UNIVERSITY OF OKLAHOMA

GRADUATE COLLEGE

# A FRAMEWORK FOR DEFINING HUMAN CARRYING CAPACITY OF A DRY-FARMED WHEAT HINTERLAND, BASED ON CORN, OKLAHOMA

A Dissertation

SUBMITTED TO THE GRADUATE FACULTY

in partial fulfillment of the requirements for the

degree of

Doctor of Philosophy

By

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Norman, Oklahoma
1998

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A Dissertation APPROVED FOR THE
DEPARTMENT OF GEOGRAPHY

BY

## Acknowledgments

This thesis was made possible by the aid of three groups of people. First, I am grateful for the advisory committee, Drs. Hans-Joachim Spaeth, Richard Anderson, Marvin Baker, Jr., David Penn, and Gary Thompson, for taking the time to read and offer suggestions for improvement. Without this input, the resulting text would have only been an imaginary concept, forever lost. I also extend gratitude to Dr. Spaeth for allowing me to use farm budget data from a previous study, greatly reducing the amount of field time and analysis required. Other faculty who were not on the committee but have influenced me throughout my graduate program are James Hartigan and A. J. Kondonassis, both from the Department of Economics, and Richard Nostrand and Bret Wallach, from the Department of Geography. These professors enabled me to gain knowledge in new literature and offered valuable insights on development of writing skills.

Second, I have a most warm gratitude to the farmers who agreed to be interviewed: Darrel Bartel, Mike Brooks, Lorin Dick, Erwin Duerkson, Monte Nickels, and Abe Peterson. Without their assistance, it would have been impossible to complete this study. They were friendly and welcomed me into their homes for interviews. This process alone made completion worthwhile. I learned much more about small town

life and economic development than can be written into this study. Also, Mr. Dirk Webb, Washita County Agent, and Mr. Steve Sweeney, Manager of the Weatherford Coop, assisted me by providing a list of farmers and delineating the hinterland, respectively.

Finally, my family and friends provided a level of support that cannot be described with justice. My parents, Mr. and Mrs. Paul Alexander, extended family, and close personal friends made completion physically possible. The deepest gratitude goes to these people. Of all the friends one could possibly have, Darby George, Irene Baltierra, and Ron Gibson rank the highest. There is no hypocrisy to them. Hee-Joon Jeong, Dongchul Jung, and Namchul Lee were my closest friends during most of dissertation writing. In fact, we helped each other in many ways; I have many fond memories of the hours spent in Bizzell Library conversing over land economics, international trade, and geographic aspects of the political economy. I also feel fortunate to have had contact with my close friends. Finally, I greatly appreciate the friendships of Chwen-Jy Chang, Pauline Dibi, Tim Leininger, John Mahlke, Ayman Omar, Sherry Reece, Steve Schlereth, Tung-Kai Shyy, Nancy Sonleitner, and Zhangshi Yin, for they gave me a type of academic and moral support not possible from others.

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Abstract

A FRAMEWORK FOR DEFINING HUMAN CARRYING CAPACITY OF A DRY-FARMED WHEAT HINTERLAND, BASED ON CORN, OKLAHOMA

Major Professor: Hans-Joachim Späth

This dissertation develops a framework for defining the human carrying capacity of a small, dryland farmed wheat hinterland. The emphasis, developing a model, requires that a near monocultural town be examined. Recent literature reveals a growing interest in defining carrying capacity but research has been limited to either less developed countries or to alpine watersheds. The technique developed here will be the first constructed on an iso-plane, with physiography and land use being evenly distributed. The hinterland is 47,860 acres, the wheat production area of the Corn, Oklahoma, grain elevator. There are three types of assumptions. General assumptions define human carrying capacity as the number of occupants that the hinterland can support and the need for low-order service study area since it would have the least economic diversification. Agricultural assumptions evaluate grain production efficiency in light of fuel, labor, chemical, on-farm transportation, and machinery inputs versus the food energy output. Socio-economic assumptions assert that people

desire a state of sufficiency such as financial well-being and the ability to pay debts and taxes.

Research methods include energy analysis to determine the production efficiency of wheat production and evaluation of socio-economic variables (educational, entertainment, housing, insurance, and retirement expenses). Energy data are derived from a 1985 data set of northwestern Oklahoma dryland wheat farms and 1996 interviews with farmers. Socio-economic data are derived from actuarial, U.S. Census, Federal Bureau of Labor Statistics, and Oklahoma State Department of Education sources. Values are calculated for the hinterland and scaled down for a family of four.

Results of analysis indicated that the hinterland can support the food needs of the population, for the output-input ratio is over five times. Socio-economic analysis revealed that based on assumed financial needs that 484 is the maximum population and average farm size of 395.53 acres. The output-input ratio with all needs considered is -2. Additional scenarios concerning the increase and decrease of current income from farming by five percent did not heavily affect the threshold of population. Future research should focus on more precise collection of data and development of frameworks to examine multi-crop, industrial, and service hinterlands.

# CHAPTER I

# INTRODUCTION

## Background

Human carrying capacity, the number of inhabitants land can support through a given economic pursuit (e.g., farming, manufacturing, or services), is a concept often cited in social science literature, but scholars and planners use varying meanings of the concept. The lack of a clear, concise definition and its applications to understanding human-environment interactions appealed to the writer. This dissertation will develop a framework that will define human carrying capacity.

The interest in this topic evolved from the writer's numerous visits to family in the central Tennessee area while a youth. Abandoned cotton gins, feed mills, general stores, schools, and homesteads always dotted the landscape. Questions concerning rural settlement in terms of location and occupance gradually became a geographic interest. Eventually, the writer decided to pursue defining a framework of the human carrying capacity, for such locations were abandoned because the land could not support the activities of the people, and occupants had to look to other towns for jobs.

## Justification: Continuing the Tradition of Human-Land Interactions

Before commencing with narrowing down the problem statement, a brief sketch of American geography will be presented in order to show how this dissertation will be a continuance of geography's quest at understanding the role of land in human societies. Pattison (1964) identified man-land relationships as one of the "Four Traditions" of geographic study. The role of land has been a cornerstone in geographic study since 1903 when the University of Chicago became the first American institution to offer a doctorate in geography. Early research focused on urban land use in relation to the social environment. Thus, it became known as the Chicago School of Ecology. The research was an attempt to explain human settlement in environmental terms, based on Social Darwinism, but nevertheless, early American geographers realized that the environment, both natural and social, plays a major role in man's activities.

During the next two decades, other emphases developed within geography. Cultural and historical geography developed at the Universities of California (Berkeley) and Wisconsin (Madison), respectively, although the latter also became a center for political and economic geography as well. Chicago remained urban and applied, but other branches of human geography such as political and historical flourished as well. Northwestern University emerged as a primary center for economic and transportation geography. Almost all geography departments offered physical geography, for an understanding of the natural environment was considered crucial for geographic analysis.

After World War Two and up through the 1980s, a number of changes occurred. First, the Quantitative Revolution in the 1950s resulted in a greater number of geographers using numerical analysis in their research. No longer was "mere description" adequate. Cultural and historical geographers, by and large, avoided the use of quantitative methods. Second, regional study largely demised. Many departments either amended their areal proficiency requirement or dissolved it altogether. Third, some geographers became interested in regions as theoretical units; modeling became more evident in both physical and human geography. In short, geographers became much more specialized.

In the 1980s, however, a number of geographers started to re-evaluate man-land relationships differently than Carl Sauer's regional approach. Those who adopted Sauer's descriptive method studied the area first, beginning with the natural environment and the imprint of human activities on the surface. Throughout this research, however, there was no attempt to define the human carrying capacity of the land.

Others, such as Thomas Whitmore and B. L. Turner, II (1992), William Doolittle (1992), and Karl Butzer (1992), began to look at this interaction from a functional or systems approach. Most of their research focused on societies in developing countries such as Mexico. In fact, the Fall 1992 issue of the *Annals of the Association of American Geographers* was a collection of articles of the state of the North American continent when Columbus arrived in 1492. Butzer (1992), Doolittle (1992), and Turner (1992) all evaluated human society in light of the natural resource base. The principal objective of these authors was to view agriculture as a farming system within the society limited by natural and human resources. Catton's (1993) study of the demise of the Easter Island population prompted him to conclude that population exceeded its carrying capacity, thereby degrading the environment and not allowing civilization to be supported. These researchers emphasized the need to thoroughly understand how societies functioned in order to know how many people the land could support. The idea of how many people that a defined unit of land could support began to warrant investigation.

Even though no standard definition of human carrying capacity is accepted, a number of working meanings do exist and are discussed in Chapter 2. Based on geography's long tradition of understanding how well mankind can relate to the earth, a framework for defining this concept holds powerful potential in both geography and the social sciences; its definition will carry numerous implications--well beyond farming systems analysis. Eventually, it will be possible to better understand whether proposed industry or increased agricultural outputs are indeed viable for a given type of location in the long term and will complement social science research in sustainable development.

## Playing with Ideas

William L. Garrison (1979) spoke of his early days as a professor at the University of Washington as playing with ideas. He and his colleagues sought to develop transportation and location models as fully as possible. As such, it would often appear that they were grabbing for straws. As something would fail, they would re-evaluate the picture and adjust their model accordingly.

The author proposes to do likewise with this quest for defining human carrying capacity. Surely, the confusion surrounding its definition and multiple meanings will not vanish at once, but at least a written attempt is being made. This "idea play" will allow researchers to lift the traditional "realistic limits" on thinking and look at problems with unconventional assumptions. Ultimately, the scientific community may reach one of two conclusions: (1) that the early abstractions have solved or have contributed to solving the problem at hand or (2) that the model(s) has (have) failed.

Geography, as a discipline and method of thought, is an ideal approach to this quest. The multi-dimensional aspect of studying an area--its resources and effects on population--may not be a pure geographical inquiry, but geographers, above all others, should innately be attracted to such problems. Depending on which problems one pursues, it may become necessary to collaborate with other colleagues who might have additional insights on either the model or problem in general.

## The Means to Develop a Framework

In spite of all the present confusion on what exactly the concept of human carrying capacity means, a brief sketch of how a framework will be developed is presented here. At this time, there are three general assumptions in settling up this train of thought. First, all questions can and will be answered in due time; maybe not in this dissertation, but the scientific community will be closer to an answer.

Second, it is assumed that people need their environment for resources (both natural and human) and that resources need human and animal exploitation to further civilization on earth. Finally, the analysis at this stage of inquiry should be limited to a small town (or "community").

The next step is to define further what is meant by a small town. First, an ideal town must be isolated. Maybe it would be physically isolated such as Telluride, Colorado, or Imlil, Morocco, both located in a mountain watershed with only one road in and out. Or it could be like Wanette, Oklahoma, minus the mountain environment. These examples are relatively isolated from the immediate outside world in terms of overland routes.

Finally, regardless of how the town would be described, two criteria would have to be fulfilled. First, the community must be isolated in the manner described above. Second, the community would also have to be a low-order service area and be supported by one (or very few) economic activities such as winter wheat cultivation. While the former implies a physical and consequently social criteria, the latter is almost completely social in nature. Extremely critical in this assumption is that the telecommunications and transportation infrastructure not be overly developed. Communities such as Socorro, New Mexico, while small, would not work because the telephone service is advanced enough to support customer support for Intuit, Inc., allowing services to have a greater role than either local agriculture or manufacturing. Likewise, with Telluride having seasonal air service, it has developed into quite a tourist center. County seats (government role) and larger urban centers (services) would not be suitable for this experiment. Therefore, the ideal town will be a small farming community with as few services as possible--perhaps a town office, fire department, or even a few stores; the essence of being a low-order service town.

Paul Krugman (1995), a noted international trade economist, writes that a number of geographical theories dealing with land use address the role of the hinterland, with von Thünen's (1966) being most well-known. A theory, however, that could *justify* the role of the local town would be most welcome in development literature. Krugman asserts that geographers and economists have long avoided questions such as these because of a fear of modeling and the early, often unrealistic, generalizations required in developing a model. This is the idea that the author desires to play with. After searching through books and articles the last two years, a question worth pursuing has emerged: What is the role of the local town in the development of the hinterland?

## Conceptualization of a Framework

### Assumptions

Currently no standardized framework is available for human carrying capacity. For any conceptual model to work, a number of phenomena must be included and some excluded. In following Krugman's (1995) call for (in *Development, Economics, and Economic Geography*) rural land use theories that examine the role of the hinterland (vs. node), four general assumptions are made.

First, this model will have both agricultural and socio-economic variables. Both variables are necessary because people do not live in the United States (or any other country) for mere subsistence existence only. A model that merely defined human carrying capacity as whether people could physically exist would be useless, given that inter-regional trade would account for regional disparities between self-sufficiency and what was available.

Second, energy analysis is the best measure of agricultural production since it avoids the spatial and temporal fluctuations that often plague economic analysis. For example, data for this analysis came from a 1981 and 1985 data set and was verified with 1996 site visits to

Corn, Oklahoma. Attempting the use of dollar amounts in 1981 with 1996 conditions would be inappropriate. In addition, the delay time from 1996 to actual publication date further compounds the problem. Factoring in spatial differences brings in additional problems; California's harvest will not be the same as that of Mississippi's. But energy analysis combats these two problems; xyz metabolically usable kilocalories (kcal)/bushel of wheat are the same in Kiev, Ukraine (in physical terms) as in Minneapolis, Minnesota. Pros and cons of economic and energy analysis are addressed in Chapter II.

Third, only one exemplary town is required for analysis in conceptualizing and subsequently testing this framework for the following reasons. First, this dissertation will build on the method *Fortune's* 1938 study of Oskaloosa, Iowa. *Fortune* editors, using a simple input-output matrix desired to see whether or not the town was self-sufficient (e.g., if the town could support its population). This study, however, will differ from *Fortune's* in that it seeks to determine whether the hinterland can support its population, both town and rural countryside.

Second, a "sample" is not appropriate at this point because the emphasis is on developing a new model, not the testing of existing models. Applying the model to other similar areas would be appropriate. Such profile information would include population, agricultural production and harvest, median incomes, and role of retirement income.

Finally, returning to the first assumption, some variables must be excluded. Two broad classes of data are used: agricultural and socio-economic. Agricultural data will be limited to tillage, machinery, labor, chemical, on-farm transportation, planting, and harvest. The data, being in energy units per 1000 acres, will be standardized. It can then be converted to economic units at a later time to be reconciled with socio-economic data. Other crops will be excluded to avoid the problem further by calculating additional energy budgets. As the title indicates, this analysis is limited to dryland farmed winter wheat.

Socio-economic data was limited to the following expenses: cost of essential health and life insurance, amount of emergency cash reserves (savings) necessary, education, entertainment, food, housing, private investments for long-term retirement needs, self-employment tax (Social Security), and transportation. All these data will be for a four-person family with two school-aged children. Other variables are excluded. Off-farm income and spousal income is excluded since that income is not derived from dryland wheat production. Social security tax is included by assuming that the farm family must pay self-employment tax, yet the family does not receive any benefits currently.

It can be argued that the inclusion of health and life insurance and cash needs (short and long term) are independent of farm production. The assumption, however, is that these socio-economic variables play an important role in whether a farmer remains a farmer. Obviously, one will seek other sources of income if he/she cannot obtain a reasonable standard of living and social and economic well-being from a given occupation. Although "reasonable" will vary from person to person, most desire the ability to handle current expenses, to have a secure financial future, and to be able to pay medical expenses--<u>regardless of occupation</u>. Property (ad valorem real) taxes will be included since taxes must be paid for the land to be farmed. Land tenure, however, will be excluded since it is assumed that land can produce wheat if cared for properly, irrespective of ownership.

## Limits to These Assumptions

Although a number of studies, mostly in ecological economics publications, attempt to define human carrying capacity, no standardized framework presently exists. This attempt to define one will be open to criticism in a number of ways. First, critics may contend that the current confusion of the meaning of human carrying capacity will remain, but a written attempt to define such a method with readily obtained data has been made.

Second, the critics will continue to cite their confusion of whether physical or economic survival is the actual objective. This research assumes that both are inextricably tied together. This does not mean, however, that trade does not enter into the picture. Just because earlier assumptions did not include trade data does not mean that the author does not acknowledge its presence. The pertinent point is that economic survival of an individual, family, or community is not possible if their physical demands for food cannot be met. Therefore, whether or not the food energy output can support an individual (summed and multiplied [divided] by number of inhabitants for the community [individual] level) is critical to the analysis before other socio-economic needs can be met.

The third and final limit of this analysis concerns the inclusion and exclusion of variables previously identified. For a dry-farmed winter wheat hinterland, these variables represent the most essential physical and socio-economic needs necessary since the analysis is concerned whether or not grain output can support the lifestyles of the hinterland population. Those who desire other crops or different hinterland socio-economic compositions (*e.g.*, tourism, services, etc.) can build on this approach by adding the variables necessary to understand those activities. This research is not seeking a general purpose model for rural hinterlands in an industrialized society and is only be one step in the direction of defining human carrying capacity in other complex settings. In addition, the findings of this research should not be the sole basis for policy-making since a number of personal attributes or lifestyles related to sense of place, political views, and moral convictions may have to be considered.

The analysis and conclusions that follow, however, are based on a stripped down example: a mono-cultural dry-farmed wheat hinterland. This analysis concerns itself with the development of a feasible and useful definition of human carrying capacity. Thus, this dissertation is a <u>start</u> on defining human carrying capacity since other areas with multi-crops and/or other economic activities must expand on this framework.

## Objectives

1. To develop a framework, based on both agricultural and social needs, for defining the human carrying capacity of a dry-farmed wheat hinterland;

2. To test this conceptual model on an actual hinterland to determine its carrying capacity; and

3. To evaluate how many people can (or cannot) be supported with minute changes in the farming system.

Following this line of thinking, this dissertation will be organized into the following chapters: Chapter 2, Literature Review; Chapter 3, Assumptions, Objectives, Methods, and Study Site; Chapter 4, Farming Data and Its Analysis; Chapter 5, Socio-economic Data and Its Analysis; Chapter 6, Discussion of Results; and Chapter 7, Conclusions and Further Research Needs.

# CHAPTER II

# LITERATURE REVIEW

## An Ambiguous Concept: Human Carrying Capacity

Use of the concept "human carrying capacity" is common throughout discussion and literature. A number of problems prevent it from being readily defined. The first type of confusion evolves from those who view the concept as an extension of animal carrying capacity as noted by Catton, 1993; Hardin, 1986; and Kirchner *et al.*, 1985. Each of these authors feel that human carrying capacity must be defined in order to understand how well the population relates to its resource base, but they note people live for more than mere space. Kirchner *et al.* (1985) especially noted the role of social needs for a population to be sustained by land.

For animals, however, the number of head per unit area refers to how well the land can sustain its animal population without soil and plant loss---an ecological relationship between animals and the land. For people, however, this ecological amniocentesis requires that human activities not degrade the land to the extent that future populations cannot enjoy a comfortable lifestyle. Therefore, the first problem, restated, is whether the concept can be defined in a meaningful, holistic manner that social scientists, planners, elected officials, and the general public can understand.

## Many Narrow Definitions, No Standard Agreement

Assuming that scholars can accept that human carrying capacity is not merely an adaptation of its animal counterpart, a number of narrow definitions exist. That is, sociologists and geographers often use the concept to reflect a specific meaning rather than attempting to define in a more generalized manner.

Budd (1992) realized that the term could be viewed eleven different ways. He listed the following types of carrying capacity: instantaneous, sustainable, maximum, optimum, human, physical, hydrologic, global biophysical, gross, real, and natural global. Each of these meanings reflects a specific point of view. Natural global, for example, refers to the human carrying capacity of the earth without factoring in technology. This would be higher if technological advances were considered. Likewise, "sustainable" means a somewhat fluid number that is not absolute but once exceeded, human lifestyles may be degraded since less natural resources will be available. "Maximum" carrying capacity emphasizes a more rigid number. In spite of these definitions, Budd does not offer a framework to determine any of these.

While no "bottom line" is given in Budd's article, Daly and Ehrlich (1992) denote two types of carrying capacity. First, biophysical refers to the maximum population size that can be sustained under technology and is more dependent on how well the natural environment can handle the population demand. Second, social carrying capacity means the maximum population that can be supported through various social systems, for example, the role of government subsidies to enable low-income families to purchase food through vouchers.

On the surface, this dichotomy seems to make sense. One definition is based predominately on the natural environment while the latter factors in social institutions. The problem remains the same; both of Daily and Ehrlich's definitions do not list any type of limit nor how to calculate one. In addition, unlike Budd (1992), these two meanings do not factor in scale (hinterland, small town, province, etc.)

Hardin (1986), in a presidential address to the American Institute of Biological Sciences, takes the other end of the spectrum; he recommends renaming 'human' carrying capacity to "cultural" capacity to avoid confusing others into believing the term is an extension of animal carrying capacity. While he is correct about the current confusion, what is the benefit of renaming a vague concept into another one that is not specified either? The closest number that he gives is that the value associated with the cultural capacity "...of a territory will always be less than its carrying capacity" (Hardin 1986:603). When social needs are factored in addition to mankind's basic physical needs for survival, the number of people that the land can support will be less. In the same address, however, he exhorts his colleagues to work towards identifying a framework so that the confusion will lessen and eventually be dissolved.

Rees and Wackernagel (1994) reached a similar conclusion but stated their finding in a different manner. They discovered that cities needed an area much larger than a traditional hinterland. They noted that an inverse relationship was present between arable land and per capita land appropriation. Less land was available per person (due to global population increases), yet more area was required to support an individual. Rees and Wackernagel, like Hardin, were noting all needs for people, not merely existence. They eventually concluded that the needs of contemporary society preclude a traditional hinterland that provides for all needs. The primary difference between Hardin (1986) and Rees and Wackernagel (1994) is that the latter tested their ideas out on the Lower Fraser Valley of

British Columbia and the Netherlands---two vastly different scales of area. Hardin, however, was more concerned about the philosophical distinction between physical and social existence of populations.

The findings of Rees and Wackernagel indicate another familiar pattern: push-pull factors associated with rural out-migration and urban in-migration. While planners, elected officials, and rural populations desire true self-sustaining communities, such as a Garden City, the reality is much more somber. Transportation and communication of modern society makes such self-sustainability inefficient when various regions of a country or world can use comparative advantage to produce goods and/or services more efficiently than one area attempting to do it alone. Wilbanks (1994) goes on to note that spatial and temporal flows will be required to achieve sustainable development; he also stated in the same article human carrying capacity cannot erode the ecological limits of the earth, if true sustainable development is to be accomplished. Wilbanks' achievement is linking both concepts together. A community cannot have true sustainable development, if the human carrying capacity is exceeded. Although he did not list a means to define this idea, he did emphasize the interrelationship between the two.

In Hardin's classic paper, "Living on a Lifeboat" (1974), human carrying capacity is corollary to discussion. Common sense tells society that the earth is limited. Soil erosion, overpopulation, and pollution can be endured by the population to an extent. Once that threshold is exceeded, any number of problems, ranging from starving masses to increased health disorders, will plague the earth's inhabitants. Society cannot expect unlimited benefits from trade and technology; there is a physical limit to all activities. Nevertheless, twenty years later in 1986, he pleads with his associates to find a means to know when the threshold has been exceeded.

## A Meeting of the Natural and Social Sciences

The latest development amongst social scientists in defining human carrying capacity has been from the interaction of natural and social scientists, engineers, and policy makers. A number of ecologists, economists, and sociologists concerned about this critical ratio have laid aside partitioning the concept into more "definitions" as well as creating new names. This type of research assumes that mere existence will not define human carrying capacity---whether at the global or community level. Some type of conceptualization must be attempted to understand what factors are important and their relationships with other variables, both internal and external.

Wisniewski (1980) emphasized that carrying capacity and any model would have to be dynamic--both spatially and temporally. He concluded that the neglect of space and time is why planners often assumed that additional technology was the answer to sustain increasing populations. Obviously, societies change, even as this thesis is being written. While a model that could identify whether Town X had exceeded its carrying capacity by current standards would be giant step, the hallmark is measuring and evaluating the variables to reflect potential changes. As this study examines the carrying capacity of a small, dry-farmed wheat hinterland, such a model must factor in variables that emphasize that the land is completely isolated in space and time. As relative isolation is necessary to develop the model, it does not mean that the model is purely static. Inputs for this year's crop must come from savings of previous years' harvest.

Catton (1993), in evaluating the demise of Easter Island civilization argued that social organization must be analyzed, along with the environment. In his study, he noted that human societies failed because basic needs could not be met. This failure resulted from too many people inhabiting the small island with limited natural resources. Catton did not argue that the natural environment determined societal fate, but it did play a predominate role since trade and technology were not available. An extreme interpretation of the Easter Island catastrophe is to assume that it is a microsm of the earth. If overshoot, population needs that exceed ecological limits, caused the collapse of this civilization, how can society be certain that excessive populations will not cause similar problems elsewhere? Simple: we cannot know for sure.

Daly and Ehrlich (1992), Gilliland and Clark (1981), Kirchner *et al.* (1985), Postel (1994), and Rees and Wackernagel (1994) all stressed this same point: human carrying capacity must factor in social variables. Gilliland and Clark (1981) and Rees and Wackernagel (1994) studied the Lake Tahoe Basin and Lower Fraser Valley and the Netherlands, respectively. These researchers discovered that factoring in technology available to populations meant that the hinterland had to be much larger. For example, a city such as Oklahoma City, Oklahoma, or Dallas, Texas, requires a much larger hinterland to support it populations because the diversified needs of their respective populations. Clothing might come the Orient, Egypt, or Bangladesh; food from a variety of United States agricultural regions; machinery from both other states and Southeast Asia; water of domestic use from far-away watersheds; and so forth.

This preceding discussion emphasizes this point rather clearly: people do not occupy land in the same manner as cattle or other domesticated animals. While this statement is rather obvious, those who view human carrying capacity as such an extension are implying that the needs of both are essentially the same. Even cattle have various levels of capacity. For grass-fed animals, rangeland has a lower capacity (more acres are needed to adequately feed one animal) since these animals are more dependent on the natural environment for food than are feedlot cattle. To emphasize the incompatibilities of extending the terms even further, most people live in the present and think of the future. They do so in a number of ways: developing their careers through training and education, saving financial resources for retirement, attending to medical needs, and participating in governmental affairs to ensure good social institutions for life in general. Cattle, however, are raised for food or dairy products, and input decisions into that end result are not made by the animals themselves. This comparison was presented to show the reader why human carrying capacity is a distinctly different concept, and its evaluation must look for a definition much more inclusive than maximum number of people per square mile.

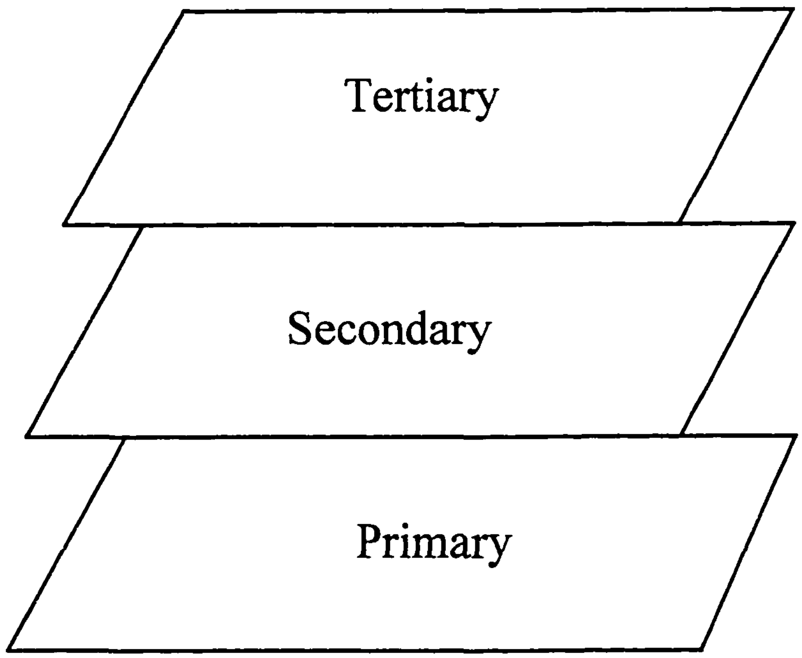
The literature cited this far shows that the concept of human carrying capacity has merit; furthermore, those articles point to the need of developing a model that will list the elements necessary for formulating the human carrying capacity of an area. The concept contains both social and physical variables that have both spatial (areal constraints and requirements) and temporal (short- and long-term) properties. Figure 2.1 graphically depicts the layers of human carrying capacity. Unlike Budd's "types" listed previously, however, all layers must be analyzed simultaneously to derive the human carrying capacity for the <u>area under investigation</u> *and* for <u>long-term occupance</u>. Even though a layer may be examined one at a time, the physical and social variables must be reviewed simultaneously. Figure 2.2 shows the overall relationship between population and areal resources. The critical point is that just because an area may not support agriculture does not mean that it cannot support industry or other services.

## Applications of Defining Human Carrying Capacity

Reich (1988) refers to a "bicoastal America" in which economic opportunities are concentrated on the East and West

Figure 2.1

## Layers of Carrying Capacity

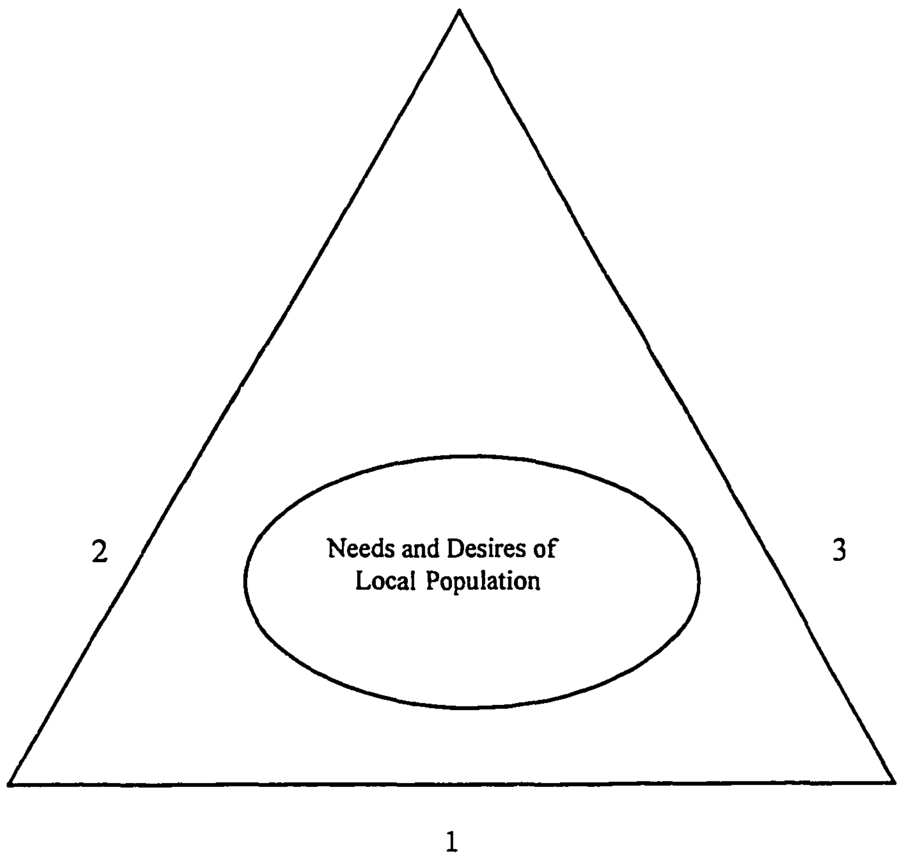



Primary needs: agriculture, mining, forestry, and fishing
Secondary needs: manufacturing and industry
Tertiary needs: services (including management)

1. All places have these layers of varying importance.
2. The task at hand is to define a framework that enables us to know to what degree these limits exist.

Figure 2.2

The Relationship Between Resources and Population




1...Base (natural resource)
2...Manufacturing and Industry
3...Transportation and Communication

Note: No area will have the exactly equal mix of these activities. Some places lack a natural resource base and have to depend on other activities. In addition, the socio-economic needs of people will determine whether the base is exploited or whether the area concerned will seek to utilize other opportunities.

coasts, while the Midwest stagnates. He supports his statement, noting the decline in commodity prices and the shift towards footloose industries. Johnson (1989) calls this economic condition the "New Economy," in that innovation, entrepreneurship, and linkages to global events are necessary for industry to flourish in these times. Both authors, therefore, note that older, natural resource industries (or those tied by traditional location constraints) are the ones most likely to be in decline. Brown and Glasgow (1991) further note that the populations associated with both types of industry, notably farming and heavy manufacturing, lost population during the 1980s.

Böventer (1970), Brown and Glasgow (1991), Daniels (1989), Daniels and Lapping (1987), Flora and Christianson (1991), Hansen (1971), Malizia (1986), and Tweeten and Brinkman (1976) all note that rural communities must look to other means for development since classical location and central place theories may not apply. Classical theories suggest that location should be near the source, if weight-losing, or near the market if perishable. With advances in transportation, perishability now means something else. It now refers to how long consumers are willing to wait for delivery of a good or service. Hobbs, New Mexico, produces dairy products for the Los Angeles market, and most recently, Seaboard's location in Guymon, Oklahoma, serves the pork needs of the western United States. Cavin (1967) pioneered in evaluating the importance that transportation played in the decentralization of feedlots into the Oklahoma Panhandle. These same advances now allow areas to have light manufacturing and value-added production not possible thirty years ago.

Thus, the traditional approach of industrialization may not be beneficial to small town development. Kedl (1984) makes a most powerful argument on 'development:'

> Economic development is indeed medicinal. If administered correctly and taken in the right doses, it's good for what ails a town. [p. 24]

Kedl's point is that any scheme must be "right" for the community concerned, but what is "right" is much easier said than done. Without a framework for determining an area's carrying capacity, planners cannot be sure whether any programs are "right."

Dillman (1991) and Lehrer (1990) suggest that development of telecommunications infrastructure would offer economic opportunities for rural residents. A number of states, including Oklahoma, are advocating such schemes since politicians see a positive change in number of jobs as beneficial to their administrations. A 1993 interview with Mr. Ray Wheatley, economic development specialist with

Panhandle Telecommunications Cooperative in Guymon, Oklahoma, revealed a different scenario. Mr. Wheatley mentioned that jobs would evolve but that tele-marketing jobs are often either part-time or seasonal--ideal for retirees or housewives. It does not appear very likely that telecommunications will provide salvation for ailing towns, although such jobs could provide supplemental income.

White (1994) in his examination of southwestern Kansas towns reached a similar conclusion. He noted that not all towns would disappear, but those isolated from the outside world, both from transportation and communications networks, had little hope of reviving their economy. Daniels and Lapping (1987) also stated that towns under 500 had little hope of economic recovery. They noted that small towns fell into a triage: under 2,500; 2,500-5,000; and 5,000-15,000. Daniels and Lapping referred to this classification as a triage, for they concluded that the middle class of towns should receive the priority for government aid for industry and expansion. The lowest category tended to have too much out-migration, and the highest category usually suffered from deteriorating infrastructures. The middle category, though, had the momentum to attract people with the proper planning and management; therefore, Daniels and Lapping reasoned, these towns should have the priority in economic assistance.

On a slightly different note, Wimberley (1991) stated that revitalization of rural railroads would benefit farming communities since rails were most economical for bulk transport. The primary problem with this proposal is that agricultural production, especially on the Great Plains, is seasonal. The larger communities might have other industries that could use year-round rail service such as manufacturing. The small, isolated towns, however, could only use rail transport during harvest. While it help keep rural elevators open, giving farmers a reason to patronize a given community, it would have to be subsidized somehow.

Literature continues to mention "human carrying capacity," and knowledge of whether the land could support the population is an obvious advantage to any development program. The problem remaining is that scholars attempt or speak of the need for a standard definition.

In addition to those studies, Berry (1971) and Daniels and Lapping (1987) all list a "minimum" number necessary for town survival. Berry discovered through examining over twenty-five metropolitan areas in the United States that the threshold was between 40,000 and 250,000; Daniels and Lapping's views, presented earlier, are based on empirical observation of rural towns throughout the United States This point of view is different; the minimum number of inhabitants for town survival is another question. This research will examine how well the land (*e.g.*, hinterland) supports its residents, both rural and town. Of particular interest is the role of the hinterland. Krugman (1995) noted that current rural land use theories focused on the role of the node, but models that would define the role of the hinterland would fill a long void. Wisniewski (1980) noted that the hinterland would have to be defined since it supports the town. Thus, the challenge at hand is to define the hinterland.

## Means to Define Human Carrying Capacity

At this point, it is apparent that the research community is interested in seeing this vague term become a realistic, working definition. In fact, Jansson *et al.* (1994) is an edited volume of essays dedicated to understanding 'natural capital,' and a few papers attempt to determine the human carrying capacity of the area investigated (*e.g.*, Krysanova and Kaganovich, 1994; Rees and Wackernagel, 1994). These papers were pioneering efforts to determine whether the hinterland of the region studied was able to support its population, yet no framework emerged from the research.

First, all models, especially one dealing with this subject, are subjective to an extent (Hardin, 1986). Hardin stressed that such modeling must be open for criticism--for the sake of discussion. Daly (1990) felt that subjectivity involved (e.g., defining "human comfort") might not render an exact number; nevertheless, he stated that society could not afford to overlook the role of carrying capacity. Krugman (1995) noted that all early economic and geographic models require large generalizations only to be eliminated by future debate and research. (His analogy of early African maps illustrates this argument most eloquently. In his example, he notes how advances in cartographic production forced mapmakers to generalize land features rather than to blatantly ignore them. Eventually, cartographers were able to reconcile these generalizations to include such features without compromising map production.) In summation, then, scholars must not expect an absolute answer to a model dealing with this problem. Bunge (1960) noted that the purpose of modeling was to develop reasonable generalizations, not to justify the unique. Although each of these scholars eloquently urge colleagues not to abandon the general for unique, Bunge's and Krugman's arguments are exceptional. Science is a search for the general truth. Although the framework presented in this thesis will not answer all questions about human carrying capacity, it will be a step in the right direction.

Second, this framework will build on *Fortune Magazine's* 1938 study of Oskaloosa, Iowa, the earliest record of using an input-output analysis on a town. Actually, however, the *Fortune* staff limited their analysis to the social accounting matrix only. The research team prepared two questionnaires, one for consumers and one for merchants. The staff discovered that the town was basically self-sufficient for most needs. Specialized services such as automobile and clothing manufacturing came from the cities. Low-order services such as insurance coverage, automobile parts, banking, and groceries were available from sources in the town. The Oskaloosa study is unique because it sought to identify needs and whether they were met from internal or external sources. This is the first step in defining human carrying; the needs of the study site must be known.

More recent studies are that build on the Oskaloosa study are Gilliland and Clark's (1981) study of the Lake Tahoe Basin and Rees and Wackernagel's (1994) study of the Lower Fraser Valley (British Columbia) and the Netherlands. Both authors isolated the inputs from outputs to see whether the local resource base could support the needs of its population---both physical and social needs. The Sunshine Farm Project, under direction of Dr. Marty Bender of The Land Institute, is researching the farming efficiency of organic farming with minimum machinery inputs (Bender, 1996). Even though carrying capacity is of interest in the outcome, the project is long-term in nature (from 1990 to 2000). Although this dissertation will build on previous studies, it is unique because the attempt is to define a <u>general</u> framework that can be adapted or fine-tuned to other locales, not to justify the uniqueness of an <u>anomaly</u>.

## Measuring Variables in a Framework

Two points remain to be resolved before discussing a framework. First, which variables to include, and second how such variables will be measured.

Human carrying capacity must evaluate how well economic, social, and environmental variables relate to supply and demand of a community. This, although obvious, is easily overlooked in analysis. It is convenient to assume that trade and technology can cure not only all socio-economic shortcomings but also environmental problems as well (Rultan, 1971). Daly (1990) in his study of the Ecuadorian Chaco discovered that the economic and ecological standing of the country was vastly different. He noted that most international sources, including the World Bank, considered Ecuador credit-worthy; therefore, the state was likely to receive any financial assistance necessary for economic setbacks. Ecologically, however, the Chaco is limited in its natural resource base. Trade and importation of necessary goods for survival would not be sustainable in the long-term. Whether or not economic analysis can adequately measure the value of natural resources remains a problem.

Early economic analysis considered the environment as a “free" asset (Hotelling, 1931), soil erosion, water contamination, and air pollution were viewed as being external to the problem. Thus factories would construct higher smokestacks so that air pollution would be less in the immediate area, and cities would dump sewerage in streams with little regard. Meanwhile, consumers would not necessarily realize the pollution in terms of cost of garbage disposal or crude oil production. The reason that economists “ignored" the environment was there was a mutual feeling that the price system could reflect environmental cost (Hotelling, 1931; Rultan, 1971; and Victor, 1991). As Costanza (1980) and Huettner (1976) noted, humans live in imperfect economies with non-equitable pricing. By the 1970s, a number of scholars were advocating the use of energy accounting, for they felt that environmental costs associated with production and consumption of goods were not adequately reflected in economic prices.

The dispute escalated when Huettner (1976) responded to Gilliland's (1976) views that energy units were superior to economic units for analysis since the latter was subject to market fluctuation. Huettner stated that prices determined demand, and the use of energy units would not reveal additional information concerning the true economic cost of production. Furthermore, he criticized energy units because of double counting. By measuring energy consumed at various stages of production and summing those values up at the final stage of a delivered product, Huettner reasoned the same units were counted more than once. For example, a consumer purchases a quart of motor oil at the store and pays $1.05 for it. Economic proponents argued that retail price factors in *all* previous expenses--from planning and operating the mining equipment through marketing and transportation costs of placing the oil on the store shelf.

Energy proponents, however, felt that hidden costs, disguised by government subsidies or hard-to-account environmental costs, are not readily apparent in the final price. This argument quickly becomes academic in the sense that both require accounting procedures; which is "best"? Costanza (1980) responded to Huettner's debate on net energy analysis he felt that embodied (production energy required for supplies, etc.), direct (such as labor), and ancillary (indirect inputs) energy must be counted separately and summed to reflect actual cost accurately.

As this literature survey comes to a close, it is useful to point out Daly's (1977) thoughts. He felt that economics began with a moral conviction of how to use scarce resources wisely, but contemporary paradigms abandoned this premise for the sake of mathematical analysis. Switching to a geographer's perspective, Muir (1997) noted a similar opinion concerning the Quantitative Revolution in geography. He felt that it alienated a number of fine scholars from ever participating in the discipline again. Both authors lamented that their respective disciplines deserted relevance for internally-consistent, logical theories. This author shares their feelings. Even though one can argue the pro's and con's of energy and economic analysis, the bottom line is to develop a framework based on sound logic, not a different mathematical expression.

Based on the preceding discussion, energy units avoid spatial (regional) and temporal (time) differences and fluctuations; hence, the preceding arguments over which accounting procedure to use are somewhat immaterial to this discussion. Thus, this analysis will utilize energy units in determining the ecological sustainability (the first part of analysis), and then the framework will offer economic units for analysis (for the final analysis). This two-step process is necessary since sustainability has both ecological and economic implications. Human carrying capacity, furthermore, must look at both components for a non-ecological farming system may appear to be reasonable or vice versa.

# CHAPTER III

# VARIABLES, ASSUMPTIONS, METHODS, AND THE STUDY AREA

## Variables and Assumptions Necessary

Since human carrying capacity concepts contains both ecological and economic variables, assumptions must be specified prior to developing a framework for analysis. Once these assumptions are set up, it will be possible to develop a framework that can evaluate their relationships to the optimum number of people the hinterland can support.

## Early and Critical Assumptions

**AS1:** Human carrying capacity, in spite of numerous definitions, will mean the maximum number of people that the hinterland can support given the inputs required for a 'reasonable' standard of living in terms of food, housing, educational, entertainment (including recreation), medical, and retirement expenses.

This assumption does not set aside an earlier discussion. Undoubtedly, many levels of carrying capacity (means of survival) may be present in a given region, and <u>each layer must be analyzed simultaneously, if the overall carrying capacity is to be known</u>. However, given the conceptual stage in defining this term, the analysis here will be limited to a dry-farming wheat community, with as few other socio-economic functions as possible.

Another point of this assumption is that the "number" will not be absolute. Planners, political officials, and rural citizens are warned not to construe the results as an ultimate truth. This 'number' is better referred to as a threshold or limit to sustainable population. Additional inhabitants, once the threshold is exceeded, will either live a 'degraded' lifestyle or seek means of support **in addition to** farming. Such means might include spousal support, off-farm income, welfare assistance (either government or family), or ultimately abandonment of farming altogether and moving elsewhere.

AS2: The hinterland will be defined as the production area served by the grain elevator.

Even though rural and agricultural analyses tend to be organized around political units (*e.g.*, town, county, etc.), such organization often misses the environmental and cultural detail critical to analysis. First, the axiom concerning the shortest distance between two points equals a straight line works well in plane geometry, but watersheds and location of family and social institutions quickly render that assumption false in the real world. Second, this assumption asserts that the presence of a grain elevator enforces a sense of community; that is, elevators give farmers a reason to go to a particular community. Other activities such as post offices, schools, or churches may be dependent on this common bond. Places such as Baker, Straight, and Eva in Texas County, Oklahoma, still have small population clusters, but people look elsewhere for sense of place, for the grain elevators are not utilized as heavily as in other communities, and Baker and Straight lost their schools years ago. Therefore, the assumption here is that the hinterland must serve a grain elevator (=node).

## Agricultural Variables and Assumptions

As discussed in the conceptualization section, the following farm factors will be analyzed: fuel, machinery, chemical application, tillage and maintenance, planting, labor time, and on-farm transportation. Amount of wheat harvested is the output. Once input and output are calculated, socio-economic variables will be included since this model assumes that people live for more than mere existence. Huettner (1976) was partially correct in noting that net energy analysis may indeed tell one the same information as economic analysis, but the latter requires new data for each time and new place. Data from energy analysis, however, may be used indefinitely <u>as long as inputs and outputs are equivalent</u>. Thus, 1950 data could be used in 1985 if the inputs and outputs of farm production were the same in terms of machinery, labor, chemical application, transportation, tillage, planting, and labor. Seeds are assumed to have the same energy value, both for production and yield per pound (AS 3.4); therefore, genetic differences in various seed grades are excluded from analysis. The following lists the specific assumptions that apply to agricultural data.

**AS3.1:** Fuel energy is calculated using Nebraska Tractor Test Data that pertains to the specific tractor model. The values in the reports list diesel, gasoline, and liquefied petroleum gas (LPG). Specific conversation factors are 34,772 (diesel), 23,256.9 (LPG), and 31,320 (gasoline); these values represent kilocalories (kcal) per gallon.

**AS3.2:** Labor will be actual time spent carrying out a task (e.g., rodweeding, harrowing, planting, etc.). This value is 465 kcal/hr considering food requirements for one adult person for a 40-hour, seven day workweek (Pimental and Pimental, 1979).

**AS3.3:** Machinery contains sub-assumptions that pertain to embodied energy, depreciation, maintenance, and repair. Different land practices have different energy expenditures. Harrowing a 160-acre field would require less energy than mold-board plowing the same field, assuming the same tractor and land conditions.

AS3.3a: The embodied energy refers to the sum of all energy required to produce an implement. The conversion factors, calculated by Doering (1978), are differentiated between tractor (1,426 kcal/lb) and tillage equipment (850 kcal/lb).

AS3.3b: Repair accounts for eight percent of total energy annually (Späth, 1985).

AS3.3c: Maintenance accounts for three percent of total energy annually (Späth, 1985).

AS3.3d: Depreciation is straight-line over ten years for motorized equipment while it is fifteen years for non-motorized equipment (Späth, 1985).

AS3.4: Seed energy refers to the amount of metabolically usable energy (1500 kcal/lb from USDA, 1975).

AS3.5: All chemicals have energy conversion factors: nitrogen, 6,486; phosphorus, 1,360.8; potassium, 725.8; sulfur, 12,100; and zinc, 1000. All values are in kcal/lb (Fritsch et al., 1975; Lockeretz, 1979).

**AS3.6:** On-farm transportation assumes that average speed between field and farmstead (actual distance) is 15 miles per hour at a 25 percent load--twice daily on days with field activities.

AS3.7: Soil erosion is not factored in this analysis. First, several site visits to Corn indicate that farmers use technology to prevent soil loss; no severely degraded fields were observed. Second, Washita County has only 6,320 acres currently in Conservation Reserve Program, CRP (Farm Service Agency, 1998, Table 1). This program offers payments for farmers to take seriously erodible land out of cultivation. This low acreage (compared to 12,030 acres in Custer County) indicates that soil erosion is not as serious in this county as in others. Erosion would have to be evaluated, however, if it were rampant in a study site.

These are the assumptions of the Agricultural Energy Flow Monitor (Späth, 1985). Furthermore, these are the only assumptions necessary to consider in evaluating wheat production. Harvest energy data is based on equipment used, whether rented or owned by the farmers. Off-farm income, spousal support, pension sources of income are assumed not to affect wheat production.

## Socio-Economic Variables and Assumptions

### General Settings for All Socio-Economic Variables

AS4.0.a: The sample family, John and Jane Sample, consists of husband and wife and two primary school aged children--40, 40, 10, and 9 years of age, respectively.

AS4.0.b: This family has no accumulated savings at this time (including inheritances); therefore, all that is earned is spent.

AS4.0.c: John and Jane Sample must spend their scarce earnings, from cash grain farming only, wisely to plan for both their and their children's futures.

### Specific Socio-Economic Assumptions

All monthly values, except health insurance, were generated by Waddell & Reed Financial Services, Inc., and United Investors Life Insurance actuarial software for financial planning. Health insurance values are the mean of what the five farmers interviewed required for coverage (1996 interviews).

AS4.1: Emergency cash reserves are necessary for the family to pay unexpected expenses. Five times average monthly expenses is necessary ($100.00/month).

AS4.2: Both the husband and wife need retirement savings--both Social Security and private pension plans.

These payments must come from farm income, not from gifts or inheritances ($770/month).

AS4.3: John and Jane Sample must plan for their children's education, whether college or vocational ($595/month).

AS4.4: The Samples, furthermore, must have life insurance so that upon their premature death, unpaid debts will be paid and the future of their children safeguarded ($70/month).

AS4.5: The family must have adequate health insurance coverage ($404/month).

AS4.6: Land occupance is not relevant here, for land will produce wheat (assuming proper practices and resource management)--regardless of ownership or lease.

AS4.7: Property tax is included in analysis since the taxes must be paid on the land for it to be farmed. It is assumed that this tax must be paid whether owned or leased. The ad valorem tax for the hinterland (Washita Heights School District) is $48.17 per $1000 of assessed property value (Oklahoma State Board of Education, 1998).

AS4.8: Off-farm income is not included either since it does not originate from grain production.

AS4.9: Other economic sectors are not analyzed since they do not contribute to farm production (*e.g.*, school employment, automotive repair shops, oil/gas mining)

## Methods of Analysis

### The Study Site

Now that the variables and assumptions have been stated, selecting the study site is the next step. Given the scope of this analysis, the community selected must meet three criteria: (1) be monocultural; (2) have as few non-agricultural activities as possible; and (3) have local farmers who are willing to assist in data collection.

To keep this project manageable, a town in Oklahoma was selected. Table 3.1 lists a number of agricultural towns that appeared suitable for analysis based on population and agricultural data, but in the end, only two were actually reasonable--Bessie and Corn, both in Washita County. Most of the other towns were inappropriate because of multi-crop hinterlands or a diversified economic base. Bessie was ultimately eliminated because wheat was not the primary cultivar; hay was.

Corn, on the other hand, produces primarily wheat. Its location is shown in Figure 3.1. Other crops include

Table 3.1

List of Small Towns in Western Oklahoma

| Town | Crops | Elev | Mining | Bank | News | School | Spec[1] | Rank |
|---|---|---|---|---|---|---|---|---|
| Bessie | wheat, hay[4] | yes | no | no | no | no | no | 4 |
| Corn | wheat[5] | yes | no | yes | yes | yes | yes | * |
| Eakly | divers.[2] | yes | no | yes | yes | yes | no | n/a |
| Eldorado | wheat, cotton | yes | no | yes | no | no | no | n/a |
| Gotebo | wheat, cotton | no | yes | no | no | elem. | no | n/a |
| Gould | wheat, cotton | no | no | yes | no | no | no | n/a |
| Grandfield | wheat, cotton | yes | no | yes | yes | yes | yes | n/a |
| Lone Wolf | wheat, cotton | yes | no | yes | no | yes | no | n/a |
| Manitou | wheat, cotton[4] | yes | no | no | no | no | no | 3 |
| Roosevelt | wheat, cotton[4] | no | no[3] | yes | no | no | no | 2 |
| Sentinel | wheat, cotton[4] | yes | no | yes | yes | yes | yes | 1 |
| Thackerville | livestock, hay | yes | yes | yes | no | yes | no | n/a |

Notes:

[1]Refers to gift shops, florists, funeral homes, insurance, legal, and medical services.

[2]Includes peanuts, wheat (irrigated and dry), and cotton.

[3]Although no oil mining was observed, an oil/gas consulting firm is located in this town.

[4]The cotton component of agriculture was not observed on the first site visit, after which this table was created. This experience served as a reminder that field work must include pertinent interviews, for the role of cotton (hay in Bessie's case) in the local economy was not known until interviews with the county extension agent.

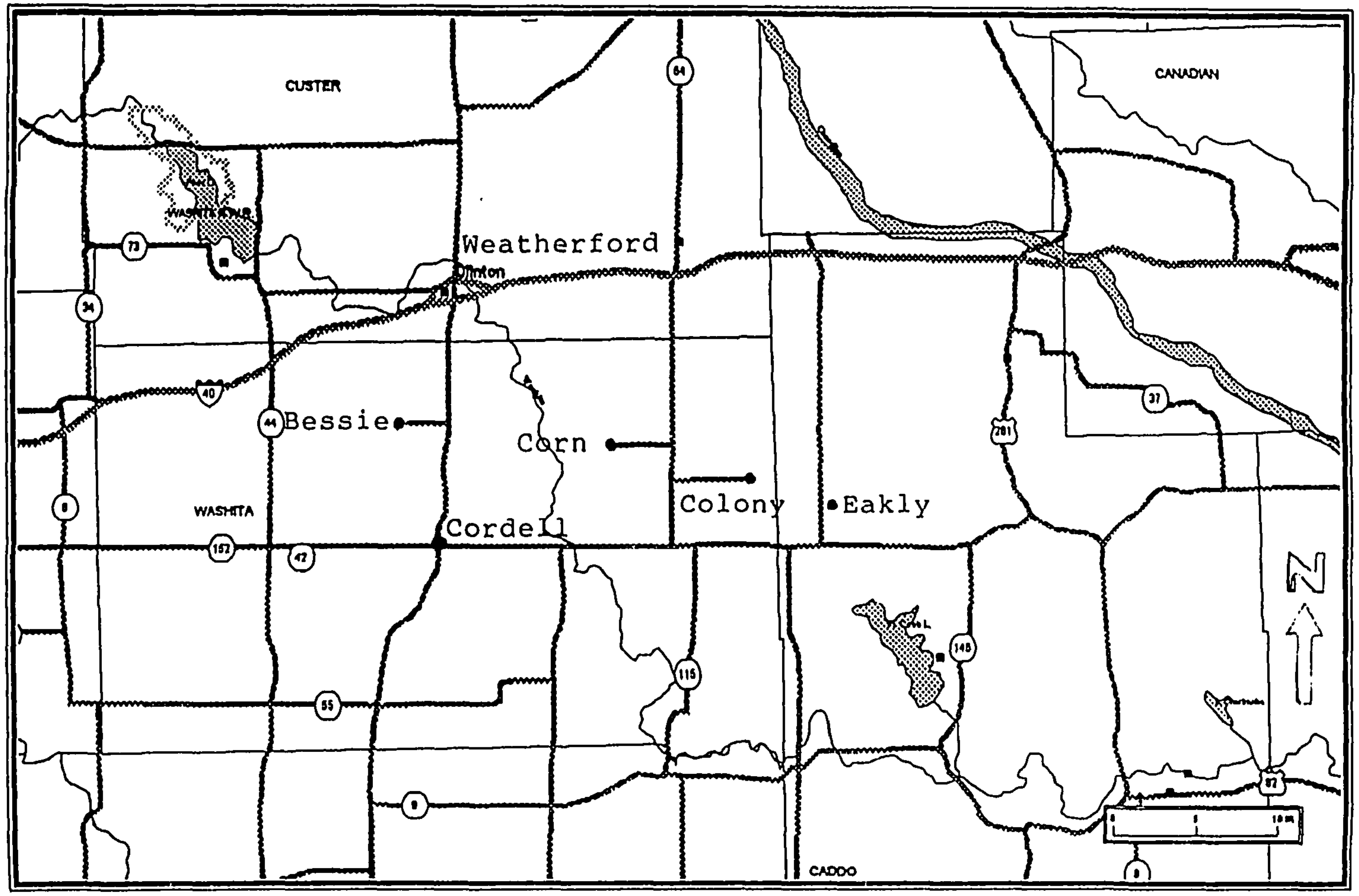
[5]Cotton and alfalfa hay are grown in a few areas. Milo and corn are sometimes grown. In all cases, wheat and some livestock production are the only certain activities present in a given crop year, as other acreages vary greatly in relation to climate.

*Corn was not an initial communty visited, but it was promptly chosen after recommended by the county agent and confirmed site visits.

soybeans, corn, alfalfa, milo, and cotton. In the case of the latter, so few operators grow it that the grain elevator manager was able to name each farmer, his location, and

Figure 3.1

Location of Corn, Oklahoma



rough estimate of the amount grown by each. Soybean and corn acreages vary largely because of projected weather data for the upcoming year; alfalfa and milo normally supplement cattle operations. In addition, the former is normally limited to floodplains and lower terraces near streams. Most operators have a livestock component to their operations, but wheat is harvested for grain rather than ensilaged.

Non-agricultural activities in the town include a town newspaper, restaurant, hardware store, two churches, service station, grocery, implement dealer, Corn Nursing Home, and two schools (Washita Heights School [public] and Corn Bible Academy [private]). The former school serves kindergarten through secondary grades while the latter serves Grades 7-12. There are two important points about Corn's economic make-up. First, most services are local in nature; few people depend on Corn's businesses from outside the county with the exceptions of the nursing home and Bible Academy. Residents do go other communities to shop. Indeed, a number of farmers interviewed indicated that Clinton, Cordell and Weatherford were frequent stops, but two operators mentioned occasional trips to the Oklahoma City metro area to malls.

Second, Corn Bible Academy and the nursing home serve more than the local population and employ people other than

Corn residents. On the surface, it is surprising that this small town, being so close to Weatherford and the interstate, would even have the means to support either a private school or nursing home. This is where the role of culture comes into play. Corn is a predominately Mennonite Brethern community, and Mennonite doctrine requires that communities dedicate considerable resources to education and care for the aged. The school and nursing facility have always been part of Corn, being built shortly after settlement (1903). While the school teaches Christian principles, non-Mennonites are allowed to attend. Thus, proximity to Interstate 40 has little to do with Corn's having a private school or nursing home. Anyone is welcome to use their services, as Mennonites believe that their lives must exhibit Christian outreach in all aspects. Penner (1976) is the definitive source that outlines the migration of Mennonites from Europe to Anglo-America and describes the development of society on the upper Washita Valley in Oklahoma.

The question now arises as to whether Corn is "representative" of small town America. After all, the towns listed in Table 3.1 seem to indicate that those towns are "normal" and that Corn is the "anomaly." Table 3.2 lists some additional towns, mostly in Colorado, that prove

Table 3.2

A Comparison of Other Small Towns

| Town | State | Pop. | House | Med. Income | Percentage | | |
|---|---|---|---|---|---|---|---|
| | | | | | I, D, & R | Soc. Sec. | Retire. |
| Campo | CO | 115 | 64 | $15,313 | 0.44 | 0.59 | 0.17 |
| Cheyenne Wells | CO | 1128 | 437 | $22,888 | 0.31 | 0.25 | 0.08 |
| Flagler | CO | 560 | 259 | $20,927 | 0.37 | 0.42 | 0.09 |
| Genoa | CO | 156 | 72 | $17,885 | 0.14 | 0.28 | 0.11 |
| Holly | CO | 868 | 332 | $18,250 | 0.29 | 0.36 | 0.06 |
| Kit Carson | CO | 303 | 177 | $20,313 | 0.39 | 0.40 | 0.11 |
| Seibert | CO | 190 | 91 | $14,271 | 0.29 | 0.45 | 0.30 |
| Vona | CO | 106 | 42 | $16,000 | 0.36 | 0.45 | 0.10 |
| Walsh | CO | 730 | 286 | $18,026 | 0.32 | 0.33 | 0.07 |
| Bessie | OK | 249 | 89 | $22,159 | 0.44 | 0.19 | 0.19 |
| Corn | OK | 559 | 300 | $17,237 | 0.28 | 0.32 | 0.06 |
| Forgan | OK | 451 | 182 | $24,167 | 0.33 | 0.30 | 0.18 |
| Gage | OK | 454 | 209 | $17,813 | 0.39 | 0.52 | 0.25 |
| Thomas | OK | 1247 | 517 | $21,250 | 0.41 | 0.40 | 0.09 |
| Vici | OK | 740 | 302 | $14,417 | 0.44 | 0.49 | 0.15 |

Notes:

1. Percentage of households receiving a type of income do not add up to 100 percent per town since families may receive more than one type of income.
2. House=number of households
3. Med. Income=median income
4. I, D, & R=Investment, dividend, and retirement income
5. Soc. Sec.=Social Security income
6. Retire.=Retirement income

Source: 1990 Census, STF3A (http://venus.census.gov/cdrom/lookup)

other similar communities do indeed exist. These communities, for the most part, produce wheat as the primary crop on uplands. Cattle grazing is typical on the floodplains and on wheat fields during the winter. Likewise, these settlements have local merchants and businesses that cater to the local population mostly. These are not extended commercial strips with billboards greeting the traveler miles from the outskirts of settlement. Thus, any arguments that Corn is "atypical" of rural America is a false over-generalization. None of these towns are fully self-sufficient, but that is not the argument here. Perhaps the major difference in these towns is that some have a rather high interest, rental, and dividend income rate. That could be attributed to either retired farmers renting out their land or in the case of Thomas, being near an oil field. The point is that other towns with similar socio-economic makeup do exist.

In summary, Corn was the best community for analysis for the following reasons. First, the presence of a grain elevator and minimal services indicated a complementarity between the hinterland and town itself. People in the hinterland have a reason to go to Corn: to market grain, purchase groceries, pay their utility bill, pick up mail, and attend worship services and school. Second, the services present are limited to local needs mostly, with the exception of the school, which also serves Colony, and the nursing home. Third, local farmers were cooperative in data collection. Finally, Corn is representative of other small, monocultural wheat communities.

## Defining the Hinterland

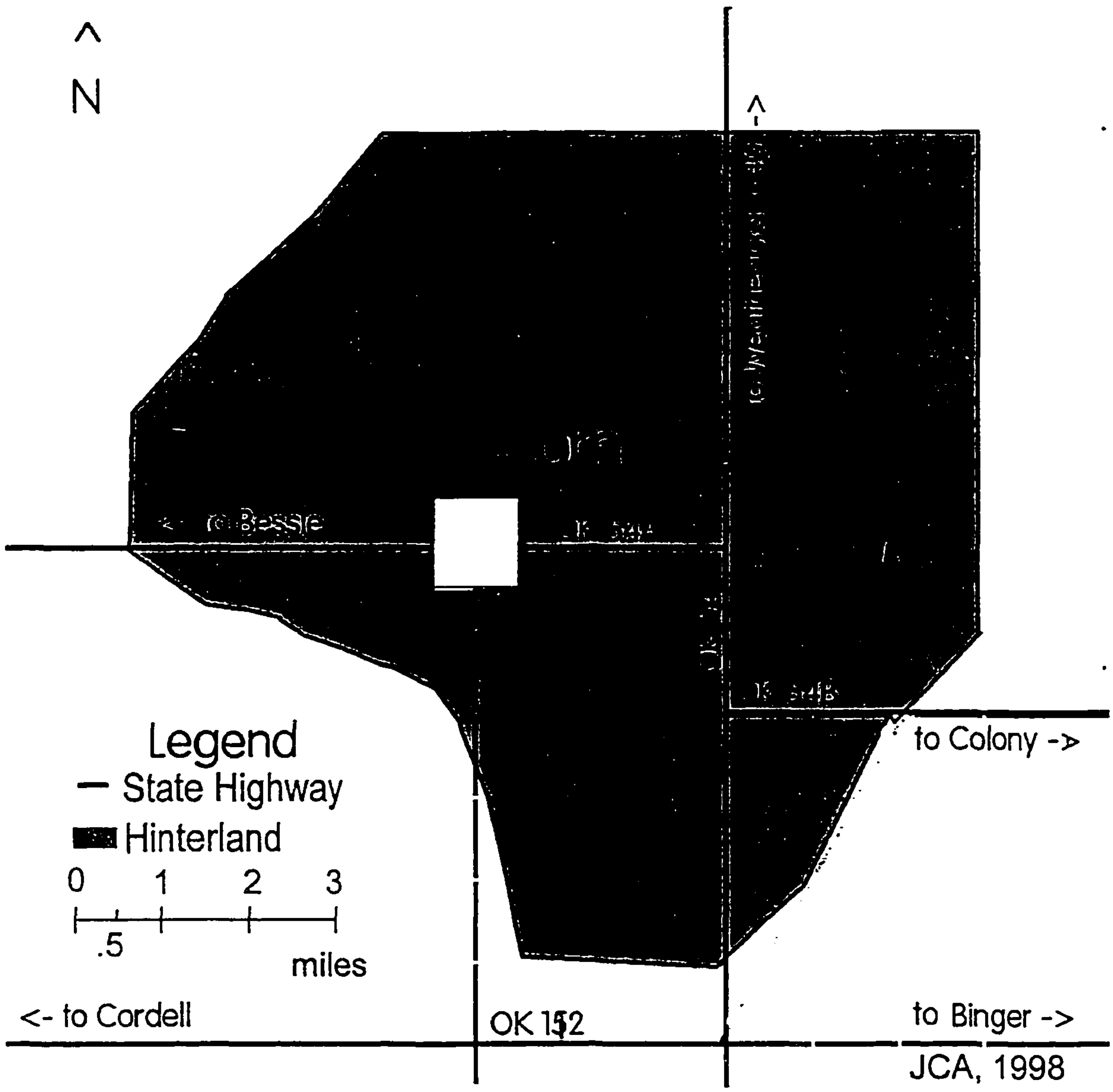
Since human carrying capacity is concerned with whether the output of the hinterland can support the demands of both its residents and the town, the hinterland's area must be defined. According to Mr. Steve Sweeney (1997 interview), manager at the Weatherford Farmland Coop, the production area of the Corn elevator is 47,840 acres (Fig. 3.2). This is the gross area, for a flat, homogenous plain is assumed. It also includes the town of Corn, drainage and stream channels, and roads as well.

## Collecting the Agricultural Data

Data collection for this analysis consisted of two steps. First, the agricultural and health insurance data came from interviewing local farmers. The Washita County Agricultural Extension Agent recommended eight to ten dryland wheat farmers who were representative in terms of operation size and production methods, given the objectives and assumptions of this project. Out of the ten recommended farmers, six operators consented and told the author the amount of health insurance, their operation size, equipment used, and following arranged by field size: tillage operations, labor, machinery, chemicals, transportation,

Figure 3.2

Location of Corn, Oklahoma, Hinterland



tillage and planting operations, and harvest. Table 3.3 is a copy of the questionnaire used.

Agricultural data collected were then compared with field budgets of northwestern Oklahoma dry farmed wheat collected over a three year period and analyzed using the Agricultural Energy Flow Monitor developed by Späth (1985). This program calculates the energy efficiency for each field, organized by the questionnaire, and compares it (along with the total input) to the output. Table 3.4 is an example of a field budget, with an explanation of each step. At this point, it is possible to know whether the farming system is energy efficient. By dividing the net number of kilocalories by the population, it is possible to discern whether the farming system can support its inhabitants in terms of food requirement and additional socio-economic needs for providing the seed material for the next crop. Thus, the output-input ratios are a measure of farming efficiency, comparing whether the inputs required for crop production exceed the output.

## Adding Socio-economic Variables

The second step of data collection is then to factor in the socio-economic needs of the population; people in consumption-oriented societies do not live for mere existence alone. Up to this point, all data are in energy

Table 3.3

Farmer's Questionnaire (Modified from Späth, 1985)

Name of Farmer ______________
Farm No. ______________
Field No. ______________
Month _____ Year _____

I. Planting

| Tractor (model and width) | variety crop | seeding rate (kg/h) | depth (mm) | tractor speed km/h | ha/hr | area done (ha) | date |
|---|---|---|---|---|---|---|---|

II. Tillage

| activity | tractor (model and width) | depth (mm) | tractor speed km/h | ha/h | area done (ha) | date |
|---|---|---|---|---|---|---|

III. Chemical Application

| chemical | application rate | tractor (model and width) | depth (mm) | tractor speed km/h | ha/h | area done (ha) | date |
|---|---|---|---|---|---|---|---|

IV. Harvest (include tractor and truck implements)

| tractor/truck (model and width) | speed km/h | ha/h | area done (ha) | date |
|---|---|---|---|---|

* Be sure to list the number of workers involved in each process.

units. Any excess energy in the farming system will not necessarily translate into a surplus for farmers, for other non-food needs must be met.

## Table 3.4

### Model Output

```
****************************************************************************
FIELD:4.1.12  ACRES: 20   LEGAL DES.:SE/NW & NE/SW - 3 - 26 - 32  SL. DES.:CD
 YR.: 83
****************************************************************************

*TL. OP.*  DATE  * NO. *AC./HR.* AC. DONE * OPERATION ENERGY (KCAL/1000 ACRES) *
*------ *  ----  * --- *-------* -------- * ---------------------------------- *

* TAND  *83/07/25* 30  *  16   *  20 / 0  * FUEL EN.=        2.007277E+07
                                          * LABOR EN.=       30659.27
                                          * EMBODIED EN.=    1278353
                                          * TRANSPORT.EN.=   1525332

* TAND  *83/08/10* 30  *  16   *  20 / 0  * FUEL EN.=        2.007277E+07
                                          * LABOR EN.=       30659.27
                                          * EMBODIED EN.=    1278353
                                          * TRANSPORT.EN.=   1525332

* CDRT  *83/08/15* 50  *  33   *  20 / 0  * FUEL EN.=        8086432
                                          * LABOR EN.=       13700.89
                                          * EMBODIED EN.=    236325.3
                                          * TRANSPORT.EN.=   0

* FDCV  *83/09/15* 49  *  27   *  20 / 0  * FUEL EN.=        1.372772E+07
                                          * LABOR EN.=       19973.02
                                          * EMBODIED EN.=    1278353
                                          * TRANSPORT.EN.=   1529332

* PLNT  *83/09/15* 35  *  19   * 11.8 / 0 * FUEL EN.=        1.921081E+07
                                          * LABOR EN.=       20876.47
                                          * EMBODIED EN.=    63917.64
                                          * TRANSPORT.EN.=   2505308
                                          * SEED EN.=        9E+07
                 CROP VARIETY:SAGE          SEEDING RATE (LBS./A): 60

* PLNT  *83/09/15* 20  *  15   *  8.2 / 0 * FUEL EN.=        1.742808E+07
                                          * LABOR EN.=       37808.78
                                          * EMBODIED EN.=    327581.8
                                          * TRANSPORT.EN.=   2843354
                                          * SEED EN.=        9E+07
                 CROP VARIETY:SAGE          SEEDING RATE (LBS./A): 60

* CSPR  *84/04/15* 30  *  20   *  20 / 0  * FUEL EN.=        1.347772E+07
                                          * LABOR EN.=       22034.02
                                          * EMBODIED EN.=    236325.3
                                          * TRANSPORT.EN.=   0

  FERTILIZER *   DATE   * FERT. % * APPL. RATE (LBS./A) * KCAL/1000 AC. *
* ---------- *   ----   * ------- * ----- ------------- * ------------- *
*  NITROGEN    83/08/15    18             100              1.232208E+08
* PHOSPHORUS   83/08/15    46             100              2.735256E+07
* ANHYDROUS    84/04/15    82             42.68293         2.39612E+08

* HARV. DATE * AC. HARV. * ACTUAL YIELD (BU./AC.) * ESTIMATED YIELD (BU./AC.) *
* ----------   ---------   ----------------------   ------------------------- *
*  84/06/07       20              30                          NA

TOTAL FUEL ENERGY:                  1.280845E+08     ( 20.7101 )
TOTAL LABOR ENERGY:                 183792.5     ( 2.971757E-02 )
TOTAL EMBODIED ENERGY:              4699129      ( .7598061 )
TOTAL SEED ENERGY:                  9E+07      ( 14.55218 )
TOTAL FERTILIZER ENERGY:            3.901996E+08     ( 63.09035 )
TOTAL HERBICIDE/PESTICIDE ENERGY: 0      ( 0 )
TOTAL TRANSPORTATION ENERGY:        1.008526E+07     ( 1.617739 )

*** TOTAL ENERGY INPUT PER 1000 ACRES: 6.184641E+08 ***
*** FOOD (OUTPUT) ENERGY PER 1000 ACRES: 1.8E+09 ***
*** THE ENERGY OUTPUT/INPUT RATIO BASED ON ACTUAL YIELD IS: 2.910438 ***
****************************************************************************
```

### Notes Concerning the AEFM Output

1. Field Name: County.Farm.Field
2. Acres: size of field
3. Legal Des.: location of field
4. Yr: sample year
5. Tl op: tillage operation (*i.e.*, TAND=tandem disk; FDCV=field cultivator; PLNT=planting; CSPR=custom sprayer)
6. Crop variety: actual seed name...in this case Sage
7. Wd.=width of implement

All of these factors, in addition to speed, factor in the assumptions and require information concerning fuel, machinery, labor, chemical, and transportation. Fuel and embodied energy make up the greatest inputs. In the final analysis, fertilizer becomes another major input. Even though almost three times the energy comes in output as what was required for input, it must be remembered that capital intensive inputs were required to achieve this ratio.

The energy units will now be converted into financial units. Fuel, chemical, machinery, labor, and harvest all have monetary values, but this value would reflect energy analysis, not a demand-side lifestyle with off-farm income or government subsidy. The purpose of using the energy budgets is to discern the major physical inputs into grain production. Any fiscal output (e.g., income) would be reflective of this input. Thus, by converting total energy inputs and harvest output into dollars, it would be possible to know the annual income from grain production and subtract the necessary annual expenses of having emergency cash reserves, life and health insurance, retirement investments, and savings for educational needs for children. In addition, people will desire to have entertainment and be able to pay for their cars and housing.

## Analyzing the Data

Once agricultural and social demands are known and the grain output is compared, either a surplus or deficit will result. At this point, it is possible to reexamine the inputs to see where inefficiencies lie. Then empirical evidence will be the test of whether this process has indeed worked.

## Concluding from this Experience

Whether or not the results define the ideal number of inhabitants is not the ultimate test of success. Once the reasons for the outcomes in Step 5 are known, the scientific community may conclude that energy budgeting, or ecological accounting as some prefer to call it, may not be the best approach. Nevertheless, a written attempt to isolate a given number of factors along with a better understanding of agricultural and socio-economic variables in a monocultural community will have been achieved.

# CHAPTER IV

# FARMING DATA AND ITS ANALYSIS

## Farming Data--Sampling Procedure

Although Späth (1985) constructed a data set for both continuous and dry-farmed wheat production in Oklahoma, it was necessary to inventory a few operations in the Corn hinterland to see whether inputs and outputs in grain production were similar, for Späth's data are from the 1983-4 crop year. From the list of operators given to the author by the Washita County Extension Agent, six farmers agreed to be interviewed concerning the machinery, fuel, labor, chemicals, transportation, planting, and harvest activities for the 1995-6 crop year. These data were collected by field, normally grouped by township-range coordinates, although one operator listed his fields differently.

## Description of Grain Production in the Corn Hinterland

The farmers interviewed are representative of other grain farmers in the area. When the author solicited names from the county agent, the agent was informed of the research objective and specific type of information needed for this analysis. Thus, the only operators listed were those who use similar machinery, land management techniques, and had operational sizes equivalent to other farmers. All the sample farmers have other crops in addition to wheat, but wheat is their primary crop in terms of both acreage and income. All have a variety of tractors, but implement width varied because of both overall operation size and individual field sizes. Table 4.1 lists summary data for each operation. Appendix 1 lists the actual inventory for each farmer's field.

A few generalizations are possible from this table. First, the 1995-6 crop year had a low harvest from a statewide drought. The Washita County average is around 30 bushels per acre, but Operators 1, 2, and 4 stated that they frequently obtained over 40 bushels/acre during a normal year. In spite of the drought, each farmer stated that he performed the same operations annually even though frequency and/or specific rates of field application may differ. Thus the sample year is still valid, notwithstanding the harvest rates.

Second, there is some disparity amongst operation size, as listed in Table 4.1. Interviews with Operators 1, 2, and 4 revealed that they had more and larger fields, and larger implement widths were required to till, maintain, and harvest those fields. These attributes may be found in the Corn sample data in Appendix 1. The typical sequence of activities for each field is for the farmer to chisel,

Table 4.1

Summary Farming Data (Implement Widths) on Field Activity

| | Farm | | | | | |
|---|---|---|---|---|---|---|
| Activity | 1 | 2 | 3 | 4 | 5 | 6 |
| Tillage | | | | | | |
| Chisel | 24' | 36' | 10' | 35' | | |
| Field Cultivate | 35' | | | | 21' | 32' |
| Springtooth | | 54' | | | | |
| Oneway | | 28' | 10' | | | 18' |
| Offset disc | | | | 35' | 20' & 12' | |
| Tandem | | | | | | 8' |
| Sweep | | | 10' | | 20' & 15' | |
| Moldboard | | | | | | 8' |
| Chemical | | | | | | |
| Anhydrous | 24' | | 30' | 35' | 20' & 15' | 32' |
| Planting | 39' | 42' | 10' | 30' | 20' | 13' |
| Dyemetholate | | air | 34' | | air | |
| N/Ph/Potash | | | 40' | 60' | | 13' |
| Glean | | | 35" | | | 60' |
| Harvest, 1996 | 20 | 26-28 | 18 | 30 | 14 | * |

Source: 1996 interviews with 6 six farmers

Notes:

1. This chart is for general inventory only.
2. Farmer 5 often works his fields with his son using another tractor.

* Farmer 6 retired in 1993 is used to show "typical" practices.

offset disk, and/or one-way plow from four to six times before planting. This rather high number is indicative of a dry year, for farmers desire to prevent the topsoil from becoming too dry. A few farmers also treated their soil with anhydrous ammonia during this pre-planting time as well. With the dry 1995-96 crop year, weeds and pests became a problem once the wheat resumed growth in late January through March. Therefore, some operators applied Glean and dymetholate, common herbicides and pesticides respectively used in the area.

Third, all operators, except the sixth farmer, engage in farming as their full-time occupation. Farmer 6 is retired; he had no harvest in 1996. Data pertaining to his operation came from the 1992-3 crop year. His data served a base line for what a typical year would be like.

Finally, it is obvious that all operators invest substantial resources into tillage and chemical operation. Labor is not the primary input here. Normally, each tillage and planting operation involves only one person, with the exception of Farm 5. Both the farmer and his son work the same field frequently. As for harvest, some operators hire that out to harvesters, and that may involve either two or three people. In the case of the latter, harvest can continue while the third person transports grain to the elevator.

## Northwestern Oklahoma Data Set

Once the data were collected for Corn area farmers, it was compared with Späth's northwestern Oklahoma data set for the 1983-4 crop year. The intention here is to use field budgets already calculated, provided that inputs are similar for unfertilized wheat. Späth's (1985) study of dryland wheat production indicated that operators had around five or six field practices before planting, normally either sweep or disc plowing. This is indicative of a similar planting environment, for farmers must keep the topsoil from drying and exposure to the elements. As with Corn farmers, these operators also applied chemicals before and during early stages of crop growth (before December of the planting year), and some had to use Glean in the spring to combat weeds. Earlier research in eastern Colorado (documented in Späth, 1987) showed similar patterns. Table 4.2 lists summary data from actual field budgets of northwestern Oklahoma.

As with the Corn data, this data set indicates that northwestern Oklahoma farmers use the same techniques. In general, Corn farmers during the 1995-96 crop year had 5-6 operations. The drought required that dryland farmers more frequently till the soil to conserve moisture. The primary difference, however, is that these operators used wider implements in tillage operations. The use of wider implements can be more efficient in the sense that labor inputs can be less. On the other hand, fuel and embodied energy will be greater since heavier machinery and implements are required. Planting implements were similar with the Corn farming operations. Harvest data, with the exception of two operations, are comparable to Corn yields during a 'normal' year.

Table 4.2

Summary of Northwestern Oklahoma Data Set

| | Farm Sample | | | | |
|---|---|---|---|---|---|
| Activity | 3.2 | 4.2 | 4.5 | 5.2 | 5.5 |
| Tillage | | | | | |
| Chisel | 17' | 32' | | 7' | 32' |
| Offset | | | 20' | 16' | 26' |
| Tandem | | 35' | | | |
| Sweep | 25' | 45' | 25' | 20' | 36' |
| Chemical | | | | | |
| N/Ph/Potash | 50' | 30' | 40' | 50' | 30' |
| Anhydrous | | | 40' | 30' | 30' |
| Iron, zinc | | 30' | | | |
| 24-D | | 30' | 50' | | |
| Glean | | 30' | | | 30' |
| Planting | 26' | 30' | 27' | 14' | 30' |
| Harvest (bu/acre) | 31 | 30 | 50 | 44 | 56 |

Source: Späth (1985) data set

## The Benefits of Energy Analysis

Two unique advantages resulted from using these energy budgets. First, energy accounting factored in the environment. The use of similar inputs indicates that Corn and northwestern Oklahoma have somewhat similar environments. With the exception of one farmer in Corn, no one used a moldboard plow; even then, this farmer stated that he did not use it each year. The use of discs, sweep plows, and field cultivators indicates that farmers in both locales must use conservation tillage techniques. Likewise, the use of chemicals indicates that soil quality and weed problems are essentially the same. If soil types and the climate were not the same, then there would be no reason for these similar practices to be present.

Finally, the use of one sample year does not imply a closed system. It is unreasonable to assume that fuel, machinery, seed, etc. are obtained in one year. Revenues from one year make it possible to purchase supplies and perform maintenance for following years. Thus, all activities, successful or not, directly affect future farming years.

## The Ability of a Hinterland to Support Its Population

Using the sample data from Späth (1985), it is possible to determine whether the hinterland can support dry-farmed wheat and the community of Corn, Oklahoma. Table 4.3 lists the breakdown of farm energy expenditures of sample farms from initial tillage to harvest. The energy values represent the same activities and field sizes of the Corn hinterland.

Fertilizer, seed, transportation, and fuel make up the greatest energy consumption in farming. Without these inputs, it would be impossible to obtain the high energy output-input ratios. These inputs also point out the role of how limited the local environment is relative to the crop output; energy analysis reveals a heavy dependence on chemicals. Such reliance indicates that the soil, while productive, must have additional nutrients to produce wheat.

Table 4.3

Production Energy Inputs and Output Per Acre (in kilocalories) for the Wheat Farming System in the Corn, Oklahoma, Hinterland

| Farm Number | 3.2 | 4.2 | 4.5 | 5.2 | 5.5 |
|---|---|---|---|---|---|
| Input | | | | | |
| Fuel | 105,808.7500 | 128,338.4615 | 106,016.6667 | 135,456.6667 | 161,521.0526 |
| Labor | 199.7149 | 179.3614 | 236.0312 | 302.8330 | 213.4129 |
| Emb. Energy | 365.9489 | 1,774.3165 | 4,216.3365 | 61.0685 | 3,437.6173 |
| Seed | 48,000.0000 | 84,461.5385 | 90,000.0000 | 90,000.0000 | 90,000.0000 |
| Fertilizer | 20,367.5000 | 188,353.8462 | 467,783.3333 | 711,966.6667 | 776,105.2632 |
| Herbicide | 0.0000 | 3,302.0096 | 383.6250 | 1,534.5000 | 137.5000 |
| Transportation | 3,533.0000 | 6,223.6923 | 7,725.4205 | 8,745.3333 | 13,975.7895 |
| Total Input | 178,274.9138 | 412,633.2261 | 676,361.4132 | 948,067.0681 | 1,045,390.6354 |
| Total Output | 2,542,500.0000 | 2,260,384.6154 | 4,485,000.0000 | 3,594,000.0000 | 4,688,526.3158 |
| O-I Ratio | 14.26 | 5.48 | 6.63 | 3.79 | 4.48 |

Source: Späth (1985) dataset.

Economic analysis, alone, would not have shown this, for it would not have factored in embodied energy--only the end user cost.

A few observations are in order at this point. First, the heavy use of fertilizer indicates that the soil may not be in the best condition to nurture wheat as is. Second, the high energy input of seed also indicates that sophisticated equipment is needed to distribute it. Although the wheat varieties of Pioneer, Karl, and Tomahawk have different strains for various purposes, the seed energy here reflects the need for motorized equipment. Seed company breeding and production energy which went into developing Tomahawk for better grazing wheat versus the same energy for development of Pioneer strains for excellent cash grain yields is not the issue. Third, high values for on-farm transportation mean that operators farm land not adjacent to their homes; it also indicates that land in different parts of the county or adjacent counties is farmed. Finally, it is obvious from these data that gas and diesel-powered equipment are a major input into crop production. Without the use of such machinery, labor values per unit area would be much higher.

The following seven steps will list the methods employed in deriving whether or not this hinterland will support its inhabitants and their farming system, based on agricultural input and output alone. First, from individual field budgets of the data sample, all inputs and outputs are summed by field and operation. The inputs summed are fuel, labor, embodied energy, seed, fertilizer, herbicide, and transportation. All values computed by the Agricultural Energy Flow Monitor (AEFM) represent kilocalories per 1000 acres. These values are further refined by dividing the sum by the farm's number of fields and then by 1,000, giving the average number of kilocalories used per acre for a given input. Then, all inputs are summed to provide the average value per sample farm. The sum of total inputs by operation will render the total number of kilocalories necessary for wheat production.

The total output is the energy provided by wheat yields, according to acreage harvested. This value does not always equal the acreage planted. Oftentimes, flooding, drought, weeds, and/or insect problems will cause the number of acres harvested to be less than what was planted.

Second, means of total input, output, and output-input ratio are obtained ($I$, $O$, $R$) by dividing the total inputs and outputs by number of sampled farms (5). This amount will indicate to what extent the output is greater than input on these sample farms. While this figure will not necessarily indicate whether the hinterland can support the farming system, it is important to note whether the farming system is efficient in converting production energy (i.e., the energy required for wheat production) into food energy.

Third, the daily number of kilocalories needed for humans is determined ($C_d$). In the AEFM, labor is assumed to need 400 kcal/hr. for an eight-hour workday. This figure is not acceptable here since the amount of energy necessary for good health goes beyond the workday. Furthermore, gender, age, and amount of activity call for varying amounts. Based on Späth (1997), 3400 kcal is a reasonable daily amount. This represents the mean lower and upper levels of energy necessary. Obviously all members of the community (e.g., elderly and children) are not in this category, but its use will require more energy for the hinterland. It is possible that this assumption will render a smaller carrying capacity, but it is better to err in underestimating rather than overestimating the optimum population size.

Fourth, the values for the total input and output per acre are multiplied by the number of acres in the hinterland, 47,860 acres ($H$); therefore, the means are in kcal/acre and are multiplied by 47,860 (almost 48). This will give the actual amount of inputs and outputs for the study site ($I_h$ and $O_h$, respectively).

Fifth, the annual caloric need for humans is calculated by multiplying the daily need times 365. Once again, the annual requirement might be too high since some populations (children and elderly) do not need 1,210,400 kcal annually; it is better to underestimate rather than overestimate. The resulting amount will be the annual caloric intake requirements ($C_{an}$) necessary to sustain one person.

Sixth, total output ($O$) is then divided by the population ($P$). In the case of Corn, this amount is both the town and census tract population. These are the two standard population areas that are most similar to the hinterland. This amount will tell how many kcal are available from the wheat crop for exchange into food or other services ($E_{ag}$).

Finally, the amounts from Steps 5 and 6 are compared. If $E_{ag}$ is greater than $C_{an}$, then there is a surplus of energy output given the annual caloric intake needs of the hinterland and town populations. If $E_{ag}$ is less than or equal to $C_{an}$, then these steps should be repeated if this is the first calculation to ensure that no computational errors were made. After the second attempt, if the result is the same, then a deficiency between the farming system output and caloric needs of the population is present, which means that the hinterland, alone, cannot support the most essential needs of the population. This process is illustrated in the Figure 4.1 with pertinent values included.

From these steps, the Corn hinterland can indeed support the basic needs of its population. Table 4.4 lists the pertinent calculations. To go one step further, dividing $C_{an}$ by $E_{ag}$ will reveal the ratio between energy required and that available per person. The energy output-input ratio indicates a modern farming system; today's agricultural production requires capital intensive inputs. Furthermore, examination of the spatial implications emphasizes that such inputs require resources <u>beyond</u> the production area. Factoring in the embodied energy through the depreciation model in the AEFM reveals that the

Figure 4.1

How to Determine the Carrying Capacity

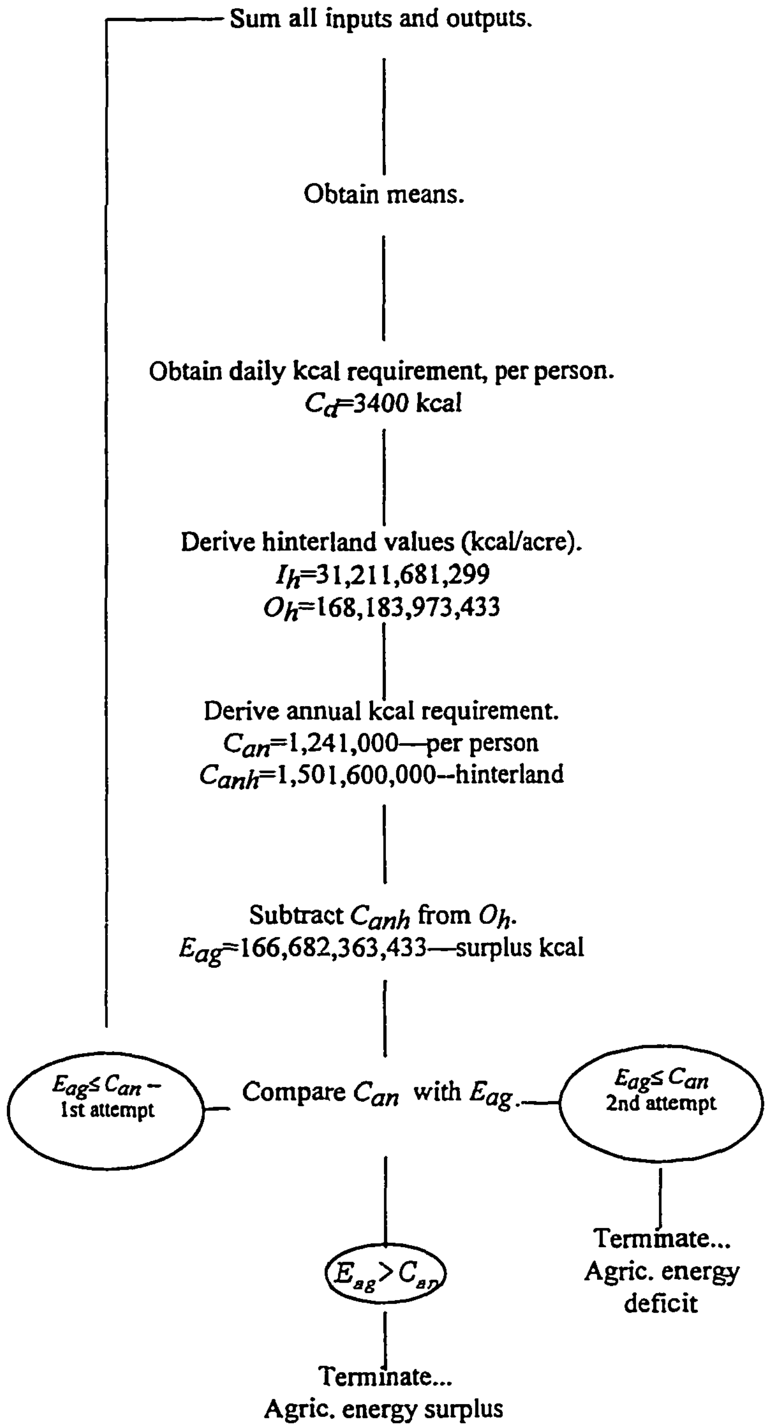


Table 4.4

List of Pertinent Values Per Acre

| Variable | Kcal/Acre |
|---|---|
| Mean Input | 652,145.4513 |
| Mean Output | 3,514,082.1862 |
| Mean Output/Input Ratio | 5.39 |
| Total Population ($P$) | 1210 |
| Annual Kcal Food Requirements per person. ($C_{an}$) | 1,241,000 |
| Hinterland Acreage ($H$) | 47,860 |
| **Total Energy *Available* per Person ($E_{ag}$)** | **1,396,300,000** |

Since $E_{ag} > C_{an}$ , an agricultural energy surplus exists from grain production, enabling exchange for other goods and/or services.

Table 4.5

List of Pertinent Values Pertaining to the Hinterland

| Variable | Kcal/Hinterland |
|---|---|
| Total Input | 31,211,681,299.0598 |
| Total Ouput | 168,183,973,433.1980 |
| Total Population | 1210 |
| Annual Caloric Requirements ($C_{an}$) | 1,501,610,000 |
| Calories Available ($E_{ag}$) | 166,682,363,433 |
| Hinterland Acreage ($H$) | 47,860 |

resources may come from outside the hinterland. In such a small area, it is unreasonable to assume that the hinterland can produce everything: machine instruments, tire, or the agricultural chemicals elements. All these implications are reflected in this analysis. As long as one understands that such a system is locked into trade of a variety of scales and the resources are available either physically or through politico-economic means, this system is indeed efficient. Whether or not it is sustainable will be addressed in the final chapter.

At this time, however, some findings result from values in Table 4.4. First, the output is slightly over five times the input required for grain production. On the surface (and until examined further), one can argue that the farming system is efficient. Second, the energy available per person on the limited land (47,860 acres) exceeds the daily caloric requirement. Inhabitants can use this excess energy for other activities. The reader must keep in mind though, that excess energy means the ability to engage in other activities, not that he/she will actually do so.

Table 4.5 indicates that the hinterland is able to support the farming with no problem in energy terms. The total population's annual food caloric needs are minimal when compared to the kcal yielded from the wheat harvest. Undoubtedly, a surplus exists, and it may be used for exchange for other food and/or goods. At this point, the energy analysis ends, for ecologically, this system is sustainable at the present time. Attention will now be focused on how well socio-economic needs can be met.

# CHAPTER V

# SOCIO-ECONOMIC VARIABLES AND ANALYSIS

## The Role of Socio-Economic Variables

Currently, the hinterland appears to be able to support the most essential needs of the population. This tract of land is able to support cash grain wheat farming system. But the analysis is only half finished at this point. Throughout the world, people live for more than mere existence. Thus, the socio-economic needs of emergency cash reserves, life and health insurance, retirement, and educational expenses must be evaluated on top of agricultural output to determine whether this farming system can indeed support the population.

Two changes take place at this time. First, previous analysis was concerned with whether the land could support the population. Since energy (or ecological) accounting avoided spatial and temporal changes in data value, all data to this point are in energy units (kilocalories). Factoring in socio-economic needs, however, evaluates the reciprocal relationship in human carrying capacity: whether human activities can support the population concerned.

Second, data values must now be converted to economic units, as it would be impractical to evaluate the energy requirements for life insurance or retirement needs. The bottom line here is whether the net income of the farming system can pay for the socio-economic needs of its members. Initial socio-economic analysis involved taking the surplus calculated from Table 4.5 ($E_{ag}$) and converting it into bushels of wheat; from this conversion, the Corn hinterland produced an excess of 1,852,026.26 bushels of wheat. Multiplying this amount by a target price of $3.68 and dividing by the number of farm families, resulted in an annual family income of $22,718.19. Based on conversion of the kcal required for food intake, the per capita annual food expense was $12,279.75 (for a family of husband, wife, and two school-aged children). Therefore, the annual gross family income, based on these figures, was $34,997.94 --- about $4,000 lower than the assumed family income of $39,000. According to this train of thought, it appears that surplus wheat production can almost support a four-person family in the hinterland.

Thus, this attempt to merge energy analysis with economic analysis was much closer than first appearance might suggest. At this point, though, it is not possible to know whether the hinterland can truly sustain the farming system in economic terms, for agricultural production costs have not been calculated yet.

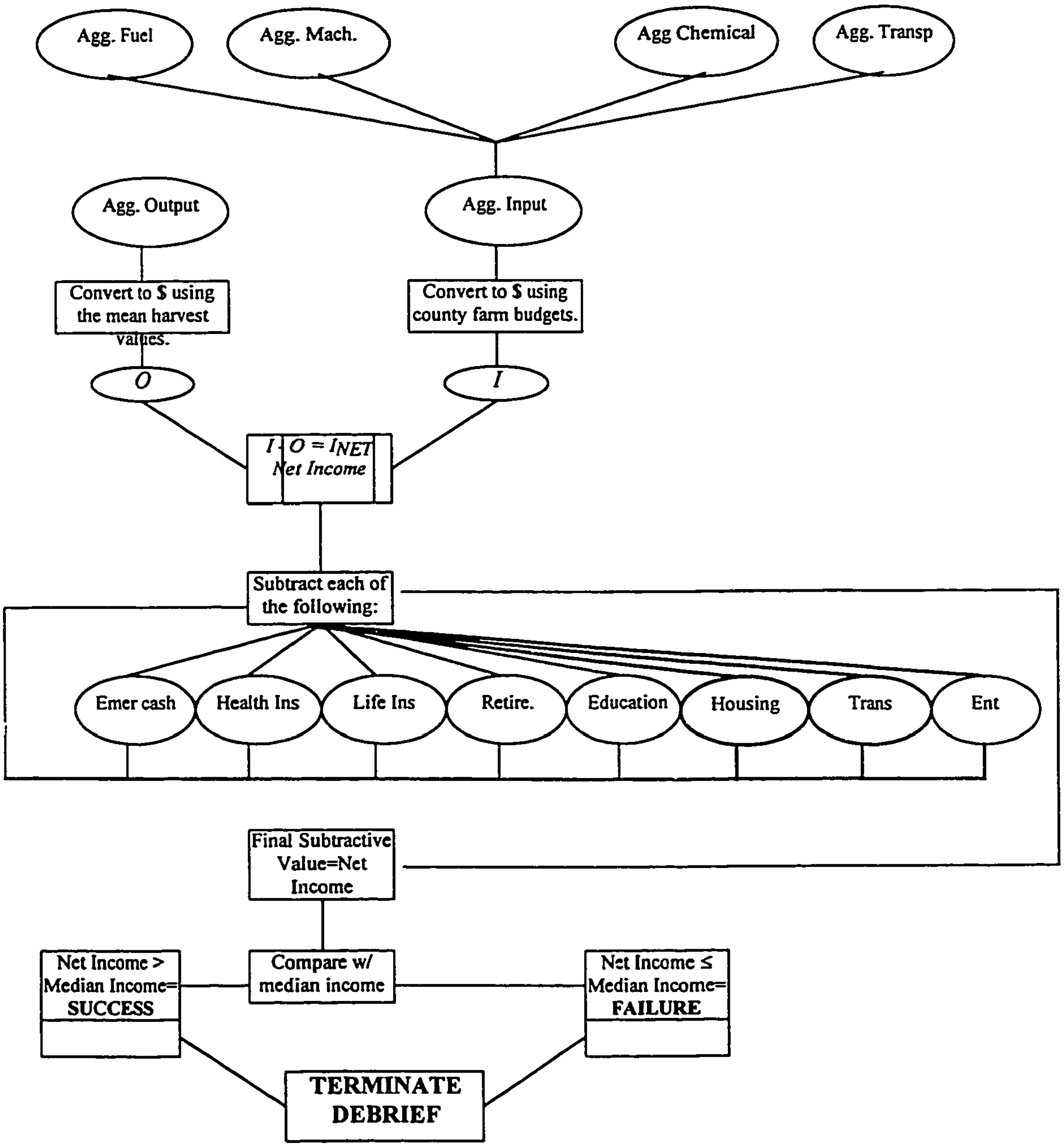
Each input was assigned a dollar value and multiplied to achieve the total amount used so that an economic value will be associated with the aggregate input and output of Corn's wheat crop. In this manner, a net income for the community may be obtained, and a per capita income obtained by dividing the net income by the number of inhabitants.

Therefore, it is possible to know whether the land provides a means for the population to support themselves through a farming system in economic terms. This is where the analysis will become crucial, for the ultimate question to be answered is whether the land can also provide the lifestyles that its inhabitants desire. This is also the breaking point, for even if the farming system can support its population but future and current socio-economic needs cannot be met, then local farmers must look to other sources of income. When interviewing local farmers, the county agent, the grain elevator manager, and the city clerk, it was obvious that the population engages in non-agricultural employment for a variety of reasons. Only the large operators did not engage in off-farm activities for income nor did their spouses. The smaller operators often did, most often with their wives working elsewhere, such as Weatherford Hospital, Corn Bible Academy, or the nursing home. Only two operators interviewed stated that they, themselves, worked full-time in other occupations.

This previous discussion is not meant to state that the downfall of farming is already known but rather as a check to see whether the socio-economic analysis will indeed reveal whether the population can be supported by farming. Even if the answer would turn out to be negative, then at least farming and socio-economic data could be evaluated to determine where the reason for the downfall lies. Heavy use of fertilizer, for example, might indicate that the soil is too depleted to offer a reasonable wheat crop. A heavy input of fuel, likewise, may point out inefficient tractors or implements that should be retired. A large expenditure from emergency cash reserves would be indicative of an environment where health or personal needs fluctuate greatly. These are but a few examples of how evaluating individual inputs would reveal *precise* reasons for the state of the current farming system; something that is currently speculated about with the lack of a framework for determining human carrying capacity. Figure 5.1 illustrates how socio-economic data builds on energy analysis and whether the population can be supported by the farming system.

Figure 5.1

Socio-Economic Data Analysis Flowchart



## The Meaning of Socio-Economic Variables

The physical existence of a population is not the primary objective in this study, for it can be assumed that people will move to another location, find other means of income, or engage in additional work should farming not be able to completely sustain them. The problem at this point is that farming data, which is in energy units, is awkward to compare with socio-economic needs of retirement income, which is in financial units. Therefore, the first undertaking in evaluating whether the hinterland can support the farming system and its population is the conversion of these variables into the same measurements as the socio-economic variables, dollar amounts. Thus, fuel, machinery, labor, chemical, seed, and transportation data must be converted to dollar amounts. Table 5.1 lists the conversion factors for each variable.

Machinery and transportation constants differ from those used in the AEFM. Depreciation values are the same time interval as the AEFM; it was not appropriate to use the Internal Revenue Service's *Farmer's Tax Guide* since tax values are not appropriate for understanding capital consumption. Normally, a farmer cannot claim depreciation after seven years; farm equipment has a useful life beyond

Table 5.1

Conversion of Energy Units into Financial Units

| Category | Variable | Constant |
|---|---|---|
| Machinery/Transportation: | depreciation | 10 years |
| | repair and maintenance | 8 years |
| Fuel: | gasoline | $1.03/gallon |
| | diesel | $.97/gallon |
| Chemical | dymethanolate | $2.93/gallon |
| | Glean | $15.90/gallon |
| | Anhydrous ammonia | $2.45/ton |

these limits. In addition to the time factor (seven year useful life on machinery), this type of deduction does not make sense. After all, if the equipment is used, then some utility is gained although it will be less as its wear increases.

Fuel costs are lower than retail prices, for it is assumed that the operator will purchase these from the local coop. A gasoline scenario was computed, was summed to reflect expenditure of the hinterland's acreage in addition to the number of field operations. In the same manner, chemical value will be derived for fertilizers and herbicides used by summing all values to reflect hinterland acreage.

The cost of seed was based on a mean between costs of the various seeds used. Each seed is developed for different purposes (e.g., grazing, cash grain, ensilage, etc.) and various soil types. Table 5.2 lists the prices

Table 5.2

Price for Various Seeds (in 50 lb. bags)

| | Type of Seed | | |
|---|---|---|---|
| Seed Variety | Registered | Certified | One Year Out |
| Karl 92 | $8.75 | $6.75 | $5.75 |
| Pioneer 2180 | 8.75 | 6.75 | 5.75 |
| Pioneer 2163 | 8.75 | 6.75 | 5.75 |
| Tomahawk | 10.75 | 8.75 | 7.75 |

Source: Ross True Value, El Reno, Oklahoma, (1996 interview).

of various seeds and differences in grades. One year out of certification was used for this analysis since it was the middle value. This value will then be multiplied by mean seeding rate times total hinterland acreage.

The final output, total bushels per acre, was multiplied times the mean value of wheat per bushel for 1997, $3.68 according to the Chicago Board of Trade (Chicago Spot Wheat Prices, 1997). This value will give the total output of the Corn hinterland in dollars. From this amount, each of the agricultural input totals can be subtracted; at this point, the reader will know whether the hinterland can support either its population or agriculture as far as farming variables are concerned. That is, whether total agricultural expenses are less than the total receipts from wheat production. Then the costs of socio-economic variables can be added to agricultural costs, giving the total costs. Total costs are subtracted from the total receipts. A deficit indicates that the hinterland cannot support its population; conversely, a surplus means that the land can support its inhabitants.

## Does the Hinterland Support Its Population?

Depreciation from machinery is incorporated in this analysis assuming ten percent for motorized equipment and eight percent for non-motorized equipment over a fifteen year period (straight line depreciation models)--same as the AEFM. This figures are annual depreciation rates. The ability to depreciate equipment from a tax standpoint is irrelevant; it is assumed that machinery will decrease in efficiency as it ages. Other variables such as land value, rent, crop loss from drought or severe weather, traveling expenses associated with marketing or other farming activities, or conservation measures employed are not included here since they do not relate to the physical production of grain farming. Most of these can be deducted on the farmer's annual tax return, however.

Table 5.3 lists the summary costs of fuel, seed, and labor for the Corn hinterland along with spatial data. Table 5.4 lists the summary costs of fuel, seed, and labor for the Corn hinterland along with spatial data. As with the energy analysis, fuel is the highest cost with

Table 5.3

Summary of the Corn Farming System, in Economic Terms

| Variable | Total Amount | Unit Price | Total Cost |
|---|---|---|---|
| Machinery | | $4,039.29/farm | $1,221,885.20 |
| Fuel: | | | |
| gasoline | 194,722.84 gal. | $1.03/gal. | $200,564.53 |
| Seed | 3,828,800 lbs. | $7.75/50 lbs. | $593,464.00 |
| Dymetholate | | $2.93/acre | $140,229.80 |
| Glean | 9572 oz. | $15.90/acre | $152,194.80 |
| Anhydrous | 1675.1 tons | $2.45/acre | $4,104.00 |
| TOTAL COST | | | $2,312442.33* |
| FINAL PRICE | 1,483,660 bu. | $3.68/bu | $6,868,867.20 |
| O/I RATIO | | | 2.97 |

Source: calculations of energy and sample data.
*This value assumes gasoline consumption only. Diesel would be less.

Table 5.4

Summary of Socio-Economic Needs of the Corn Hinterland with 300 Families

| Variable | Unit Price | Total Cost |
|---|---|---|
| Agric. Production | Total Inputs | $2,312,442.33 |
| Emergency Cash Reserves | $6,000.00/family | 360,000.00 |
| Entertainment | 1,977.25/family | 593,175.00 |
| Food | 5,860.25/family | 1,758,075.00 |
| Housing | 12,612.88/family | 3,783,864.00 |
| Health and Life Insurance | 5,640.00/family | 1,692,000.00 |
| Retirement | 9,240.00/family | 5,544,000.00 |
| Educ. Expenses | 7,140.00/family | 2,142,000.00 |
| Self-Employed Tax | 5,850/family | 1,755,000.00 |
| Transportation | 7,995.63/family | 2,398,689.00 |
| Property Tax | 593.98/family | 179,680.00 |
| TOTAL S/E EXPENSES | 20,026,803.00 | $20,026,483.00 |
| TOTAL EXPENSES | 22,339,245.33 | $22,518,925.33 |
| TOTAL RECEIPTS | 6,868,867.20 | $6,868,867.20 |
| NET INCOME | -15,370,378.13 | $-15,650,058.13 |

Source: interviews with farmers, United Life Investors Insurance data, *Consumer Expenditure Survey*, Table 3020, BLS (1996), and *Oklahoma State Board of Education 1996-7 Annual Report*. See Appendix 2 for details on calculating the hinterland and individual property tax.

labor being slightly more. The irony is that the output-input ratio is now -4.44. It appears that the hinterland is not able to support a farming system that requires these major inputs.

not able to support a farming system that requires these major inputs.

Once socio-economic variables are factored in, however. The picture looks different. Table 5.5 lists a continuation of Table 5.1, this time focusing on emergency cash reserves, insurance needs, retirement, educational, housing, and entertainment (including recreation) expenses.

This deficit in net income further reinforces the earlier analysis concerning energy production. There are too many people living in this hinterland. Clearly retirement and housing expenses make up the largest expenditures. Perhaps this loss is best explained by the fact that a number of spouses and children of farmers have off-farm employment. In addition, a number of the assumptions concerning the rate of retirement contributions or housing payments may not fit each individual's particular case. In sum, the use of this standardized data and assumptions associated with their use further test this validity of whether the hinterland can support its inhabitants through farming. Receipts from farming alone cannot sustain the hinterland.

Supplementing this discussion, Table 5.5 presents this information per acre from a sampled farm. Labor and fuel remain the highest costs, and a paradoxical output-input

Table 5.5

Individual Farm Family Annual Expenses

| Expense | Amount |
|---|---|
| Agricultural Production | $7708.14 |
| Emergency Cash Reserves | $1200.00 |
| Entertainment | $1977.25 |
| Food | 5860.25 |
| Housing | $12,612.88 |
| Insurance | $5,640.00 |
| Education | $7,140.00 |
| SS Tax | $5,850.00 |
| Transportation | $7,995.63 |
| Property Tax | 593.98 |
| TOTAL EXPENSES | $56,578.13 |
| FAMILY INCOME FROM WHEAT | $22,896.22 |
| DEFICIT | -$33,681.91 |

Source: Interviews with farmers (1996); United Investors Life Insurance data; and BLS, 1996, .

ratio results. With energy analysis, the o-i ratio was over 5; when converted to economic units, it drops to almost 3. Thus, the farming does not appear to be as efficient in economic terms. Factoring in social-economic variables renders the o-i ratio to -4.44. Economically, the hinterland cannot sustain farming. The data that comprise Table 5.5 defend this analysis. Essentially, these listings are scaled down from Table 5.4; multiplying each category by 300 will produce the values in the former table. Interestingly to note, the per farm deficit is about $33,000 in a given year.

This rather high number can be reduced, though. First, the reader must assume that each and every family has identical needs in terms of insurance, education, etc.

Second, Internal Revenue Service regulations will allow a farmer to deduct up to fifty percent of agricultural costs, providing that the figure does not exceed any other deduction (*1997 Farmer's Tax Guide*). Thus, if agricultural expenses could be reduced by one-half through tax deductions, then the individual farmer's total debt would be slightly more than $16,000 for this given year. Annual crop yields would render a different figure, however.

Two statements are possible. Variables that have been excluded from analysis might indeed indicate that the deficit may be more or less. In addition, a number of farmers' spouses and children have off-farm jobs as do many of the small operators. According to the 1990 Census of both Corn and the hinterland, the majority of residents are non-farm, meaning that most income is derived from non-agricultural jobs. Second, according to the Oklahoma Fact Sheet published by the USDA Economic Research Service (1998), investments in cooperatives, land, buildings, and dwellings make up over fifty percent of farm assets, none of which were included in this study. At the same time, these data are for the Southern Plains region, not merely Oklahoma; it is likely that urban populations have influenced these costs so that they may be higher than the needs of a Corn family. Nevertheless, these data are the best standardized data available. It is possible that model assumptions were too high, and that all farmers do not spend their finances on the categories listed in these tables. It is obvious that people can live here in Corn but not with the assumed expenses, or they will have to rely on non-farm income or farm more acres per family.

These figures do indicate, however, that the hinterland can support farming <u>but not the present levels of population unless additional income is derived from outside or non-farm sources at current farm size</u>. Driving through the area and visiting a few farmers indicate that farmers have access to advanced technology; one farmer had a microwave link to a computer service that hooked his computer up to real-time Chicago Board of Trade updates on commodities. Few houses were in dilapidated condition. There seems to be a pride, both individual and community, in how houses, businesses, and streets look. There is also a community spirit which was evidenced when three students of Southwestern Oklahoma State University were killed in October, 1996, some town residents attended a memorial service. Charitable giving, especially in the church, is high, but education ranks highly amongst Corn area residents.

Therefore, it is reasonable to assume at this point that the hinterland cannot support dryland wheat farming including the socio-economic needs at the current level of population, unless some farmers engage in off-farm work. While this finding can be expected, given the demise in rural population and living conditions, this is not the conclusion nor final result. The final task is to determine, given these assumptions, how many people can live in this hinterland, based on dryland wheat production.

# CHAPTER VI

# RESULTS AND DISCUSSION OF ANALYSIS

At this point, sample data on both farming and socio-economic variables have been computed for the Corn, Oklahoma, hinterland. This chapter will offer a discussion of Tables 4.4 and 5.5, the summary of both sets of data. Although the bottom line here is how many people the hinterland can support through dryland wheat farming, the numbers will be limited to the "community" only. Community here refers to the population of both the hinterland and town (1,210).

## The State of Agriculture

Based on calculations in Table 4.4, there is no doubt that the hinterland <u>can</u> support the farming system. Energy analysis reveals that output is over five times the amount of energy necessary for production inputs. In addition, the total energy available from grain harvest exceeds the amount required for human caloric intake (basic food needs).

On the surface, it may appear that this farming system is indeed efficient, all being well with no need for concern for the future. The overly optimistic reader, however, is reminded that this "efficiency" comes at great expense in terms of natural resources, capital required, and time. Therefore, it is one of the findings of this research that when these three factors are considered, the farming system is not nearly as efficient as it appears on the surface.

First, the natural resources required for production of local dry-farmed wheat are anything but local. While sustainability does not require self-sustainability, the ability of a hinterland to provide its inhabitants with most of their inputs is important. A society that must rely on trade and/or technology for most inputs is not sustainable in the long run, when competition for scarce resources are evaluated. At this time, farming is sustainable here, but there are other Corn-like hinterlands that depend on natural resources that are not peculiar to the immediate land.

Reviewing Table 4.3 brings this to light quickly. While oil and natural gas are present around Corn, these resources are not locally refined and then sold to area farmers for use in tractors and other machinery. Although it is not uncommon for farmers to tap into natural gas wells on their property, provided that they own the mineral rights, this is not likely to explain the source of this major input. Likewise, the chemicals necessary for anhydrous ammonia, dyemetholate, Glean, and potash are not local natural resources either. Just as petroleum products, operators purchase these goods from supply stores, whether the local co-op or another source. Finally, the energy required to sustain labor (e.g., food) is not completely local either. Consumers purchase groceries from stores that obtain their products outside the immediate region. Thus, this agriculture is not locally sustainable, for it must rely on inputs external to the area.

Second, the amount of capital required for each operation is high. These are capital-intensive firms, just like other agricultural regions. Although a few operators farmed small tracts of land, they too had to invest in equipment and chemicals just as the large farmers did. Once again, energy analysis revealed fuel, chemicals, and transportation as the major inputs, and these high energy values translate into high capital values as well. Embodied energy values prove that capital must sustain these energy expenditures for the operation to be competitive.

Third, history questions the efficiency of this type of system. Economists have identified economic cycles, both short and long term. As a geographer, this author feels strong correlation between economic and ecological cycles, but this topic must be pursued at a later time, given the scope of the current undertaking. The former refers to long-term Kondratiev and short-term Kuznet's cycles, respectively. The latter refers to the common drought cycles that plague the Great Plains. It appears that environmental fluctuations precede agricultural changes in the market, as witnessed in higher prices for wheat resulting from a 1996 drought. Less production meant less supply, but the same demand for grain resulted in slightly higher grain prices received at the elevator. Since this study is not cross-sectional in a temporal sense, the writer only can speculate that such cycles impact Corn area farmers.

The relevant point here is that as these cycles come and go, one can expect to see differences in agricultural production and subsequently output. In a previous study, the author discovered how an economic crisis forced Oklahoma Panhandle farmers not to irrigate because of lack of funds. In particular, this was a political conflict between a group of farmers and an oil company. These operators owned their mineral rights but felt that the oil company was not paying them enough for the right to mine natural gas. In a unified fashion, the operators throughout the county boycotted the firm and refused to renew leases. As a result, these farmers returned to dryland farming, for their leases allowed a portion of gas mined to be used to power irrigation equipment. The oil company nearly went bankrupt after a few years as a result of this action. Political-economic conflicts between the operator, government, intermediaries (e.g., banks, co-ops, equipment dealers, etc.) and market play a vital role in understanding why crops are grown where, when, and how.

In summation, then, the preceding three paragraphs point out that this farming system may not be as efficient as one would think. By efficiency, this author refers to a farming system that uses resources wisely with as little outside dependence as possible. Currently, Middle Eastern oil and agricultural chemicals from other regions are required for this capital-intensive farming system to be supported. There is no way for the current system to exist without these specific inputs. The phenomenal output in kilocalories is assumed to be available for other inputs. Thus, even though the analysis discovered that the hinterland could support the farming and subsequently food needs of its population at current levels, this research suggests that external policies (e.g., grain pricing, farm subsidies, low interest loans) are necessary to sustain this agricultural economy.

## Socio-Economic Demands on the Farming System

These variables were included in analysis since people in the United States live for more than mere existence. The first task was to convert energy values into financial values. At the point where the question of economic survival begins, energy analysis ends. The latter only tells the reader of the input-output efficiency, not whether people can financially live off the output.

Table 5.3 is a summary list of agricultural variables in economic units. This table confirms earlier comments on natural resources, capital, and economic cycles but in a more understandable manner. Fuel is the major input here, although even seed costs for the hinterland are more than the average American will earn in his/her lifetime. Clearly, money is required to farm in American society. The final income from price indicates, however, a negative output-input ratio, approaching five times.

Evaluating summary data indicates yet more disturbing news. Table 5.4 lists summary information with the socio-economic variables factored in. Retirement planning expenses are highest, but even then, socio-economic needs appear to be little in light of total agricultural expenses. A pertinent observation here is that land is indeed the natural resource base of the hinterland.

These data are alarming for a number of reasons. First, agricultural expenses are too high for the average farmer to make it at farming alone. Of course, this study assumed that everyone farmed equal tracts of land and 300 farmers were in a hinterland of 47,860 acres; nevertheless, at current prices for fuel and assumed labor costs, the typical farm here is not economically sustainable. All of the equipment used by sample operators had lived its "useful" life, although it was still maintained and utilized. This writer finds something missing whenever equipment expenses are greater than the general needs of the population (e.g., insurance, health care, housing, etc.) since people are required to work a farming system, not to mention that output for human consumption is the reason for farming.

Second, disparity amongst socio-economic variables is somewhat reasonable. Retirement planning costs the most since it takes up a greater portion of one's life to achieve. Emergency cash reserves, conversely, are much more short-term in nature. Education expenses, likewise, diminish after twenty-two years, assuming that children will have completed either university or vocational instruction by then. Insurance needs, likewise, will remain basically the same. By the time that children are removed from parents' expenses, the parents will have aged to the extent that higher premiums take its place. Thus, it seems logical that the socio-economic expenses in Tables 5.5 and 5.6 are correct.

Finally, returning to the first point, the disparity between assumed farm income and actual income available is relatively high (almost $20,000). The most reasonable explanation is that model assumptions were not realistic even though reasonable. All assumptions can be justified, but the financial reality of crop production does not enable the assumed income (=target) to be compatible with actual income ($18,350.15, from 1990 Census). In addition, agricultural expenses, based on the sample data, are correct for dividing total receipts by 300 heads of household renders $18,049.15. Once again, it appears that either model assumptions were not realistic or this hinterland cannot support the current population through farming.

This prompts one to ponder whether the price structure for farming has the wrong priorities. Should the priority be cheap food for consumers or a fair return for operators? These are the extremes, but much of government policy towards the "family" farm in a time of increasing scales of economy sends a mixed message to farmers as to the role of the government in commodity pricing. A number of years ago, an agricultural economist in Guymon, Oklahoma, told the writer that most people in the United States wasted food because it was cheap and since the country had never experienced a famine in recent years. The economist went on further to say that he felt this unparalleled success created a false sense of security, eventually causing the government to set wrong pricing schemes for agriculture. Certainly higher returns on grain farming are likely to reduce farm debt, but other issues are at work here, namely whether human carrying capacity has been exceeded.

At this point, the author will return to a statement made much earlier: that the hinterland can support farming but not at current population levels. Table 6.1 presents some calculations with various population numbers assuming that agricultural needs are the same as those listed in Chapter IV. The primary factor is the difference between the minimum annual kcal required for human survival (1,210,400,000) and those provided by farming based on hinterland population. The economies of scale portrayed in Table 6.1 pose an interesting paradox. While more energy is required to farm a smaller tract of land, fewer people can farm more land efficiently, common knowledge in today's capital-intensive agriculture. Dividing the annual energy required by the average acreage shows an interesting trend: Fewer farmers can expend less energy per acre to farm more acres. Currently, a wide array of individuals cannot be supported by an average grain production of 31 bushels/acre.

Factoring in socio-economic variables raises some concerns. While the hinterland can support a dryland wheat farming system (with fewer occupants), the socio-economic

Table 6.1

Changes in Energy Requirements--Population Size

| Pop. | No. of Farmers | Avg. Acreage | Ann. Energy Req. |
|---|---|---|---|
| 1300 | 325 | 147.26 | 1.5735 E9 |
| 1200 | 300 | 159.53 | 1.4525 E9 |
| 1100 | 275 | 174.04 | 1.3314 E9 |
| 1000 | 250 | 191.44 | 1.2104 E9 |
| 900 | 225 | 212.71 | 1.0894 E9 |
| 800 | 200 | 239.3 | 9.6832 E8 |
| 700 | 175 | 273.49 | 8.4728 E8 |
| 600 | 150 | 319.07 | 7.2624 E8 |
| 500 | 125 | 382.88 | 6.052 E8 |
| 400 | 100 | 478.6 | 4.8416 E8 |
| 300 | 75 | 638.13 | 3.6312 E8 |

Notes:
1. Calculations assume that individual caloric intakes remains at 1.1204 E6.
2. No. of farmers coincides with a four person family; all families are assumed to farm.
3. Avg. acreage assumes a flat plain hinterland of 47,860 acres.
4. Overall, less energy is required to farm more acres with fewer inhabitants.

needs required (with same earlier assumptions) will not. Table 6.2 lists a reduction in population and number of farmers with the appropriate increase in income. The reader is cautioned to remember that the grain prices have not changed in these scenarios. Thus, the number of inhabitants must be reduced by over fifty percent, if the social needs outlined earlier are to be met with current cash grain receipts.

## Current and Future Status of the Hinterland

One of the primary purposes of modeling is to attempt to predict outcomes under various scenarios. Currently, calculations show that the human carrying capacity of Corn's hinterland and town with the present farming system to be no larger than 490. Since the population will change over time, Table 6.2 lists some changes in human carrying capacity if agricultural sales were to vary by five percent (positive and negative). These data are listed per farm. Other scenarios could be run, but the intent here is to show the corresponding changes on the human carrying capacity of the Corn hinterland based on changes in cash grain receipts. At this time, a few observations may be made. First, economic and ecological (energy) accounting do not achieve the identical results in this analysis. The energy analysis presented in Table 6.1 indicates that enough food energy is not produced by this hinterland to sustain a wide range of population sizes. But the difference comes from within economic analysis. The current population, 1210, nearly conforms to the average household income, but an economically sustainable income (according to social assumptions) requires a much lower population, 484 as a maximum. Any changes in the amounts of socio-economic needs from inflation or rises in cost-of-living will change these figures even more.

Second and based on field energy budgets, fuel and chemical inputs are the two primary inputs that will affect output the quickest, provided that the natural environment

Table 6.2

Number of Inhabitants and Price Changes

| Pop. | Gross Income (Annual, $) |
|---|---|
| 1300 | $21,134.98 |
| 1210 | $22,707.00 |
| 1200 | $22,896.22 |
| 1100 | $24,977.70 |
| 1000 | $27,475.47 |
| 900 | $30,528.30 |
| 800 | $34,344.34 |
| 700 | $39,250.67 |
| 600 | $45,792.45 |
| 500 | $54,950.94 |
| 400 | $68,688.67 |
| 300 | $91,584.90 |
| 200 | $137,377.34 |

Notes:
1. Target income is $39,000; this is assumed to be the minimum necessary for social needs.
2. Avg. income is $18,350.50 (1990 Census).

Table 6.3

Reactions to Income by Fluctuating Grain Prices

| | | | | Income | |
|---|---|---|---|---|---|
| Pop. | Farmers | Acreage | -5% | Current | +5% |
| 1300 | 325 | 147.26 | $20,078.23 | $21,134.98 | $22,191.72 |
| 1210 | 302.5 | 158.21 | $21,571.65 | $22,707.00 | $23,842.35 |
| 1200 | 300 | 159.53 | $21,751.41 | $22,896.22 | $24,041.04 |
| 1100 | 275 | 174.04 | $23,728.81 | $24,977.70 | $26,226.58 |
| 1000 | 250 | 191.44 | $26,101.70 | $27,475.47 | $28,849.24 |
| 900 | 225 | 212.71 | $29,001.88 | $30,528.30 | $32,054.71 |
| 800 | 200 | 239.30 | $32,627.12 | $34,344.34 | $36,061.55 |
| 700 | 175 | 273.49 | $37,288.14 | $39,250.67 | $41,213.20 |
| 600 | 150 | 319.07 | $43,502.83 | $45,792.45 | $48,082.07 |
| 500 | 125 | 382.88 | $52,203.39 | $54,950.94 | $57,698.48 |
| 484 | 121 | 395.53 | $53,929.13 | $56,767.50 | $59,605.88 |
| 400 | 100 | 478.60 | $65,254.24 | $68,688.67 | $72,123.11 |
| 300 | 75 | 638.13 | $87,005.65 | $91,584.90 | $96,164.14 |
| 200 | 50 | 957.20 | $130,508.48 | $137,377.34 - | $144,246.21 |

Notes:
1. All socio-economic variables remain constant.
2. Target income remains at $39,000 annual gross.

does not change much. If these resources were not available, then the output would decrease rapidly. What output remained would be higher in price, perhaps to the extent of making farming uneconomical.

Third, the role of the natural environment will become more critical in future years than ever before. Currently, the United States government is phasing out farm subsidies, partially in response to economic reform and partially due to environmental activists who feel that certain lands should not be farmed because of the erosion potential. Although most unsuitable land in the Corn area has been abandoned as farmland or reverted to grassland for livestock, these politico-economic changes affect overall price structure of United States commodities, including what Corn farmers will receive at the elevator. Factoring in cyclical El Niños and the debate over enhanced global warming introduce yet more complicated scenarios. Whether or not the general public and/or scientific community believes in long-term environmental consequences is not the issue. To destroy or degrade this resource beyond utility is jeopardize the future of others.

Fourth, some findings result from Tables 6.2 and 6.3. It is important to note that the population sizes listed are hypothetical calculations; only five families were actually interviewed in this analysis. Appendix 3 lists the procedure to calculate these tables. The only absolute figure is the income available from the hinterland since land area is limited to 47,860 acres.

The first finding of Table 6.3 is that 484 is the maximum population that this hinterland can support with current expenses. That means that no more than 121 families can farm with the given assumptions. Second, fewer operators mean larger farms. Finally, larger farms, along with fewer farmers allow for greater income from cash wheat receipts. Figs. 6.1-6.3 graphically portray the data relationships in Table 6.3.

Fifth, it is useful to return to the sample data. Table 6.4 lists energy expenditures per farm and field size. All model assumptions were based on the <u>summation</u> and <u>scaling</u> of these data and assumed that they were representative of wheat production. A qualitative comparison of sample data and the previous diagrams is now in order.

The data analysis reveal what rural specialists have known all along; the economies of scale are against a small operator. Such farmers must be prepared to have off-farm income to make ends meet. It was not possible to ascertain

Figure 6.1
Relationship Between Population and Annual Family Income

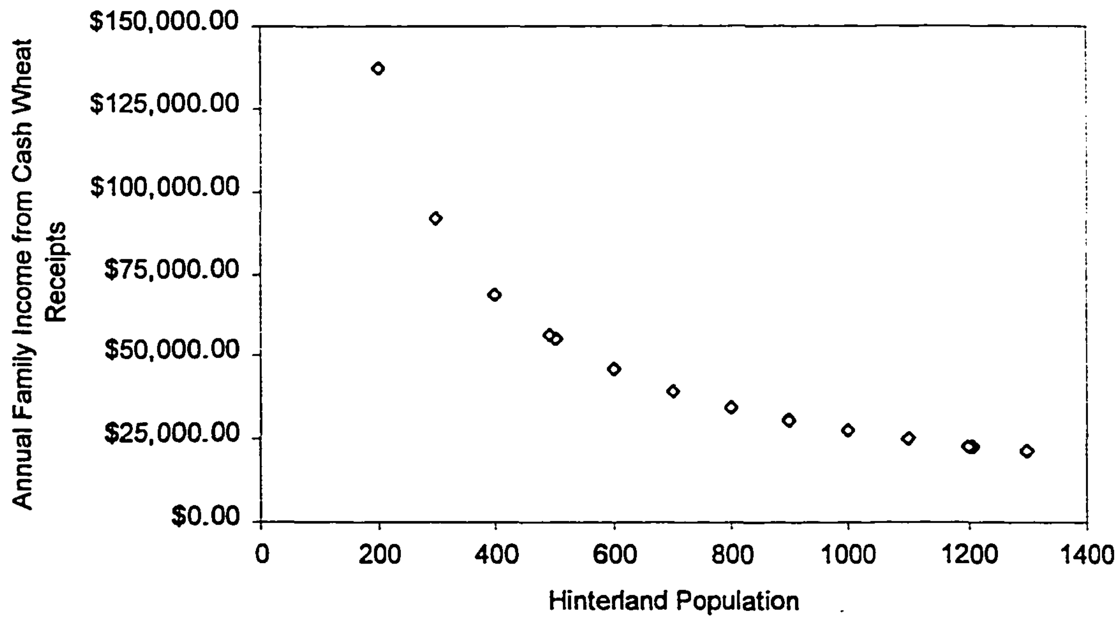



Figure 6.2
Relationship Between Farm Size and Population

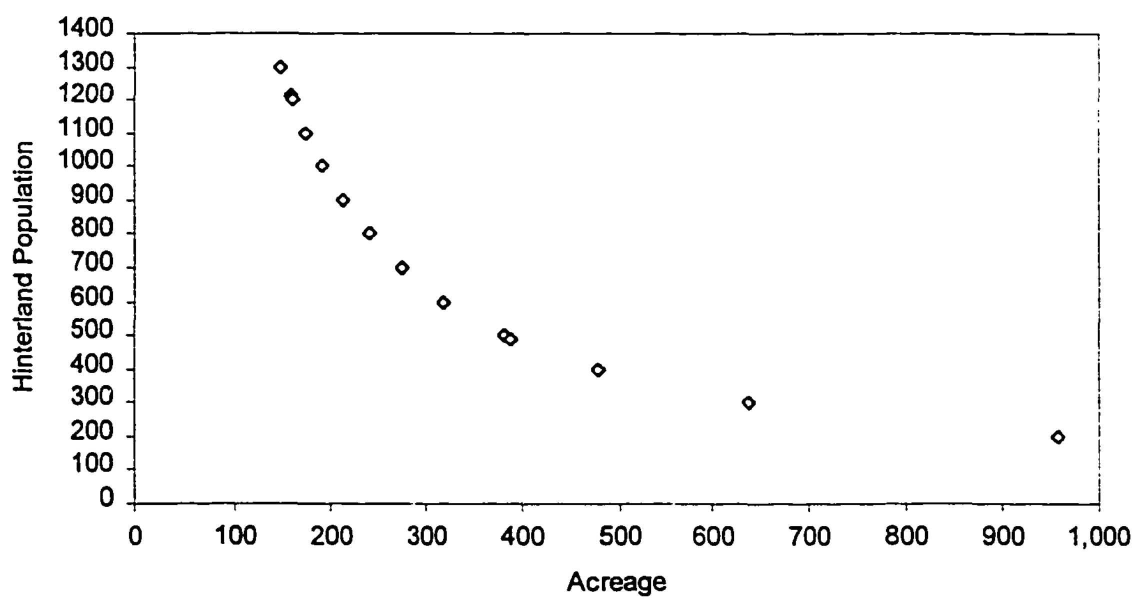


Figure 6.3
Relationship Between Farm Size and Income

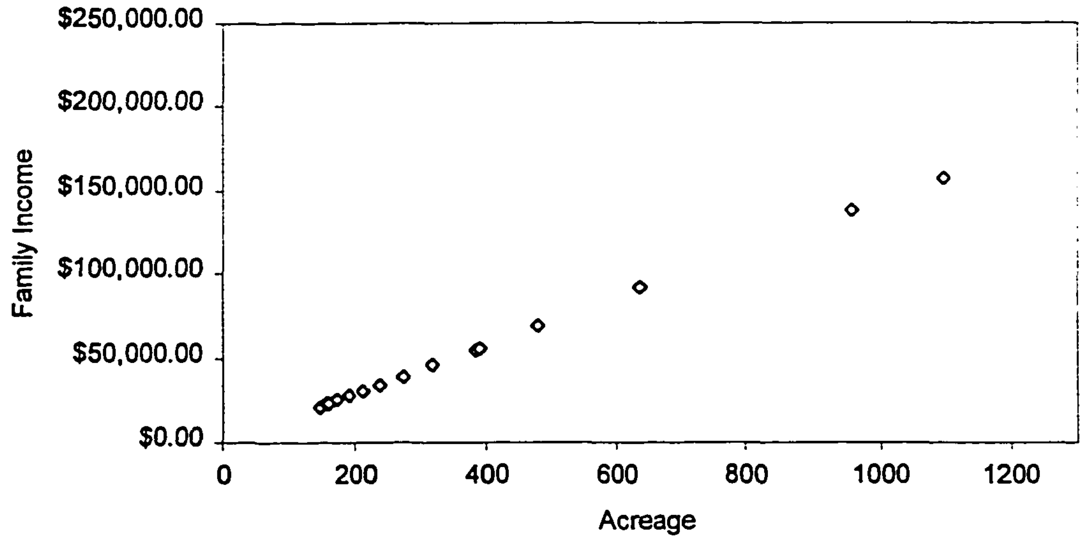



Table 6.4

Energy Expended per Sample Farm

| Input | Farm 3.2 | 4.2 | 4.5 | 5.2 | 5.5 |
|---|---|---|---|---|---|
| Fuel | 846,470,000 | 1,668,400,000 | 636,100,000 | 406,370,000 | 3,068,900,000 |
| Labor | 1,597,719 | 2,331,699 | 1,416,187 | 908,499 | 4,054,845 |
| Emb. Energy | 2,927,591 | 23,066,115 | 25,298,019 | 183,205 | 65,314,728 |
| Seed | 384,000,000 | 1,098,000,000 | 540,000,000 | 270,000,000 | 1,710,000,000 |
| Fertilizer | 162,940,000 | 2,448,600,000 | 2,806,700,000 | 2,135,900,000 | 14,746,000,000 |
| Herbicide | 0 | 42,926,125 | 2,301,750 | 4,603,500 | 2,612,500 |
| Transp. | 28,264,000 | 80,908,000 | 46,352,523 | 26,236,000 | 265,540,000 |
| Total Input | 1,426,199,310 | 5,364,231,939 | 4,058,168,479 | 2,844,201,204 | 19,862,422,073 |
| Total Output | 20,340,000,000 | 29,385,000,000 | 26,910,000,000 | 10,782,000,000 | 89,082,000,000 |
| O-I Ratio | 14.26 | 5.48 | 6.63 | 3.79 | 4.48 |
| Total Acr. | 1387 | 2639.3 | 428.5 | 579.8 | 2639 |

that a given acreage was best in light of energy analysis even though data in Table 6.4 indicate that one of the higher output-input ratios is over 1,000 acres. The inconclusive evidence of this table is caused by two factors. First, only five farms were sampled; thus it is difficult to draw any hard conclusions. Second, it is unreasonable to perform any hypothesis testing on such a small sample size. While it is difficult for the data to be conclusive with only five observations, a trend does exist. Larger and fewer farms are required for the operator who desires income from dryland wheat production only.

This step completes a circle of analysis: from energy analysis to examine production efficiency to fiscal analysis to evaluate how well farming can support a family's needs to examination of farm size and energy output-input ratios to see where the individual sampled farms fit into the generalizations of the hinterland. Throughout each analysis, the question was whether the hinterland could support a farming system and its population. Socio-economic analysis, moreover, revealed that approximately 400 acres was adequate for a family.

Energy and economic analysis was not merged at this time. But the difference between 158.21 (current average size based on present population) and 390.69 acres (target size) reveals that farm size would have to be almost tripled for a family to be sustained through farming. According to the grain elevator manager, the typical Corn farm is over 600 acres, although the larger operators farm well over 1,000 acres. Therefore, even though this analysis is not fully conclusive, empirical evidence does suggest that farm sizes are too small for economic existence. The findings do give further understanding why farmers must have other sources of income.

## Is Corn an Anomaly After All?

Modeling should seek to explain the general not justify the unique. But this model shows that the hinterland cannot support its population through farming, yet Corn and its area residents are not lacking the sense of place that is typical of other communities nearby. This community feeling is attributable in large part to the role of the church in this community. Even though a small Baptist church is present, most residents are members of the Mennonite Brethern Church. Members do not treat church membership in the same manner as do many Americans. Outreach programs for all ages entail that the young, elderly, and mentally disadvantaged receive assistance---not merely spiritual. Visits and spiritual outreach is conducted for nursing home residents, and other able-bodied members will help a family in need harvest or round up livestock. Most residents feel that their lives must exhibit the teachings of Jesus Christ in all ways. The family retains importance; divorce is neither encouraged nor readily accepted.

It would be unreasonable to after all this analysis to concede that it proved Corn was an anomaly. Surely, the church plays a larger role than a great many other farm communities, but still the model showed that the hinterland could not provide a farming system that could solely support the current population. The role of the church and dependence of trade are two areas that enable farming to thrive in this community. Both of these variables are hard to quantify, yet without them, life would be different in Corn (and in most other farming communities). One of the farmers interviewed once told the author that he was a resident of "western Oklahoma." He did not give any boundaries when questioned further. It is obvious that Corn is heavily dependent on outside regions, just as Great Plains communities have been since settlement in the 1800s.

International trade literature (Krugman, 1995), and even economic and political geographers (Michalek and Gibb, 1997), are beginning to note that future global relations will not evolve from one single multilateral organization but rather the trade of numerous super-regional groups, with the European Union, ASEAN, and NAFTA being the most influential. Therefore, the current farming will require links to other global regions if regional sustainability is to be achieved. Sustainability, now more than ever, must be viewed in global terms. One of the primary quests to implementing sustainable development is to find efficient ways to allow comparative advantage to make use of scarce resources in the wisest manner possible <u>at the micro level</u>.

Both "efficient" and "scarce resources" are not specified and for good reason. This writer has discovered that model overspecification often sidetracks the important issues concerning the general nature of the subject being modeled. Scholars need to return to the basics of understanding how phenomena are interrelated in general terms and stop parceling data into more academic "turf." It is hoped that this thesis will prod discussion on understanding the role of local population in global resource use.

# CHAPTER VII

# CONCLUSIONS

## Synopsis

A few results evolve from this experience. First, the Corn hinterland is typical of other Great Plains communities and of rural America in general. Other crops are grown, although wheat is primary, and cattle serve as supplementary activities in addition to farming. Smaller operators engage in other occupations and depend on income from their wives. Older children often work in Weatherford to finance their college tuition and supplement allowances. Operation size generally is greater than 600 acres, thereby not allowing the traditional family farm to be economically sustainable in the long-term. With the assumptions governing the data in Tables 6.1 and 6.2, an average farm size of 158.47 (with 302.5 farms) would render a gross income of $18,990.85 at $3.68 per bushel of wheat. Operations are capital intensive as well with heavy dependence on agricultural technology and chemicals.

## Conclusions

First, this approach is valid. It appears that the discrepancy between the actual median household income and minimum income and acreage presented in the last chapter point out some alarming conclusions. First, the typical Corn hinterland farm is not the 1000 acre operation suggested earlier. Second, the typical Corn family does not have the resources to fund the assumed socio-economic needs. Third, the average family must rely on non-farm income to help pay expenses. And finally, there must be some combination of the first two points. Even though the outcome reveals something that will not surprise a planner, a framework to reach these conclusions has been developed from data that are rather easily obtained.

Second, although this model is limited, it produced tangible results. The hinterland is able to support the agricultural needs of the community but not at current population levels. Either each family must farm additional acres or rely on off-farm income. This analysis showed that the return, in energy units, was greater than five times the input placed into the wheat crop. Economically, the human carrying capacity has been exceeded. For needs to be met according to assumptions, the population under current conditions cannot exceed 484 (maximum of 121 farmers).

Third, the framework can be expanded into other agricultural sectors and fine-tuned for other regions. The agricultural production system of the Corn, Oklahoma, area is more than capital intensive; it is also energy intensive.

Clearly fuel, chemical, and machinery made up the largest amounts of energy consumed in production and harvest. It was impossible to achieve the high output ratios necessary without the use of advanced technology. This energy intensive system is coupled with other variables as well: low farming population (versus non-farm population) and a small number of farmers who cultivate almost 50,000 acres, according to field interviews.

Fourth, and building on the third observation, this energy intensive manner of farm production indicates the importance of inter-regional trade in physical terms. This was readily apparent from the use of energy analysis. Differences in prices of machinery or fuel is often more reflected in the area's price (socio-economic) structure than the actual process of refining oil for diesel. It is the latter interest that is more important; how well the analysis indicates the physical production relative to output. The energy analysis given in this research drives home the critical necessity for inter-regional trade. No amount of subsidies could allow a small community such as Corn to have oil processing, tractor assembly, seed production, and so on. The use of energy units emphasizes this point much clearer than economic analysis alone.

Fifth, economic analysis served as an extension of energy analysis, for sustainability requires both ecological and economic review. Although it was hoped that both it and energy analysis would produce similar results, that was not possible at this stage. Although both types of analysis contained the same general trends (high capital = high energy input qualitatively), dollars and kilocalories are not constants linked by a steady multiplier. The fact that 500,000 kcal are necessary for production of an implement and that its median value is $8,000 does not mean that the ratio between these two figures will carry over into machinery or amount of health insurance necessary. Thus, economics and ecology were not formally joined at this stage, although the link was emphasized with the presence of non-linear trends.

Finally, this exercise was an application into merging the natural and social sciences. The author's intent was to try to link natural processes of the land (food production) to the socio-economic needs of its population (enforced through social institutions), nothing else. No policy decisions should be based on this analysis alone.

The reader should not discern that certain agricultural practices are recommended for future economic development or that various human socio-economic needs are or are not necessary for small town survival. The gross difference between actual mean income of the Corn hinterland and the income necessary to achieve social well-being point out that the price structure of American agriculture and/or social needs of the population may need readjusting. This author is not advocating the blatant changing of personal values or grain pricing, both of which carry implications well beyond the Corn hinterland. The target annual income of $39,000 could be easily accounted for by substituting total household income in lieu of a single wage-earner as assumed. The application of this research into policy making is a different process, and while it is hoped that this thesis will prompt collective actions on the part of society, no guarantees or strategies should be inferred from the results.

"Sustainability"

Early on in this dissertation, the writer referred to examples and interests and cited literature that dealt with rural welfare. Currently, social science literature is seeing an influx of sustainability specialists, yet "sustainable" renders various definitions. It is the opinion of this writer, that all "sustainable," "viable," or "environmentally conscious" planning or research is weakened without first determining the human carrying capacity of the site involved. The idea "if you build it, they'll come" is a legacy of the throwaway society, and the earth's inhabitants are facing population pressures at increasing rates with a reduction in the amount of space in which we can live. At the same time, one's sense of place is being challenged, and that can escalate into political actions on the part of groups that feel threatened. Any type of public policy that advocates restructuring farm ownership is likely to meet with opposition.

In the midst of this bleak point of view, there is some hope. By continuing the quest to define human carrying capacity, both as outlined in this presentation and with some suggestions presented below, specialists can recommend truly sustainable activities for people. In spite of this framework, the concept remains a specialized definition, including only a few variables in evaluating whether the land can support dryland wheat production. Further work is necessary to ensure that the meaning of carrying capacity will entail different societal structures (e.g., tourism, services, industry, etc.). No longer will mass industrialization be the blanket answer to somewhat isolated, small towns. Now planners and others will have a means to better understand, at least for agricultural production, that the land in the base for farming productivity. Economics and ecology are growing closer than ever before.

Unless governments plan economic activities in harmony with their resource base (natural and/or human), the increasing population numbers will continue to degrade the earth's resources. Until planners can prove that human carrying capacity has been exceeded both economically and ecologically, they cannot expect even the most traditional societies to understand the importance of technology and birth control. Therefore, while this dissertation rendered an answer that one might have guessed all along, i.e., that the hinterland cannot support its population through agriculture, it is a success in its own right. The remaining task is for other social scientists to cooperate in refining this framework.

Unfortunately, carrying capacity is often viewed as whether a given economic pursuit can support its population. The problem with this view is that it ignores the natural base of society: land. Tourism, financial services, industry, and certainly farming have land as its base. Even with technology and interregional trade, land gives society a reason to work, whether it be to tour exotic landscapes for vacations, a source for minerals, or even grain production. So unless the land is considered the base of all human endeavors, it will not be possible to either understand or define human carrying capacity.

Table 7.1 shows how Washita County's and Corn's population has changed since the 1900s. On the surface, the dwindling population numbers indicate that people cannot support their families It is incomplete, yet may be correct, to assume that the people left the county because there were no jobs or means to support their families. Assuming that the land could not support its population, however, opens up a more complete answer. With farming and oil production being important in the county, when the land could not provide for its population, its inhabitants had to seek other places to reside. This latter interpretation is a more complete and realistic interpretation of understanding the role of occupance and human carrying capacity. This framework indicated that Corn residents cannot rely on receipts from grain farming alone to sustain the current population. Some other means of income is necessary; essentially this model is a qualitative interpretation of the population change in Washita County over time.

Table 7.1

Changes in Washita County, Oklahoma, Population

| Year | Population |
|---|---|
| 1910 | 25,034 |
| 1920 | 22,237 |
| 1930 | 29,435 |
| 1940 | 22,279 |
| 1950 | 17,657 |
| 1960 | 18,121 |
| 1970 | 12,141 |
| 1980 | 13,798 |
| 1990 | 11,441 |

Source: *Statistical Abstract of Oklahoma, 1957* (p. 8) and *1995* (p. 49)

## Further Research Needs

A few tasks remain that will reduce confusion concerning the definition of human carrying capacity. First, agricultural variables need more precise accounting. The AEFM conveniently develops output-input ratios, but the tractor and implement database needs to be updated for future analysis. Inclusion of more recent equipment is necessary for the complete accounting of modern agricultural production.

Second, the inclusion of building structures, in embodied energy terms, will render additional information concerning the output-input ratio. Larger operators will often store grain during periods of low prices, and grain production must be able to sustain the need of such storage facilities. In addition, equipment storage facilities should be included as well, since most operators perform routine maintenance on their equipment.

Third, research must continue the quest to lessen the gap between physical (energy) and fiscal (economic) data units. Although it is possible, in a mathematical sense, to translate services and wages into energy units, the results are not readily apparent, for most people equate hours worked with wages earned, not kilocalories expended. For the general public and ultimately policy makers to use this analysis, additional work is required for fine-tuning this model, eventually to close this gap.

Fourth and building on the third need, some means of including land tenure and lifestyle must be found. Although land tenure does not affect grain production in energy terms, it does in economic terms. Whether land is rented or owned may influence whether it is farmed. As for lifestyles, inputs from rural sociologists will help identify means of measuring variables such as satisfaction of career, work ethic, and sense of community. It will not be easy to analyze such variables, but a comprehensive evaluation of land use warrants their analysis.

## Going Further Towards Defining Human Carrying Capacity

The preceding has referred to the author's own suggestions for improving an analysis of a monocultural, dry-farmed wheat hinterland. It is useful to view these observations as _internal_ affairs of human carrying capacity. In this section, some _external_ comments will be presented.

First, the typical agricultural community that most often comes to mind is crop and/or livestock diversified. If the importance of the hinterland in relation to its providing a base for those activities is to be found, then _all_ agricultural activities must be inventoried and evaluated. In addition, the process used in this thesis will not work for fiber crops such as cotton. Cotton is not harvested for food, and another accounting procedure must be developed. Input from agricultural economists will be required to develop additional accounting procedures.

Second, manufacturing activities will need an accounting process as well. Traditional industry would not pose much of a problem, since it was raw-material intensive. The question here is how well the hinterland supplies raw materials for industrial production. Recent industrial location, however, renders this line of thinking somewhat obsolete in the United States. The once prosperous Manufacturing Belt of the lower Great Lakes has been forced to compete with more efficient factories on a global basis. Thus, it is probable that fewer manufacturing towns will be found in the United States as in years past. The rise of mini-mills in the American South, owned by Japanese firms, makes an interesting study. With this type of firm, the steel is shipped by rail or truck to towns where labor is plentiful and low-cost. Blytheville, Arkansas, would make an excellent study in this regard, as the mill has recently expanded, and a new rail yard is being constructed about forty miles south. Thus, any framework to evaluate manufacturing must include the role of footloose industrial factors in addition to traditional location factors. This is perhaps a most promising and exciting area of future research.

Finally, the role of services must be evaluated. This will be the most difficult, for energy analysis may not produce relevant results here. In addition, isolating the flow of capital and people outside a hinterland may constrain analysis to the extent that there would be no reason to conduct it. Potential communities include Sun City, Arizona; Telluride and Steamboat Springs, Colorado; and Tunica, Mississippi. Each of these towns appeals to either tourists or an elderly population. Even though agriculture and industry are often present in these communities, services rank most important. The question then becomes whether the value of real estate is enough to support the population. Or stated another way, is the land valuable enough to entice outsiders to visit and/or move.

These points indicate much excitement lies ahead for geographers. Our community has the opportunity to thrust itself in the middle of darkness and shed some much needed light on the exact role of land in the midst of human settlement--the very essence of the nature of geography. Perhaps once we "play with ideas," as Garrison (1979) referred to his years at the University of Washington, geographers will eventually return to the earth's surface with information to help society utilize scarce resources--natural, human, capital, and technological--in a most efficient manner.

References

Batey, P. W. J. 1985. Input-output models for regional demographic-economic analysis: some structural comparisons. *Environment and Planning A* 17:73-99.

Berry, Brian J. L. 1970. Labor market participation and regional potential. *Growth and Change* 1(4):3-10.

Bender, Martin, The Land Institute, Salina, Kansas. 1996. Personal interview, 18 June.

Blair, P., and R. E. Miller. 1983. Spatial aggregation in multiregional input-output models. *Environment and Planning A* 15:187-206.

Böventer, Edwin von. 1970. Towards a united theory spatial economic structure. In Dean *et al.*, pp. 325-55.

Brown, David L., and Nina L. Glasgow. 1991. Capacity building and rural government adaptation to population change. In Flora and Christianson, eds., pp. 194-208.

Budd, William W. 1992. What capacity the land? *Journal of Soil and Water Conservation* 47:28-31.

Bunge, William Wheeler. 1960. Theoretical Geography. Ph.D. Dissertation, University of Washington.

Bureau of Business Research. 1957. *Statistical Abstract of Oklahoma.* Norman: University of Oklahoma.

Bureau of Labor Statistics (BLS). 1996. Consumer Expenditures Survey, Selected Southern Metropolitan Statistical Areas. Washington: GPO.

Butzer, Karl. 1992. The Americas before and after 1492: An introduction to current geographical research. *Annals, Assn. Of American Geographers* 82:345-68.

Catton, William R., Jr. 1993. Carrying capacity and the death of a culture: a tale of two autopsies. *Sociological Inquiry* 63:202-23.

Cavin, William Burdette. 1967. The Development of Feedlots in the Oklahoma Panhandle. Master's Thesis, University of Oklahoma.

Center for Economic and Management Research. 1995. *Statistical Abstract of Oklahoma*. Norman: University of Oklahoma.

Chicago Spot Wheat Prices, 1841-1996. 1997. Global Financial Data, Chicago, Illinois.

Costanza, Robert. 1980. Embodied energy and economic valuation. *Science* 210:1219-24.

Czamanski, Stanislaw, and Emil E. Malizia. 1969. Applicability and limitations in the use of national input-output tables for regional studies. *Papers, Regional Science Assn.* 23:65-77.

Daly, Herman. 1977. *Steady State Economics*. San Francisco: W. H. Freeman.

Daly, Gretchen C., and Paul R. Ehrlich. 1992. Population, sustainability, and earth's carrying capacity. *Bioscience* 42:761-71.

Daniels, Thomas L. 1989. Small town economic development: growth for survival. *Journal of Planning Literature* 4:413-29.

Daniels, Thomas L., and Mark B. Lapping. 1987. Small town triage: a rural settlement policy for the American Midwest. *Journal of Rural Studies* 3:273-280.

Davidson, Donald A. 1992. *The Evaluation of Land Resources*. New York: Longman.

_____. 1980. *Soils and Land Use Planning*. New York: Longman.

Dean, Robert D., *et al*. 1970. *Spatial Economic Theory*. New York: Free Press.

Dillman, Don A. 1991. Telematics and rural development. In Flora and Christianson, eds., pp. 292-306.

Doering, O. C., III. 1978. A General Procedure for Counting Energy in Farm Machinery. Purdue Univ., Dept. of Agricultural Economics, West Lafayette, Indiana.

Doolittle, William E. 1992. Agriculture in North America on the eve of contact: a reassessment. *Annals, Assn. Of American Geographers* 82:386-401.

Economic Research Service, United States Department of Agriculture. 1998. Oklahoma Fact Sheet. Washington: GPO.

Farm Services Agency. 1998. Conservation Reserve Program Web Page. (http://www.fsa.usda.gov/dafp/cepd/appendix.htm).

Flora, Cornelia B., and James A. Christenson, eds. 1991. *Rural Policies for the 1990s.* Boulder (Colo.): Westview.

_____. 1991. Critical times for rural America: the challenge for rural policy in the 1990s. In Flora and Christianson, pp. 1-7.

Food and Agricultural Organization. 1976. *A Framework for Land Evaluation.* Rome: FAO.

Food and Drug Administration (FDA). 1996. Caloric Requirements. Circular. Washington: GPO.

Fox, Karl A. 1962. Area economic interaction models. *Journal of Farm Economics* 44:1-34.

Frisch, A. J., *et al.* 1979. Energy Impact Control Policies: Energy Impact Report. Dept. of Food and Agriculture, California.

Garrison, William L. 1979. Playing with Ideas. *Annals, Assn. of American Geographers* 69:118-20.

Gilliland, Martha W., and B. David Clark. 1981. Lake Tahoe Basin: A systems analysis of its characteristics and human carrying capacity. *Environmental Management* 5:397-407.

Go, Delfin S. 1994. External shocks, adjustment policies and investment in a developing country: Illustrations from a forward-looking CGE model of the Philippines. *Journal of Development Economics* 44:229-61.

Hamilton, Joel R., and Chaipant Pongtanakorn. 1983. The economic impact of irrigation development in Idaho: an application of marginal input-output methods. *Annals of Regional Science* 17(2):60-70.

Hansen, Niles M. 1971. *Intermediate-Size Cities and Growth Centers*. New York: Praeger.

Hardin, Garrett. 1986. AIBS News: Cultural carrying capacity: a biological approach to human problems. *Bioscience* 36:599-606.

_____. 1974. Living on a lifeboat. *BioScience* 10:

Hoover, Edgar M. 1975. *An Introduction to Regional Economics, Second Edition*. New York: Knopf.

Hotelling, Harold. 1931. The economics of exhaustible resources. *Journal of Political Economy* 39:137-75.

Huettner, David A. 1976. Net energy analysis: an economic assessment. *Science* 192:101-4.

Isard, Walter. 1951. Interregional and regional input-output analysis: a model of a space-economy. *Review of Economics and Statistics* 33:318-28.

Jackson, Wes. 1996. *Becoming Native to this Place*. Washington (DC): Counterpoint.

Jansson, AnnMari, et al. Eds. 1994. *Investing in Natural Capital: The Ecological Economics Approach to Sustainability*. Washington (DC): Island Press.

Johnson, Thomas G. 1989. Entrepreneurship and development finance: keys to rural revitalization. *American Journal of Agricultural Economics* 71:1324-6.

Kedl, Kent. 1984. A philosophical look at economic development. *Small Town* Nov./Dec.:23-5.

Kirchener, James W., *et al*. 1985. Carrying capacity, population growth, and sustainable development. In Mahar, ed., pp. 41-89.

Kraybill, David S. 1993. Computable general equilibrium analysis at the regional level. In Otto and Johnson, eds., pp. 198-215.

Krugman, Paul. 1995. *Development, Geography, and Economic Theory*. Cambridge (Mass.): MIT Press.

Lehner, J. Chris. 1990. Toward rural revival: the telco-community partnership. *Rural Telecommunications* Summer:10-5.

Leontief, Wasily. 1986. *Input-Output Economics, Second Edition*. New York: Oxford UP.

_____. 1966. *Input-Output Economics*. New York: Oxford UP.

Lockeretz, William. 1979. Energy inputs, for nitrogen, phosphorus, and potash fertilizers. *CRC Handbook Series*. West Palm Beach: CRC.

Malizia, Emil E. 1986. Economic development in smaller cities and rural areas. *American Planning Association Journal* 52:489-99.

Mahar, Denis J., ed. 1985. *Rapid Population Growth and Human Carrying Capacity*. World Bank Staff Working Papers, No. 690. Washington (DC): World Bank.

Maydell, Hans-Jurgen von. 1984. Possibilities of increasing the human-ecological carrying capacity of semi-arid tropical and subtropical mountain regions by agroforestry land-use practices. *Applied Geography and Development* 24:102-11.

Michalak, Wieslaw, and Richard Gibb. 1997. Trading blocs and multilateralism in the world economy. *Annals, Assn. of American Geographers* 87:264-79.

Miller, Ronald E., *et al*. 1989. *Frontiers of Input-Output Analysis*. New York: Oxford UP.

Muscat, Robert. 1985. Carrying capacity and rapid population growth: definition, cases, and consequences. In Mahar, ed., pp.1-40.

National Agricultural Statistics Service. 1997. Farm Production Expenditures: 1996 Summary. Washington: GPO.

Oklahoma State Board of Education. 1998. *1996-97 Annual Report*. Oklahoma City: State Department of Education.

Oskaloosa vs. the United States. 1938. *Fortune* 17(April):55-62+.

Otto, Daniel M., and Thomas G. Johnson, eds. 1993. *Microcomputer-Based Input-Output Modeling: Applications to Economic Development*. Boulder (Colo.): Westview.

Penner, Lloyd Chester. 1976. The Mennonites on the Washita River: the Culmination of Four Centuries of Migrations. Doctoral dissertation, Oklahoma State University.

Pimental, David, and Martha Pimental. 1979. *Food, Energy, and Society*. New York: Science.

Postel, Sandra. 1994. Carrying capacity: earth's bottom line. *Challenge* 9(2):4-12.

Rees, William E., and Mathis Wackernagel. 1994. Ecological footprints and appropriated carrying capacity: measuring the natural capital requirements of the human economy. In Jansson et al., eds., pp. 362-90.

Reich, Robert B. 1988. The rural crisis, and what to do about it. *Economic Development Quarterly* 2:3-8.

Richardson, Harry W. 1972. *Input-Output and Regional Economics*. New York: Wiley.

Ross Seed Company. 1997. Price quote on various wheat seed varieties and grades.

Rultan, Vernon W. 1971. Presidential address: technology and the environment. *American Journal of Agricultural Economics* 53:707-17.

Späth, Hans-Joachim. 1997. Land Use and Desertification in North and West Africa: Case Studies for Morocco, Niger, and Togo. *Paderborner Geographische Studien Band 6*.

______. 1987. Dryland wheat farming on the central Great Plains: Sedgewick County, northeast Colorado. In Turner and Brush, eds., pp. 313-44.

______. 1986. Energy-efficiency of wheat production under semi-arid climatic conditions. *Plant Research and Development* 23:109-25.

______. 1985. Energy efficiency of rainfed wheat production in northwest Oklahoma. *Arid Lands: Today and Tomorrow*, pp. 499-509.

Sweeney, Mr. Steve, Manager of Farmland Coop, Weatherford, Oklahoma. 1997. Personal interview, 12 January.

Taylor, Lance, ed. 1990. *Socially Relevant Policy Analysis: Structuralist Computable General Equilibrium Models for the Developing World*. Cambridge (Mass.): MIT Press.

Thünen, Johann Henreich von. 1966. *The Isolated State*. English translation of the 1825 German edition by Carla M. Wartenburg. New York: Pergammon.

Turner, B. L., II, and Stephen Brush. 1987. *Comparative Farming Systems*. New York: Guilford.

Tweeten, Luther, and George L. Brinkman. 1976. *Micropolitan Development: Theory and Practice of Greater-Rural Economic Development*. Ames (IA): Iowa State UP.

United Investors Life Insurance Company. nd. Social-economic data generated for a 4 person family.

U.S. Bureau of Census. 1992. *1990 Census of Population and Housing*. Washington: GPO.

Victor, Peter A. 1991. Indicators of sustainable development: some lessons from capital theory. *Ecological Economics* 4:191-213.

Vink, A. P. A. 1975. *Land Use in Advancing Agriculture*. New York: S-V.

Wheatley, Mr. Ray, economic development specialist for Panhandle Telecommunications, Inc., Guymon, Oklahoma. 1993. Telephone interview, 2 April.

White, Stephen E. 1994. Ogallala oases: water use, population redistribution, and policy implications in the High Plains of western Kansas, 1980-90. *Annals of the Assn. of American Geographers* 84:29-45.

Whitmore, Thomas M., and B. L. Turner, II. 1992. Landscapes of cultivation in Mesoamerica on the eve of the conquest. *Annals, Assn. Of American Geographers* 82:402-25.

Williamson, Robert B. 1970. Simple input-output models for area economic analysis. *Land Economics* 46:333-8.

Wimberley, Ronald C. 1991. Rural transportation. In Flora and Christianson, eds., pp. 209-221.

Wisniewski, Robert L. 1980. Carrying capacity: understanding our biological limitations. *Humboldt Journal of Social Relations* 7(2):55-70.

# Appendix 1. Corn Farm Inventory

Farm Inventory

Farm No. 1
Field No. 1
Year 1992-3

I. Planting

| Tractor (model and width) | variety crop | seeding rate (lb/ac) | depth (in) | mph | area done (ac) | date |
|---|---|---|---|---|---|---|
| JD 4440 (39') | Tomahawk | 90 | 1.5 | 6.5 | 285 | 950920 |

II. Tillage

| activity | tractor (model & width) | depth (in) | mph | area done (ac) | date |
|---|---|---|---|---|---|
| chisel | JD 4840 (24') | 5 | 5 | 142.5 | 950615 |
| chisel | JD 4640 (24') | 5 | 5 | 142.5 | 950615 |
| chisel | JD 4840 (24') | 5 | 5 | 142.5 | 950715 |
| chisel | JD 4640 (24') | 5 | 5 | 142.5 | 950715 |
| chisel | JD 4840 (24') | 5 | 5 | 142.5 | 950815 |
| chisel | JD 4640 (24') | 5 | 5 | 142.5 | 950815 |
| field cultivate | JD 4640 (35') | 5 | 5 | 285 | 950915 |

III. Chemical Application

| chemical | appl rate | tractor (model & width) | depth (in) | mph | area done (ac) | date |
|---|---|---|---|---|---|---|
| anhydrous | 80 lb/ac | JD 4840 (24') | 5 | 5 | 142.5 | 950615 |
| anhydrous | 80 lb/ac | JD 4640 (24') | 5 | 5 | 142.5 | 950615 |
| anhydrous | 80 lb/ac | JD 4840 (24') | 5 | 5 | 142.5 | 950715 |
| anhydrous | 80 lb/ac | JD 4640 (24') | 5 | 5 | 142.5 | 950715 |
| anhydrous | 80 lb/ac | JD 4840 (24') | 5 | 5 | 142.5 | 950815 |
| anhydrous | 80 lb/ac | JD 4640 (24') | 5 | 5 | 142.5 | 950815 |

IV. Harvest (include tractor and truck implements): 20 bu/ac

| tractor/truck (model and width) | mph | area done (ac) | date |
|---|---|---|---|
| ITT 1460 (24') | 5 | 80 | 960607 |

Farm Inventory

Farm No. 1
Field No. 2
Year 1995-96

I. Planting

| Tractor (model and width) | variety crop | seeding rate (lb/ac) | depth (in) | mph | area done (ac) | date |
|---|---|---|---|---|---|---|
| JD 4440 (39') | Tomahawk | 90 | 1.5 | 6.5 | 285 | 950925 |

II. Tillage

| activity | tractor (model & width) | depth (in) | mph | area done (ac) | date |
|---|---|---|---|---|---|
| chisel | JD 4840 (24') | 5 | 5 | 142.5 | 950620 |
| chisel | JD 4640 (24') | 5 | 5 | 142.5 | 950620 |
| chisel | JD 4840 (24') | 5 | 5 | 142.5 | 950720 |
| chisel | JD 4640 (24') | 5 | 5 | 142.5 | 950720 |
| chisel | JD 4840 (24') | 5 | 5 | 142.5 | 950820 |
| chisel | JD 4640 (24') | 5 | 5 | 142.5 | 950820 |
| field cultivate | JD 4640 (35') | 5 | 5 | 285 | 950920 |

III. Chemical Application

| chemical | appl rate | tractor (model & width) | depth (in) | mph | area done (ac) | date |
|---|---|---|---|---|---|---|
| anhydrous | 80 lb/ac | JD 4840 (24') | 5 | 5 | 142.5 | 950620 |
| anhydrous | 80 lb/ac | JD 4640 (24') | 5 | 5 | 142.5 | 950620 |
| anhydrous | 80 lb/ac | JD 4840 (24') | 5 | 5 | 142.5 | 950720 |
| anhydrous | 80 lb/ac | JD 4640 (24') | 5 | 5 | 142.5 | 950720 |
| anhydrous | 80 lb/ac | JD 4840 (24') | 5 | 5 | 142.5 | 950820 |
| anhydrous | 80 lb/ac | JD 4640 (24') | 5 | 5 | 142.5 | 950820 |

IV. Harvest (include tractor and truck implements): 20 bu/ac

| tractor/truck (model and width) | mph | area done (ac) | date |
|---|---|---|---|
| ITT 1460 (24') | 5 | 285 | 960612 |

Farm Inventory

Farm No. 1
Field No. 3
Year 1992-3

I. Planting

| Tractor (model and width) | variety crop | seeding rate (lb/ac) | depth (in) | mph | area done (ac) | date |
|---|---|---|---|---|---|---|
| JD 4440 (39') | Tomahawk | 90 | 1.5 | 6.5 | 480 | 950930 |

II. Tillage

| activity | tractor (model & width) | depth (in) | mph | area done (ac) | date |
|---|---|---|---|---|---|
| chisel | JD 4840 (24') | 5 | 5 | 480 | 950625 |
| chisel | JD 4640 (24') | 5 | 5 | 480 | 950625 |
| chisel | JD 4840 (24') | 5 | 5 | 480 | 950725 |
| chisel | JD 4640 (24') | 5 | 5 | 480 | 950725 |
| chisel | JD 4840 (24') | 5 | 5 | 480 | 950825 |
| chisel | JD 4640 (24') | 5 | 5 | 480 | 950825 |
| field cultivate | JD 4640 (35') | 5 | 5 | 480 | 950925 |

III. Chemical Application

| chemical | appl rate | tractor (model & width) | depth (in) | mph | area done (ac) | date |
|---|---|---|---|---|---|---|
| anhydrous | 80 lb/ac | JD 4840 (24') | 5 | 5 | 480 | 950625 |
| anhydrous | 80 lb/ac | JD 4640 (24') | 5 | 5 | 480 | 950625 |
| anhydrous | 80 lb/ac | JD 4840 (24') | 5 | 5 | 480 | 950725 |
| anhydrous | 80 lb/ac | JD 4640 (24') | 5 | 5 | 480 | 950725 |
| anhydrous | 80 lb/ac | JD 4840 (24') | 5 | 5 | 480 | 950825 |
| anhydrous | 80 lb/ac | JD 4640 (24') | 5 | 5 | 480 | 950825 |

IV. Harvest (include tractor and truck implements): 24 bu/ac

| tractor/truck (model and width) | mph | area done (ac) | date |
|---|---|---|---|
| ITT 1460 (24') | 5 | 480 | 960617 |

## Farm Inventory

Farm No. 1
Field No. 4
Year 1995-96

### I. Planting

| Tractor (model and width) | variety crop | seeding rate (lb/ac) | depth (in) | mph | area done (ac) | date |
|---|---|---|---|---|---|---|
| JD 4440 (39') | Tomahawk | 90 | 1.5 | 6.5 | 160 | 950930 |

### II. Tillage

| activity | tractor (model & width) | depth (in) | mph | area done (ac) | date |
|---|---|---|---|---|---|
| chisel | JD 4840 (24') | 5 | 5 | 80 | 950625 |
| chisel | JD 4640 (24') | 5 | 5 | 80 | 950625 |
| chisel | JD 4840 (24') | 5 | 5 | 80 | 950725 |
| chisel | JD 4640 (24') | 5 | 5 | 80 | 950725 |
| chisel | JD 4840 (24') | 5 | 5 | 80 | 950825 |
| chisel | JD 4640 (24') | 5 | 5 | 80 | 950825 |
| field cultivate | JD 4640 (35') | 5 | 5 | 160 | 950925 |

### III. Chemical Application

| chemical | appl rate | tractor (model & width) | depth (in) | mph | area done (ac) | date |
|---|---|---|---|---|---|---|
| anhydrous | 80 lb/ac | JD 4840 (24') | 5 | 5 | 80 | 950625 |
| anhydrous | 80 lb/ac | JD 4640 (24') | 5 | 5 | 80 | 950625 |
| anhydrous | 80 lb/ac | JD 4840 (24') | 5 | 5 | 80 | 950725 |
| anhydrous | 80 lb/ac | JD 4640 (24') | 5 | 5 | 80 | 950725 |
| anhydrous | 80 lb/ac | JD 4840 (24') | 5 | 5 | 80 | 950825 |
| anhydrous | 80 lb/ac | JD 4640 (24') | 5 | 5 | 80 | 950825 |

### IV. Harvest (include tractor and truck implements): 20 bu/ac

| tractor/truck (model and width) | mph | area done (ac) | date |
|---|---|---|---|
| ITT 1460 (24') | 5 | 160 | 960617 |

Farm Inventory

Farm No. 1
Field No. 5
Year 1995-96

I. Planting

| Tractor (model and width) | variety crop | seeding rate (lb/ac) | depth (in) | mph | area done (ac) | date |
|---|---|---|---|---|---|---|
| JD 4440 (39') | Tomahawk | 90 | 1.5 | 6.5 | 160 | 950930 |

II. Tillage

| activity | tractor (model & width) | depth (in) | mph | area done (ac) | date |
|---|---|---|---|---|---|
| chisel | JD 4840 (24') | 5 | 5 | 80 | 950625 |
| chisel | JD 4640 (24') | 5 | 5 | 80 | 950625 |
| chisel | JD 4840 (24') | 5 | 5 | 80 | 950725 |
| chisel | JD 4640 (24') | 5 | 5 | 80 | 950725 |
| chisel | JD 4840 (24') | 5 | 5 | 80 | 950825 |
| chisel | JD 4640 (24') | 5 | 5 | 80 | 950825 |
| field cultivate | JD 4640 (35') | 5 | 5 | 160 | 950925 |

III. Chemical Application

| chemical | appl rate | tractor (model & width) | depth (in) | mph | area done (ac) | date |
|---|---|---|---|---|---|---|
| anhydrous | 80 lb/ac | JD 4840 (24') | 5 | 5 | 80 | 950625 |
| anhydrous | 80 lb/ac | JD 4640 (24') | 5 | 5 | 80 | 950625 |
| anhydrous | 80 lb/ac | JD 4840 (24') | 5 | 5 | 80 | 950725 |
| anhydrous | 80 lb/ac | JD 4640 (24') | 5 | 5 | 80 | 950725 |
| anhydrous | 80 lb/ac | JD 4840 (24') | 5 | 5 | 80 | 950825 |
| anhydrous | 80 lb/ac | JD 4640 (24') | 5 | 5 | 80 | 950825 |

IV. Harvest (include tractor and truck implements): 20 bu/ac

| tractor/truck (model and width) | mph | area done (ac) | date |
|---|---|---|---|
| ITT 1460 (24') | 5 | 160 | 960617 |

Farm Inventory

Farm No. 2
Field No. 1
Year 1995-6

I. Planting

| Tractor (model and width) | variety crop | seeding rate (lb/ac) | depth (in) | mph | area done (ac) | date |
|---|---|---|---|---|---|---|
| JD4450 (42') | Pioneer 2163 | 70 | 2.5 | 4.5 | 231 | 950923 |

II. Tillage

| activity | tractor (model & width) | depth (in) | mph | area done (ac) | date |
|---|---|---|---|---|---|
| springtooth | JD 8770 (54') | 3.5 | 6 | 231 | 950820 |
| springtooth | JD 8770 (54') | 3.5 | 6 | 231 | 950920 |
| one-way | JD 8770 (28') | 3.5 | 5 | 231 | 960630 |
| chisel | JD 8770 (36') | 9 | 5 | 231 | 960715 |
| chisel | JD 8770 (36') | 9 | 5 | 231 | 960715 |

III. Chemical Application

| chemical | appl rate | tractor (model & width) | depth (in) | mph | area done (ac) | date |
|---|---|---|---|---|---|---|
| dyemetholate | pint/ac | air spray | | | 231 | 960315 |
| dyemetholate | pint/ac | air spray | | | 231 | 960315 |

IV. Harvest (include tractor and truck implements): 37 bu/ac

| tractor/truck (model and width) | mph | area done (ac) | date |
|---|---|---|---|
| JD 9600 | 6.5 | 231 | 960615 |
| Ford Tandem diesel | 6.5 | 231 | 960615 |
| Ford Tandem diesel | 6.5 | 231 | 960615 |

Farm Inventory

Farm No. 2
Field No. 2
Year 1995-6

I. Planting

| Tractor (model and width) | variety crop | seeding rate (lb/ac) | depth (in) | mph | area done (ac) | date |
|---|---|---|---|---|---|---|
| JD4450 (42') | Pioneer 2180 | 70 | 2.5 | 4.5 | 76 | 950925 |

II. Tillage

| activity | tractor (model & width) | depth (in) | mph | area done (ac) | date |
|---|---|---|---|---|---|
| springtooth | JD 8770 (54') | 3.5 | 6 | 76 | 950810 |
| springtooth | JD 8770 (54') | 3.5 | 6 | 76 | 950915 |
| one-way | JD 8770 (28') | 3.5 | 5 | 76 | 960701 |
| chisel | JD 8770 (36') | 9 | 5 | 76 | 960730 |
| chisel | JD 8770 (36') | 9 | 5 | 76 | 960730 |

III. Chemical Application

| chemical | appl rate | tractor (model & width) | depth (in) | mph | area done (ac) | date |
|---|---|---|---|---|---|---|
| dyemetholate | pint/ac | air spray | | | 76 | 960315 |
| dyemetholate | pint/ac | air spray | | | 76 | 960315 |

IV. Harvest (include tractor and truck implements): 23 bu/ac

| tractor/truck (model and width) | mph | area done (ac) | date |
|---|---|---|---|
| JD 9600 | 6.5 | 76 | 960615 |
| Ford Tandem diesel | 6.5 | 76 | 960615 |
| Ford Tandem diesel | 6.5 | 76 | 960615 |

Farm Inventory

Farm No. 2
Field No. 3
Year 1995-6

I. Planting

| Tractor (model and width) | variety crop | seeding rate (lb/ac) | depth (in) | mph | area done (ac) | date |
|---|---|---|---|---|---|---|
| JD4450 (42') | Karl 92 | 70 | 2.5 | 4.5 | 77 | 950927 |

II. Tillage

| activity | tractor (model & width) | depth (in) | mph | area done (ac) | date |
|---|---|---|---|---|---|
| springtooth | JD 8770 (54') | 3.5 | 6 | 77 | 950812 |
| springtooth | JD 8770 (54') | 3.5 | 6 | 77 | 950917 |
| one-way | JD 8770 (28') | 3.5 | 5 | 77 | 960703 |
| chisel | JD 8770 (36') | 9 | 5 | 77 | 960720 |
| chisel | JD 8770 (36') | 9 | 5 | 77 | 960720 |

III. Chemical Application

| chemical | appl rate | tractor (model & width) | depth (in) | mph | area done (ac) | date |
|---|---|---|---|---|---|---|
| dyemetholate | pint/ac | air spray | | | 77 | 960315 |
| dyemetholate | pint/ac | air spray | | | 77 | 960315 |

IV. Harvest (include tractor and truck implements): 25 bu/ac

| tractor/truck (model and width) | mph | area done (ac) | date |
|---|---|---|---|
| JD 9600 | 6.5 | 77 | 960620 |
| Ford Tandem diesel | 6.5 | 77 | 960620 |
| Ford Tandem diesel | 6.5 | 77 | 960620 |

Farm Inventory

Farm No. 2
Field No. 3
Year 1995-6

I. Planting

| Tractor (model and width) | variety crop | seeding rate (lb/ac) | depth (in) | mph | area done (ac) | date |
|---|---|---|---|---|---|---|
| JD4450 (42') | Pioneer 2163 | 70 | 2.5 | 4.5 | 104 | 950927 |

II. Tillage

| activity | tractor (model & width) | depth (in) | mph | area done (ac) | date |
|---|---|---|---|---|---|
| springtooth | JD 8770 (54') | 3.5 | 6 | 104 | 950812 |
| springtooth | JD 8770 (54') | 3.5 | 6 | 104 | 950917 |
| one-way | JD 8770 (28') | 3.5 | 5 | 104 | 960703 |
| chisel | JD 8770 (36') | 9 | 5 | 104 | 960720 |
| chisel | JD 8770 (36') | 9 | 5 | 104 | 960720 |

III. Chemical Application

| chemical | appl rate | tractor (model & width) | depth (in) | mph | area done (ac) | date |
|---|---|---|---|---|---|---|
| dyemetholate | pint/ac | air spray | | | 104 | 960315 |
| dyemetholate | pint/ac | air spray | | | 104 | 960315 |

IV. Harvest (include tractor and truck implements): 21 bu/ac

| tractor/truck (model and width) | mph | area done (ac) | date |
|---|---|---|---|
| JD 9600 | 6.5 | 104 | 960620 |
| Ford Tandem diesel | 6.5 | 104 | 960620 |
| Ford Tandem diesel | 6.5 | 104 | 960620 |

Farm Inventory

Farm No. 2
Field No. 5
Year 1995-6

I. Planting

| Tractor (model and width) | variety crop | seeding rate (lb/ac) | depth (in) | mph | area done (ac) | date |
|---|---|---|---|---|---|---|
| JD4450 (42') | Karl 92 | 70 | 2.5 | 4.5 | 90 | 950927 |

II. Tillage

| activity | tractor (model & width) | depth (in) | mph | area done (ac) | date |
|---|---|---|---|---|---|
| springtooth | JD 8770 (54') | 3.5 | 6 | 90 | 950812 |
| springtooth | JD 8770 (54') | 3.5 | 6 | 90 | 950917 |
| one-way | JD 8770 (28') | 3.5 | 5 | 90 | 960703 |
| chisel | JD 8770 (36') | 9 | 5 | 90 | 960720 |
| chisel | JD 8770 (36') | 9 | 5 | 90 | 960720 |

III. Chemical Application

| chemical | appl rate | tractor (model & width) | depth (in) | mph | area done (ac) | date |
|---|---|---|---|---|---|---|
| dyemetholate | pint/ac | air spray | | | 90 | 960315 |
| dyemetholate | pint/ac | air spray | | | 90 | 960315 |

IV. Harvest (include tractor and truck implements): 27 bu/ac

| tractor/truck (model and width) | mph | area done (ac) | date |
|---|---|---|---|
| JD 9600 | 6.5 | 90 | 960620 |
| Ford Tandem diesel | 6.5 | 90 | 960620 |
| Ford Tandem diesel | 6.5 | 90 | 960620 |

Farm Inventory

Farm No. 2
Field No. 6
Year 1995-6

I. Planting

| Tractor (model and width) | variety crop | seeding rate (lb/ac) | depth (in) | mph | area done (ac) | date |
|---|---|---|---|---|---|---|
| JD4450 (42') | Pioneer 2180 | 70 | 2.5 | 4.5 | 64 | 950927 |

II. Tillage

| activity | tractor (model & width) | depth (in) | mph | area done (ac) | date |
|---|---|---|---|---|---|
| springtooth | JD 8770 (54') | 3.5 | 6 | 64 | 950812 |
| springtooth | JD 8770 (54') | 3.5 | 6 | 64 | 950917 |
| one-way | JD 8770 (28') | 3.5 | 5 | 64 | 960703 |
| chisel | JD 8770 (36') | 9 | 5 | 64 | 960720 |
| chisel | JD 8770 (36') | 9 | 5 | 64 | 960720 |

III. Chemical Application

| chemical | appl rate | tractor (model & width) | depth (in) | mph | area done (ac) | date |
|---|---|---|---|---|---|---|
| dyemetholate | pint/ac | air spray | | | 64 | 960315 |
| dyemetholate | pint/ac | air spray | | | 64 | 960315 |

IV. Harvest (include tractor and truck implements): 24 bu/ac

| tractor/truck (model and width) | mph | area done (ac) | date |
|---|---|---|---|
| JD 9600 | 6.5 | 64 | 960620 |
| Ford Tandem diesel | 6.5 | 64 | 960620 |
| Ford Tandem diesel | 6.5 | 64 | 960620 |

Farm Inventory

Farm No. 2
Field No. 7
Year 1995-6

I. Planting

| Tractor (model and width) | variety crop | seeding rate (lb/ac) | depth (in) | mph | area done (ac) | date |
|---|---|---|---|---|---|---|
| JD4450 (42') | Karl 92 | 70 | 2.5 | 4.5 | 50 | 950928 |

II. Tillage

| activity | tractor (model & width) | depth (in) | mph | area done (ac) | date |
|---|---|---|---|---|---|
| springtooth | JD 8770 (54') | 3.5 | 6 | 50 | 950815 |
| springtooth | JD 8770 (54') | 3.5 | 6 | 50 | 950919 |
| one-way | JD 8770 (28') | 3.5 | 5 | 50 | 960705 |
| chisel | JD 8770 (36') | 9 | 5 | 50 | 960722 |
| chisel | JD 8770 (36') | 9 | 5 | 50 | 960722 |

III. Chemical Application

| chemical | appl rate | tractor (model & width) | depth (in) | mph | area done (ac) | date |
|---|---|---|---|---|---|---|
| dyemetholate | pint/ac | air spray | | | 50 | 960315 |
| dyemetholate | pint/ac | air spray | | | 50 | 960315 |

IV. Harvest (include tractor and truck implements): 33 bu/ac

| tractor/truck (model and width) | mph | area done (ac) | date |
|---|---|---|---|
| JD 9600 | 6.5 | 50 | 960622 |
| Ford Tandem diesel | 6.5 | 50 | 960622 |
| Ford Tandem diesel | 6.5 | 50 | 960622 |

Farm Inventory

Farm No. 2
Field No. 7
Year 1995-6

I. Planting

| Tractor (model and width) | variety crop | seeding rate (lb/ac) | depth (in) | mph | area done (ac) | date |
|---|---|---|---|---|---|---|
| JD4450 (42') | Pioneer 2180 | 70 | 2.5 | 4.5 | 125 | 950928 |

II. Tillage

| activity | tractor (model & width) | depth (in) | mph | area done (ac) | date |
|---|---|---|---|---|---|
| springtooth | JD 8770 (54') | 3.5 | 6 | 125 | 950815 |
| springtooth | JD 8770 (54') | 3.5 | 6 | 125 | 950919 |
| one-way | JD 8770 (28') | 3.5 | 5 | 125 | 960705 |
| chisel | JD 8770 (36') | 9 | 5 | 125 | 960722 |
| chisel | JD 8770 (36') | 9 | 5 | 125 | 960722 |

III. Chemical Application

| chemical | appl rate | tractor (model & width) | depth (in) | mph | area done (ac) | date |
|---|---|---|---|---|---|---|
| dyemetholate | pint/ac | air spray | | | 125 | 960315 |
| dyemetholate | pint/ac | air spray | | | 125 | 960315 |

IV. Harvest (include tractor and truck implements): 15 bu/ac

| tractor/truck (model and width) | mph | area done (ac) | date |
|---|---|---|---|
| JD 9600 | 6.5 | 125 | 960622 |
| Ford Tandem diesel | 6.5 | 125 | 960622 |
| Ford Tandem diesel | 6.5 | 125 | 960622 |

Farm Inventory

Farm No. 2
Field No. 9
Year 1995-6

I. Planting

| Tractor (model and width) | variety crop | seeding rate (lb/ac) | depth (in) | mph | area done (ac) | date |
|---|---|---|---|---|---|---|
| JD4450 (42') | Pioneer 2163 | 70 | 2.5 | 4.5 | 73 | 950928 |

II. Tillage

| activity | tractor (model & width) | depth (in) | mph | area done (ac) | date |
|---|---|---|---|---|---|
| springtooth | JD 8770 (54') | 3.5 | 6 | 73 | 950815 |
| springtooth | JD 8770 (54') | 3.5 | 6 | 73 | 950919 |
| one-way | JD 8770 (28') | 3.5 | 5 | 73 | 960705 |
| chisel | JD 8770 (36') | 9 | 5 | 73 | 960722 |
| chisel | JD 8770 (36') | 9 | 5 | 73 | 960722 |

III. Chemical Application

| chemical | appl rate | tractor (model & width) | depth (in) | mph | area done (ac) | date |
|---|---|---|---|---|---|---|
| dyemetholate | pint/ac | air spray | | | 73 | 960315 |
| dyemetholate | pint/ac | air spray | | | 73 | 960315 |

IV. Harvest (include tractor and truck implements): 29 bu/ac

| tractor/truck (model and width) | mph | area done (ac) | date |
|---|---|---|---|
| JD 9600 | 6.5 | 73 | 960622 |
| Ford Tandem diesel | 6.5 | 73 | 960622 |
| Ford Tandem diesel | 6.5 | 73 | 960622 |

Farm Inventory

Farm No. 2
Field No. 10
Year 1995-6

I. Planting

| Tractor (model and width) | variety crop | seeding rate (lb/ac) | depth (in) | mph | area done (ac) | date |
|---|---|---|---|---|---|---|
| JD4450 (42') | Pioneer 2163 | 70 | 2.5 | 4.5 | 80 | 950930 |

II. Tillage

| activity | tractor (model & width) | depth (in) | mph | area done (ac) | date |
|---|---|---|---|---|---|
| springtooth | JD 8770 (54') | 3.5 | 6 | 80 | 950817 |
| springtooth | JD 8770 (54') | 3.5 | 6 | 80 | 950921 |
| one-way | JD 8770 (28') | 3.5 | 5 | 80 | 960707 |
| chisel | JD 8770 (36') | 9 | 5 | 80 | 960724 |
| chisel | JD 8770 (36') | 9 | 5 | 80 | 960724 |

III. Chemical Application

| chemical | appl rate | tractor (model & width) | depth (in) | mph | area done (ac) | date |
|---|---|---|---|---|---|---|
| dyemetholate | pint/ac | air spray | | | 80 | 960315 |
| dyemetholate | pint/ac | air spray | | | 80 | 960315 |

IV. Harvest (include tractor and truck implements): 17 bu/ac

| tractor/truck (model and width) | mph | area done (ac) | date |
|---|---|---|---|
| JD 9600 | 6.5 | 80 | 960624 |
| Ford Tandem diesel | 6.5 | 80 | 960624 |
| Ford Tandem diesel | 6.5 | 80 | 960624 |

Farm Inventory

Farm No. 2
Field No. 11
Year 1995-6

I. Planting

| Tractor (model and width) | variety crop | seeding rate (lb/ac) | depth (in) | mph | area done (ac) | date |
|---|---|---|---|---|---|---|
| JD4450 (42') | Karl 92 | 70 | 2.5 | 4.5 | 45 | 950930 |

II. Tillage

| activity | tractor (model & width) | depth (in) | mph | area done (ac) | date |
|---|---|---|---|---|---|
| springtooth | JD 8770 (54') | 3.5 | 6 | 45 | 950817 |
| springtooth | JD 8770 (54') | 3.5 | 6 | 45 | 950921 |
| one-way | JD 8770 (28') | 3.5 | 5 | 45 | 960707 |
| chisel | JD 8770 (36') | 9 | 5 | 45 | 960724 |
| chisel | JD 8770 (36') | 9 | 5 | 45 | 960724 |

III. Chemical Application

| chemical | appl rate | tractor (model & width) | depth (in) | mph | area done (ac) | date |
|---|---|---|---|---|---|---|
| dyemetholate | pint/ac | air spray | | | 45 | 960315 |
| dyemetholate | pint/ac | air spray | | | 45 | 960315 |

IV. Harvest (include tractor and truck implements): 34 bu/ac

| tractor/truck (model and width) | mph | area done (ac) | date |
|---|---|---|---|
| JD 9600 | 6.5 | 45 | 960624 |
| Ford Tandem diesel | 6.5 | 45 | 960624 |
| Ford Tandem diesel | 6.5 | 45 | 960624 |

Farm Inventory

Farm No. 3
Field No. 1 & 2
Year 1995-6

I. Planting

| Tractor (model and width) | variety crop | seeding rate (lb/ac) | depth (in) | mph | area done (ac) | date |
|---|---|---|---|---|---|---|
| JD4010 (10') | Karl 92 | 102 | 1 | 5.5 | 30 | 951030 |
| JD4010 (10') | Karl 92 | 102 | 1 | 5.5 | 100 | 951105 |
| JD4010 (10') | Karl 92 | 102 | 1 | 5.5 | 138 | 951105 |

II. Tillage

| activity | tractor (model & width) | depth (in) | mph | area done (ac) | date |
|---|---|---|---|---|---|
| one-way | JD 4010 (10') | 4 | 5 | 69 | 950615 |
| one-way | JD 4010 (10') | 4 | 5 | 69 | 950630 |
| chisel | JD 4010 (10') | 7.5 | 4.5 | 138 | 950715 |
| sweep | JD 4010 (10') | 5 | 5.5 | 138 | 960815 |
| springtooth | JD 4010 (24') | 4.5 | 5.5 | 138 | 951015 |

III. Chemical Application

| chemical | appl rate | tractor (model & width) | depth (in) | mph | area done (ac) | date |
|---|---|---|---|---|---|---|
| spike/fertilizer | | JD 4010 (30') | 5 | 6 | 20 | 950905 |
| spike/fertilizer | | JD 4010 (30') | 5 | 6 | 20 | 950915 |
| N phosphorus | | spreader (40') | | 7.5 | 64 | |
| dyemetholate | pint/ac | ground spray (34') | | 7 | 138 | 960225 |
| dyemetholate | pint/ac | ground spray (34') | | 7 | 138 | 960305 |

IV. Harvest (include tractor and truck implements): 31 bu/ac

| tractor/truck (model and width) | mph | area done (ac) | date |
|---|---|---|---|
| JD 9600 | 6.5 | 85 | 960624 |
| Ford Tandem diesel | 6.5 | 85 | 960624 |
| Ford Tandem diesel | 6.5 | 85 | 960624 |

Farm Inventory

Farm No. 4
Field No. 1
Year 1995-6

I. Planting

| Tractor (model and width) | variety crop | seeding rate (lb/ac) | depth (in) | mph | area done (ac) | date |
|---|---|---|---|---|---|---|
| Versatile895 (30') | Pioneer 2163 | 90 | 1.5 | 5 | 252 | 951015 |

II. Tillage

| activity | tractor (model & width) | depth (in) | mph | area done (ac) | date |
|---|---|---|---|---|---|
| offset disk | Versatile 895 (24') | 6 | 4 | 252 | 950630 |
| chisel | Versatile 895 (35') | 10 | 4.5 | 252 | 950705 |
| chisel | Versatile 895 (35') | 6 | 5 | 252 | 950810 |
| chisel | Versatile 895 (35') | 4 | 5.5 | 252 | 950905 |

III. Chemical Application

| chemical | appl rate | tractor (model & width) | depth (in) | mph | area done (ac) | date |
|---|---|---|---|---|---|---|
| anhydrous | 80lb/ac | Versatile 895 (35') | 6 | 5 | 252 | 950810 |
| nitrogen (28/00) | 100lb/ac | Bigwheels (60') | | 12 | 252 | 960115 |
| glean | 1.5 ou/ac | Bigwheels (60') | | 12 | 252 | 960115 |

IV. Harvest (include tractor and truck implements): ~31 bu/ac

| tractor/truck (model and width) | mph | area done (ac) | date |
|---|---|---|---|
| JD 9600 | 5 | 252 | 960605 |
| Ford Tandem diesel | 5 | 252 | 960605 |
| Ford Tandem diesel | 5 | 252 | 960605 |

Farm Inventory

Farm No. 4
Field No. 2
Year 1995-6

I. Planting

| Tractor (model and width) | variety crop | seeding rate (lb/ac) | depth (in) | mph | area done (ac) | date |
|---|---|---|---|---|---|---|
| Versatile895 (30') | Karl 92 | 75 | 1.5 | 5 | 575 | 951015 |

II. Tillage

| activity | tractor (model & width) | depth (in) | mph | area done (ac) | date |
|---|---|---|---|---|---|
| chisel | Versatile 895 (35') | 10 | 4.5 | 575 | 950705 |
| chisel | Versatile 895 (35') | 10 | 4.5 | 575 | 950805 |
| chisel | Versatile 895 (35') | 6 | 5 | 575 | 950810 |
| chisel | Versatile 895 (35') | 4 | 5.5 | 575 | 950905 |

III. Chemical Application

| chemical | appl rate | tractor (model & width) | depth (in) | mph | area done (ac) | date |
|---|---|---|---|---|---|---|
| anhydrous | 60lb/ac | Versatile 895 (35') | 6 | 5 | 575 | 950810 |
| nitrogen (28/00) | 100lb/ac | Bigwheels (60') | | 12 | 575 | 960115 |
| glean | 1.5 ou/ac | Bigwheels (60') | | 12 | 575 | 960115 |

IV. Harvest (include tractor and truck implements): ~30 bu/ac

| tractor/truck (model and width) | mph | area done (ac) | date |
|---|---|---|---|
| JD 9600 | 5 | 375 | 960605 |
| Ford Tandem diesel | 5 | 375 | 960605 |
| Ford Tandem diesel | 5 | 375 | 960605 |

Farm Inventory

Farm No. 4
Field No. 3
Year 1995-6

I. Planting

| Tractor (model and width) | variety crop | seeding rate (lb/ac) | depth (in) | mph | area done (ac) | date |
|---|---|---|---|---|---|---|
| Versatile895 (30') | Pioneer 2163 | 75 | 1.5 | 5 | 373 | 951017 |

II. Tillage

| activity | tractor (model & width) | depth (in) | mph | area done (ac) | date |
|---|---|---|---|---|---|
| chisel | Versatile 895 (35') | 10 | 4.5 | 373 | 950707 |
| chisel | Versatile 895 (35') | 10 | 4.5 | 373 | 950807 |
| chisel | Versatile 895 (35') | 6 | 5 | 373 | 950812 |
| chisel | Versatile 895 (35') | 4 | 5.5 | 373 | 950907 |

III. Chemical Application

| chemical | appl rate | tractor (model & width) | depth (in) | mph | area done (ac) | date |
|---|---|---|---|---|---|---|
| anhydrous | 40lb/ac | Versatile 895 (35') | 6 | 5 | 373 | 950812 |
| nitrogen (28/00) | 100lb/ac | Bigwheels (60') | | 12 | 373 | 960117 |
| glean | 1.5 ou/ac | Bigwheels (60') | | 12 | 373 | 960117 |

IV. Harvest (include tractor and truck implements): ~30 bu/ac

| tractor/truck (model and width) | mph | area done (ac) | date |
|---|---|---|---|
| JD 9600 | 5 | 373 | 960607 |
| Ford Tandem diesel | 5 | 373 | 960607 |
| Ford Tandem diesel | 5 | 375 | 960605 |

Farm Inventory

Farm No. 4
Field No. 3
Year 1995-6

I. Planting

| Tractor (model and width) | variety crop | seeding rate (lb/ac) | depth (in) | mph | area done (ac) | date |
|---|---|---|---|---|---|---|
| Versatile895 (30') | Pioneer 2163 | 75 | 1.5 | 5 | 200 | 951017 |

II. Tillage

| activity | tractor (model & width) | depth (in) | mph | area done (ac) | date |
|---|---|---|---|---|---|
| chisel | Versatile 895 (35') | 10 | 4.5 | 200 | 950707 |
| chisel | Versatile 895 (35') | 10 | 4.5 | 200 | 950807 |
| chisel | Versatile 895 (35') | 6 | 5 | 200 | 950812 |
| chisel | Versatile 895 (35') | 4 | 5.5 | 200 | 950907 |

III. Chemical Application

| chemical | appl rate | tractor (model & width) | depth (in) | mph | area done (ac) | date |
|---|---|---|---|---|---|---|
| anhydrous | 40lb/ac | Versatile 895 (35') | 6 | 5 | 200 | 950812 |

IV. Harvest (include tractor and truck implements): ~30 bu/ac

| tractor/truck (model and width) | mph | area done (ac) | date |
|---|---|---|---|
| JD 9600 | 5 | 200 | 960607 |
| Ford Tandem diesel | 5 | 200 | 960607 |
| Ford Tandem diesel | 5 | 200 | 960605 |

Farm Inventory

Farm No. 5
Field No. 1
Year 1995-6

I. Planting

| Tractor (model and width) | variety crop | seeding rate (lb/ac) | depth (in) | mph | area done (ac) | date |
|---|---|---|---|---|---|---|
| JD 4440 (20') | Karl 92 | 90 | 1 | 4 | 152.5 | 951020 |

II. Tillage

| activity | tractor (model & width) | depth (in) | mph | area done (ac) | date |
|---|---|---|---|---|---|
| off-set | JD 4840 (20') | 7 | 5 | 76.5 | 950615 |
| off-set | JD 4440 (12') | 7 | 5 | 76 | 950615 |
| sweep | JD 4840 (25') | 5.5 | 5 | 76.5 | 950708 |
| sweep | JD 4440 (15') | 5.5 | 5 | 76 | 950708 |
| field cultivate | JD 4840 (27') | 5.5 | 5 | 152.5 | 951005 |

III. Chemical Application

| chemical | appl rate | tractor (model & width) | depth (in) | mph | area done (ac) | date |
|---|---|---|---|---|---|---|
| anhydrous | 75 lb/ac | JD 4840 (20') | 7 | 5 | 152.5 | 950915 |
| dimetholate | | air spray | | | 152.5 | 960203 |

IV. Harvest (include tractor and truck implements): 14 bu/ac

| tractor/truck (model and width) | mph | area done (ac) | date |
|---|---|---|---|
| JD 9600 | 5 | 200 | 960610 |
| Ford Tandem diesel | 5 | 200 | 960610 |
| Ford Tandem diesel | 5 | 200 | 960610 |

Farm Inventory

Farm No. 5
Field No. 2
Year 1995-6

I. Planting

| Tractor (model and width) | variety crop | seeding rate (lb/ac) | depth (in) | mph | area done (ac) | date |
|---|---|---|---|---|---|---|
| JD 4440 (20') | Karl 92 | 90 | 1 | 4 | 148 | 951020 |

II. Tillage

| activity | tractor (model & width) | depth (in) | mph | area done (ac) | date |
|---|---|---|---|---|---|
| off-set | JD 4840 (20') | 7 | 5 | 74 | 950615 |
| off-set | JD 4440 (12') | 7 | 5 | 74 | 950615 |
| sweep | JD 4840 (25') | 5.5 | 5 | 74 | 950708 |
| sweep | JD 4440 (15') | 5.5 | 5 | 74 | 950708 |
| field cultivate | JD 4840 (27') | 5.5 | 5 | 148 | 951005 |

III. Chemical Application

| chemical | appl rate | tractor (model & width) | depth (in) | mph | area done (ac) | date |
|---|---|---|---|---|---|---|
| anhydrous | 75 lb/ac | JD 4840 (20') | 7 | 5 | 148 | 950915 |
| dimetholate | | air spray | | | 148 | 960203 |

IV. Harvest (include tractor and truck implements): 14 bu/ac

| tractor/truck (model and width) | mph | area done (ac) | date |
|---|---|---|---|
| JD 9600 | 5 | 148 | 960610 |
| Ford Tandem diesel | 5 | 148 | 960610 |
| Ford Tandem diesel | 5 | 148 | 960610 |

Farm Inventory

Farm No. 5
Field No. 3
Year 1995-6

I. Planting

| Tractor (model and width) | variety crop | seeding rate (lb/ac) | depth (in) | mph | area done (ac) | date |
|---|---|---|---|---|---|---|
| JD 4440 (20') | Karl 92 | 90 | 1 | 4 | 120 | 951025 |

II. Tillage

| activity | tractor (model & width) | depth (in) | mph | area done (ac) | date |
|---|---|---|---|---|---|
| off-set | JD 4840 (20') | 7 | 5 | 60 | 950620 |
| off-set | JD 4440 (12') | 7 | 5 | 60 | 950620 |
| sweep | JD 4840 (25') | 5.5 | 5 | 60 | 950713 |
| sweep | JD 4440 (15') | 5.5 | 5 | 60 | 950713 |
| field cultivate | JD 4840 (27') | 5.5 | 5 | 120 | 951010 |

III. Chemical Application

| chemical | appl rate | tractor (model & width) | depth (in) | mph | area done (ac) | date |
|---|---|---|---|---|---|---|
| anhydrous | 75 lb/ac | JD 4840 (20') | 7 | 5 | 120 | 950920 |
| dimetholate | | air spray | | | 120 | 960208 |

IV. Harvest (include tractor and truck implements): 14 bu/ac

| tractor/truck (model and width) | mph | area done (ac) | date |
|---|---|---|---|
| JD 9600 | 5 | 120 | 960615 |
| Ford Tandem diesel | 5 | 120 | 960615 |
| Ford Tandem diesel | 5 | 120 | 960615 |

Farm Inventory

Farm No. 5
Field No. 4
Year 1995-6

I. Planting

| Tractor (model and width) | variety crop | seeding rate (lb/ac) | depth (in) | mph | area done (ac) | date |
|---|---|---|---|---|---|---|
| JD 4440 (20') | Karl 92 | 90 | 1 | 4 | 40 | 951025 |

II. Tillage

| activity | tractor (model & width) | depth (in) | mph | area done (ac) | date |
|---|---|---|---|---|---|
| off-set | JD 4840 (20') | 7 | 5 | 40 | 950620 |
| sweep | JD 4840 (25') | 5.5 | 5 | 40 | 950713 |
| field cultivate | JD 4840 (27') | 5.5 | 5 | 40 | 951010 |

III. Chemical Application

| chemical | appl rate | tractor (model & width) | depth (in) | mph | area done (ac) | date |
|---|---|---|---|---|---|---|
| anhydrous | 75 lb/ac | JD 4840 (20') | 7 | 5 | 40 | 950920 |
| dimetholate | | air spray | | | 40 | 960208 |

IV. Harvest (include tractor and truck implements): 10 bu/ac

| tractor/truck (model and width) | mph | area done (ac) | date |
|---|---|---|---|
| JD 9600 | 5 | 40 | 960615 |
| Ford Tandem diesel | 5 | 40 | 960615 |
| Ford Tandem diesel | 5 | 40 | 960615 |

Farm Inventory

Farm No. 6
Field No. 1
Year 1992-3

I. Planting

| Tractor (model and width) | variety crop | seeding rate (lb/ac) | depth (in) | mph | area done (ac) | date |
|---|---|---|---|---|---|---|
| JD 3020 (13') | Pioneer 2180 | 72 | 1 | 6 | 104 | 950925 |

II. Tillage

| activity | tractor (model & width) | depth (in) | mph | area done (ac) | date |
|---|---|---|---|---|---|
| one-way | JD 4440 (18') | 6 | 5 | 104 | 920630 |
| tandem disk | JD 4440 (18') | 6 | 5 | 104 | 920805 |
| moldboard | JD 616 (8') | 8 | 5 | 104 | 920825 |
| field cultivate | JD 616 (32') | 3.5 | 6 | 104 | 920830 |
| field cultivate | JD 616 (32') | 3.5 | 6 | 104 | 920905 |

III. Chemical Application

| chemical | appl rate | tractor (model & width) | depth (in) | mph | area done (ac) | date |
|---|---|---|---|---|---|---|
| anhydrous | 80 lb/ac | JD 3020 (32') | | 6 | 104 | 920905 |
| N 60/48/0 | | JD 3020 (13') | 1 | 6 | 104 | 920925 |
| N 16/48/6 | | JD 3020 (13') | 1 | 6 | 104 | 920925 |
| glean | 1.5 ou/ac | spreader (60') | | 12 | 104 | 930105 |

IV. Harvest (include tractor and truck implements): 36 bu/ac

| tractor/truck (model and width) | mph | area done (ac) | date |
|---|---|---|---|
| JD 4400 | 5 | 104 | 960605 |
| Chevrolet Truck (2ton) | 5 | 104 | 960605 |

Farm Inventory

Farm No. 6
Field No. 2
Year 1992-3

I. Planting

| Tractor (model and width) | variety crop | seeding rate (lb/ac) | depth (in) | mph | area done (ac) | date |
|---|---|---|---|---|---|---|
| JD 3020 (13') | Pioneer 2180 | 72 | 1 | 6 | 30 | 950925 |

II. Tillage

| activity | tractor (model & width) | depth (in) | mph | area done (ac) | date |
|---|---|---|---|---|---|
| one-way | JD 4440 (18') | 6 | 5 | 30 | 920630 |
| tandem disk | JD 4440 (18') | 6 | 5 | 30 | 920805 |
| moldboard | JD 616 (8') | 8 | 5 | 30 | 920825 |
| field cultivate | JD 616 (32') | 3.5 | 6 | 30 | 920830 |
| field cultivate | JD 616 (32') | 3.5 | 6 | 30 | 920905 |

III. Chemical Application

| chemical | appl rate | tractor (model & width) | depth (in) | mph | area done (ac) | date |
|---|---|---|---|---|---|---|
| anhydrous | 80 lb/ac | JD 3020 (32') | | 6 | 30 | 920905 |
| N 60/48/0 | | JD 3020 (13') | 1 | 6 | 30 | 920925 |
| N 16/48/6 | | JD 3020 (13') | 1 | 6 | 30 | 920925 |
| glean | 1.5 ou/ac | spreader (60') | | 12 | 30 | 930105 |

IV. Harvest (include tractor and truck implements): 36 bu/ac

| tractor/truck (model and width) | mph | area done (ac) | date |
|---|---|---|---|
| JD 4400 | 5 | 30 | 960605 |
| Chevrolet Truck (2ton) | 5 | 30 | 960605 |

Farm Inventory

Farm No. 6
Field No. 3
Year 1992-3

I. Planting

| Tractor (model and width) | variety crop | seeding rate (lb/ac) | depth (in) | mph | area done (ac) | date |
|---|---|---|---|---|---|---|
| JD 3020 (13') | Pioneer 2180 | 72 | 1 | 6 | 40 | 950927 |

II. Tillage

| activity | tractor (model & width) | depth (in) | mph | area done (ac) | date |
|---|---|---|---|---|---|
| one-way | JD 4440 (18') | 6 | 5 | 40 | 920630 |
| tandem disk | JD 4440 (18') | 6 | 5 | 40 | 920807 |
| moldboard | JD 616 (8') | 8 | 5 | 40 | 920827 |
| field cultivate | JD 616 (32') | 3.5 | 6 | 40 | 920830 |
| field cultivate | JD 616 (32') | 3.5 | 6 | 40 | 920907 |

III. Chemical Application

| chemical | appl rate | tractor (model & width) | depth (in) | mph | area done (ac) | date |
|---|---|---|---|---|---|---|
| anhydrous | 80 lb/ac | JD 3020 (32') | | 6 | 40 | 920907 |
| N 60/48/0 | | JD 3020 (13') | 1 | 6 | 40 | 920927 |
| N 16/48/6 | | JD 3020 (13') | 1 | 6 | 40 | 920927 |
| glean | 1.5 ou/ac | spreader (60') | | 12 | 40 | 930107 |

IV. Harvest (include tractor and truck implements): 36 bu/ac

| tractor/truck (model and width) | mph | area done (ac) | date |
|---|---|---|---|
| JD 4400 | 5 | 40 | 960607 |
| Chevrolet Truck (2ton) | 5 | 40 | 960607 |

## Appendix 2

### Calculating the Property Tax for the Hinterland

1. Determine the hinterland's school district (Washita Heights).

2. Find the mills on real property; add all levies to obtain the total ($48.17 per $1,000 fair assessed value).

3. Divide the total value of real property ($3,730,129) by the number of farmers (302.5) to obtain the current tax on the farm ($593.98). By dividing the number of farmers by the hinterland acreage (47,860), average farm size is 158.21 acres.

Sources: *1996-1997 Annual Report* of the Oklahoma State Board of Education (p. 90).

## Appendix 3

### Calculating Values in Table 6.3 and Figures 6.1-6.3

The following is an excerpt from Table 6.3:

| Pop. | Farmers | Acreage | -5% | Current | +5% |
|---|---|---|---|---|---|
| 1300 | 325 | 147.26 | $20,078.23 | $21,134.98 | $22,191.72 |
| 1210 | 302.5 | 158.21 | $21,571.65 | $22,707.00 | $23,842.35 |
| 1200 | 300 | 159.53 | $21,751.41 | $22,896.22 | $24,041.04 |

In this example, there are only two constants. First, the hinterland is limited to 47,860 acres, including bottomland, roads, drainage channels, and the town of Corn. Second, grain receipts are $6,868,867 for the Corn hinterland. This value reflects grain yields as outlined in Table 5.3 (p. 86). These two values cannot be exceeded in this framework. While population can vary, it is divided by four since each family is assumed to have four members.

With these points, dividing a population of 1300 by four renders 325 farmers. Then dividing 47,860 acres by 325 renders an average farm size of 147.26 acres. Finally, dividing $6,868,867 by 325 gives an family income of $21,134.98 from dryland wheat production. The other columns reflect adding and subtracting five percent of the current income.

## VITA

Name: J. C. Alexander
Date of Birth: 24 May 1969
Birthplace: Shelby County, Tennessee

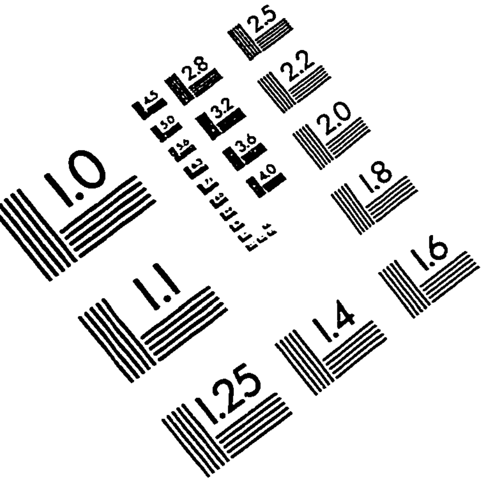
## EDUCATION

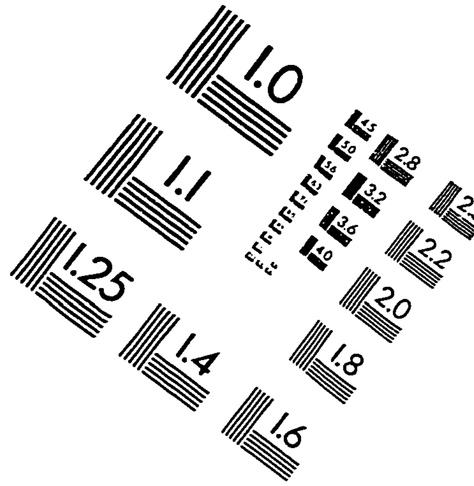
| Institution | Attended | Degree | Major |
|---|---|---|---|
| University of Oklahoma | 1993-8 | Ph.D. | Geography |
| University of Oklahoma | 1990-2 | M.A. | Geography |
| Memphis State University | 1987-90 | B.A. | Geography |
| Harding Academy of Memphis | 1983-7 | Diploma | Mathematics |

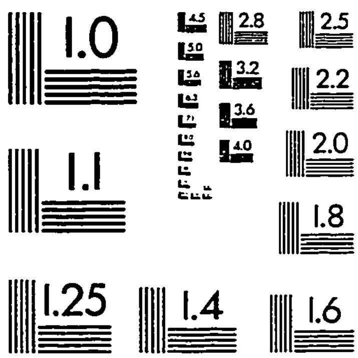
Thesis Title: A Framework for Determining the Human Carrying Capacity of the Corn, Oklahoma, Hinterland

Major Professor: Dr. Hans-Joachim Späth

# IMAGE EVALUATION
# TEST TARGET (QA-3)

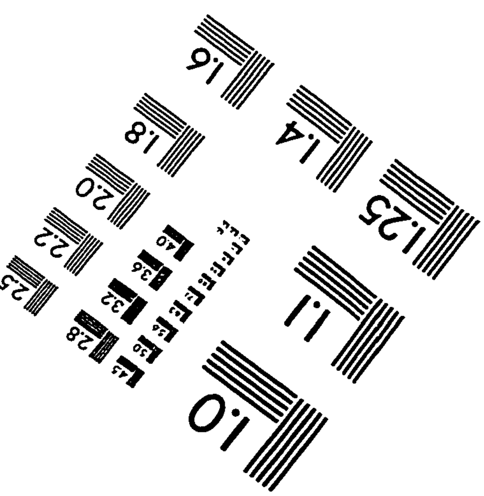


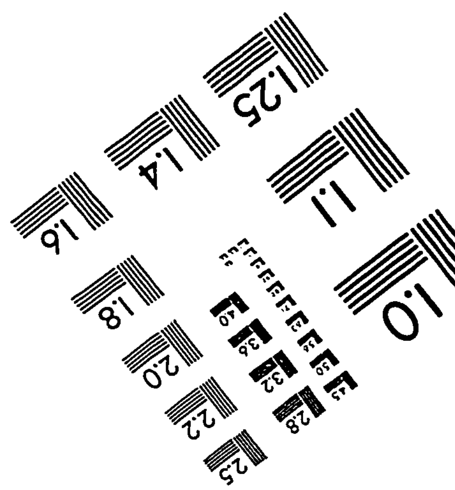





150mm

6"





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