2861 (6) P=0.583	0.1470 (6) P=0.781	-1.0000 (2) P=*****	-0.1117 (6) P=0.833	-0.1889 (6) P=0.720	0.3113 (6) P=0.548	-0.4635 (6) P=0.355
Crops $year^{-1}$	-0.4542 (6) P=0.366	-0.7769 (6) P=0.069	-0.4863 (6) P=0.328	-0.6925 (6) P=0.127	-1.0000 (2) P=*****	-0.8602 (6) P=0.028	0.3863 (6) P=0.449	-0.6783 (6) P=0.139	0.5214 (6) P=0.289
Energy	0.9607 (6) P=0.002	0.1116 (6) P=0.833	-0.0980 (6) P=0.854	0.9369 (6) P=0.006	1.0000 (2) P=*****	0.2738 (6) P=0.600	-0.0090 (5) P=0.987	0.9743 (6) P=0.001	-0.3508 (6) P=0.495
Management	0.0705 (6) P=0.894	-0.5013 (6) P=0.311	-0.4715 (6) P=0.345	-0.0123 (6) P=0.982	-1.0000 (2) P=*****	-0.2903 (6) P=0.577	0.9858 (6) P=0.000	-0.0532 (6) P=0.920	0.8946 (6) P=0.016
Irrigation	0.1132 (5) P=0.856	0.8908 (5) P=0.043	0.8176 (5) P=0.091	0.2575 (5) P=0.676	1.0000 (2) P=*****	0.8358 (5) P=0.078	-0.8857 (5) P=0.046	0.2895 (5) P=0.637	-0.7126 (5) P=0.177
Efficiency	0.1222 (6) P=0.818	-0.4487 (6) P=0.372	-0.1607 (6) P=0.761	-0.3523 (6) P=0.493	-1.0000 (2) P=*****	-0.5502 (6) P=0.258	0.7340 (6) P=0.097	-0.2575 (6) P=0.622	0.5703 (6) P=0.237
Age	0.1359 (6) P=0.797	-0.1764 (6) P=0.738	0.1992 (6) P=0.705	-0.2725 (6) P=0.601	-1.0000 (2) P=*****	-0.3310 (6) P=0.522	-0.1205 (6) P=0.820	-0.1494 (6) P=0.778	-0.1044 (6) P=0.844
Education	0.0521 (6) P=0.922	0.5517 (6) P=0.256	0.3655 (6) P=0.476	0.4152 (6) P=0.413	1.0000 (2) P=*****	0.6491 (6) P=0.163	-0.7801 (5) P=0.067	0.3617 (6) P=0.481	-0.6325 (6) P=0.178
Experience	0.2466 (6) P=0.638	-0.8863 (6) P=0.019	-0.6952 (6) P=0.126	-0.0275 (6) P=0.959	-1.0000 (2) P=*****	-0.8464 (6) P=0.034	0.2410 (6) P=0.646	0.0191 (6) P=0.971	0.1758 (6) P=0.739
Cultivation	-0.9052 (5) P=0.035	0.2565 (5) P=0.677	0.3684 (5) P=0.542	-0.7412 (5) P=0.152	99.0000 (1) P=*****	0.2660 (5) P=0.665	-0.0106 (5) P=0.986	-0.8024 (5) P=0.102	0.4082 (5) P=0.495
Greenhouse	99.0000 (6) P=*****	99.0000 (6) P=*****	99.0000 (6) P=*****	99.0000 (6) P=*****	99.0000 (2) P=*****	99.0000 (6) P=*****	99.0000 (6) P=*****	99.0000 (6) P=*****	99.0000 (6) P=*****

	Electricity	Crops $year^{-1}$	Energy	Management	Irrigation	Efficiency	Age	Education	Experience	Cultivation	Greenhouse
Electricity	1.0000 (0) P=*****										
Crops $year^{-1}$	-0.1421 (6) P=0.788	1.0000 (0) P=*****									
Energy	0.4341 (6) P=0.390	-0.6565 (6) P=0.157	1.0000 (0) P=*****								
Management	-0.2907 (6) P=0.576	0.3221 (6) P=0.534	0.0568 (6) P=0.915	1.0000 (0) P=*****							
Irrigation	0.2808 (5) P=0.647	-0.8093 (5) P=0.097	0.2644 (5) P=0.667	-0.8699 (5) P=0.055	1.0000 (0) P=*****						
Efficiency	0.4301 (6) P=0.395	0.5302 (6) P=0.279	-0.0615 (6) P=0.908	0.6215 (6) P=0.188	-0.6607 (5) P=0.225	1.0000 (0) P=*****					
Age	0.6242 (5) P=0.185	0.3961 (6) P=0.437	-0.0708 (6) P=0.894	-0.2206 (6) P=0.674	0.1779 (5) P=0.775	0.4191 (6) P=0.408	1.0000 (0) P=*****				
Education	-0.1762 (6) P=0.738	-0.5996 (6) P=0.208	0.2063 (6) P=0.695	-0.6900 (6) P=0.129	0.8628 (5) P=0.060	-0.9082 (6) P=0.012	-0.0826 (6) P=0.876	1.0000 (0) P=*****			
Experience	0.1804 (6) P=0.732	0.7025 (6) P=0.120	0.0166 (6) P=0.975	0.2330 (6) P=0.657	-0.5729 (5) P=0.313	0.4143 (6) P=0.414	0.5641 (6) P=0.244	-0.3376 (6) P=0.513	1.0000 (0) P=*****		
Cultivation	-0.7040 (5) P=0.185	0.3612 (5) P=0.550	-0.8243 (5) P=0.086	-0.0279 (5) P=0.965	0.1111 (4) P=0.889	-0.2486 (5) P=0.687	-0.1021 (5) P=0.870	0.1667 (5) P=0.789	-0.4399 (5) P=0.458	1.0000 (0) P=*****	
Greenhouse	99.0000 (6) P=*****	99.0000 (6) P=*****	99.0000 (6) P=*****	99.0000 (6) P=*****	99.0000 (5) P=*****	99.0000 (6) P=*****	99.0000 (6) P=*****	99.0000 (6) P=*****	99.0000 (6) P=*****	99.0000 (5) P=*****	1.0000 (0) P=*****

(COEFFICIENT / (CASES) / SIGNIFICANCE)   (A VALUE OF 99.0000 IS PRINTED IF A COEFFICIENT CANNOT BE COMPUTED)

G. GROUP 3
(12 cases)

	Yield	Farm size	Lettuce area	Fuel	Fertilizer	Pesticide	Labour	Machinery	Chemicals	Electricity	Crops year $^{-1}$	Energy	Management	Irrigation	Efficiency	Age	Education	Experience	Cultivation	Greenhouse
Yield	1.0000 (0) P=*****																			
Farm size	0.0266 (12) P=0.935	1.0000 (0) P=*****																		
Lettuce area	0.0959 (12) P=0.767	0.9226 (12) P=0.000	1.0000 (0) P=*****																	
Fuel	0.4531 (12) P=0.139	-0.2566 (12) P=0.421	-0.1896 (12) P=0.555	1.0000 (0) P=*****																
Fertilizer	0.6863 (10) P=0.028	0.1412 (10) P=0.697	0.2068 (10) P=0.567	0.2730 (10) P=0.445	1.0000 (0) P=*****															
Pesticide	0.0185 (12) P=0.955	0.8170 (12) P=0.001	0.6623 (12) P=0.019	-0.1861 (12) P=0.562	0.1184 (10) P=0.745	1.0000 (0) P=*****														
Labour	0.1583 (11) P=0.642	-0.5627 (11) P=0.072	-0.4001 (11) P=0.223	0.1922 (11) P=0.571	0.4940 (10) P=0.147	-0.5255 (11) P=0.097	1.0000 (0) P=*****													
Machinery	0.5268 (12) P=0.078	-0.0303 (12) P=0.926	0.0510 (12) P=0.875	0.9365 (12) P=0.000	0.3732 (10) P=0.288	-0.0245 (12) P=0.940	0.0879 (11) P=0.797	1.0000 (0) P=*****												
Chemicals	-0.3443 (12) P=0.273	0.0724 (12) P=0.823	-0.1875 (12) P=0.560	-0.2079 (12) P=0.517	99.0000 (10) P=*****	0.0336 (12) P=0.917	-0.3778 (11) P=0.252	-0.2301 (12) P=0.472	1.0000 (0) P=*****											
Electricity	0.1546 (12) P=0.631	0.6938 (12) P=0.012	0.7188 (12) P=0.008	-0.1969 (12) P=0.540	0.2619 (10) P=0.465	0.5377 (12) P=0.071	-0.3604 (11) P=0.276	0.1545 (12) P=0.632	-0.0143 (12) P=0.965	1.0000 (0) P=*****										
Crops year $^{-1}$	0.2583 (12) P=0.418	-0.6370 (12) P=0.026	-0.4643 (12) P=0.128	0.5520 (12) P=0.063	0.1276 (10) P=0.725	-0.5948 (12) P=0.041	0.4972 (11) P=0.120	0.3476 (12) P=0.268	-0.1666 (12) P=0.605	-0.5920 (12) P=0.043	1.0000 (0) P=*****									
Energy	0.6794 (12) P=0.015	-0.0696 (12) P=0.830	0.0205 (12) P=0.949	0.7497 (12) P=0.005	0.8293 (10) P=0.003	-0.0244 (12) P=0.940	0.5377 (11) P=0.088	0.7676 (12) P=0.004	-0.2914 (12) P=0.358	0.0243 (12) P=0.940	0.4236 (12) P=0.170	1.0000 (0) P=*****								
Management	-0.3257 (11) P=0.328	-0.5375 (11) P=0.088	-0.4458 (11) P=0.169	-0.4128 (11) P=0.207	-0.2113 (10) P=0.558	-0.7253 (11) P=0.012	0.4899 (11) P=0.126	-0.4930 (11) P=0.123	-0.1000 (11) P=0.770	-0.3056 (11) P=0.361	0.0088 (11) P=0.980	-0.3400 (11) P=0.306	1.0000 (0) P=*****							
Irrigation	-0.0544 (10) P=0.881	-0.3398 (10) P=0.337	-0.0912 (10) P=0.802	-0.3826 (10) P=0.275	-0.0820 (8) P=0.847	-0.1088 (10) P=0.765	0.3765 (9) P=0.318	-0.4949 (10) P=0.146	-0.4821 (10) P=0.158	-0.2652 (10) P=0.459	0.1709 (10) P=0.637	-0.1914 (10) P=0.596	0.4004 (9) P=0.286	1.0000 (0) P=*****						
Efficiency	0.4592 (12) P=0.133	0.2674 (12) P=0.401	0.1818 (12) P=0.572	-0.1529 (12) P=0.635	-0.0963 (10) P=0.791	0.1930 (12) P=0.548	-0.5711 (11) P=0.066	-0.0101 (12) P=0.975	-0.0584 (12) P=0.857	0.3506 (12) P=0.264	-0.4028 (12) P=0.194	-0.2055 (12) P=0.522	-0.0951 (11) P=0.781	-0.1878 (10) P=0.603	1.0000 (0) P=*****					
Age	0.0652 (12) P=0.840	0.0324 (12) P=0.920	-0.1837 (12) P=0.568	-0.4116 (12) P=0.184	-0.1757 (10) P=0.627	0.2232 (12) P=0.486	-0.2990 (11) P=0.372	-0.4622 (12) P=0.130	0.2012 (12) P=0.531	-0.1658 (12) P=0.606	-0.1808 (12) P=0.574	-0.3390 (12) P=0.281	-0.0365 (11) P=0.915	-0.0268 (10) P=0.941	0.5447 (12) P=0.067	1.0000 (0) P=*****				
Education	-0.4763 (10) P=0.164	0.3242 (10) P=0.361	0.4255 (10) P=0.220	0.0684 (10) P=0.851	-0.1471 (8) P=0.728	0.1557 (10) P=0.667	0.1008 (9) P=0.796	0.1625 (10) P=0.654	-0.2485 (10) P=0.489	0.2924 (10) P=0.412	-0.1679 (10) P=0.643	0.0668 (10) P=0.876	0.0036 (9) P=0.993	-0.1124 (8) P=0.791	-0.4766 (10) P=0.164	-0.5417 (10) P=0.106	1.0000 (0) P=*****			
Experience	0.3253 (11) P=0.329	-0.1409 (11) P=0.680	-0.2531 (11) P=0.453	-0.2412 (11) P=0.475	0.5119 (9) P=0.159	0.2244 (11) P=0.507	0.4678 (10) P=0.173	-0.2026 (11) P=0.550	-0.1298 (11) P=0.704	0.0143 (11) P=0.967	-0.0436 (11) P=0.899	0.3828 (11) P=0.245	-0.0456 (10) P=0.900	0.1641 (9) P=0.573	0.2086 (11) P=0.538	0.7214 (11) P=0.012	-0.3360 (9) P=0.377	1.0000 (0) P=*****		
Cultivation	0.1774 (10) P=0.624	0.4892 (10) P=0.151	0.4506 (10) P=0.191	-0.5435 (10) P=0.104	0.4491 (8) P=0.264	0.5520 (10) P=0.098	0.1534 (9) P=0.694	-0.5485 (10) P=0.101	-0.1111 (10) P=0.760	0.2938 (10) P=0.410	-0.3758 (10) P=0.285	0.0181 (10) P=0.960	-0.0698 (9) P=0.858	0.6073 (8) P=0.110	0.0298 (10) P=0.935	0.3644 (10) P=0.301	-0.2294 (9) P=0.553	0.4974 (9) P=0.173	1.0000 (0) P=*****	
Greenhouse	-0.0256 (12) P=0.937	-0.2540 (12) P=0.426	-0.1069 (12) P=0.741	0.2539 (12) P=0.426	-0.3689 (10) P=0.294	-0.3031 (12) P=0.338	-0.3011 (11) P=0.368	0.1868 (12) P=0.561	-0.1741 (12) P=0.588	-0.1648 (12) P=0.609	0.2597 (12) P=0.415	-0.1692 (12) P=0.599	0.0998 (11) P=0.770	0.2201 (10) P=0.541	0.2370 (12) P=0.458	-0.1284 (12) P=0.691	0.0 (10) P=1.000	-0.4664 (11) P=0.148	-0.5833 (10) P=0.077	1.0000 (0) P=*****

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APPENDIX III: MEAN AND RANGE OF VALUES FOR ALL VARIABLES FOR THE TOTAL SAMPLE AND FOR ALL SUBGROUPS

Variable		Total Sample (27 cases)	Group A (23 cases)	Group B (4 cases)	Group 1 (5 cases)	Group 2 (10 cases)	Group 2a (6 cases)	Group 3 (12 cases)
Yield (cartons/ crop ha)	Mean=	1578	1514	1941	2133	1811	1724	1152
	Range=	3398	3398	1012	2027	2936	2936	2198
	Max=	3553	3553	2452	3086	3553	3553	2353
	Min=	156	156	1440	1059	617	617	156
	Missing=	0	0	0	0	0	0	0
Efficiency (gross sales/ $ energy)	Mean=	12.3	12.3	12.4	31.5	11.3	10.6	5.2
	Range=	39.7	39.7	8.5	19.9	8.5	4.9	4.7
	Max=	42.2	42.2	16.1	42.2	16.1	13.1	7.3
	Min=	2.5	2.5	7.5	22.3	7.5	8.1	2.5
	Missing=	0	0	0	0	0	0	0
Energy ($energy/ crop ha)	Mean=	969	983	890	359	880	872	1298
	Range=	3296	3296	331	251	1814	1814	3140
	Max=	3419	3419	1066	514	1938	1938	3419
	Min=	124	124	735	263	124	124	279
	Missing=	0	0	0	0	0	0	0
Fuel ($/ crop ha	Mean=	156	176	45	31	129	185	232
	Range=	838	838	54	54	555	555	838
	Max=	846	846	83	71	563	563	846
	Min=	7	7	29	16	7	7	7
	Missing=	0	0	0	0	0	0	0
Fertilizer (kg/ crop ha)	Mean=	206	216	162	122	154	138	278
	Range=	582	582	190	172	205	205	582
	Max=	593	593	234	224	241	241	593
	Min=	11	11	45	53	36	36	11
	Missing=	6	6	0	0	4	4	2
Fertilizer ($/ crop ha)	Mean=	622	655	435	265	534	600	844
	Range=	2404	2404	500	325	1127	1127	2320
	Max=	2474	2474	691	395	1201	1201	2474
	Min=	71	71	191	71	74	74	154
	Missing=	0	0	0	0	0	0	0
Pesticide ($/ crop ha)	Mean=	159	118	392	45	209	87	165
	Range=	508	508	144	58	465	185	508
	Max=	508	508	465	81	465	185	508
	Min=	0	0	321	24	0	0	0
	Missing	0	0	0	0	0	0	0
Machinery (MJ/ crop ha)	Mean=	18378	20695	5057	4032	14683	21101	27434
	Range=	79257	79257	4555	6882	59155	59155	77712
	Max=	79955	79955	8086	8420	59854	59854	79955
	Min=	699	699	3532	1539	699	699	2243
	Missing=	0	0	0	0	0	0	0
Other chemicals ($/ crop ha)	Mean=	7.2	7.3	6.2	2.8	9.9	12.3	6.7
	Range=	80.2	80.2	24.7	14.1	74.1	74.1	80.2
	Max=	80.2	80.2	24.7	14.1	74.1	74.1	80.2
	Min=	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Missing=	0	0	0	0	0	0	0
Electricity ($/ crop ha)	Mean=	45.4	51.2	12.5	15.5	34.9	49.8	66.7
	Range=	395.1	395.1	23.6	49.4	123.5	123.5	395.1
	Ma =	395.1	395.1	24.7	49.4	123.5	123.5	395.1
	Min=	0.0	0.0	1.1	0.0	0.0	0.0	0.0
	Missing=	0	0	0	0	0	0	0
Farm size (ha)	Mean=	15.3	5.9	69.1	2.8	32.6	8.2	6.0
	Range=	113.0	21.9	72.9	3.8	113.0	21.9	18.6
	Max=	113.4	22.3	113.4	4.9	113.4	22.3	20.3
	Min=	0.4	0.4	40.5	1.0	0.4	0.4	1.6
	Missing=	0	0	0	0	0	0	0
Lettuce area (crop ha)	Mean=	6.8	5.4	15.0	1.9	10.3	7.1	6.0
	Range=	28.3	28.3	23.7	4.0	27.6	27.6	19.4
	Max=	28.4	28.4	27.7	4.1	28.4	28.4	20.3
	Min=	0.1	0.1	4.1	0.1	0.8	0.8	0.8
	Missing=	0	0	0	0	0	0	0

		Total Sample (27 cases)	Group A (23 cases)	Group B (4 cases)	Group 1 (5 cases)	Group 2 (10 cases)	Group 2a (6 cases)	Group 3 (12 cases)
Labour (hours/ crop ha)	Mean=	1597	1858	230	2009	1103	1685	1897
	Range=	4094	3941	142	1172	4094	3941	3150
	Max=	4267	4267	315	2765	4267	4267	3657
	Min=	173	326	173	1594	173	326	507
	Missing=	2	2	0	1	0	0	1
Age (years)	Mean=	46	45	51	37	49	48	46
	Range=	38	38	26	18	26	13	38
	Max=	64	64	63	46	63	52	64
	Min=	26	26	37	28	37	39	26
	Missing=	1	1	0	1	0	0	0
Education (1 to 5)	Mean=	2.8	2.6	3.8	2.8	3.1	2.7	2.5
	Range=	4.0	2.0	2.0	1.0	3.0	1.0	2.0
	Max=	5.0	3.0	5.0	3.0	5.0	3.0	3.0
	Min=	1.0	1.0	3.0	2.0	2.0	2.0	1.0
	Missing=	2	2	0	0	0	0	2
Experience (years)	Mean=	20.0	19.2	24.5	12.2	24.6	24.7	19.5
	Range=	48.0	48.0	26.0	17.0	26.0	15.0	48.0
	Max=	50.0	50.0	36.0	20.0	36.0	30.0	50.0
	Min=	2.0	2.0	10.0	3.0	10.0	15.0	2.0
	Missing=	1	1	0	0	0	0	1
Crops (number/ year)	Mean=	2.4	2.6	1.3	2.6	2.4	3.2	2.4
	Range=	4.0	4.0	1.0	1.0	4.0	4.0	2.3
	Max=	5.0	5.0	2.0	3.0	5.0	5.0	3.5
	Min=	1.0	1.0	1.0	2.0	1.0	1.0	1.3
	Missing=	0	0	0	0	0	0	0
Management (hours/ crop ha)	Mean=	486	873	51	598	369	582	561
	Range=	1632	1628	47	603	1632	1628	826
	Max=	1659	1659	74	922	1659	1659	1037
	Min=	28	32	28	319	28	32	211
	Missing=	3	3	0	2	0	0	1
Irrigation (% lettuce area)	Mean=	61	57	79	67	59	44	60
	Range=	100	100	50	83	85	60	100
	Max=	100	100	100	100	100	75	100
	Min=	0	0	50	17	15	15	0
	Missing=	4	4	0	1	1	1	2
Cultivation (1 to 3)	Mean=	2.1	2.0	3.0	1.8	2.2	1.6	2.2
	Range=	2.0	2.0	0.0	1.0	2.0	1.0	2.0
	Max=	3.0	3.0	3.0	2.0	3.0	2.0	3.0
	Min=	1.0	1.0	3.0	1.0	1.0	1.0	1.0
	Missing=	3	3	0	0	1	1	2
Greenhouse (1 or 2)	Mean=	1.3	1.1	2.0	1.0	1.4	1.0	1.3
	Range=	1.0	1.0	0.0	0.0	1.0	0.0	1.0
	Max=	2.0	2.0	2.0	1.0	2.0	1.0	2.0
	Min=	1.0	1.0	2.0	1.0	1.0	1.0	1.0
	Missing=	0	0	0	0	0	0	0

APPENDIX IV: INTERCEPTS, BETA VALUES, CORRELATION COEFFICIENTS, ERROR ESTIMATES AND SIGNIFICANCE LEVELS FOR CURVES FITTED TO SCATTER PLOTS IN FIGURES 6-9

	x	y	a	B	r	r^2	standard error	sign.
Figure 6	energy	efficiency	2.55	6534.13	-0.63	0.40	8.42	0.001
	fuel	"	6.07	309.78	-0.61	0.37	8.68	0.001
	fertilizer	"	0.98	2347.48	-0.78	0.61	8.04	0.000
	machinery	"	6.11	34681.74	-0.62	0.39	8.53	0.000
Figure 7	fuel	energy	-839.46	426.98	0.80	0.64	428.00	0.000
	machinery	"	-2928.14	426.87	0.77	0.59	458.04	0.000
Figure 8	labour	farm size	2.16	666.30	-0.72	0.51	2.83	0.000
	management	"	3.10	81.07	-0.54	0.30	3.60	0.006
	crops/year	"	0.50	4.80	-0.79	0.62	2.41	0.000
	labour	lettuce area	1.89	360.86	-0.41	0.17	3.60	0.041
	management	"	2.18	49.84	-0.35	0.13	3.86	0.089
	crops/year	"	0.67	3.10	-0.52	0.27	3.35	0.006
Figure 9	labour	pesticide use	26.52	578.73	-0.48	0.23	5.53	0.015
	management	"	36.53	70.36	-0.36	0.13	6.36	0.081
	crops/year	"	7.25	4.32	-0.55	0.30	4.81	0.003
	farm size	"	-23.67	104.06	0.80	0.64	105.41	0.000
	lettuce area	"	19.96	104.13	0.61	0.37	147.09	0.003

APPENDIX V: DATA MATRIX

Group	Efficiency rank	Location	Yield (cartons/crop-ha)	Energy efficiency ((yield x price)/ $ energy)	Energy ($/crop-ha)	Fuel ($/crop-ha)	Fertilizer (kg N/crop-ha)	Fertilizer ($/crop-ha)	Pesticides & herbicides ($/crop-ha)	Machinery (MJ/crop-ha)	Chemicals ($/crop-ha)	Electricity ($/crop-ha)	Farm size (ha)	Lettuce area (crop-ha)	Labour (hours/crop-ha)	Age (years)	Education (1-5)	Experience (years)	Crops/year	Management (hours/crop-ha)	Irrigation (%)	Cultivation (1-3)	Greenhouse (1-2)
Group 1	1	B	1975	42.19	263.23	16.30	52.72	219.90	27.04	1538.59	0.0	0.0	1.0	0.067	2765.43	46	3	10	3.00	921.80	NA	1	1
	2	B	2941	35.59	378.67	20.40	123.31	308.89	46.30	1923.20	0.0	0.0	2.0	2.430	1659.26	28	3	3	3.00	553.09	100	2	1
	3	S	3086	33.44	514.30	24.69	224.20	395.06	45.19	6356.05	0.0	49.38	4.9	4.050	2016.47	38	3	18	2.00	NA	50	2	1
	4	B	1605	23.81	376.02	20.40	98.87	332.10	23.53	1923.20	0.0	0.0	2.4	2.430	1593.97	37	3	10	3.00	318.79	17	2	1
	5	B	1059	22.32	264.54	70.54	112.10	70.54	81.14	8420.36	14.10	28.22	3.6	0.709	NA	NA	2	20	2.00	NA	100	2	1
Group 2 (* indicates farms >40 ha)	6*	S	2452	16.08	850.12	36.72	145.73	407.41	404.94	3531.55	0.0	1.06	54.7	4.050	222.22	37	5	10	1.00	53.33	80	3	2
	7*	S	2432	14.90	909.88	82.89	221.96	449.06	374.74	8086.05	0.0	3.19	113.4	16.200	210.52	54	4	20	1.33	47.26	100	3	2
	8	B	2316	13.07	987.65	123.46	35.87	740.74	0.0	20626.86	0.0	123.46	3.2	3.240	1913.58	50	2	28	4.00	555.56	30	1	1
	9	B	988	13.04	422.22	7.41	NA	296.30	44.44	698.88	74.07	0.0	0.4	0.759	4266.66	47	2	27	5.00	1659.26	15	2	1
	10*	S	1440	10.94	734.72	28.54	44.84	191.36	465.43	4236.20	24.69	24.69	40.5	12.150	172.84	51	3	32	2.00	27.65	50	3	2
	11	S	1323	10.48	703.70	61.73	NA	740.74	185.19	11456.65	0.0	86.42	22.3	28.350	738.22	52	3	18	2.00	79.19	75	2	1
	12	B	3553	10.22	1937.78	562.49	NA	1200.86	98.07	59853.78	0.0	76.35	4.9	0.810	1699.51	50	3	30	2.00	691.36	50	1	1
	13	S	617	8.92	123.46	12.35	NA	74.07	24.69	1936.68	0.0	12.35	2.0	1.266	325.53	50	3	30	5.00	31.60	NA	2	1
	14	S	1543	8.12	1059.33	339.51	241.01	548.15	171.68	32032.59	0.0	0.0	16.2	8.100	1167.41	39	3	15	1.00	474.07	50	NA	1
	15*	S	1442	7.54	1065.85	32.27	234.33	691.36	320.99	4372.98	0.0	21.23	68.8	27.742	314.91	63	3	36	1.00	74.37	85	3	2
Group 3	16	S	1852	7.26	1777.78	197.53	448.40	987.65	395.06	51925.16	0.0	395.06	18.2	20.250	1121.98	37	3	20	1.25	342.40	20	NA	1
	17	B	1647	6.97	1316.89	752.49	44.84	470.32	94.07	70998.06	0.0	0.0	2.0	1.063	506.99	46	2	6	3.00	210.69	20	1	2
	18	B	1111	5.75	918.12	100.84	247.14	817.28	0.0	9514.27	0.0	0.0	1.6	0.810	2074.07	53	NA	20	2.00	1037.04	100	NA	2
	19	B	2353	6.05	1784.27	149.70	494.27	1634.57	0.0	15629.87	0.0	0.0	2.0	3.645	2733.16	50	1	26	3.00	705.18	100	3	1
	20	B	721	6.02	667.19	41.04	164.76	544.84	23.53	12601.47	0.0	57.78	2.4	2.430	2419.75	59	NA	28	2.00	967.90	25	2	1
	21	S	1235	5.46	1260.00	91.93	313.88	578.59	501.14	14490.16	0.0	87.11	6.1	3.240	1719.18	64	2	50	2.00	221.23	100	3	1
	22	S	889	5.27	939.83	74.07	209.63	296.30	507.73	10848.30	0.0	61.73	20.2	20.250	860.32	52	3	10	1.66	239.90	NA	3	1
	23	R	464	4.86	530.86	49.38	NA	154.32	185.19	8518.59	80.25	61.73	7.5	1.620	762.89	54	2	14	2.00	467.14	0	2	1
	24	B	1235	4.00	1718.52	282.20	254.47	1422.89	13.43	26625.45	0.0	0.0	2.0	2.126	2773.33	52	3	31	3.50	616.30	NA	2	1
	25	B	617	3.58	960.20	192.05	NA	548.69	109.73	25858.34	0.0	109.73	6.1	12.150	NA	31	3	2	3.00	NA	100	2	2
	26	B	156	3.08	279.01	7.41	11.21	197.53	49.38	2242.57	0.0	24.69	1.6	1.620	2237.04	28	3	7	2.00	933.33	100	2	1
	27	B	1543	2.52	3418.96	845.56	593.12	2474.07	96.49	79955.44	0.0	2.84	2.0	2.430	3656.52	26	3	NA	3.00	430.17	30	2	1

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