1329862

Towne, Douglas Clark

THE RELATIONSHIP BETWEEN IRRIGATED FARMLAND DECLINE AND PHYSICAL LANDSCAPE FACTORS: A SPATIAL ANALYSIS

The University of Arizona M.A. 1986

University
Microfilms
International 300 N. Zeeb Road, Ann Arbor, MI 48106

PLEASE NOTE:

In all cases this material has been filmed in the best possible way from the available copy. Problems encountered with this document have been identified here with a check mark __√__.

1. Glossy photographs or pages __√__
2. Colored illustrations, paper or print __√__
3. Photographs with dark background __√__
4. Illustrations are poor copy ______
5. Pages with black marks, not original copy ______
6. Print shows through as there is text on both sides of page ______
7. Indistinct, broken or small print on several pages __√__
8. Print exceeds margin requirements ______
9. Tightly bound copy with print lost in spine ______
10. Computer printout pages with indistinct print ______
11. Page(s) ________ lacking when material received, and not available from school or author.
12. Page(s) ________ seem to be missing in numbering only as text follows.
13. Two pages numbered ______. Text follows.
14. Curling and wrinkled pages ______
15. Dissertation contains pages with print at a slant, filmed as received ________
16. Other ________________________________

THE RELATIONSHIP BETWEEN IRRIGATED FARMLAND DECLINE AND PHYSICAL LANDSCAPE FACTORS: A SPATIAL ANALYSIS

by

Douglas Clark Towne

A Thesis Submitted to the Faculty of the

DEPARTMENT OF GEOGRAPHY AND REGIONAL DEVELOPMENT

In Partial Fulfillment of the Requirements
For the Degree of

MASTER OF ARTS
WITH A MAJOR IN GEOGRAPHY

In the Graduate College

THE UNIVERSITY OF ARIZONA

1 9 8 6

STATEMENT BY AUTHOR

This thesis has been submitted in partial fulfillment of requirements for an advanced degree at The University of Arizona and is deposited in the University Library to be made available to borrowers under rules of the Library.

Brief quotations from this thesis are allowable without special permission, provided that accurate acknowledgment of source is made. Requests for permission for extended quotation from or reproduction of this manuscript in whole or in part may be granted by the head of the major department or the Dean of the Graduate College when in his or her judgement the proposed use of the manual is in the interests of scholarship. In all other instances, however, permission must be obtained from the author.

SIGNED: ______________________

APPROVAL BY THESIS DIRECTOR

This thesis has been approved on the date shown below:

Michael C. Parton
Instructor of Geography
Date: December 12, 1986

Richard W. Reeves
Professor of Geography
Date: 12 Dec 1986

ACKNOWLEGDEMENTS

The author is grateful to Dr. Michael Parton whose guidance and assistance helped make this thesis possible. Appreciation is expressed to Lin Ning Hui, Dr. Martin Karpiscak, Tina Kennedy, Dr. David Plane and Dr. Richard Reeves for their support and criticism.

Thanks goes to the students of the Geography Department and residents of Babcock Inn who helped keep me sane through this endeavor. Special gratitude is extended to Catherine Weiler for the optimism, energy and companionship she provided me during this period.

A final thanks goes to my parents for their understanding.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF TABLES -- Continued

LIST OF ILLUSTRATIONS

ABSTRACT

As the cost of groundwater increases with greater pumping lifts and increasing energy prices, retired farmland is becoming a prevelent feature in the southwestern United States. The goal of this study is to identify significant relationships between retirement of agricultural land and its physical characteristics -- particularly soil and groundwater conditions.

Data on agricultural land status derived from remotely sensed imagery are compared with soil data, acquired from a recent soil survey, and data on groundwater depth and change in a study area in southeastern Arizona.

Results indicate that agricultural land retirement is a complex but rational process that does not occur randomly. Aggregating thirty-three soil types coinciding with farmland into capability classes developed by the Soil Conservation Service shows that farmland retirement is more likely to occur on soils with severe limitations on use than on prime agricultural soils with few or moderate limitations to use. Retirement of agricultural land also coincides with substantial groundwater change and depth. While retirement is more likely to occur where groundwater is deep or where levels are falling rapidly, other factors such as availability of credit may influence this relationship.

INTRODUCTION

Agriculture in Arizona

Agriculture has played a major role in Arizona's history. While it was of primary importance in the original siting and subsequent growth of many communities, including Phoenix, the initial dependence on farming of many settlements has declined.

Farms in Arizona are distinguished by their large size, high capitalization, professional management, high per-acre yields, substantial use of seasonal labor and use of water for irrigation (Hecht and Reeves 1981, p. 44). Crops harvested in the state include cotton, wheat, barley, corn, sorghum, alfalfa, lettuce, citrus, and other fruits and vegetables.

In 1984, about 1.5 percent (434,252 hectares) of Arizona's land area was cultivated. Nearly all of this land is irrigated and concentrated on broad alluvial plains and within valleys associated with major river systems. Agriculture is by far the major consumer of water, the state's most critically limited resource, using 89 percent annually (Arizona Water Commission 1977).

Groundwater Irrigation Conditions

Irrigation has greatly expanded the amount of land suitable for agriculture in arid regions. Almost all the field agriculture in the southwestern United States is irrigated because of insufficient or unreliable rainfall. An otherwise ideal climate and fertile soils, as well as the availability of surface and groundwater, has stimulated the growth of irrigated agriculture in this region.

The total cost of water used for irrigation depends both on the quantity of water applied and on its unit cost. When groundwater is used, most of the unit cost of water depends on the pumping lift and the cost of the energy used to run pumps.

Increased energy prices since the mid-1970s have increased water costs in the Southwest, and have thus severely affected the amount of land area cultivated. Agriculture is the largest user of Southwestern water and, as a marginal-profit industry, is also less capable of absorbing cost changes than urban and industrial consumers (Frederick 1982). The prospect of higher water costs has not only restrained expansion, but has actually decreased the economic viability of many farmers. This phenomena has been observed in Arizona as planted area declined by 66 percent from 1977 to 1983 (Arizona Crop and Livestock Reporting Service 1977,1983).

The overall impact of changes in the water supply and energy price on irrigation depends on the decisions of farmers responding individually to a wide variety of conditions, prices and opportunities. The effect of these impacts on irrigated farming depends partially on adjustments farmers can make to changes in production costs. Green (1973) observed the response of farmers to a declining groundwater level in west Texas. Four strategies were found:

1) farmers experimented with other crops and increased livestock production;

2) the average irrigated farm increased in size;

3) groundwater districts began to play a more aggressive role in groundwater conservation; and,

4) the farmers began to look elsewhere for water.

Keith (1977, p. 48) indicates the impact of declining groundwater is expressed by a farmer through a combination of some of the following responses. These include declines in:

1) water pumped,

2) irrigated acreage,

3) low marginal value crops,

4) agricultural output,

5) cost of production, and,

6) total revenue.

Increases in farm size and dryland production are also expected. She hypothesizes that these factors can bring about a decline in population, a decrease in taxes collected and a decline in land values, community expenditures, and services on a regional basis. Famisa (1977, p. 2) states that the loss of agricultural land can affect the land use pattern, the intensity of land use by farmers, the location of crop types and even the attitude of farmers regarding such things as investment in agriculture and improvement of farmland.

Groundwater irrigators are susceptable to cost increases stemming from rising energy costs and declining water levels. These costs vary widely depending on pumping depth, the type and cost of fuel, and the maintenance needed to keep the pump in operation (Frederick 1982). Increased pumping cost due to increased lift has become a major problem only since the rapid rise in energy costs in the early 1970's. Prior to that, for the period 1891-1967 in Arizona, Martin and Archer (1971) show that pumping costs per foot of lift declined rapidly in actual dollars from 1910 through the 1940's, and then remained relatively constant until 1967. They attribute this to improved efficiencies both in the energy industry and in pumping plants.

The decline of planted acreage was anticipated with rising energy costs in the early 1970's (Kelso, Martin, and Mack 1973). This decline was temporarily delayed because crop values rose at a much greater rate than the energy costs of water; thus, cost for water as a percent of gross net value actually decreased (Carr 1977). With the recent stabilizing of crop prices, many farmers have reduced the area farmed or terminated irrigated agriculture altogether.

Groundwater drawdown is associated with two principal water cost increases. First is the decrease in saturated thickness as the aquifer is exploited. As saturated thickness declines, so does well yield. A second effect is an increased pumping lift. Drawdown is more severe in aquifers with little lateral flow. With an aquifer having significant lateral flow, the influence of one farmer's pumping is diffused over a large area. Because of these two effects, additional wells and pumps are eventually needed to maintain the flow (Frederick 1982).

Agriculture and the Physical Environment

The physical environment influences the profitability of irrigated farming. Geographers studying agriculture cite restrictions imposed by physical variables (climate, soil, hydrology and surface features) as important factors in agricultural decline (Hart 1968). While this relationship is difficult to quantify, some studies have demonstrated success.

Roet (1985) found that while poor land was not a direct cause of agricultural failure (economic and climatic factors such as falling grain prices and drought were found to be linked), evidence suggests that farmland retirement was more likely on infertile soils and less likely on the best soils in homesteads located away from towns or railroads in the Northern Great Plains from 1900 to 1920.

Close associations between soil and patterns of both land use and crop yield were found by Edwards (1967) while assessing the quality of agricultural land in Somerset, England. Utilizing soil survey data, he classified land quality by the relationship between soil, land use and crop yield with a weighting factor based on farm size. He observed that physical factors are not the only influences on land use: factors such as farm location, farm layout, and the enterprise and preferences of the individual farmer also influence observed patterns.

Pifer (1969) studied declining groundwater levels and associated agricultural patterns in the Salt River Valley of Arizona. He found distinctive patterns of land use relating to crops varying in market value. High value crops dominated in areas with the greatest water cost. Although other factors such as environment, markets, and capital investment influenced agriculture in this area, the patterns of land use were directly related to groundwater depth and the resulting cost of water.

Using aggregate county statistics, Hart (1968, p. 439) failed to derive a strong relationship between a land capability index based on soil productivity and the acreage of retired farmland in the eastern United States. Fravega (1970) also compared retired agriculture to a land quality index using aggregate county data. Again, land quality was not shown to be a major factor in agricultural decline.

These studies may have failed to find relationships between the physical environment and agricultural decline because the resolution of data was too coarse. The studies utilized data showing the amount of retired agriculture by county in the eastern United States. These aggregated data were compared to an average soil productivity index calculated for each county, a unit typically with great variability within its borders.

This study differs from earlier geographic research conducted in the eastern United States in a number of ways. Individual farm units are examined instead of aggregate county agricultural statistics, irrigation efficiency is studied in place of soil depletion, and the economic conditions causing the decline of agriculture are the increasing production costs relative to the market, rather than the decreasing productivity of the farmland.

Statement of Hypothesis

While numerous physical, economic and political factors influence a farmer's decision as to how land will be used, the hypothesis of this study is that the retirement of irrigated farmland in Southern Arizona is influenced by one or more measureable physical variables that occur with a significant level of spatial coincidence. The three variables examined are soil irrigability, groundwater depth and change in groundwater depth.

The soils are examined for their suitability in producing field crops under irrigation. Capability classes developed by the Soil Conservation Service are used which rank soils by their progressively greater limitations and narrower choices for practical use. Soils are classified according to their limitations when used for field crops, the risk of damage when they are so used, and the way they respond to treatment (Richmond 1976). This is determined by a combination of factors including texture, presence of salts and alkali, depth of root zone, rate of water intake at the surface, permeability of the soil below the surface, available water capacity, need for drainage, susceptibility to flooding, and hazards of erosion and deflation (Vogt 1980).

Groundwater depth and change in groundwater depth are other physical variables relevent to southwestern irrigated agriculture. Deeper groundwater levels require greater energy outputs to use the water for irrigation.

Irrigated farmland on soil with severe cultivation limitations, deep groundwater levels or large declines in groundwater levels are less economically viable. This infers that soils with severe cultivation limitations are more likely to have a greater amount of retired agricultural land, than the prime agriculural soils with few or moderate limitations to use. Areas with deep groundwater levels are more likely to have a greater amount of retired agricultural land, than areas of shallow groundwater depth. Areas experiencing large declines in depth to groundwater are more likely to have a greater amount of retired agriculture than areas with stable groundwater levels. The economic ramifications of these factors should influence the farmer's decision to grow crops or to take farmland out of production, according to market price fluctuations.

A test of these hypotheses may be performed by comparing the mapped distribution of retired farmland to the distribution of mapped soil and groundwater data. A measure of statistically-significant association between these variables is the basis for the acceptance of this hypothesis.

STUDY AREA

Cochise County, which has experienced the greatest decline in irrigated farmland of any county in Arizona during the 1980s (Figure 1), has several areas of irrigated farmland, with the greatest amount in the Sulphur Springs Valley (Meitl, Hathaway and Gregg 1983). This valley lies within the Mexican Highland section of the Basin and Range Physiographic Province. The valley is northwest-trending averaging about 32 kilometers in width. The Willcox Basin includes about 3,885 square kilometers in the northern part of the Sulphur Springs Valley and is topographically and hydrologically separate from the southern part of the valley. The basin is bounded on the west by the Galiuro, Winchester, Little Dragoon, and Dragoon mountains; and on the east by the Pinaleno, Dos Cabezas and Chiricahua mountains. The north and south drainage divides are not well defined. The southern divide is a partially buried alluvium extension of the Swisshelm Mountains, while the valley narrows to the north, where an ancient alluvial fan forms a divide.

An area within the Willcox Basin of the Sulphur Springs Valley was chosen for study for a number of reasons. The factors that contributed to this selection process include:

1) presence of substantial irrigated farmland;

2) significant recent retirement of irrigated farmland;

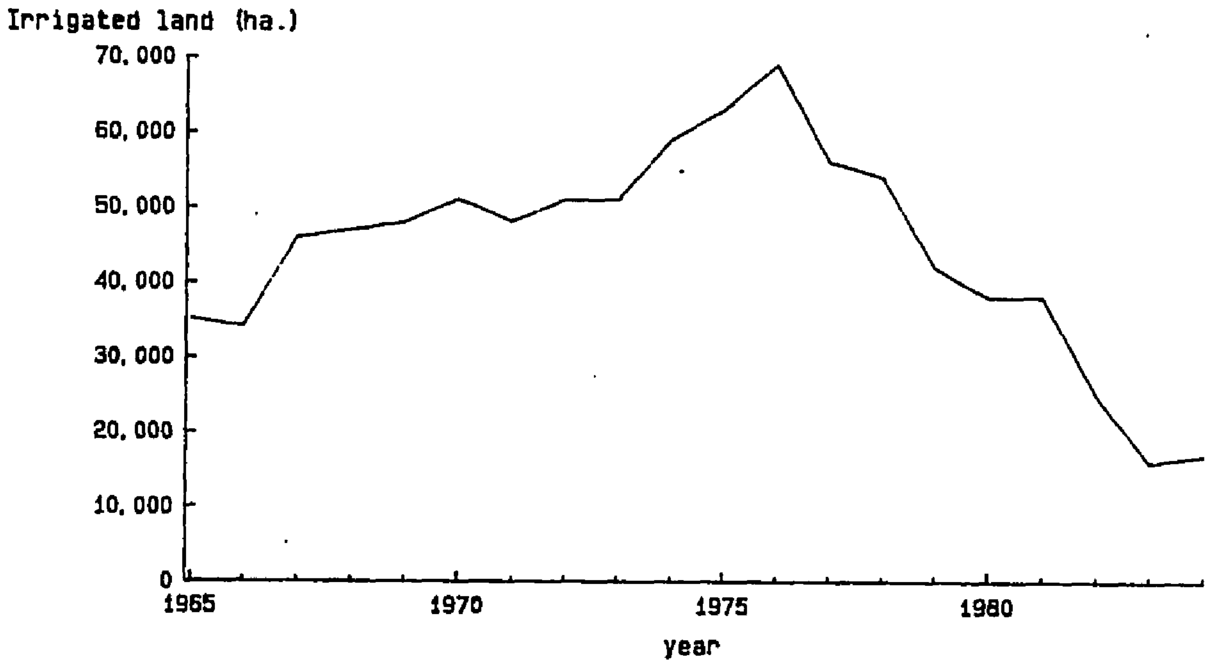

Figure 1. Amount of Harvested, Irrigated Farmland in Cochise County, Arizona (Arizona Crop and Livestock Reporting Service 1965–1984).

3) irrigated farmland is not typically retired for urban land use or other competitive uses;
4) the location and status of irrigated farmland in Cochise County as of the fall of 1984 had been mapped by the Office of Arid Lands Studies, University of Arizona, using remotely-sensed imagery;
5) availability of a recent Soil Conservation Service soil survey for the area; and,
6) availability of recent data on depth and change in depth of groundwater for the area.

The different boundaries of soil and groundwater data require two different study areas (Figure 2). The two major areas of farming within the Willcox Basin -- the Kansas Settlement-Cochise District and the Stewart District -- comprise a soil study area, which contains 66,259 hectares. Kansas Settlement-Cochise, the largest farming area comprising 47,685 hectares, extends east and southeast of the Willcox Playa and between the towns of Cochise and Pearce. The Stewart District, which is situated northwest from the town of Willcox, includes 18,574 hectares of land. With two exceptions these areas encompass all the farmland within the Willcox Basin. Various areas of farmland lying outside the limit of the soil survey are not within the soil study area. The lack of data on agricultural land within Graham County excludes this administrative area from study.

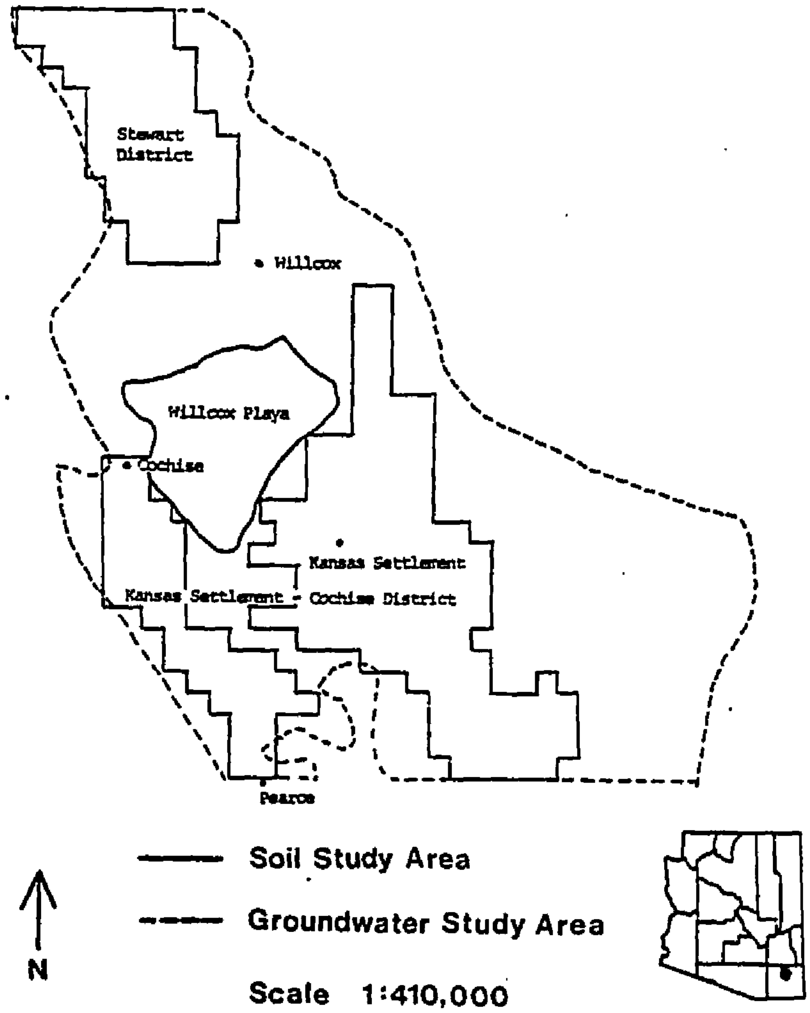

Figure 2. Soil and Groundwater Study Areas Within the Willcox Basin.

The groundwater study area, which contains 205,468 hectares of land, includes the Willcox Basin valley floor lying within Cochise County. It includes all farmland found within the soil study area and some farmland lying outside the soil study area in Cochise County, but excludes farmland within Graham County.

Land Use

The dominant land uses in the Willcox Basin are livestock grazing and irrigated agriculture (Richmond 1976). The cattle industry grew quickly and dominated the region during the 1870's. The first farming community, Kansas Settlement, was established in 1905 as the result of heavy precipitation that year. During the period beganning in 1910, both dry and irrigated farming were practiced. As precipitation levels returned to normal, farmers began to depend on groundwater pumping for a reliable water supply. The formation of a cooperative rural electrical system helped bring the total irrigated farmland to about 4,000 hectares by 1948 (Poulson 1954). Irrigated agricultural land increased rapidly with improved efficiency of motors for pumps. This was an important factor in the expansion of cropland upward on slopes where groundwater is deeper than near the playa. About 60,750 hectares were irrigated in the early 1970s (Richmond 1976, p. 70).

Crops grown in the area currently include corn, cotton, alfalfa, apples, lettuce, pecans, grain sorghum, wheat, and other vegetables and fruits (Arizona Crop and Livestock Reporting Service 1984).

Climate

The climate of the area is relatively arid, but is moderated somewhat by the elevation of the basin and by the nearby mountains. Precipitation is about 30 centimeters per year average in Willcox. The amount of precipitation increases gradually with elevation in the valley, from about 23 centimeters at the south end of the Willcox Playa to about 38 centimeters at the lower edge of the foothills (Richmond 1976, p. 71). There are two major periods of precipitation. Moderate to heavy afternoon thunderstorms provide more than half of the total annual precipitation from July through September. The period from October through March accounts for most of the remainder, which is frontal cyclonic. Normal agricultural production is seldom hindered by the late spring and fall dry periods.

The average annual temperature is about 16.0 degrees Celsius. Maximum temperatures range from 33 to 38 degrees Celsius in the summer months, while the winters are mild with minimum temperatures ranging typically between -4 and 2 degrees Celsius (Richmond 1976, p. 70).

The growing season in the Sulphur Springs Valley extends from mid-April to mid-October, and normally includes approxmately 180 frost-free days. This period is shorter than in most other Arizona farming areas because of the valley's higher elevation.

Physiography

The valley floor of the Willcox Basin is approximately 2,460 square kilometers in area and has an elevation of 1,260 meters at its lowest point, the Willcox Playa. The basin is underlain by the Willcox Aquifer, which consists of unconsolidated and moderately consolidated sedimentary deposits composed of gravel, sand, silt, and clay. The sedimentary deposits, which are composed of stream deposits and lake bed deposits, are the principal sources of groundwater. This is generally of good quality except for that under the Willcox Playa, which is highly saline.

Because of its dependence on groundwater, irrigated cropland is the greatest user of the Willcox Aquifer. Large scale withdrawal of groundwater has altered the direction of groundwater movement in and near the heavily pumped areas. It formerly flowed from the perimeter of Sulphur Springs Valley toward the Willcox Playa, but has changed towards the several pumping centers in the main agricultural areas (Mann, White, and Wilson 1975). Well yields ranging from about 750 to more than 13,250 liters per minute, depending on the thickness of penetrated gravel and sand beds, the size and depth of the well, and the size of the pump. The exact amount of groundwater available is not known (Richmond 1976).

The depth to groundwater has been gradually increasing since heavy pumping began in the mid 1950s. The groundwater depth varies from about 6 meters near the Playa to 135 meters at higher elevations (Hathorn 1985). Table 1 lists the approximate area and proportional extent of each groundwater depth class in the study area.

This change has been severe in some parts of the study area. Individual well levels have been reported to drop 1.5 to 2.5 meters in a given year (Richmond 1976, p. 70) and some areas have experienced a decline of over 30 meters in the past 30 years. Table 2 lists the approximate area and proportional extent of change in groundwater depth from 1963 to 1975.

Soils

The soils in the Willcox Basin can be divided into two major groups: those formed during the pluvial periods of Pleistocene time, and those formed afterward. The beach deposits of Pleistocene Lake Cochise and the alluvial fans, stream deposits, and erosional surfaces upslope mark the boundary between the two groups (Richmond 1976, p. 59). In general, the soils are fairly light-colored because of the relatively low organic-matter content, and somewhat reddish because of the high degree of oxidation and lack of hydration of the iron compounds.

The soils near the center of the basin formed from lacustrine material of Lake Cochise and its associated alluvial deposits. These soils are fine textured and poorly drained. Water tends to collect and stand on the surface, which has led to a reduction of iron and manganese and an accumulation of salts. Willcox Playa is devoid of vegetation because of the high level of

Table 1. Approximate Area and Proportional Extent of Groundwater Depth Classes in the Groundwater Study Area.

Groundwater Depth Class	Area (hectares)	Extent (%)
< 30.5 Meters	37,620	18.4
30.5 - 61 Meters	41,007	20.0
61 - 91.5 Meters	32,051	15.7
> 91.5 Meters	8,788	4.3
Unknown	71,276	34.8
Willcox Playa	13,864	6.8
Total	204,606	100.0

Table 2. Approximate Area and Proportional Extent of Change in Groundwater Depth Classes in the Groundwater Study Area.

Groundwater Depth Change Class	Area (hectares)	Extent (%)
< 7.5 Meters	44,577	21.7
7.5 - 15 Meters	14,883	7.2
15 - 30 Meters	29,340	14.3
> 30 Meters	2,649	1.3
Unknown	100,268	48.8
Willcox Playa	13,751	6.7
Total	205,468	100.0

sodium and potassium salts.

Immediately upslope from the Lake Cochise deposits of are deep, well-drained, moderately alkaline soils with accumulations of calcium carbonate. While soils in higher areas have better natural drainage and are free of salts and alkali, calic horizons are found. Soils at higher elevations are frequently coarse in texture and of more irregular relief.

Many of the soils in the study area are not well suited for irrigated farmland. Those having certain inherent defects such as coarse texture, excessive permeability, low water-holding capacity, hardpan, and the saline-alkali soils adjacent to the Willcox Playa are avoided for agriculture.

Soils considered suitable for irrigated agriculture must be carefully managed to prevent damage. Minimum or limited tillage is practiced on many farms to lower costs of operation, to improve tilth, to prevent formation of a plowpan, and to obtain better water intake (Richmond 1976). Proper crop rotation and incorporation of crop residue, manures, and fertilizers into the soil improves the soils' relatively low amounts of organic matter and nitrogen. Phosphorus is available, but additional amounts are usually applied. Almost all soils are rich in potassium and mineral compounds such as lime carbonate and gypsum.

The study area contains 39 different soil types. Table 3 lists the approximate area and proportional extent of each soil type. The soils covering the greatest area are, in descending order, Pima loam, Tubac sandy clay loam, Gothard fine sandy loam, Karro loam, McAllister loam, and Elfrida silty clay loam. These six soils constitute 49.4 percent of the study area.

The Soil Conservation Service ranks soils by their suitability for field crops. The specific soil units are divided into eight capability classes, designated by Roman numerals I through VIII. The numerals indicate progressively greater limitations and narrower choices for practical use. Only classes I through IV are considered potentially irrigable (Richmond 1976, p. 30). These classes are described in Table 4. In the study area, all capability classes are represented by soil units except classes V and VIII. Table 5 lists the aggregation of study area soils by their classes.

Table 3. Approximate Area of Soil Types in the Soil Study Area.

Soil			Area (hectares)	Extent (%)
1.	Ca	Cave gravelly loam	76	0.12
2.	Cc	Cogswell clay loam	3,003	4.53
3.	Ce	Cogswell clay loam, alkali	402	0.61
4.	Cg	Cogswell clay	181	0.27
5.	CmA	Comoro sandy loam	3,108	4.69
6.	CnA	Comoro gravelly sandy loam, ls	576	0.87
7.	CnC	Comoro gravelly sandy loam, hs	138	0.21
8.	Co	Comoro sandy loam, alkali	180	0.27
9.	Cs	Cowan sandy loam	859	1.30
10.	Ct	Crot sandy loam	1,027	1.55
11.	Dr	Dry Lake loamy sand	756	1.14
12.	Du	Duncan loam	1,595	2.41
13.	Dv	Duncan loam, shallow	18	0.03
14.	Ef	Elfrida silty clay loam	4,210	6.35
15.	FoA	Forrest loam	2,477	3.74
16.	FrA	Forrest gravelly sandy clay loam, ls	467	0.70
17.	FrB	Forrest gravelly sandy clay loam, hs	56	0.24
18.	Fy	Frye sandy loam	1,790	2.70
19.	Go	Gothard fine sandy loam	5,562	8.39
20.	Gr	Grabe sandy loam	2,668	4.03
21.	Gs	Grabe loam	4,008	6.05
22.	Gt	Guest clay loam	2,521	3.80
23.	Gu	Guest clay	311	0.47
24.	Ka	Karro loam	4,730	7.14
25.	KbE	Kimbrough gravelly loam	110	0.17
26.	KhE	Kimbrough very cobbly loam	167	0.25
27.	Mc	McAllister loam	4,628	6.99
28.	Mk	McAllister loam, alkali	709	1.07
29.	Pm	Pima loam	7,126	10.76
30.	Pr	Pridham loam	380	0.57
31.	SnA	Sonoita sandy loam, ls	3,573	5.39
32.	SnB	Sonoita sandy loam, hs	122	0.19
33.	SoA	Sonoita gravelly sandy loam	154	0.23
34.	St	Stewart loam	280	0.42
35.	To	Torrifluvents	54	0.08
36.	TrC	Torrifluvents, hummocky	14	0.02
37.	TuA	Tubac sandy loam	1,515	2.29
38.	TwA	Tubac sandy clay loam	6,495	9.80
39.	Vn	Vinton loamy sand	57	0.09
Total			66,252	100.00

Table 4. Description of Soil Capability Classes (Richmond 1976).

Class I	- soils have few limitations that restrict their use.
Class II	- soils have moderate limitations that reduce the choice of plants or that require moderate conservation practices.
Class III	- soils have severe limitations that reduce the choice of plants, require special conservation practices, or both.
Class IV	- soils have very severe limitations that reduce the choice of plants, require very careful management, or both.
Class V	- soils are not likely to erode but have other limitations, impractical to remove, that limit their use largely to pasture, range, woodland, or wildlife.
Class VI	- soils have severe limitations that make them generally unsuited to cultivation and limit their use largely to pasture or range, woodland, or wildlife.
Class VII	- soils have very severe limitations that make them unsuited to cultivation and that restrict their use largely to pasture or range, woodland, or wildlife.
Class VIII	- soils and landforms have limitations that preclude their use for commercial plants and restrict their use to recreation, wildlife, water supply, or to esthetic purposes.

Table 5. Classification of Soil Types by Capability Classes in the Soil Study Area (Richmond 1976).

Class I	- Ef	Elfrida silty clay loam
	Gr	Grabe sandy loam
	Gs	Grabe loam
	Mc	McAllister loam
	Pm	Pima loam
Class II	- CmA	Comoro sandy loam
	Ka	Karro loam
	SnA	Sonoita sandy loam, ls
	SnB	Sonoita sandy loam, hs
Class III	- Cc	Cogswell clay loam
	Ce	Cogswell clay loam, alkali
	Cg	Cogswell clay
	CnA	Comoro gravelly sandy loam, ls
	CnC	Comoro gravelly sandy loam, hs
	Cs	Cowan sandy loam
	Dr	Dry Lake loamy sand
	FoA	Forrest loam
	FrA	Forrest gravelly sandy clay loam, ls
	FrB	Forrest gravelly sandy clay loam, hs
	Fy	Frye sandy loam
	Gt	Guest clay loam
	Gu	Guest clay
	Mk	McAllister loam, alkali
	SoA	Sonoita gravelly sandy loam
	TuA	Tubac sandy loam
	TwA	Tubac sandy clay loam
Class IV	- Pr	Pridham loam
Class VI	- KbE	Kimbrough gravelly loam
	Vn	Vinton loamy sand
Class VII	- Ca	Cave gravelly loam
	Co	Comoro sandy loam, alkali
	Ct	Crot sandy loam
	Du	Duncan loam
	Dv	Duncan loam, shallow
	Go	Gothard fine sandy loam
	KhE	Kimbrough very cobbly loam
	St	Stewart loam
	To	Torrifluvents
	TrC	Torriorthents, hummocky

METHODOLOGY

Although a review of agricultural statistics indicates that irrigated agriculture has declined substantially in Cochise County, current published data on the location and status of agricultural land is unavailable. The following method has been used to provide information.

Remote sensing products were chosen as a data source because they provide a temporal record of change along with location and extent of agriculture at a resolution that aggregate county statistics can not approach. While Reeves (1975) notes that land use data compiled over a period of years and stored for rapid retrieval can be mapped for several useful purposes, many agricultural studies are not possible today because historical records of field size, crop type, or production are not available. He concludes that studies based on detailed local data may hold promise for substantially improving agricultural theory.

Meitl, Hathaway, and Gregg (1983, p. 6) devised a terminology to describe rural lands removed from active agricultural uses. Three categories are used to define successive stages:

1) Seasonal withdrawal - reflects an operator's decision not to plant for temporary periods, normally because of fallowing, anticipated low market prices and government production control programs. These lands will remain under active management for agricultural purposes and have the capability to return to irrigated crop production in a short time.

2) Indefinite retirement - includes lands withheld or likely to be withheld from production for a period of years, but with the possibility of resuming production. Reasons are usually economic problems -- credit constraints, low market prices, high production costs -- not subject to correction by the operator under current conditions.

3) Abandonment - covers lands no longer occupied and/or farmed by agricultural operators and no longer being considered for further intensive agricultural use. While the contrast between farmland under active management (cropped or fallow) and inactive fields (retired or abandoned) is usually discernable with remote sensing, specific information on inactive agricultural field status beyond this resolution is subjective.

The Office of Arid Lands Studies, University of Arizona has mapped the location and status of agricultural lands in Cochise County (Karpiscak and Kennedy 1984). This information, derived from high altitude color photography taken in Fall 1984 by the Soil Conservation Service, was mapped at a scale of 1:120,000. Four categories were used to describe the status of farmland: active, fallow, retired and unknown. This unknown category was used when it was unable to determine if a field was fallow or retired.

To improve the accuracy of the agricultural status areal data for this study, individual field boundaries were identified on 1964 high altitude (1:20,000) black and white photography reproduced in the Soil Survey of Willcox Area, Arizona (Richmond 1976). These boundaries were mapped onto five topographic quadrangles (Cochise, Dos Cabezas, Pearce, Squaretop Hills and Willcox) at a scale of 1:62,500. This was accomplished by reproducing the topographic maps on mylar and transferring the field boundaries by the use of a Kargl reflecting projector. Farmland identified in the 1964 photography that was not indexed on the 1984 agricultural map was assumed to be retired. Base maps of agricultural field location and status were produced for the Kansas Settlement-Cochise and Stewart District areas. The Kansas Settlement-Cochise area map was compiled by combining the data derived from Cochise, Dos Cabezas, Pearce and Squaretop Hills topographic quadrangles. The Stewart District area map is comprised solely of data from the digitized Willcox topographic quadrangle.

The status and location of irrigated farmland was digitized from the topographic maps using an Earth Resources Data Analysis System (ERDAS) installed at the University of Arizona. This is a processing system for analyzing and displaying image map data. The digitizing subsystem allows the entry of coordinate data from mapped geographic information. These data were encoded into geometrically rectified files for overlay analysis. The State Plane Coordinate System was used for as a grid system for all locations of map information.

Soil map units at a scale of 1:20,000 were derieved from the Soil Survey of Willcox Area, Arizona (Richmond 1976). The Kansas Settlement-Cochise District mapped soil units are depicted in Figure 3, while Stewart District mapped soil units are depicted in Figure 4. Data on groundwater depth as of 1975 and change in groundwater depth from 1963 to 1975 at a scale of 1:250,000 were obtained from maps showing groundwater conditions in the Willcox Area, Cochise and

Graham counties (Mann, White and Wilson 1975). These mapped groundwater units are depicted for the entire study area in Figures 5 and 6. Soil survey and groundwater data of the study area were similarly entered into ERDAS. The coincidence of agricultural status data with each soil unit and groundwater depth level was compiled through overlay analysis. The overlay analysis involved a cell-wise comparison from two or more thematic overlays, which are cross tabulated.

These data were analyzed using Chi-square analysis to test the randomness of the coincidence of physical variables with agricultural status. Although Chi-square tests are used for making inferences from sample data to conditions existing in the larger population, Winch and Campbell (1969) feel it is also appropriate to use for decision making when data from an entire population is available.

Because of the strong influence that sample size has upon Chi-square, this test measures only whether the variables are independent or related, not how strongly they are related. Cramer's V is used to test for this purpose. Cramer's V is a slightly modified version of phi, which is suitable for larger tables. In this statistical test, Cramer's V ranges from 0 when no relationship exists, to +1 when a perfect relationship exists. However, a large value of Cramer's V signifies only that a high degree of association exists without revealing the manner in which the variables are associated (Nie 1975, p.224).

Figure 3. Agricultural Class Map of Kansas Settlement-Cochise District.

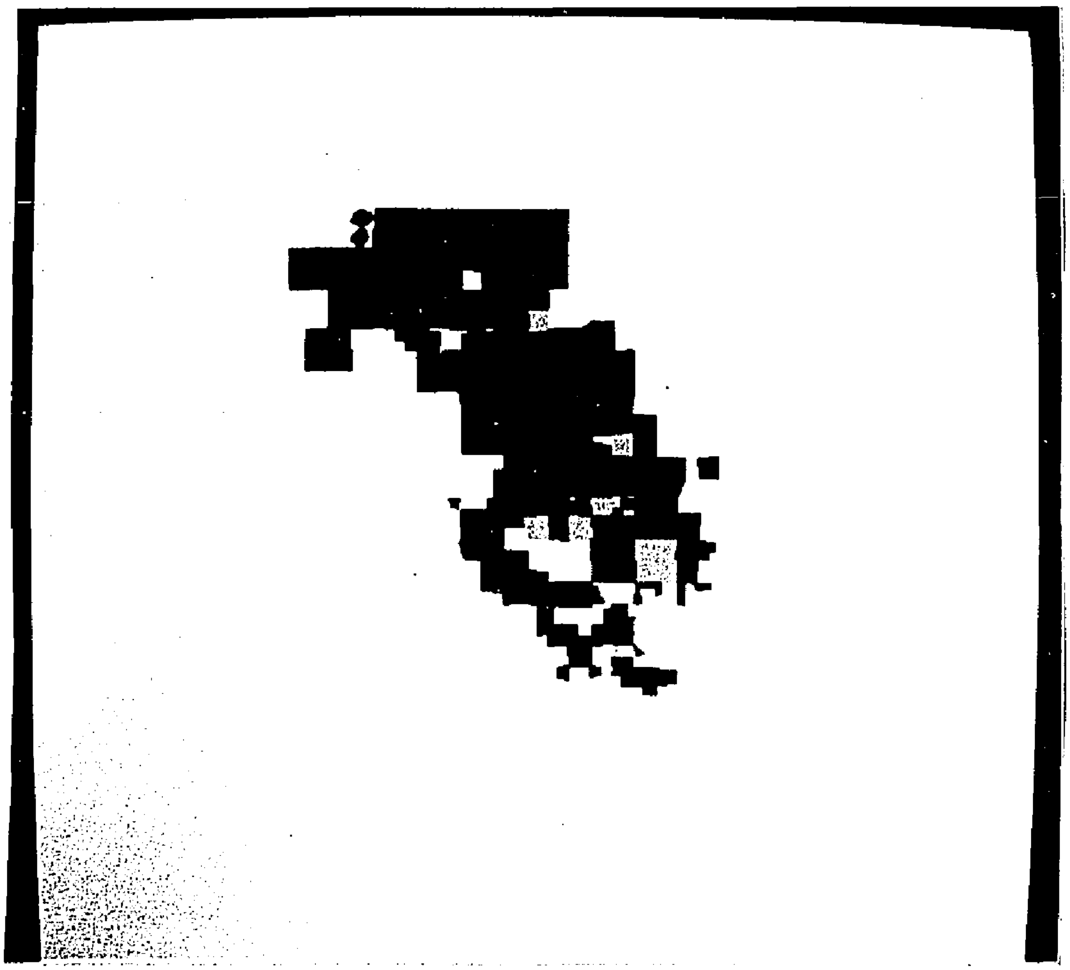

Figure 4. Agricultural Class Map of Stewart District.

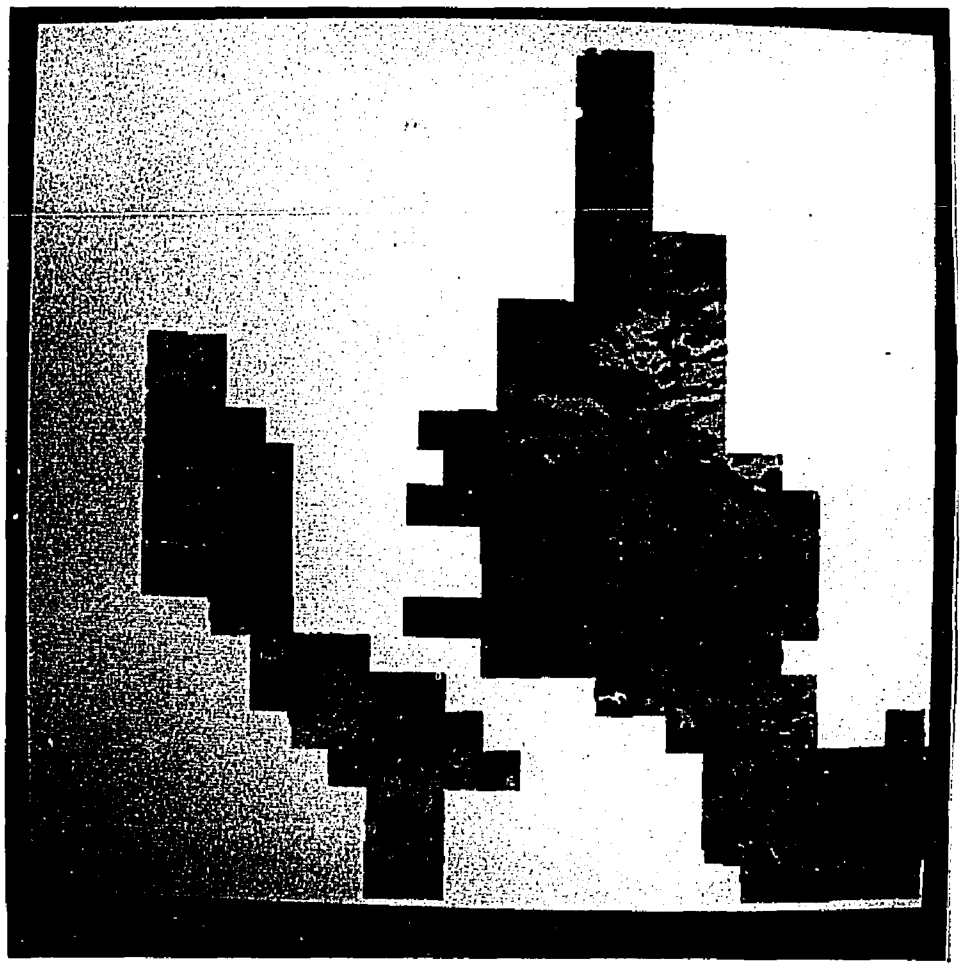

Figure 5. Soil Map of Kansas Settlement-Cochise District.

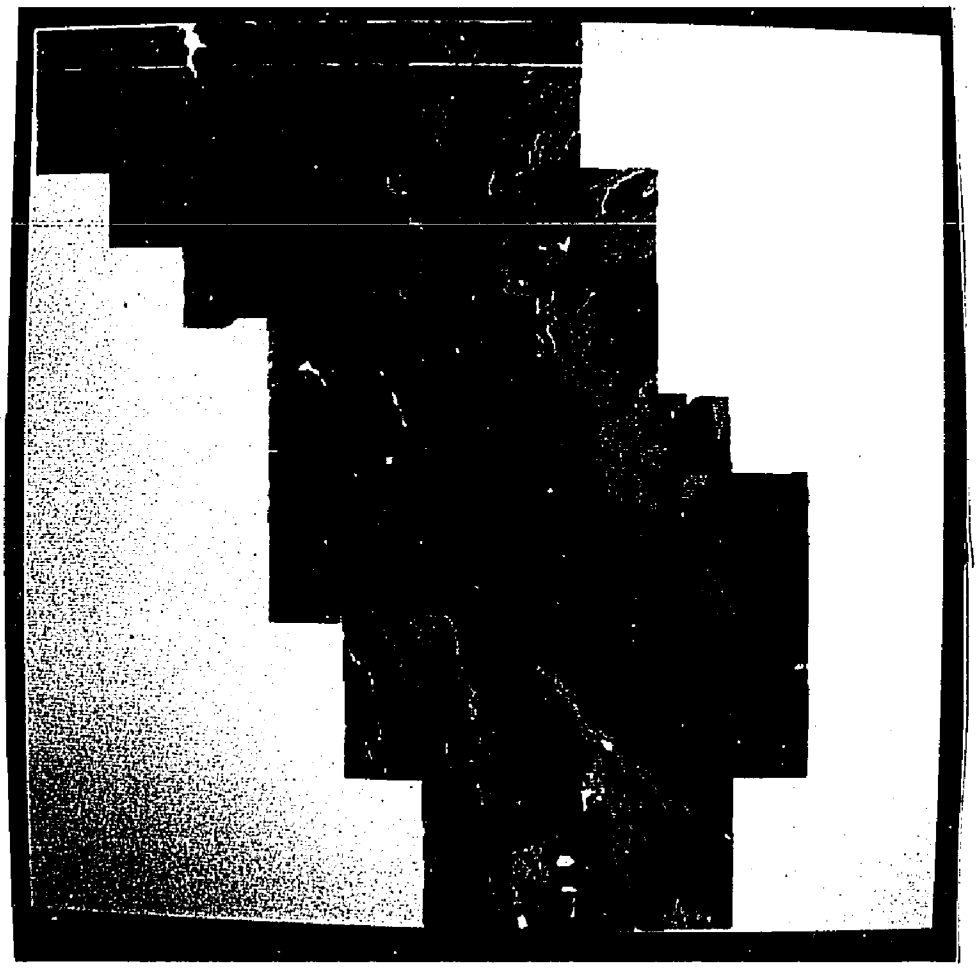

Figure 6. Soil Map of Stewart District.

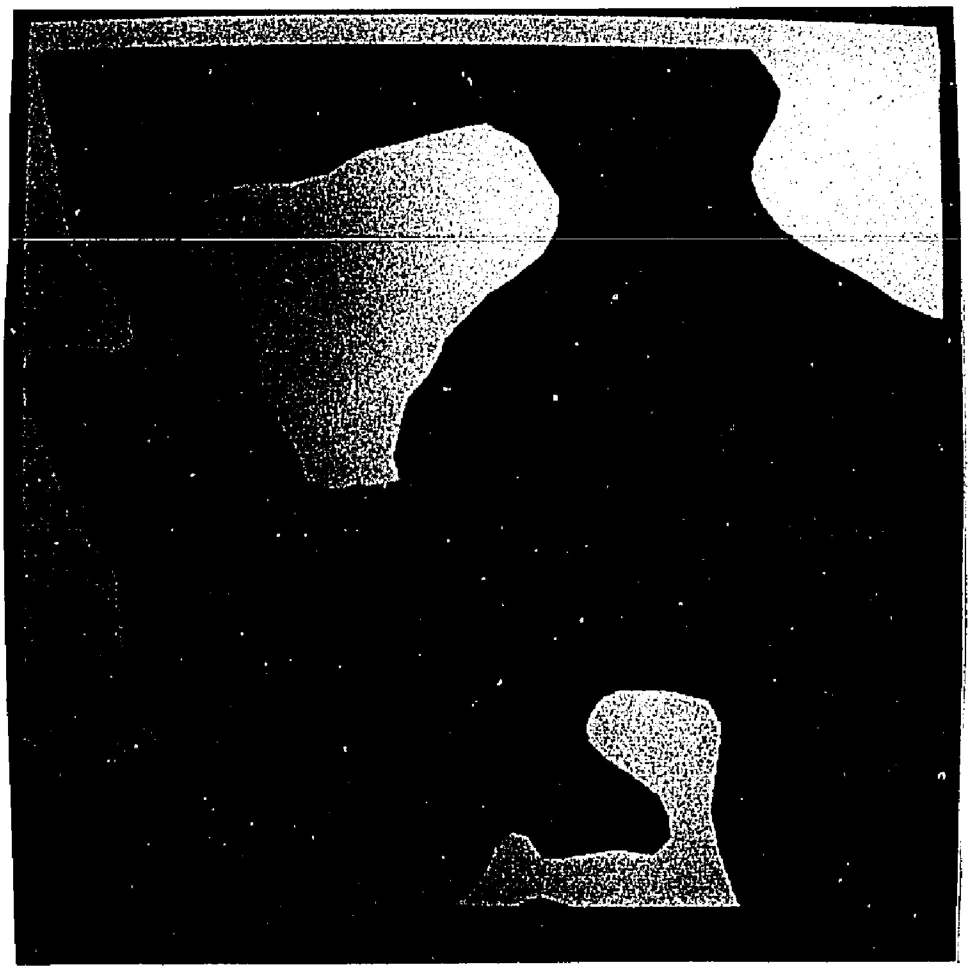

Figure 7. Groundwater Depth Map of Groundwater Study Area.

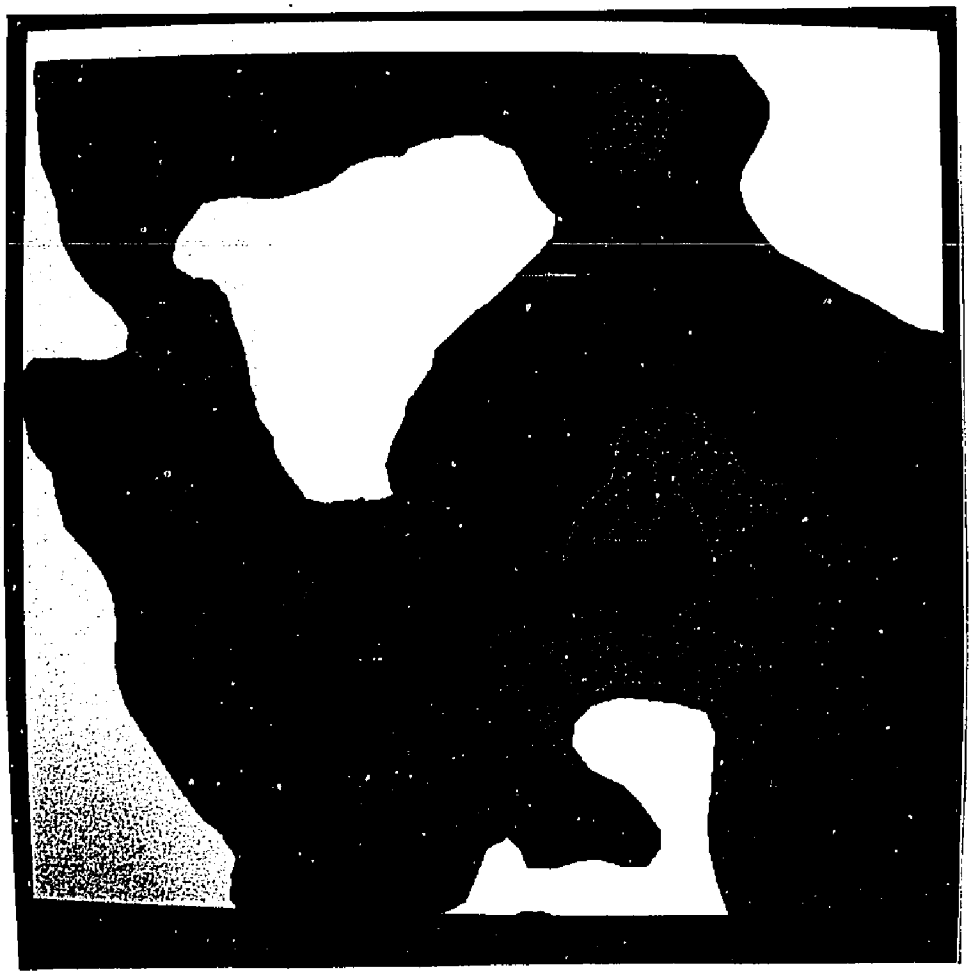

Figure 8. Change in Groundwater Depth Map of Groundwater Study Area.

RESULTS

Soils and Farmland Retirement

A total of 33,599 hectares of agricultural land were identified in the study area. Table 6 shows the breakdown of this area by agricultural class, while Table 7 depicts the breakdown of the Kansas Settlement-Cochise and Stewart District study areas into agricultural classes.

Soil Type and Retirement of Farmland

Thirty-three soil units coincide with farmland in the study area. The coincidence of each soil unit by class of irrigated farmland was determined with overlay tabulation on a cell-by-cell basis, with cells of approximately 0.5718 hectares each. Table 8 shows this cell tabulation for the study area.

The soils coinciding the most with agriculture are, in descending order, Pima loam, Tubac sandy clay loam, Grabe loam, Karro loam, Elfrida silty clay loam and Grabe sandy loam. Together, these soils compose 55.8 percent of the agricultural land in the study area. The soils with the greatest area of retired farmland are, in descending order, Tubac sandy clay loam, Pima loam, Gothard fine sandy loam, Grabe loam, Grabe sandy loam and Karro loam. These soils coincide with 53.5 percent of the the retired agricultural land in the study area.

Table 6. Approximate Area and Extent of Agricultural Classes in the Soil Study Area.

Agricultural Class	Area (hectares)	Extent (%)
Active	6,840	20.4
Fallow	6,228	18.5
Retired	18,906	56.3
Unknown	1,625	4.8
Total	33,599	100.0

Table 7. Approximate Area and Extent of Agricultural Classes in the Kansas Settlement-Cochise and Stewart Districts.

Class	Kansas Settlement-Cochise		Stewart	
	Area (hectares)	Extent (%)	Area (hectares)	Extent (%)
Active	6,063	19.8	777	25.9
Fallow	5,935	19.4	293	9.7
Retired	17,140	56.0	1,766	56.7
Unknown	1,454	4.8	171	5.7
Total	30,592	91.0	3,007	9.0

Table 8. Cell Coincidence of Soil Types and Agricultural Classes In the Soil Study Area.

Soil	Active	Fallow	Retired	Unknown	Total
1) Cave gravelly loam	0	0	8	4	12
2) Cogswell clay loam	491	58	888	16	1,453
3) Cogswell clay loam, alk.	237	0	122	152	511
4) Cogswell clay	225	89	3	0	317
5) Comoro sandy loam	699	692	1,702	164	3,257
6) Comoro grav. sandy loam, ls	92	106	227	29	454
7) Comoro grav. sandy loam, hs	10	0	37	0	47
8) Cowan sandy loam	208	168	301	26	703
9) Crot sandy loam	69	17	99	0	185
10) Dry Lake loamy sand	133	62	161	53	409
11) Duncan loam	2	0	0	0	2
12) Elfrida silty clay loam	1,211	1,289	1,465	245	4,210
13) Forrest loam	453	448	1,574	66	2,541
14) Forrest grav. sd. clay loam	38	57	382	14	491
15) Frye sandy loam	361	128	986	157	1,632
16) Gothard fine sandy loam	195	127	2,295	8	2,625
17) Grabe sandy loam	706	685	1,983	231	3,605
18) Grabe loam	1,168	1,233	1,986	352	4,739
19) Guest clay loam	286	410	1,751	14	2,461
20) Guest clay	39	92	365	0	496
21) Karro loam	1,323	844	1,888	326	4,381
22) Kimbrough very cobbly loam	0	0	22	0	22
23) McAllister loam	477	591	1,692	147	2,907
24) McAllister loam, alkali	0	0	54	0	54
25) Pima loam	1,792	1,417	4,397	393	7,999
26) Pridham loam	3	0	628	0	631
27) Sonoita sandy loam, ls	508	896	1,533	39	2,976
28) Sonoita sandy loam, hs	6	1	64	0	71
29) Sonoita gravelly sandy loam	3	4	176	0	183
30) Stewart loam	0	0	3	0	3
31) Torrifluvents	0	0	34	5	39
32) Tubac sandy loam	134	257	1,098	19	1,508
33) Tubac sandy clay loam	1,093	1,219	5,136	380	7,828
Totals	11,962	10,890	33,062	2,840	58,754

Some soils coincide with low percentages of retired farmland. These include Cogswell clay (1.0 percent), Cogswell clay loam, alkali (29.7 percent), Elfrida silty clay loam (34.8 percent), Dry Lake loamy soil (39.4 percent) and Grabe loam (41.9 percent). Others such as Kimbrough very cobbly loam (100.0 percent), McAllister loam, alkali (100.0 percent), Pridham loam (99.5 percent), Sonoita gravelly sandy loam (96.2 percent), Sonoita sandy loam, high slope (90.1 percent), Gothard fine sandy loam (87.4 percent) and Torrifluvents (87.2 percent) have the majority of agricultural land found on them retired. This suggests that with respect to soil type the retirement of agricultural land is not random.

A Chi-square analysis of this relationship shows an association between retirement of agricultural land and soil type: rejection of independence at the .005 level requires a Chi-square greater than 53.672 (degrees of freedom: 30); however, the measured Chi-square value across the 31 soil units is 2146.1 (Table 9). From this test, the null hypothesis of randomness in association is rejected. There is, therefore, a definite relationship between soil type and the retirement of agricultural land in the soil study area. Cramer's V has a value of 0.2549, indicating a moderate relationship.

When the area of retired agricultural land is compared with the distribution of soils, coincidence of the retired farmland with soils significantly exceeds that expected due to chance. This

Table 9. Chi-square Summary for Retired Agricultural Land and Soil Types.

Soil Type			Observed	Expected
1.	Ca	Cave gravelly loam	8	7
2.	Cc	Cogswell clay loam	888	818
3.	Ce	Cogswell clay loam, alkali	122	287
4.	Cg	Cogswell clay	3	178
5.	CmA	Comoro sandy loam	1,702	1,833
6.	CnA	Comoro gravelly sandy loam, ls	227	256
7.	CnC	Comoro gravelly sandy loam, hs	37	27
8.	Cs	Cowan sandy loam	301	396
9.	Ct	Crot sandy loam	99	104
10.	Dr	Dry Lake loamy sand	161	230
11.	Ef	Elfrida silty clay loam	1,465	2,369
12.	FoA	Forrest loam	1,574	1,430
13.	FrA	Forrest gravelly sandy clay loam, ls	382	276
14.	Fy	Frye sand loam	986	918
15.	Go	Gothard fine sandy loam	2,295	1,477
16.	Gr	Grabe sandy loam	1,983	2,029
17.	Gs	Grabe loam	1,986	2,667
18.	Gt	Guest clay loam	1,751	1,385
19.	Gu	Guest clay	365	279
20.	Ka	Karro loam	1,888	2,465
21.	KhE	Kimbrough very cobbly loam	22	12
22.	Mc	McAllister loam	1,692	1,636
23.	Mk	McAllister loam, alkali	54	30
24.	Pm	Pima loam	4,397	4,501
25.	Pr	Pridham loam	628	355
26.	SnA	Sonoita sandy loam, ls	1,533	1,675
27.	SnB	Sonoita sandy loam, hs	64	40
28.	SoA	Sonoita gravelly sandy loam	176	103
29.	To	Torrifluvents	34	22
30.	TuA	Tubac sandy loam	1,098	849
31.	TwA	Tubac sandy clay loam	5,138	4,405

relationship is the strongest of any of the physical variables compared. As hypothesized, generally, soils with severe limitations to use for irrigated cultivation are more likely to have a greater percentage of retired farmland than soils with few or moderate limitations for use. Examples of this pattern are Elfrida silty clay loam, a Class I soil had 904 less cells of retired agricultural land than expected, while at the other end of the spectrum, Gothard fine sandy loam, a Class VII soil not recommended for irrigated farming had 818 more cells of retired agricultural land than expected. A possible explanation for farmland being located on soils such as Gothard fine sandy loam, which tend to surround the Willcox Playa, are the small pump lifts which may have influenced farmers to cultivate the saline-alkali soils in this area.

Capability Classes and Retirement of Farmland

Capability classes considered potentially farmable are in desending order of irrigability, I through IV, while Classes V through VIII have physical limitations that make then largely unsuitable to cultivation. Within the study area, capability classes are represented by soil units coinciding with agricultural land except classes V, VI, and VIII. The other classes are represented by at least four soil units with the exception of Class IV, which contains only a single soil unit. Aggregating the soil units by capability classes shows that the greatest amount of farming in the study area is done on soils with few or moderate limitations to use as in Classes I, II and III, while relatively little is found on Class IV soils, with their more severe limitations to use. Suprisingly, a substanial amount of agricultural land is located on Class VII soils on which irrigated farming is not recommended (Richmond 1976). Data on map cell coincidence between capability class and farmland status are listed in Table 10.

For a null hypothesis of randomness, these data show more area of farmland to be active or fallow than expected in Classes I and II, while less than expected is active or fallow in Classes III, IV and VII. Consequently, less than the expected amount of retired farmland is located on Class I and II soils, while more is on Class III, IV and VII soils. Table 11 shows the percentages of each farmland status within each capability class. A very large percentage of retired land is in Classes IV and VII. These data suggest the relationship between agricultural retirement and capability classes may not be random.

A Chi-square analysis of this relationship shows an association between retired farmland and capability classes: rejection of independence at the .005 level requires a Chi-square greater than 14.860 (degrees of freedom: 4); however, the measured Chi-square value across the five capability classes is 1131.0 (Table 12). On this basis, the null hypothesis of randomness in association is rejected. There is, therefore, a relationship between agricultural capability class and the retirement of agricultural land in the soil study area. Cramer's V shows a weak

Table 10. Cell Coincidence of Capability Classes and Agricultural Classes in the Soil Study Area.

	Active	Fallow	Retired	Unknown	Total
Class I	5,354 44.76%	5,215 47.89%	11,523 34.85%	1,368 48.17%	23,460 39.93%
Class II	2,536 21.20%	2,433 22.34%	5,187 15.69%	529 18.63%	10,685 18.19%
Class III	3,803 31.79%	3,098 28.45%	13,263 40.12%	926 32.61%	21,090 35.90%
Class IV	3 0.02%	0 0.00%	628 1.90%	0 0.00%	631 1.07%
Class VII	266 2:22%	144 1.32%	2,461 7.44%	17 0.59%	2,888 4.92%
Totals	11,962 100.0%	10,890 100.0%	33,062 100.0%	2,840 100.0%	58,754 100.0%

Table 11. Percentage of Agricultural Classes Within Each Capability Class in Soil Study Area.

	Active	Fallow	Retired	Unknown	Total
Class I	22.82%	22.23%	49.12%	5.83%	100.0%
Class II	23.73%	22.77%	48.55%	4.95%	100.0%
Class III	18.03%	14.69%	62.89%	4.39%	100.0%
Class IV	0.48%	0.00%	99.52%	0.00%	100.0%
Class VII	9.21%	4.99%	85.22%	0.59%	100.0%
Total	20.36%	18.54%	56.27%	4.83%	100.0%

relationship between retired agriculture and soil capability class with a value of 0.1850.

When the area of retired agricultural land is compared with the distribution of soils aggregated into agricultural capability classes, the coincidence of retired farmland with capability classes significantly exceeds that expected due to chance alone. This relationship is not as strong as that between soil type and retired agricultural land. Aggregating the soils into capability classes tends to smooth out individual soil descrepancies. As hypotheized, soil capability classes with severe limitations for use in irrigated cultivation are more likely to have a greater percentage of retired farmland than soil capability classes with few or moderate limitations.

Reasons for this may include many factors such as available water capacity, permeability, texture, depth of root zone, presence of salts and alkali, need for drainage and hazards of erosion and deflation that place soils into capability classes with few agricultural limitations. This classification makes them more economically viable for irrigated farmland because of lower water useage, lower management costs and generally higher crop yields (Richmond 1976, p. 35).

Groundwater and Farmland Retirement

A total of 43,696 hectares of agricultural land are identified in the groundwater study area. Table 13 shows the

Table 12. Chi-square Summary for Retired Agricultural Land and Soil Capability Class.

Soil Capability Class	Observed	Expected
I	11,523	13,201
11	5,187	6,013
III	13,263	11,867
IV	628	355
VII	2,461	1,625

Table 13. Approximate Area and Extent of Agricultural Classes in the Groundwater Study Area.

Agricultural Class	Area (hectares)	Extent (%)
Active	9,456	21.64
Fallow	7,184	16.44
Retired	24,886	56.95
Unknown	2,170	4.97
Total	43,696	100.00

breakdown of this farmland by agricultural classes.

Depth to Groundwater and Retirement of Farmland

The shallowest groundwater is found in a belt surrounding Willcox Playa. The deepest groundwater levels are found in areas to the east and southeast of the Kansas Settlement, north of Pearce and along both upland areas of the valley near Graham County.

These data in the are divided into five categories of depth to water: less than 30.5 meters, 30.5 to 61 meters, 61 to 91.5 meters, greater than 91.5 meters and unknown depth. The cellwise coincidence between groundwater depths and agricultural classes is given in Table 14. The greatest amount of irrigated farmland is located in areas where the groundwater depth is between 30.5 and 61.5 meters below the surface. The greatest amount of retired farmland is also in this category.

The percentage of each agricultural class within groundwater depth class is presented in Table 15. Farmland with groundwater depths of 61 to 91.5 meters and in areas with no data have, for a random association, greater than expected amounts of retired farmland. All other groundwater classes have less retired farmland than would be expected. Suprisingly, the areas with the deepest groundwater depth (greater than 91.5 meters), have the lowest percentage of retired agriculture. These data indicate that the relationship between groundwater depth and agricultural retirement is not random.

Table 14. Cell Coincidence of Groundwater Depth Classes and Agricultural Classes in Groundwater Study Area.

Class	Active	Fallow	Retired	Unknown	Total
> 30.5 Meters	2,361 14.28%	1,070 8.52%	5,720 13.14%	1,080 28.46%	10,231 13.39%
30.5 - 61 Meters	10,284 62.19%	5,098 40.58%	17,299 39.75%	1,396 36.79%	34,077 44.59%
61 - 91.5 Meters	2,501 15.12%	3,650 29.05%	16,106 37.01%	726 19.13%	22,983 30.08%
> 91.5 Meters	804 4.86%	2,570 20.46%	2,198 5.05%	439 11.57%	6,011 7.87%
No Data	587 3.55%	176 1.40%	2,200 5.05%	154 4.06%	3,117 4.08%
Total	16,537 100.00%	12,564 100.00%	43,523 100.00%	3,795 100.00%	76,419 100.00%

Table 15. Percentage of Agricultural Classes Within Groundwater Depth Classes.

Class	Active	Fallow	Retired	Unknown	Total
< 30.5 Meters	23.08%	10.46%	55.91%	10.56%	100.00%
30.5 - 61 Meters	30.18%	14.96%	50.76%	4.10%	100.00%
61 - 91.5 Meters	10.88%	15.88%	70.08%	3.16%	100.00%
> 91.5 Meters	13.38%	42.76%	36.57%	7.30%	100.00%
No Data	18.83%	5.65%	70.58%	4.94%	100.00%
Total	21.64%	16.44%	56.95%	4.97%	100.00%

A Chi-square analysis of this relationship shows an association between retired agriculture and groundwater depth: rejection of independence at the .005 level requires a Chi-square greater than 14.860 (degrees of freedom: 4); however, the measured Chi-square value across the five groundwater depth classes is 1466.9 (Table 16). On this basis, the null hypothesis of randomness in association is rejected. There is, therefore, a relationship between groundwater depth and the retirement of agricultural land in the groundwater study area. Cramer's V, shows a weak relationship between groundwater depth and retirement of farmland with a value of 0.1836.

The coincidence of area of retired agriucltural land and the distribution of groundwater depth significantly exceeds that expected due to chance. This relationships strength is similar to that found between retired agricultural land and soil capability classes. As hypothesized, the second deepest groundwater depth class had a very high percentage of retired farmland, while shallower areas had lower percentages of retired farmland. Contrary to the hypothesis, the deepest groundwater depth class had the lowest percentage of retired farmland.

While shallow groundwater depth and its associated lower energy cost are a positive factor for the farm operator, deep groundwater levels and their higher energy costs can be compensated for by other factors. These areas of deep groundwater levels are located in the main agricultural centers. These areas contain some of the most suitable agricultural soils in area. Other factors such as size of the farm operation and its related ability to obtain credit could also have a significant impact. Credit is important not only to pay farm debts, but in a farmers ability to improve profit by planting resource-intensive fruit and nut crops and installling their associated drip irrigation systems that use substantially less water than irrigation systems for field crops. Many of the surviving farms in the study area have converted to this new crop profile and are pumping less groundwater which has resulted in lower energy costs, or using a similar amount of water as before but are getting a larger monetary return on their crops.

Change in Depth to Groundwater and Retirement of Farmland

Groundwater withdrawls have resulted in general declines of groundwater depths, particularly in the most intensely developed agricultural areas. The greatest decline in groundwater level has occurred south and southeast of the Kansas Settlement, northeast of Pearce and along the border of Graham County. These are major areas of groundwater pumping. The cell coincidence of agricultural status and change in groundwater level from 1963-1975 for the study area is shown in Table 17.

The greatest area of farmland is located in the 15-to-30 meter groundwater depth change class, while moderate areas are found in all the other classes with the exception of the less-than-30 meter class. The distribution of retired farmland follows a similar

Table 16. Chi-square Summary For Retired Agricultural Land and Groundwater Depth Class.

Groundwater Depth Class	Observed	Expected
< 30.5 Meters	5,720	5,827
30.5 - 61 Meters	17,299	19,408
61 - 91.5 Meters	16,106	13,090
> 91.5 Meters	2,198	3,424
No Data	2,200	1,775

Table 17. Cell Coincidence of Change in Groundwater Depth and Agricultural Classes in the Groundwater Study Area.

Class	Active	Fallow	Retired	Unknown	Total
< 7.5 Meters	5,069 30.65%	2,088 16.62%	8,623 19.81%	1,455 38.34%	17,235 22.55%
7.5 - 15 Meters	3,096 18.72%	1,781 14.18%	6,260 14.38%	172 4.53%	11,309 14.80%
15 - 30 Meters	3,727 22.54%	4,773 38.00%	19,958 45.86%	1,026 27.04%	29,484 38.58%
> 30 Meters	701 4.24%	1,383 11.01%	1,754 4.03%	376 9.91%	4,214 5.51%
No Data	3,944 23.85%	2,539 20.21%	6,928 15.92%	766 20.19%	14,177 18.55%
Total	16,537 100.00%	12,564 100.00%	43,523 100.00%	3,795 100.00%	76,419 100.00%

pattern. The percentage of each agricultural status class within each depth change class (Table 18) shows this 15-to-30 meter groundwater change class is the only one with more retired agriculture than expected. The class showing the largest groundwater decline has the lowest percentage of retired agricultural land. As the depth change class with the greatest decline was expected to have the highest percentage of retired land, this is contrary to the hypothesis. These data indicate that the relationship between agricultural land retirement and groundwater depth change are not random.

A Chi-square analysis of this relationship shows an association between retired agricultural land and change in groundwater depth classes: rejection of independence at the .005 level requires a Chi-square greater than 14.860 (degrees of freedom: 4); however the measured Chi-square value across the five groundwater depth change classes is 1083.6 (Table 19). On this basis, the null hypothesis of randomness in association is rejected. There is, therefore, a relationship between groundwater depth change and the retirement of agricultural land in the groundwater study area. Cramer's V, shows a relationship of weak strength with a value of 0.1579.

The coincidence of area of retired agricultural land and the distribution of groundwater depth change significantly exceeds that expected due to chance. While this relationship is the weakest of any physical variable compared with retired agricultural land, it

Table 18. Percentage of Agricultural Classes Within Each Change in Groundwater Depth Class.

Class	Active	Fallow	Retired	Unknown	Total
< 7.5 Meters	29.41%	12.11%	50.03%	8.44%	100.00%
7.5 - 15 Meters	27.38%	15.75%	55.35%	1.52%	100.00%
15 - 30 Meters	12.64%	16.19%	67.69%	3.48%	100.00%
> 30 Meters	16.64%	32.82%	41.62%	8.92%	100.00%
No Data	27.82%	17.91%	48.87%	5.40%	100.00%
Total	21.64%	16.44%	56.95%	4.97%	100.00%

Table 19. Chi-square Summary for Retired Agricultural Land and Change in Groundwater Depth Class.

Groundwater Depth Change Class	Observed	Expected
< 7.5 Meters	8,623	9,816
7.5 - 15 Meters	6,260	6,441
15 - 30 Meters	19,958	16,792
> 30 Meters	1,754	2,400
Unknown	6,928	8,074

shows a pattern similar to the relationship between groundwater depth and retired farmland. As hypothesized, the second deepest groundwater decline class had a very high percentage of retired agricultural land, while groundwater classes with lesser changes had lower percentages of retired agricultural land. Contrary to the hypothesis, the largest groundwater depth change class had the smallest percentage of retired farmland.

While small or no change in groundwater depth is a positive factor for the farm operator, large changes in groundwater depth can be compensated for by other factors. These areas of the largest groundwater declines are mainly located in the main agricultural centers. Factors discussed in the groundwater depth section such as more suitable soils and the possability of a greater access to credit in these areas are also relevant with declines in groundwater levels.

CONCLUSION

The results of this study support the hypothesis that the retirement of irrigated farmland in Southern Arizona is influenced by one or more measureable physical variables: soil irrigability, groundwater depth and change in groundwater depth. Analysis of data indicates that retirement of agricultural land is more likely on soils with greater agricultural limitations than on prime agricultural soils with few or moderate agricultural limitations. Reasons for this include the many inherent soil characteristics that make prime soils more economically viable for irrigated farmland.

The relationship between the retirement of agricultural land and groundwater conditions also provides some interesting results. While farmland retirement is less likely to occur in areas of shallow groundwater or small decline in groundwater depth, the relatively small areas of with the greatest depths or the largest declines in groundwater occured where the smallest amount of farmland was retired. These areas of deep groundwater are found in the primary agricultural areas. Factors such as prime agricultural soil, size of a farm operation and its influence on credit availability could have a significant impact on these areas.

The geographical method employed here uses comparison of spatial data to identify covariation between potentially related phenomena. While simple spatial coincidence does not substantiate a casual relationship, it provides a justification for more intensive study. The Earth Resources Data Analysis System (ERDAS) used in this study enabled a much larger population to be accurately sampled than could have been achieved by conventional methods.

Later studies could benefit from additional analysis of data and different sources of data. An overlay analysis showing the agricultural status, soil type and groundwater depth of each cell would be an improvement over this study's agricultural status - soil type and agricultural status - groundwater conditions cell information. This would enable interpretation of the soil type and groundwater data interaction to be less empirical. Data on the area and extent of individual farm land holdings, including portions under government production control and crop subsidy, would also improve a study of this nature. This would provide an indication of each farmer's availability of credit. It is widely accepted that farmers with large land holdings tend to have preferential access to credit because of their greater assets and their ability to convert appreciation in land values into credit worthiness (Buttel and Youngberg 1982). Credit is important not only in paying farm debts, but is important in allowing a farmer to plant resource-intensive fruit and nut cash crops and install associated drip irrigation systems that conserve water. However, information of this type is not readily available.

Geographical analysis of the association of retired agricultural land with soil and groundwater depth in southeastern Arizona provides some insights into the relationship between land use change and the physical environment. This study can be used not only for determining where agricultural land has been retired in the Willcox Basin, but for predicting which farm areas could be retired in the future. This information could help target and mitigate erosion, noxious weeds and other problems associated with retired agricultural land, and allow a change of these areas to productive lands for grazing or wildlife habitat.

As the region's crop profile slowly changes from domination by field crops such as cotton, sorghum and grains to more resource-intensive cash crops such as fruit, nut and specialty crops, this study will be useful identifying and mapping land with the most suitable soil and groundwater conditions for potential crops.

REFERENCES

Arizona Crop and Livestock Reporting Service. Annual. Arizona agricultural statistics. Phoenix: Arizona Crop and Livestock Reporting Service.

Arizona Water Commission. 1977. Arizona State Water Plan-Alternative Futures. Phoenix: Arizona Water Commission. 145 pp.

Buttel, Frederick H. and Youngberg, Garth I. 1982. "Energy policy and agriculture" in Food policy and farm programs. Montclair: Allanheld. 376 pp.

Carr, T.E. 1977. Agricultural response to changing water prices in Arizona. MA thesis, Department of Economics, University of Arizona, Tucson, Arizona. 62 pp.

Edwards, C.J.W. 1967. "The assessment of the quality of agricultural land in central Somerset" in Liverpool essays in geography. London: Longhams. pp. 461-477.

Famisa, Zacchaeus S. 1977. The conversion of agricultural land to non-agricultural uses in the Phoenix-Tucson corridor, 1940-75. PhD dissertation, Department of Geography, Arizona State University, Phoenix, Arizona. 149 pp.

Fravega, E.M. 1970. Farm land abandonment-problemic or polemic? Southeastern geographer 10(1): 55-61.

Frederick, Kenneth D. 1982. Water for western agriculture. Washington: Resources For the Future. 241 pp.

Green, D.E. 1973. Land of the underground rain: irrigation on the Texas high plains, 1910-1970. Austin: University of Texas Press. 295 pp.

Hart, John F. 1968. Loss and abandonment of cleared farm land in the eastern United States. Annals of the association of American geographers 58(12): 417-440.

Hathorn, Scott. 1985. Arizona pump water budgets: Cochise county. Tucson: College of Agriculture, University of Arizona. 99 pp.

Hecht, Melvin E. and Richard W. Reeves. 1981. The Arizona atlas. Tucson: Office of Arid Lands Study, University of Arizona. 164 pp.

Karpiscak, Martin and Tina Kennedy. 1985. Unpublished agricultural data for Cochise County. Tucson: Office of Arid Lands Study, University of Arizona.

Keith, Susan Jo. 1977. The impact of groundwater development in arid lands: a literature review and annotated bibliography. Tucson: Office of Arid Lands Study, University of Arizona. 39 pp.

Kelso, M.M., W.E. Martin, and L.E. Mack. 1973. Water supplies economic growth in an arid environment: an Arizona case study. Tucson: University of Arizona Press. 327 pp.

Mann, Larry J., Natalie D. White, and R.P. Wilson. 1975. Maps showing groundwater conditions in the Willcox area, Cochise and Graham counties, Arizona. Department of the Interior: United States Geological Society. 3 pp.

Martin, W.E. and T. Archer. 1971. Cost of pumping irrigated water in Arizona: 1891 to 1967. Tucson: Water Resources Research 7:1.

Meitl, J.M., P.L. Hathaway, and F. Gregg. 1983. Alternative uses of Arizona lands retired from irrigated agriculture. Tucson: Department of Agriculture, University of Arizona. 50 pp.

Nie, Norman H., et al. 1975. SPSS: statistical package for the social sciences. New York: McGraw-Hill Book Company. 675 pp.

Pifer, Joseph. 1969. Water table decline and resultant agricultural patterns in the Salt River valley of Arizona. Journal of geography 48: 545-549.

Poulson, E.N. 1954. Soil survey of the Sulphur Springs valley area, Arizona. Washington: United States Department of Agriculture. 129 pp.

Reeves, Robert G., ed. 1975. Manual of remote sensing. Falls Church, VA: American Society of Photogrammetry. 867 pp.

Richmond, Davie L. 1976. Soil survey of Willcox area, Arizona. Washington: United States Department of Agriculture. 71 pp.

Roet, Jeffrey B. 1985. Land quality and land alienation on the dry farming frontier. Professional geographer 37(2): 173-183.

Vogt, Kenneth D. 1980. Soil survey of San Simon area, Arizona. Washington: United States Department of Agriculture. 148 pp.

Winch, Robert J. and Donald T. Campbell. 1969. Proof? No. Evidence? Yes. The significance of tests of significance. The American sociologist 4: 140-143.