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El Milagro De Almeria, Espana: A Political Ecology of Landscape Change and Greenhouse Agriculture

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EL MILAGRO DE ALMERÍA, ESPAÑA:

A POLITICAL ECOLOGY OF LANDSCAPE CHANGE AND

GREENHOUSE AGRICULTURE

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Abstract

The purpose of this thesis is to investigate changes in the landscape of Almería in southeastern Spain, particularly in relation to the emergence of the 80,000-acre greenhouse sector. This thesis examines how the province of Almería has become the site of the greatest concentration of greenhouses in the world and identifies the processes that have led to this industry. The research focuses on local-global scale interactions and environmental history analysis within a political ecology framework. The methods for data collection included an analysis of secondary sources, interviews, and four months of fieldwork in Almería. Expanding on the geographer David Tout's 1980s research on Almería greenhouses, this thesis assesses historic and contemporary local-global exchanges, resource control, economic development, and technologies within the greenhouse sector. Located in Europe's driest desert, the greenhouses of Almería produce millions of tons of produce for European markets. Initially fueled by abundant aquifer water, the greenhouse sector is attempting to adapt to water scarcity through innovative methods of water conservation and the use of desalination. Moreover, the complex hydropolitics associated with the control and distribution of water highlight the importance of the greenhouse sector to various levels of government. This case study of the Almería greenhouse industry demonstrates the most recent iteration of an ongoing and profound trend of climate and landscape modifications by human actions in this part of the Mediterranean region.

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Chapter I
Introduction

El Milagro de Almería, or "The Miracle of Almería," is indicative of the drastic changes that have occurred in the province of Almería. Almería, Spain is located in the southeastern corner of Spain and is the furthest eastern province of *la Comunidad Autónoma de Andalucía* (the autonomous community of Andalucía) (see appendix IV for location maps). The northern part of Almería is a mountainous boundary dividing climatic zones between the relatively wet, cold, and vegetated Granada province and the arid, warm, and barren Almería landscape. The Spanish Sierra Nevada Mountains serve as a boundary that protects Almería from cold winter winds and storms, and correspondingly, the climatic conditions along with greenhouses allow Almería to produce summer crops during the winter months. The so called "miracle" that has taken place in the Almería landscape entails the transformation of this arid, sun scorched-land with a stagnated population into a booming province with 80,000 acres of greenhouse horticulture, an expanding wine and olive industry, rapidly growing population, and tourist or expat attractor for northern Europeans seeking the sunny, warm climate.

The purpose of this thesis is to investigate changes within the Almería landscape that have largely been driven by the rapid development and expansion of the greenhouse sector. The analysis focuses on local-global scale interactions and environmental history within a political ecology framework. Expanding on David Tout's 1980s research on Almería greenhouses allowed for comparisons between current and past issues, development, and technologies within the greenhouse sector. The processes that shaped the environmental history through local-global exchanges are unique to Almería. Similar to elsewhere in the Mediterranean region, Almería's environmental history has been influenced by human actions, resource extraction, and local-global market exchanges that have caused dramatic climatic and landscape alterations. Almería's history shows a timeline of reoccurring fundamental alterations in local ecology as the area has served as a zone of extraction for various resources. As the world struggles with rising food prices and climate change, Almería's greenhouses produce millions of tons of produce in

Europe's driest desert. The scale and expansive nature of the agriculture sector and the intensive water use raise fundamental questions about sustainability.

Research Questions and Approach

The 80,000 acres of plastic greenhouses covering Almería's two greenhouse-growing areas, the Campo de Dalias and Campo de Nijar, create one of a few visible human-made objects from space. Spanish greenhouse use is the second highest in the world after China, which has substantially more land and a higher population. The Campo de Dalias growing area has the highest concentration of greenhouses in the world with 60,000 acres. The "plastic sea" of greenhouses in the Campo de Dalias stretches for miles from the Barjali mountains to the Mediterranean Sea, and with the right sunlight glimmers like a body of water. This transformation to a region covered in plastic with a booming population has taken only forty years. For the fifty to hundred years prior to the introduction of greenhouses in Almería the province was the poorest of all Spain's fifty provinces and typically described as an "uninhabitable no man's land." The city of El Ejido located in the heart of the Campo de Dalias growing area had a population of 1000 in 1960. By 2007, the population was estimated at 100,000. The nearby capital city Almería now boasts a population of more than 189,798 and continues to grow each year (INE 2008). The contrasting views between the early descriptions of Almería compared to the importance and physical appearance of the province today are incredible for such a short time period.

The questions framing this research include the following: Why does the province of Almería contain the largest concentration of greenhouses in the world? How has Almería's environmental history influenced the landscape and the emergence of greenhouse agriculture? What recent factors, both environmental and social, have led to the boom in greenhouse agriculture since the geographer David Tout (1990) undertook research on the greenhouse industry in Almeria in the 1980s? How has the province and the government attempted to sustain 80,000 acres of greenhouse agriculture in light of water scarcity in an arid province?

Almería provides a regional example of the positive and negative impacts of greenhouse agriculture. New technologies that recycle water, use recycled growing mediums (substrate), encourage integrated pest management systems, and use renewable energy sources like wind and solar to power these greenhouses offer opportunities and examples of possible solutions to current industrial agriculture woes. The possibility of desalination using wind and solar is a proven tool for taking advantage of abundant salt water with fewer environmental downsides than other solutions (Garcia-Rodriguez 2003). Negative impacts associated with greenhouse agriculture center on issues that can be fixed by incorporating the technologies mentioned above and reducing energy-intensive systems.

The environmental history of Almería is one that reflects a long-term pattern of international control, either directly or indirectly, of natural resources. Governments and markets have taken advantage of Almerían resources with little regard to long-term environmental degradation, and instead focused strictly on the short-term economic gains. A region known for forests and a wide range of fauna during Roman times was transformed by human modification into an arid landscape. Almería offers an example of a region affected by years of intensive resource use and currently an example of how large-scale greenhouse agriculture affects the landscape.

In the long-term human-environment interactions in Almería, we see some tendencies of a society drifting towards 'collapse' as defined in Jared Diamond's thought-provoking, yet controversial, book *Collapse*. Here Diamond (2005, 3) defines collapse as a "drastic, decrease in human population size and/or political/social complexity, over a considerable area, for an extended time." The environment of Almería historically and in the contemporary context has been undermined by deforestation and habitat destruction, soil erosion, depletion of surface and groundwater, over hunting, human population growth, and recently the introduction of foreign species to combat invasive insects. Population growth and international markets for produce stimulated the intensification of agricultural production and the expansion of the greenhouses onto more and more land. In the past forty years, people and the government have inadvertently destroyed the environmental resources on which the greenhouse sector depends. Almería's history additionally shows different groups of people damaging the landscape beyond repair with no thought of the long-term affect they were having on the environment and the very resources they wanted.

Nevertheless, in contrast to Diamond's theory mentioned above, we see a province that has developed a successful agriculture sector in an unlikely place with innovative technologies. Diamond points to five factors that contribute to a society's possible collapse: environmental damage, climate change, hostile neighbors, friendly trade partners, and a society's responses to its environmental problems. Diamond's (2005, 15) fourth factor for possible collapse, "decreased support by friendly neighbors" arises "if your trade partner becomes weakened for any reason (including environmental damage) and can no longer supply the essential import or the cultural tie your own society may become weakened as a result" (ibid, 14). While Diamond's theory certainly offers an alternative perspective on "the miracle" of Almería and its dependencies on global markets and consumers, a systematic analysis of Almería using Diamond's model is beyond the scope of this thesis project. Rather, this study aims to uncover the negative and positive effects of the greenhouse sector of Almería from past, current, and possible future directions.

The world of agriculture is going in two separate directions. One way is toward sustainable, organic, local civic agriculture systems and the other way is chugging toward a continuation and enlargement of a globalized agriculture system (Lyson 2004). Short-term benefits will come with the latter for Almería, but will only heighten the dependency on foreign trade partners for the province. A turn to a local or regional agriculture system, while not an immediate money making undertaking, would be the best solution for Almería in the long-term. A more localized or regionalized "commitment to developing and strengthening an economically, environmentally, and socially sustainable system of agriculture and food production that relies on local resources and serves local market and consumers" should be the ultimate goal (ibid, 63).

Conceptual Framework

This thesis is structured around the political ecology framework and two analytical approaches: local-global scales of interaction and environmental history analysis. Political ecology is the framework guiding the analysis for this research. Political ecology combines a variety of data and methods of analysis with emphasis on extensive field work to determine influences behind ecological change. Political ecology has its roots in the 1970s work of the anthropologist Eric Wolf, the journalist Alexander Cockburn, and the environmental scientist Grahame Beakhurst (Peet and Watts 1996, 6). These three individuals coined political ecology as a way of "thinking about questions of access and control over resources," and how this was obligatory for "understanding both the forms of geography of environmental disturbance and degradation, and the prospects for green and sustainable alternatives" (ibid, 6). A new direction for political ecology in the 1990s was to "refine political economy within the circumference of political ecology." This connection would make a "rigorous and explicit connection between logics and dynamics of capitalist growth and specific environmental outcomes" (Peet and Watts 1996, 12). Michael Watts (2000, 257), one of the foremost political ecologists, provides us with this definition of political ecology: "to understand the complex relations between nature and society through a careful analysis of what one might call the forms of access and control over resources and their implications for environmental health and sustainable livelihoods."

Most work undertaken by political ecologists has focused on problems in developing countries, yet more recently interest has turned to the global north for research. Using the framework of political ecology, I assess how changes in the Almería landscape and the greenhouse water systems have happened and the ways political systems have played a role in these changes. The political systems affecting the landscape and water systems include organizations of local greenhouse farmers, province or regional governments, the Spanish government, and international governments or bodies like the European Union. Each level of government has affected the Almería landscape and water supply in some aspect, either directly or indirectly.

Two examples of research undertaken in the field of political ecology provide an understanding of the relationships between landscape and the systems that influence that landscape. In Nathan Sayre's 1999 article on the cattle boom in the southwestern United States during the late 1800s, he uses a political ecology framework to analyze the systems that led to cattle overpopulation. Because of locals' desire to gain money from ranching on free land and a global market for cheap beef, the southwestern landscape was overgrazed and overused in twenty years. Brogden and Greenberg's (2003) article explores the desire for people to live in the sunny, warm weather of Arizona, and a interrelated national real estate boom, that led to another landscape transformation in the southwest in the form of development growth. The article examines the transformation from desert to a booming urban/suburban development region in southern Arizona and the city of Phoenix. These two examples of landscape change show how quickly local endeavors of personal betterment can turn into large-scale activities which transform a landscape. Using a political ecology framework, the authors investigated the relationships of various systems and their impact on the landscape. In this study, an assessment of the changes in the Almería water system and local-global scales of interaction within a political ecology framework will help to address the aforementioned guiding questions.

Landscape is a term that refers to "the appearance of an area, the assemblage of objects used to produce that appearance, and the area itself" (Johnston et al. 2000, 429). During the mid-1990s, landscape change began to be looked at through the scope of political ecology because of the feminist and Marxist movements of that same decade (Brogden and Greenberg 2003, Mitchel 1996, Rose 1993, Sayre 1999). These movements showed how landscape forms an important part of social, cultural and political systems (Johnston et al 2000). In the same aspect, the social, cultural, and political systems play an important role in the transformation of the landscape. For clarity, a system is "a group of elements organized such that each one is in some way interdependent with every other element" (Johnston et al. 2000, 818). The political ecology framework is useful, in part, owing to its power to analyze the inter connection between human systems and landscapes. Knowledge of the systems (society) that influence Almería's landscape (nature) in the past and present will deepen our understanding of processes of landscape change.

The second chapter constructs an analysis of landscape change through the perspective of environmental history. Environmental history is the study of humans and landscape or nature and their past relationships (McNeil 2001). Environmental history centers around three different themes: material environmental history focuses on changes in the biological and physical environment; cultural/intellectual environmental history focuses on representations of the environment; and political environmental history focuses on the role of government regulation, law, and official policy (McNeil 2003). This thesis uses a combination of all three of these themes. Historically, the physical environmental changes of the Almería landscape were influenced by both cultural and political actions. The history of transformations in the Almería landscape backed by local-global interactions gave rise to the current landscape development. Using political ecology to understand the complex relationships between the environmental history of Almería and the recent developments in the landscape sheds light on why and how Almería's landscape currently appears.

Organization of Thesis

The thesis is organized into six chapters. The methodology chapter (Chapter II) presents the principles and procedures employed in this thesis. The research setting is presented in Chapter III through a discussion of the physical geography, climate, and the historical landscape of Almería. The historical section of Chapter III traces the changes in Almería's landscape since the Copper and Bronze Age until the era before the introduction of greenhouse agriculture. Extraction of minerals, clear-cutting of forest, unsustainable terrace farming on steep slopes, and various agricultural endeavors include some of the processes that transformed Almería historically, culturally, and ecologically. A thorough environmental history scoped in the framework of political ecology is shown in the landscape change chapter.

Mar de Plástico: The Sea of Plastic on Arid Almería (Chapter IV) covers both the various components of the greenhouse agriculture sector and the landscape change involved with the development of the greenhouse industry in Almería. The section on landscape change focuses on the analysis of local-global interactions within political ecology. This section of the chapter examines landscape change in Almería, Spain over the last thirty years. The recent transformation of the Almería landscape centers on demands by international food markets from northern European countries seeking warm weather produce in winter months. An overview of local-global exchanges involved with food systems is discussed to offer insight into its importance to the chapter. The Almería greenhouse system section of the chapter draws on field data and secondary data to describe the greenhouse sector and all of its various components. This section of the chapter covers the physical makeup of the actual greenhouses, statistics on crops, water and production, and new or recent technologies that are reshaping the Almería greenhouse industry. Understanding the structure and technologies of the greenhouses helps to show the complexity of the greenhouse systems and the changes that have taken place to these systems in the past thirty years.

The political ecology of Almería greenhouse water systems (Chapter V) looks in detail at the water issues surrounding Almería's greenhouse sector. This chapter begins with a summary of the issues of water shortages in Almería and Spain. Water is the essential element to the success of Almería's greenhouse sector and population boom. The location of shallow, abundant aquifers in the Campo de Dalias and Campo de Nijar in the 1950s allowed Almería to move forward with plans for commercial agriculture on the arid land. Liberal policies on well drilling and the Spanish government's actions to provide incentives for population growth in the province led to a rise in population and wells for watering agriculture. The introduction of greenhouses to the region provided farmers with a solution to growing unprotected crops in Almería and higher yields of produce from less land. The agriculture boom that followed the greenhouse introduction put more pressure on the Almería aquifers to the point of shortages and salt-water intrusion. This chapter details the history of the water systems, historical or current attempts and actions for providing or limiting water, and the politics that control or push these changes.

The synthesis and conclusion chapter (Chapter VI) draws the thesis to a close. The synthesis section covers the positives and negatives of the greenhouse agriculture boom in Almería. The economic success of Almería has been due to the greenhouse sector's growth and has provided a declining province the opportunity to become one of the most successful provinces in Spain. An area of 80,000 acres is now covered in plastic. The growth associated with greenhouse, the water necessary to sustain the agriculture and correlating population growth has created various environmental problems. New technologies to grow vegetables in greenhouses for large markets have come with environmental problems. These two differing ideologies and benefits opposed to cost are summarized in the synthesis section.

The conclusion section ties the previous chapters together and describes why this research is important. The case of Almería strikes at the heart of fundamental questions about food production, land use, and sustainability. The major findings of the research extend David Tout's (1990) initial conclusions. The importance of this research on the Almería greenhouse sector goes beyond the local level to one of global importance. Almería has been quickly transformed into a thriving agricultural hub for Spain and Europe using limited space, advantages of warm weather year round, and a high demand for produce in winter months. The reliance on foreign markets that control what and how much is farmed, the introduction of large biotech companies for integrated control systems for pest and recycling water, and future water prices raise issues and concerns for future investigation. The role and influence of Almería farmers in decision-making and political pressures is discussed. The drastic environmental changes with the potential for conflict, evident in the hydropolitics, present additional problems for the future. The final section offers unanswered questions, as well as suggestions to guide future research.

Chapter II

Methodology

Chapter II presents the principles and procedures employed in this thesis. A short introduction containing a timeline for where and how my research was carried out begins this chapter. The use of three different data sources and a qualitative approach allowed for the triangulation of data. The three major data chapters of this thesis – Landscape Change (Chapter III), Greenhouse Industry (Chapter IV), and Greenhouse Agriculture (Chapter V) – draw on a range of data sources and the methods for gathering and analyzing this data. The final part of the chapter discusses the overarching goal and logic behind the approach and organization of the research methodology utilized in this study.

Approach

To research the topic of greenhouse agriculture, I used a qualitative research scheme. This research included both qualitative field research conducted in Spain and a survey and analysis of the literature. Qualitative research is concerned with understanding the processes that underlie certain behavioral patterns. Research typically involves detailed, verbal descriptions of characteristics, cases, and settings. Qualitative research normally uses observation, interviewing, and document review to collect data. Field research is "the systematic study, primarily through long-term, face to face interactions and observations, of everyday life" (Bailey 2007, 2). A primary goal of field research is to "understand daily life from the perspectives of people in a setting or social group of interest to the researcher" (ibid, 2). My field research included semi-structured interviewing, unstructured interviewing, and ground truthing. In order to establish my qualitative research I have chosen the critical paradigm to form my qualitative research. The critical paradigm "seeks to empower the people in a setting and to work toward a meaningful social change" without actually being involved in the change (ibid 55).

Fieldwork was necessary to draw out names, conduct interviews, and to observe the operation of the greenhouse sector. From September to December of 2007, I lived in Almería, Spain in order to conduct research regarding the Almería greenhouse industry. I spent September through December in the province researching the greenhouses and improving my Spanish by enrollment in the Universidad de Almería. Fifteen interview questions were established prior to arrival in Almería and topics were dependent on the interviewee. My travels abroad in Iberia during the summer of 2007 before the fall semester (initially non-research oriented), left me with two possible contacts upon my future return to Almería. The first interviews I conducted were with individuals I had met on my previous trip, who then provided me with the names of other possible contacts. Enrollment at the Universidad de Almería international language program gave me many opportunities for unstructured interviews with students or faculty in greenhouse related fields and semi-structured interviews with professors. Friends provided additional information during conversations regarding greenhouses. Before, during, and after my trip to Spain, intensive literature review was conducted from books, articles, and online publications.

An unstructured or informal interview is similar to having a conversation with an individual. One distinction between a conversation and an unstructured interview is during an unstructured interview, "interaction between the participant and the field researcher targets primarily the interests of the researcher" (Bailey 2007, 96). During my four months in Almería, I made friends with individuals who worked in or knew about some facet of the greenhouse industry. By acknowledging that my field of study was researching greenhouses and that the research had brought me to the region, individuals would elaborate on what they knew. In a semi-structured interview, "the interviewer uses an interview guide with specific questions that are organized by topics but are not necessarily asked in a specified order" (ibid, 100). Typically, semi-structured interviews consist of open-ended questions that keep a constant flow going but are not asked in a specific order, and come either in response or to continue the flow of the conversation. I conducted seven semi-structured interviews during my time in Almería. Five of these interviews were done in Spanish and then translated upon my return with the help of a native Spanish speaker studying English. One unstructured interview with written notes was conducted during a visit to a greenhouse. The interview participants ranged from professors at the Universidad de Almería, greenhouse farmers, greenhouse industrial staff, and students studying greenhouse agriculture. Pseudonyms are used for all interview participants to protect their identity. For more information regarding the interview participants, see Appendix II. Interviews were recorded using a digital voice recorder. Locations for interviews were chosen by the interviewees and ranged from cafes, schoolrooms, cars, and offices. Additional information was obtained from conversations with residents in the cities of Almería and El Ejido. Interviews allowed collection of data on local perceptions of the greenhouse sector.

To confirm or refute secondary sources and data gathered from interviews, observations of the greenhouses were necessary. Ground truthing is an interpretation of the landscape based on prior knowledge (Lofland et al 2006). I read or heard about specific issues regarding the Almería greenhouse sector and then went to that area to see if they were true. The majority of ground truthing was done through tours organized with farmers or on car trips with friends. The touring of greenhouses and the surrounding areas allowed a firsthand perspective of the landscape and greenhouse structures. The interpretation of literature regarding similar issues was used to build a better understanding of the issues specific to Almería's greenhouse agriculture and where these issues stand in the context of a broader spectrum. Literature regarding the theoretical framework of political ecology was read and analyzed to establish how the Almería horticulture industry fit into the ideologies of this framework. Literature regarding the greenhouse industry, landscape, and water of Almería was researched to build on the above research techniques. Investigation into David Tout's (1990) research showed the differences in the greenhouse sector in twenty years, and any changes or contrasting perspectives regarding the past of Almería. Pictures taken from field research are included as visual aides to the written descriptions.

The landscape change chapter relies on a survey of secondary data and field observations. Literature review on research regarding Almería was analyzed within context of the current transformations of the landscape. Observations of the Almería landscape showed visible traces of past societies. Roman walls, Moorish castles and irrigation systems, terraced farming no longer in use, and a landscape devoid of any tree vegetation provide evidence of the historical past of Almería's landscape. The greenhouse industry chapter uses interviews and conversations, analysis of these interviews, field observations, and secondary data. The water systems and landscape change analysis presented in chapters IV and V used interviews and conversations along with a survey or secondary data. The combination of these research and analysis tools created a triangulation of information (Figure 1).

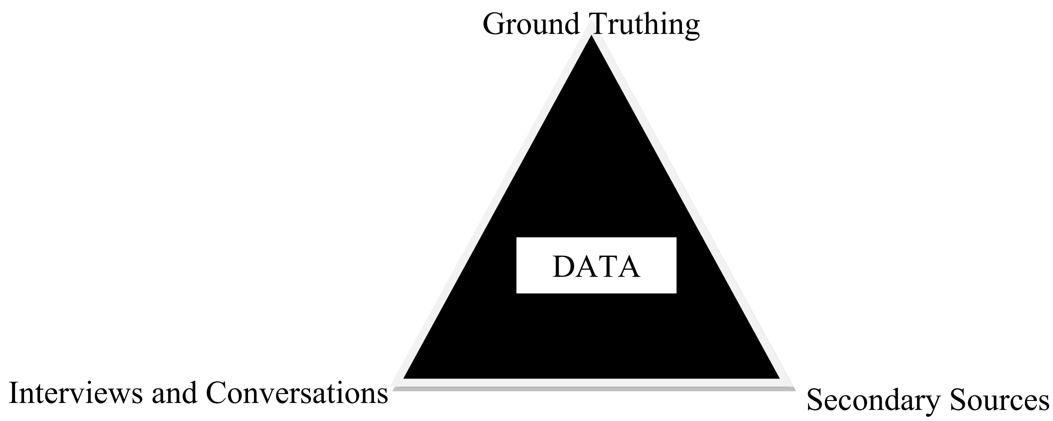

FIGURE 1 Triangulation of three methods and approaches to data collection.

This study combines a variety of data and methods to analyze the research questions. The three methods used - secondary data, interviews, and fieldwork - are commonly used in political ecology research. Without any of the three methods, the richness of data collected would be lacking. Interview information is strengthened or weakened by field observations and/or through research into secondary data regarding similar topics. The same idea works starting at any data collection method (see Figure 1). The goal of this methodology was ultimately to capture the local experience and impact of the greenhouse sector and to make connections between local and global processes that influence both the operations and expansion of greenhouse agriculture and landscape change in southeastern Spain.

Chapter III

Research Setting

Chapter III discusses the physical geography, climate, and historical landscape of Almería. The arid province of Almería has historically been under modifications since the bronze and copper ages. The province of Almería is located in southeastern Spain in the autonomous community of Andalucía at 36°50′N 2°27′W. Almería is a mountainous province with 69 percent of its area over 300 meters and rising to 2519 meters in the Sierra de Gador, part of the Sierra Nevada Mountain range. The mountains of Almería provide a protective boundary against cold northerly winds and winter storms, and help provide Almería with the warm winter months that make the horticulture industry viable (Tout 1990). Immense parts of the province are mountainous semi-desert, with arid lowlands and dry creek beds. This landscape was used for filming "spaghetti westerns" in the 1960s and 1970s. Sergio Leone's *Man with No Name* series and David Lean's *Lawrence of Arabia* are among the more famous films with Almería's landscape. To an American, the landscape resembles the deserts of Arizona or New Mexico.

Two descriptions used by locals give a better understanding of the sheer amount of greenhouses: *El Milagro de Almería* (The miracle of Almería) and *Mar de Plástico* (The Plastic Sea). For many locals, the turn of Almería from the poorest province in Spain to one of the richest because of agriculture is a miracle. From atop the mountains to the north of the Campo de Dalias or the Campo de Nijar, the landscape gives the resemblance of a sea cut by various arteries of roads, and only seems to stop because of the actual sea, the Mediterranean. In 2007, Almería had a population of 646,633 with the greatest concentration in the province's capital Almería with 189,798 residents. The city of El Ejido, located in the center of the greatest concentration of greenhouses, the Campo de Dalias, had a population of 1,000 in 1960 and now estimates have population nearing one hundred thousand (INE 2008). The boom in population correlates with the growth in greenhouse agriculture in the last thirty years and recent tourism development.

Landscape of Almería

Rough land, marginal soil, low precipitation totals, and frequent strong winds give the land a lonely, uninhabitable appearance. The most fertile land is in the lower valleys of the *Rio* Adra, the *Rio* Andarax, and the *Rio* Almanzora. Of the 55 *ramblas* (a dry ravine or the dry bed of an intermittent river) leading from the northern mountains, only five intermittent rivers reach the Mediterranean Sea. Much of the province is semi-arid and its southeast coastal fringe is considered one of the driest regions in Europe (Tout 1990). The influence of the rain-shadow created by the Sierra Nevada allows an average of only 9.84 inches of rain in Almería and an average temperature of 63 degree Fahrenheit (Downward and Taylor 2005). Because of the intermittent river flows and low rain, Almería depends on groundwater as the main water source, and recently, desalination plants as an alternative. Large groundwater aquifers give Almería a "short-term buffer to climatic variations" and provide the agricultural sector with an ample supply of water (ibid, 281). To the immediate east of Almería the sedimentary basin of the Campo de Nijar and to the west the coastal plains of the Campo de Dalias provide Almería with suitable greenhouse horticulture sites. The arid climate with yearlong sunny weather, warm winters, strong winds that ventilate and cool the greenhouses in the hot summer and reduce humidity and condensation in the winter, and an abundance of groundwater all give Almería an advantage for greenhouse horticulture.

Background on Almería

The conditions that allowed for the emergence of greenhouses were laid out in the environmental history of Almería, contemporary globalized economies, and expedited and cheap refrigerated transportation. There are seven periods of landscape transformation in Almería (See Appendix I for a timeline and short summary of these periods). Small changes in the landscape of Almería can be traced to the Copper and Bronze Ages when cultures used various pines and oaks for firewood. Palaeoecological research has confirmed that current dry riverbeds had water regularly in the Copper Age. During the Roman Empire occupation of Almería, "expansion of the cities and dry farming crops such as cereals, vines (wine), and olive trees, together with a significant demographic upswing" led to increased landscape alterations (Latorre 2001, 2). Almería's first episode with economic specialization and international commercial networks began with the Romans exporting minerals such as lead and silver. After the collapse of the Roman Empire in the fifth century, the majority of cities and population disappeared from Almería. For the next two centuries, the environment experienced a recovery period from centuries of exploitation by the Romans. References to these medieval landscapes describe enormous wooded surfaces and forest vegetation that are presently unknown and non-existent in Almería except for limited parts of the mountain regions (Latorre 2001).

During the Nasrid Moorish occupation (711-1492), the city of Almería was considered the second richest city in all of Europe after Constantinople. Almería's use as a port for the Granada based Nasrid Moorish dynasty led to the city's early economic success. "Moors" has no ethnographic meaning, but the word can be used to refer to all Muslims, Berbers, or Arabs who conquered the Iberian Peninsula (Spain and Portugal). The Moors introduced citrus fruits and almonds to the province and agriculture based on an extensive system of irrigation that was a key to these perishable crops (Tout 1990; Ruggles 2003; Harvey 1992). Today non-greenhouse horticulture of almonds, introduced by the Moors, makes up 182,000 acres of agriculture (about 50% of Spanish production) in Almería (Martin 1999). The Moors were defeated and expelled from Iberia in 1492, and Almería's importance as an agricultural center, its agricultural infrastructure, and population of 70,000 began to erode (Latorre 2001).

In 1494, two years after the Spanish *reconquista* (reconquest), Almería's irrigated fields (*vegas*) were described as "paradises and gardens" which were "cultivated only where it was possible to irrigate," near towns and villages (Latorre 2001, 4). Ten percent of the landscape was transformed into irrigated lands of terraces with channels and reservoirs built by the Moors providing the water, while ninety percent of the land was used for hunting, gathering, and grazing (ibid). Information regarding the historical landscape and agricultural transformations of the Moorish controlled areas near the cities of Granada and Córdoba, as documented in Arabic scientific literature, is available from research by Ruggles (2003). Ruggles describes in detail the history of these areas and how and why the Moors transformed the dry landscape. Using systems of irrigation from mountain water the Moors grew extravagant gardens with bathing pools, tranquil ponds, and fountains that exist even today.

In the sixteenth century intensive agriculture of silk, linked to international markets, became an important part of annual agriculture production. In the sixteenth century, the total population of Almería was only 55,000. The feudal lords that arrived in the *reconquista* leased uncultivated land to owners of 200,000 head of sheep that came to Almería every winter for grazing. Wool intended for the Italian textile industry became the second most common export after silk. The wool and silk markets are another example of Almería's resources being used in response to a global demand. The collapse of the Spanish wool and silk market in the 1620s due to lack of demand and a dry period of weather forced Almería to look in a new direction for agriculture. From 1600-1750, the availability of cheap land increased population by 400 percent and shrub lands and forest began to be cleared and converted to dry farming. Despite low yields and long uncultivated periods, dry farming took the place of irrigated agriculture. By 1750, the availability of open land for agriculture encouraged the expansion of settlements and a population to 124,000 (Latorre 2001). The historical consequences of deforestation by the Moors, the sheep and silk industries, and expansion of settlements and agriculture culminated in a forest inventory completed at the end of the 18th century that found only small patches of forest still remaining in the lowlands.

During the early 19th century, an increase in the population and in the mining industry occurred. Population increased to above 300,000 by the mid 1800s and Almería mines provided 80 percent of Spanish lead. During this population and mining boom, half a million evergreen oaks disappeared, an area of 69,000 acres of vegetation cover was lost, and olive plantation trees were converted to lumber. The bulk of this vegetation loss came from the necessity to fuel the iron and lead foundries with firewood. After 1850, the mining industry folded because of a lack of fuel. An increase in cultivated areas and domestic firewood use, both processes driven by population increase, furthered the extraction of the forest (Latorre 2001). The majority of resources produced from agriculture were used exclusively for domestic use. The key ecological problem of the late 1800s was the "enormous growth of dry farming crops (cereals)" on steep slopes in the mountain ranges that caused strong erosion and destructive floods (Picón et al 2001, 4). The potential for agricultural growth was possible because of "the liberal revolution that eliminated feudal right and the rights of peasants on common lands", thus forests and pastures became privately owned and were cultivated (ibid, 4).

The landscape was formed by these modern events and the effect of economic behaviors. "Agricultural expansion, mining, which consumed large amounts of wood, and a demographic explosion destroyed the forests, provoked great erosive processes and altered the ecosystems of the zone" (Latorre 2001, 1). Population stagnated in the late 1800s and even declined in the early 1900s as workers looked to the larger cities for job opportunities. By 1910, Almería had become principally desert and the poorest province in Spain. From that point until the introduction of greenhouse agriculture, Almería was described as a depleted, "depopulated wasteland", and as the "forgotten province" for its backwardness and lack of development (Tout 1990, 304). Before the greenhouse boom, "human disturbances in a short period, led to extreme environmental alternations and to economic and demographic stagnation" (Latorre 2001, 7). In 1954, the author Juan Goytisolo (2001) mentions Almería in his book *Campos de Nijar*, an account of his travels around Almería:

> We drive up the slope and up again, the landscape is almost lunar. Parched white land, scrub, and screeds follow each other until they disappear over the horizon. The floor is covered in stone fragments. In summer the stones retain the heat and bake until cracking. For numerous kilometers around there is not a single tree to be seen.

Up to the 1950s, agriculture in Almería was autonomous in nature, self-governing and independent, and yields were low except for the production of table grapes. In the fertile floodplains (*vegas)*, alfalfa, beet, cotton, maize, and rice were grown. Otherwise, cultivation was limited to dry farming (*secano*) with limited irrigation where almonds, olives, and grapes grew. With the arrival of modern transportation and the accessibility of other varieties, the table grape industry suffered a decline in the 1950s and became an unproductive source of cropping for farmers, encouraging them to look to new sources of income. In 1954, the sand-plot (*enarenado*) technique was introduced to the province particularly to the southwest corner, *Campo de Dalias*. The sand-plots origins are traced to discovery either by chance in the 1880s when crops covered in sand from flooding were observed to be grow better, or to long established growing practices on the island of

Lanzarote, the eastern most Canary Island. This technique developed and evolved by farmers' input and output to the 1950s form.

The procedure for making sand-plots is "firstly to level the land mechanically, then to surface it with a layer of compacted clay, followed by a layer of well fermented manure… and finally a layer of 10 centimeters of well-washed beach sand or coarse grit" (Tout 1990, 306). The layer of manure or organic material is typically 2-3 centimeters thick and the compacted clay layer is 20 centimeters (Hernandez 2000). Vegetables and plants not purchased, rotten, or are at the end of their growing cycle were transformed into vegetable material, and used in the manure layer of the sand-plot. According to Tout (1990, 306), the clay acts as an "impervious layer between the undesirable soil and the growing medium," preventing water from leaking into the ground and on greenhouses located near the sea, the clay layer prevents salty water being drawn to the surface. The sand helps increase the soil temperature, decrease evapotranspiration (evaporation of water into the air), produce constant moisture, increase yields, and combat salinity, allowing low-quality irrigation waters. The roots of the crops concentrate in the sand-manure-soil interface. It was on these sand-plots that greenhouse agriculture was literally built. Protection for the sand-plots was progressively increased by developing windbreaks that would limit damage from high winds and sand loss (Tout 1990, Castilla and Hernandez 2005). An issue not examined in this paper but an important aspect of the greenhouse industry is the displacement of soil from other regions into the sand-plots. Several authors (Faulkner et al 2004, De la Rosa et al 1999) researched the issue of soil removal thoroughly.

Summary

The consequences of environmental degradation on Almería's landscape are complex. The changes lasted from Roman occupation until the collapse in the table wine industry. An area once known for forests, streams, and a wide array of plant and animal life is now parched, cracked, and shade less. One of the keys to transformations in Almería was the relationship between foreign forces controlling the province of Almería and the use of resources available and profit from the extraction of these resources. Foreigners and foreign entities took these resources to international markets and sold them without any reinvestment back into Almería. Almería's history shows a timeline of recurring modifications on the landscape either directly by powerful foreigners or indirectly through local-global markets for resources (food, wool, silk, mining, etc.). The Romans and Moorish occupants subjected the land to crop and farming techniques unknown to Almería and the landscape was altered to accompany these changes. When Almería was not directly ruled by foreign powers, Almería's resources were at the demand of international markets and extraction of resources was kept at unsustainable levels. The extraction of resources eventually led to the stripping of Almería's lowland forest, land degradation from open mines, soil erosion from terraced farming, and possibly resulting in a climatic shift to a more arid climate (Picón et al 2001, Latorre 2001). The Mediterranean regions and Almería more specifically are "the best and most tragic example of how mankind has removed the foundations for his existence through the overexploitation of natural resources" (H. Walter quoted in Picón et al 2001). Almería has thus long been a zone extraction for resources at local-global scales. The most recent phase of exploitation on the landscape of Almería and profitable industry for international and domestic forces has come in the form of greenhouse agriculture.

Chapter IV

Mar de Plástico: The Sea of Plastic on Arid Almería

Introduction

Chapter IV covers both the makeup of the Almería greenhouse sectors systems and the landscape change involved with the development of the greenhouse industry in Almería. The landscape change section examines the transformation of the Almería landscape with the introduction of greenhouses. The greenhouse systems section details the makeup of the greenhouse industry of Almería. This chapter integrates both these sections to describe the complexity of the greenhouse sector.

The purpose of the landscape change section is to examine landscape change in Almería, Spain over the last thirty years. The landscape in Almería has been transformed from a sparsely populated and ignored region to a flourishing horticulture epicenter for European agriculture. Only able to grow drought resistant crops in intermittent riverbeds, farmers in Almería started growing grapes and vegetables when they were introduced to greenhouse agriculture in the 1960s. After China, Spain now possesses the second highest number of greenhouses in the world, with the main concentration of greenhouses located in Almería. What began as a local agricultural endeavor to boost production of viticulture, has turned to a large-scale greenhouse industry that produces vegetables for Spain and other European Union countries. This rapid change in the landscape has turned what the geographer David Tout (1990, 1) describes as a "depleted wasteland" into a "plastic sea" of greenhouse horticulture and one of the most important areas for European agriculture. Tourist brochures for Almería even tout the province as a Mar de Plástico, Milagro de Almería, and Jardín de Europa (garden of Europe). By analyzing the long-term process of landscape change associated with Almería's greenhouse agriculture industry, a deeper understanding of the complex interconnections between local-global food systems can be arrived at.

‘System’ is defined here as the in and outs of the physical structure, different growing techniques, types of produce grown, method for selling produce, and any other interrelated topics directly concerning Almería’s greenhouses. An interior and exterior description of the greenhouses' physical structure is provided to give the reader a better understanding of what a greenhouse actually entails. This chapter will introduce previous methods used for growing under plastic or glass in Almería and the timeline progression of the greenhouse system into the 21st Century. The type of products grown under the greenhouses and various techniques used to grow these products is depicted in detail as well. The system of selling the produce is discussed along with industries connected to the growth in greenhouse agriculture.

FIGURE 2 The Plastic Sea of Almería greenhouses, leading from the Barjali mountains to Mediterranean Sea (Source: http://www.tecnoponiente.com).

Theoretical Framing

To analyze the transformation of the landscape during the current greenhouse era it is necessary to look at the system that forces this change. Other markets and forces transformed the landscape in Almería's past, but now international markets of produce demand and interconnected ideologies fuel transformation. The focus here on local-global food systems reflects the "understanding of the process of globalization as the interaction between global processes and local circumstances" and the relations between "globalizing and localizing tendencies" (Johnston et al 2000, 456). Food system is defined as "the set of activities and relationships that interact to determine what, how much, by what method and for whom, food is produced and distributed" (Fine 1998, 3). The local-global food system examines the "social, economic and technological ties between three sets of industrial activities, those of food raising (farming); agricultural technology products and services; and food processing and retailing" (Johnston et al 2000, 11). Food systems and markets play an important role in landscape change by "enhancing demand for commodities" that increase produce output and greenhouse construction (Hecht 2004, 66). Globalization of local food systems is an important driver in landscape change as international demand for Almería produce expands and increases greenhouse construction and produce output, and stimulates local farmers and other economic actors to respond to the demand pressures (ibid). Globalization in the local-global food system is interpreted as "liberal international trading of agriculture and food products; the dominance of that trade by corporate" food processing and retailing; "new international divisions of labor; and the replacement of national by international institutions to regulate trading relations" of food products (Atkins and Bowler 2001, 38-39). In Almería, produce is shipped to northern European countries or sold at corporate owned chain supermarkets within Spain. The European Union acts as the international institution that regulates trading with Europe.

Analyzing the relationship between local and global factors and process associated with food systems has drawn the attention of political ecologists. The "organization of food production and processing is a matter of investment and regulation" and thus is an issue of "commercial and political judgment" (Atkins and Bowler, 188). The environmental history of Almería proves to be one of change influenced by outside global sources on the local landscape and environment. Currently, the greenhouse agricultural sector's success is a result of international and Spanish demand for fresh produce in winter months. The relationship between global demands and local productions continuing transformation of the landscape is a common theme in Almería starting in Roman times and flowing almost unchecked to the present.

The introduction of forced cultivation via greenhouse agriculture has transformed the previous unproductive, arid countryside of Almería into a booming economic region for produce production. According to Tout (1990), greenhouse agriculture began in the early 1960s, "after the first greenhouse was erected in 1962," but did not really get going until the 1980s. Before the intrusion of greenhouse agriculture, Almería consisted of fertile floodplain agriculture (*vegas*), dry-farming (*secano*), and limited irrigation farming (*regadio*). What recent factors, both environmental and social, have led to the boom in greenhouse agriculture since the geographer David Tout (1990) undertook research on the greenhouse industry in Almeria in the 1980s? How has the province and the government attempted to sustain 80,000 acres of greenhouse agriculture in light of water scarcity in an arid province? The region copes with drought, salination of the water, and desertification, yet it remains an agriculture hub for winter produce in Europe.

The total acreage covered by greenhouses in Almería is about 80,000 acres with the greatest number and concentration in the Campo de Dalias followed by the newly developed Campo de Nijar. The area of farms dedicated to greenhouses matches with the structure of the land ownership in the coastal areas, where small properties are principal. The typical greenhouse is around three acres and farmed by part or full time family farmers (IEEP 2000). Typically, three to four workers are necessary per greenhouse, explaining the influx of migrant workers in Almería because farmers need cheap labor for higher production yields and demands from international markets. For three acres, it cost 200,000 to 300,000 US dollars to buy the land, strip it down, build the greenhouse, buy compost, sand, and the irrigation systems, and set the greenhouse up (Webster 2001). The approximate gross annual income is 60,000 US dollars per greenhouse. Input cost from labor, pesticides, fertilizers, water, and bank loans make the net annual income around 20,000 to 30,000 US dollars (ibid). The total annual value of 2.7 million metric tons of greenhouse production in Almería is 1.65 billion Euros or over 2.57 billion US dollars (S&G Peppers 2007). Aid grants for farmers in Almería rose from 990 thousand Euros (1.5 US million dollars) in 2006 to an estimated 4.5 million Euros (7 US million dollars) in 2007. Those farmers who implement a number of obligatory measures and who make a commitment to fulfilling certain obligations receive the aid (ibid).

History of the Almería Greenhouse Sector

Throughout the 1900s until the 1980s, the population of Almería remained in the 300,000s and saw little growth (INE 2008). In 1953 the Spanish government with the "General Plan for the Colonization of the Irrigation Sector at Aguadulce" (a town in the Campo de Dalias) offered land to mountain villagers in return for their relocation into the agricultural sector of Almería (IEEP 2000, 69). National government programs were established to "raise the rural standard of living nationally by providing water for irrigation" (Wilvert 1993). These programs hoped to alleviate poverty by providing water and land, as well as jobs created by construction projects. The majority of Spanish provinces dealt with providing water by building hundreds of dams throughout the country, but the province of Almería drilled deep wells into the aquifers of the Campo de Dalias. The government then "subdivided land into parcels, typically 2.47 acres, and sold them, sometimes along with new houses in small, planned villages, to family farmers" (ibid, 258). The early success of the agricultural sector in Almería was a result of the use of family labor, which freed farmers from labor costs; and to the government's deliberate attempt to promote small-scale farming.

Several additional factors have led to the greenhouse agriculture boom in this region. One factor was the 1956 agricultural development of a 19 x 7 mile area of the Campo de Dalias because of prior studies that confirmed the existence of plentiful ground water. Second, sand-plot cultivation was introduced to Dalias in 1958 and in 1961 experiments with plastic mulching led to the use of low plastic tunnels. The procedure for making sand-plots is described on page 19 of chapter III. In 1960, only 1100 acres were irrigated in Almería with only a minuscule percentage of these being greenhouses. The tunnels gave way to the third factor, the introduction of plastic greenhouses to Almería began in 1962, using "techniques and skills associated with the table grape industry" (IEEP 2000, 69).

The flat roofed "parallel type" greenhouse was an adaptation of the wire and wood structure locally used to support vines for growing table grapes (Castilla and Hernandez 2005). The parallel greenhouses were constructed over the existing sand-plot system of cultivation. Fourth, the geometry and height of the parallel type roofs changed to shed rain and improve solar-radiation. The usability and affordability of greenhouses increased the popularity of the parallel type greenhouses for growing produce in Almería.

Fifth, spray lines superseded furrow irrigation and in 1971, trickle irrigation (drip irrigation) was introduced from Israel. The watering system was not integrated into the majority of greenhouses until 1977 because adaptation to this new technique was not perceived as necessary at the time. Figure 3 shows an example of what the current sand-plot system looks like with drip irrigation. Drip irrigation reduces the amount of water used, loss of water to evapotranspiration, damage to the foliage, salinity levels, and because the soil on top remains dry, reduces the amount of weeds. By 1975, the irrigated area of Almería was approximately 16,580 acres with approximately a quarter of those acres in greenhouse agriculture. In the early 1980s, water for the greenhouses was extracted via thirty meter (100 feet) deep individual wells on each farmer's plot of land in the growing area. In 1980, the Spanish Geological and Mining Institute (now the Technological and Geomining Institute) began a series of studies intended to identify possible marine intrusion (salination) into the Campo de Dalias aquifer (IEEP 2000). In 1984, with evidence of the over-exploitation of the aquifers and marine intrusion, The Junta de Andalucía (Government of Andalucía) froze the expansion of irrigated greenhouses, implementing legal restrictions (Castilla and Hernandez 2005).

FIGURE 3 On the left is the top layer of the sand-plot that is made up of sand. The black tube in the right hand picture is used for drip irrigating this crop. (Source: R.T. Wolosin 2007)

In 1985, the intensification of water use by the booming greenhouse industry led to water shortages and seawater intrusion into the shallow water wells. The *Junta de Andalucía*, in response to water shortages and farmers' demand, funded the construction of a community well 700 meters (2000 feet) deep in the mountains to the north of the

Campo de Dalias. The intention of the well was to produce water for the agriculture industry of Almería, as well as the increasing population in the province. The water is pumped from the mountains and through pipes to artificial holding reservoirs where another series of pumps and pipes sends water to the greenhouses. Because the well is used for not only agricultural purposes but also urban/rural populations, the government regulates the amount of water farmers receive per day. Restrictions on water from the new well were imposed on the greenhouses' water consumption making drip irrigation a legal and logical necessity to reduce water use while increasing the efficiency of water distribution on the plants. The regulation of water made drip irrigation a necessity for any greenhouse farmer wishing to maintain high production and low water input. The government's intervention in Almería's salination issue shows the early importance of the agricultural sector to the economy not only of Almería but to the region of Andalucía and the country of Spain as a whole. Because of the water issues and restrictions, Almería experienced little to no greenhouse construction from 1985-1989 (Hernandez 2000).

Since the late 1980s, drip irrigation has been a requirement for the approval of loans for new greenhouse development. Tout (1990, 307) writes that all greenhouse crops "are dependent on soluble fertilizers and pesticides, added to the water" and that during periods of substantial drought "the salinity of the water rises to levels where cucumbers and green beans can no longer be grown." During times of longer drought, crops more resistant to salinity, like tomatoes and peppers, are grown. In 1983, total irrigated agriculture in Almería was 50,000 acres with 21,000 in greenhouse agriculture. In two years, the total greenhouse acreage increased to more than 28,000 acres. After 1989, immigrant labor mostly from Africa and South America helped to change the family farm to a commercial one, by allowing farmers to increase their production area (Hernandez 2000). The immigrant labor of Almería is not covered in detail in this paper and little English research exists on Almería's specific immigrant workers, but it is certainly an important topic in need of research. Current estimates have total irrigated acreage at 110,000 acres with 80,000 acres of greenhouse horticulture.

High land prices, a globalized market for produce demand and the increased economic growth of northern European countries (countries that can afford to buy

Almería produce), promoted "technological innovations in order to improve productivity" and led to the increasing amount of greenhouses in Almería. The "globalization of the markets has increased competitiveness, highlighting the need for increased quality of the greenhouse produce" through better growing techniques (Castilla and Hernandez 2005, 19).

Sixty percent of Almería produce is shipped across country borders, with Germany, France, the Netherlands, the United Kingdom, and Italy being the biggest importers (in that order). In the 1997-1998 growing season, there was production of 2.7 million metric tons (2.7 billion kilograms) of produce from Almería greenhouses at a value of 1,651 million Euros or 2.5 billion US dollars (Cantliffe and Vansickle 2003; S & G Peppers 2007a). Half of the bell peppers, and a quarter of cucumbers and tomatoes consumed in Europe come from Almería, showing the importance of continued production (Hernandez 2000). Distances from the Almería producing area to the areas of distribution to customers average around 1700 kilometers (1000 miles), with the furthest more than 3000 kilometers and the closest, the local supermarket in El Ejido, less than 10 kilometers. Outside of Europe, Canada makes up the next biggest importer of Almería produce with two to three percent (The Olive Press 2007b). Almería started to export tomatoes to the USA after a 1994 trade agreement. The conditions to the agreement stipulated that "the tomatoes must be cultivated in the province of Almería and grown in greenhouses registered with and inspected by the Spanish Ministry of Agriculture" (Martin 1999, 33). The period of allowed exportation is limited to December-April and in 1997 only made up one percent of tomato exports from Almería. Exportation to the USA and Canada would not only increase the distance between grower and customer, but would increase the variety of markets available for Almería farmers. The prospect of more customers, and thus more money for farmers and Spain, overshadows the negative consequences and carbon footprint that comes with increased globalized trade with North America.

Alternative Greenhouse Growing Systems

As of 2000, at least seventy-five percent of greenhouses use the sand-plot system as their soil base. Twenty percent of greenhouses use a substrate-based system not involving the sand-plot technique. Substrate is the "base on which an organism lives" and in plants refers to the soil or other material in which the plant lives (Merriam-Webster 2008). The remaining five percent use expensive alternative growing methods such as, New Growing Systems that recycle water, nutrient solutions, and temperature-controlled environments. The substrate systems use peat, rock wool, perlite (a natural occurring porous rock), sand, coco peat and fiber, foam, and/or cork in combination with a hydroponic watering system to grow the plants (The Olive Press 2007b). The substrates can be grown in a bag, pot, canal, slab, or plank system depending on what a farmer deems to be most beneficial. According to Manuel Lucas (2000), general manager of an Almería Perlite Company, perlite offers, "far better control over water usage and makes what water is used more available to the plants." One of the farmers I spoke with was in the process of switching to the coco peat and fiber method instead of perlite because she found increased yields and that the product tasted better. A main determinant in farmers switching to the substrate growing system is the price of transforming their greenhouse(s) to comply with a new system. The substrate system leaches approximately thirty to fifty percent of the fertilizer solution added to the plants, bringing up issues of contamination of soil and aquifers (Hernandez 2000). The substrate system makes better use of the water than the sand-plot by reducing the amount necessary for each plant and by retaining water at higher levels. Only recently have water prices risen to levels that have motivated farmers to reconsider the substrate system. As water becomes more of a constraint and issues of sand and clay extraction continue to increase, the substrate system will ascend in usage. Figure 4 gives an example of two of the types used in the Campo de Dalias.

FIGURE 4 The picture on the left is an example of the perlite substrate system in a bag growing system, while the picture on the right shows a coco peat and fiber substrate system in a pot growing system. In both pictures, tomatoes are being grown. (Source: R.T. Wolosin 2007)

One final growing system that only makes up one percent of growing techniques is the New Growing System® using the Nutrient Film Technique®. The remaining four percent are unknown alternatives or exploratory growing techniques for greenhouses. In this system a constant flow of nutrient solution pumped from a tank flows over the roots of the plants in a tube or tray and then returns to the tank. The water pumped from the recycled water tank is infused with a series of nutrients that the plant needs like nitrogen, potassium, magnesium, etc. The amount of nutrients is controlled by computer system with which a technician punches in the computer information to release the correct cocktail of inputs into the recycled water, and varies on the plant and environmental conditions. There is no growing medium other than that which was used to start the plant from a seed or cutting and is usually a small block of rock wool or a small pot of perlite that the roots rapidly grow out of leaving them directly exposed to the nutrient. The lack of a growing medium saves on cost of replacement but means that the roots of the plants are prone to drying out if the pump stops working or the inlet blocks. The recycled water must be checked regularly to adjust nutrient strength and pH, the measure of the acidity or alkalinity of a solution (Merriam-Webster 2008). The greenhouse I toured with this system was using recycling water purely for exploratory research into determining whether it was a viable replacement for the substrate system. Another benefit to the New Growing System is the reduction in wastewater and leaching of contaminating nutrients into the soil and shallow aquifers. The recirculation capabilities of the New Growing System by recycling water would combat any issues of contamination and would make any future jump in the cost of water not as an important an issue. The greenhouse technician concluded that while preliminary analysis showed positive outcomes (yields, product), the cost of implementation was far greater than the budget of most greenhouse owners in Almería. Figure 5 shows examples of a New Growing System.

FIGURE 5 The first picture is an example of what the roots looks like when they grow out of the growing medium, the second picture shows water flowing into a canal system which will take the water to the underground storage facility, and the final picture shows the tanks of nutrients that will be introduced into the recycled water being pumped back into the plants. (Source: R.T. Wolosin 2007)

The majority (ninety percent) of the three systems of growing addressed above use an automatic watering system that uses automatic fertigation or the application of nutrients through irrigation systems, to apply nutrients to the plants (Follett 1992; IEEP 2000). In systems where water is not recycled, the sand-plot and substrate, water running through drip irrigation system must first pass through a mixing tank. The mixing tank is where the various nutrients, nitrogen, minerals, phosphorus, etc., are added to the water before flowing to the individual plants via the irrigation system. Leaching of these various nutrients is what makes the New Growing System's recycling capability a solution to aquifer and soil contamination. Upon touring one of the greenhouses I talked with a chemist, who is hired by individual greenhouses to mix a solution that best fits the crop growing in that particular greenhouse. The chemist, at least in this case, works for a locally owned fertilizer company that produces the various nutrients and then hires out a chemist to travel to the greenhouses. The necessity of a background in chemistry to understand the inputs for the plants has led to greenhouse family members going to the University for an education in chemistry.

The Structures

In the industry of greenhouses, two major greenhouse structure groups exist: the artisan and the industrial. For the Spanish greenhouse industry, the artisan group is more common and is generally in the form of the parallel greenhouse type. The parallel greenhouse is made by "a vertical structure of rigid pillars (of wood, iron, or steel) on which a double grid of wire is placed, to attach the plastic film" (Castilla and Hernandez 2001, 16). Two varieties of the parallel system exist in Almería, the flat roof and the saddle roof. The flat roofed parallel uses a passive ventilation (lateral and roof vents), equipped with a hot air heating system. In comparison the saddle roof uses passive ventilation (lateral and roof vents) and mechanical ventilation, a shading-thermal screen and hot water heating system (Hita el al 2007). Crops grown in this way have lower yields than Northern Europe's climate controlled greenhouses, but production costs are significantly cheaper (Martin 1999). Some of the differences I noticed while touring the two types of parallel greenhouses was the difference in ventilation and floor to roof distance. The flat roof type typically has passive ventilation going around the sides of the greenhouses or manual crank roof ventilation and the roof was closer to the ground, while the saddle roof greenhouse uses mechanical ventilation systems located in the rooftops. I did not see any passive ventilation saddle roof greenhouses but was told that while not as common, they did occur. Besides the ventilation, the biggest visual difference between the two is the roof shape with one being flat and the other being rounded. The hot water heating system is used in other areas of the Mediterranean but not in Almería (less than one percent) because temperatures remain above freezing all year (Castilla and Hernandez 2001). The availability and cost of local materials for the construction of the greenhouses has been important to the expansion of the industry in Almería. According to Inigo Martin (1999), the parallel type's inability to incorporate new technologies means that its use in Almería is quickly disappearing. Figure 6 shows an example of the two types of parallel greenhouses.

FIGURE 6 The left side is an example of the flat roofed parallel greenhouse and the right hand is a picture of the saddle-roofed greenhouse. The bottom picture is the inside

of a flat roofed parallel type with roof ventilation. Note the rounded roof of the saddle type and the side ventilation of the flat roof type in the upper left. (Source: R.T. Wolosin 2007)

The “arch-shaped multispan (multitunnel) system” exists amongst the industrial types, mostly covered with plastic film, or with “rigid or semi rigid materials (polycarbonate)” (Castilla and Hernandez 2001, 16). These greenhouses are popular with ornamental growers and nurseries but make up only four percent of the total greenhouse area. Heating is installed in some of the multitunnel systems purely for experimental purposes. Figure 7 shows an experimental climate controlled multitunnel greenhouse with heated metal tubing and implementing the New Growing System and a multitunnel greenhouse using the substrate perlite system. Figure 7 shows the roof and multi semi-tunnels shape that are indicative of the name. One new greenhouse facility started by a Dutch company built all their greenhouses in the multitunnel system. I was told that the price of the multitunnel system made it only possible for new growers with enough money or companies wanting to do experimental work. Maria, the owner of the family owned greenhouse, Clisol®*,* has transformed her greenhouse into not only a multitunnel system but also into a tourist endeavor, where foreigners can visit to see the latest in greenhouse technology. Maria said that most visitors to the greenhouse signed up at a local tourist information center and generally were Japanese tours or English retiree tours. For the average farmer switching to a new greenhouse structure is not necessary because the cost of the parallel type is substantially cheaper to maintain. The flat roof parallel plastic greenhouse make up thirty three percent of Almería greenhouses, but they are decreasing in popularity (Maria). The saddle roof parallel greenhouse has increased in popularity and in 2004 made up sixty three percent of greenhouses. A common addition to all types of greenhouses recently has been the collection of rainwater for use in the greenhouses; however, rainwater amounts to only a small yearly total.

FIGURE 7 On the right is a multitunnel greenhouse using the New Growing System near El Ejido, Spain and on the left is a multitunnel greenhouse with the substrate system. The bottom picture is a multitunnel prior under construction. (Source: R.T. Wolosin 2007)

In ninety seven percent of Almería greenhouses whitewashing, a form of painting the exterior of greenhouses, before periods of high radiation in the summer growing period, is the common form of cooling greenhouses (Maria). The reduction in solar radiation, while keeping the greenhouse cooler, limits potential photosynthesis and production. Part of the reason the major growing season in Almería is in cooler months and not the hot summer is the issue of cooling the greenhouse. High priced fogging systems cool three percent of Almería greenhouses (Jose Hernandez). While fogging systems in conjunction with a climate controlled multitunnel greenhouse have the potential for year round crop production, the cost for farmers remains too high. The poor ventilation of side vented flat roof parallel types has led to issues of carbon dioxide depletion and to the popularity of improved ventilation from higher greenhouses (saddle type) with roof ventilation.

Integrated Pest Management

The increase in competition from other Mediterranean countries, with which it is difficult to compete price-wise, and a greater demand for quality from the European market, has forced Almería to seek to strengthen its production with added quality (S & G Peppers 2007a). The growth and competition in Morocco pepper production from greenhouses has led to Almería farmers growing less peppers, more alternative produce, or higher quality peppers. Spain has the advantage of belonging to the European Union that guarantees or persuades Union countries to purchase from other Union countries. For the interviewees competition from other countries was not an issue because they felt that the quality of Almería produce would make it more attractive to importers.

In addition to climate control as a way to increase production and quality, biological forms of Integrated Pest Management in the greenhouse system have given growers an alternative to pesticides and chemical treatments that are damaging to the soil, ground water, farmer, and consumer. Integrated Pest Management involves the "integration of cultural, physical, biological, and chemical practices to grow crops with minimal use of pesticides" (Greer and Diver 1999, 1). Major insect and mite pests of Almería greenhouse crops include aphids, thrips, and whiteflies (most problematic, particularly for tomato growers). Some insects bear diseases like tomato spotted wilt virus that can be devastating to a greenhouse crop (ibid). The simplest form of pest management or pest indicator without pesticides is the hanging sticky paper (see figure 8) which insects fly into, sticking, and consequently dying. Although the sticky paper works and is cheap, it only decreases and does not eliminate the usability of pesticides. By integrating predatory insects or spiders that specialize in a particular pest or pests, Integrated Pest Management can eliminate the necessity of pesticides. These insects arrive in packaged bags (see figure 9), bred at an Almería industrial pest management facilities that specializes in Integrated Pest Management insects.

FIGURE 8 An example of sticky paper being used for a simple version of Integrated Pest Management in a tomato greenhouse and a bumblebee shipment box (Source: R.T. Wolosin 2007, Biobest® 2008).

One example, *Amblyseius swirskii* is a predatory mite that breeds extremely quickly under warm and humid environmental conditions. It predates on whiteflies, thrips, and other pests. In the absence of prey, it can also survive on the plant, feeding on pollen or mould (Syngenta Bioline® 2008). Biological pollination via bumblebees is a popular addition to the Integrated Management system. Bumblebees, *Bombus terrestris*, are shipped (see figure 8) to the greenhouse when pollinators are needed and live out their four to eight week cycle (depending on type) pollinating the crops. Finally, the introduction of biological pesticides has introduced a non-chemical or insect combatant to the repertoire of the Integrated Pest Management system. PreFeRal WG©, a Biobest® product, contains spores of a naturally occurring strain of the fungus *Paecilomyces fumosoroseus*. This fungus is “highly efficient against the greenhouse whitefly and can infect all stages (egg, larva, pupa and adult) of this harmful insect” (Biobest 2008). The Swiss owned Syngenta® and Belgium owned Biobest® are two large agro corporations with Integrated Pest Management facilities in Almería. Bioline®, Syngenta’s wing of biological control research and sales claims, “Over the next year or so, Almería will be regarded as the most successful example of Integrated Pest Management” and biological control for agriculture production (S&G Today 2007).

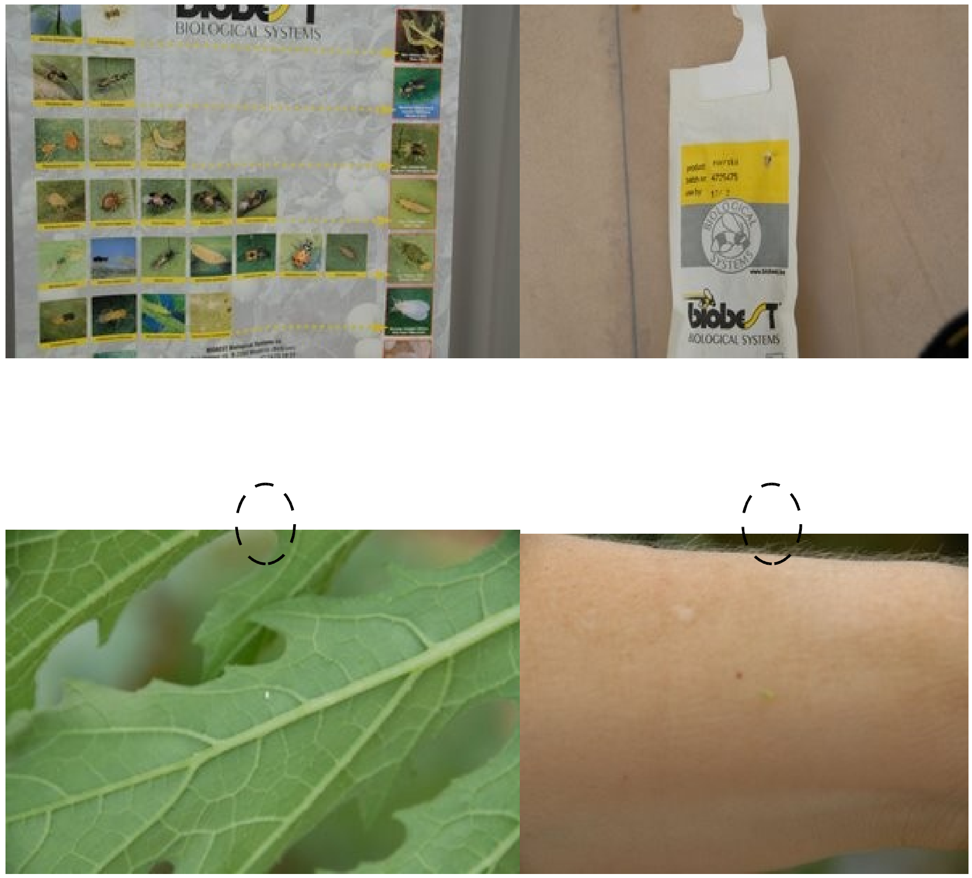

FIGURE 9 The upper left picture is a poster on a greenhouse wall that describes which predatory insects feed on which pest insect. The upper right is an example of the package in which predatory insects arrive. In the lower left picture, the *white fly* is circled, and in the lower right, the predatory mite is circled. (Source: R.T. Wolosin 2007)

With competition from a globalized market, Almería has highlighted the need for increased quality of greenhouse produce. In the winter growing season of 2006/2007, German authorities tested an Almería green pepper positive for Irofem Fosmetil, an illegal pesticide, and banned all imports of Almería produce (The Olive Press 2007a). The ban was abridged to only peppers but caused serious economic strain on Almería and forced/persuaded farmers to look into new farming techniques that are not pesticide and herbicide dependent. This needed increase in quality is being tested through climate control, integrated pest management through biological growing, recycling water, and substrate based growing systems. In 2007, the autonomous regional government of Andalusia invested five million Euros to promote integrated pest management in Almería. The budget is four times higher than the investment made in 2006 (€1.2m) and the money will be used to combat pests as well as to develop biological agriculture (S & G Peppers 2007b). According to S & G Peppers (2007a), 15,000 acres or seventy-five percent of pepper producing greenhouses will be under biological control for the 2007-2008 growing season. Before the 2006-2007 pepper scare, approximately only seven percent or 1400 acres of pepper greenhouses had implemented biological control, showing how quick the industry changes to demand (ibid). Almería exports 265,000 tons of peppers a year to EU countries, a figure that accounts for seventy percent of Spain's exports of peppers to the EU. Twenty-seven percent of all the peppers commercialized in Europe are grown in Almería (ibid). The large investment in new growing techniques by the regional government demonstrates the importance of Almería's agricultural sector at the regional level.

According to a farmer using the substrate system and biological techniques, before the ban on Almería produce, only five percent of farmers were using the new system and techniques, compared to the current ten to fifteen percent of Almería greenhouses using this system. She felt the new techniques were the future of greenhouse agriculture and expected a further increase in the number of biological substrate greenhouses. The substrate system along with biological growing allows for a product free of pesticides and herbicides.

Buying and Selling of Produce

In 1999, thirty-nine different varieties of fruits and vegetables were exported from Almería, making up forty eight percent of covered agriculture in Spain and fourteen percent of all Spanish agriculture (Martin 1999, Hernandez 2000). In the 1997-1998 growing season, there was production of 2.7 million metric tons (2.7 billion kilograms) of produce from Almería Greenhouses at a value of 1,651 million Euros or 2.5 billion US dollars (Cantliffe and Vansickle 2003; S & G Peppers 2007a). Production peaks in December-January in which tomatoes (percentage of greenhouse area assigned: 22%), cucumber (3%), green beans (6%), peppers (19%), and eggplant (3%) are harvested and when demands from the cold northern countries are at their height (S & G Peppers 2007a). Half of the bell peppers, and a quarter of cucumbers and tomatoes consumed in Europe come from Almería, showing the importance of continued production (Hernandez

2000). During May-June, the melon (21%) and zucchini (9%) season gives farmers a chance for a second growing. Currently, for tomatoes, the most important variety is the long-shelf life tomato "Daniella" which embodies eighty percent of the total production (Cantliffe and Vansickle 2003). Almería does grow green beans, melons, tomatoes, and watermelons outdoors but total acreage and yields are significantly smaller than greenhouse totals (less than five thousand acres). Additionally, Almería grows 168,000 acres of unirrigated almonds and 15,000 acres of irrigated almonds (Martin 1999).

The selling and buying of produce in Almería is composed of a unique system of auctions controlled by traditional marketing companies and by co-ops that are either privately owned or a conglomerate of local greenhouse owners. In the 1960s, the agricultural produce was marketed through a system called "*alhondigas*," a name of Arabic origin referring to a coin exchange and translated to mean public granaries (Tout 1990). This system of private party marketing traces its start to the Moorish (North African Muslims) occupation of Almería for six hundred plus years. The *alhondigas* act as a private marketer that buy from the producers in small or large amounts, and in turn auction the produce. The system works with "descending prices," in which a buyer indicates his desire to purchase at a certain price (ibid, 308). The grower then obtains the auction price, minus an eight percent fee (Wilvert 1993). In 1973 MercoAlmería, a state backed marketing organization, was set up in an effort to sever the reliance of the cultivators on the *alhondigas.* Concurrently the cooperative movement started as a response to the "speculative behavior of buyers" (Tout 1990, 308). In 1977, the cooperatives created COEXPHAL, an exporter's organization with seventy-seven members, to compete with the *alhondigas* in the domestic market (ibid). In 1990, there were twenty-six *alhondigas* in the Almería province marketing seventy percent of Almería produce. Grower cooperatives made up twenty percent, Quash-Tierras de Almería (another private marketing company) five percent, and MercoAlmería with five percent of marketing for Almería produce. In the earlier years, southern France served as an intermediate market, but now refrigerated semi-trucks deliver directly to their destination throughout Europe (ibid). Along with marketing, the cooperatives can advise a member to grow a certain crop depending on what is in demand and what is being grown already.

Ejidomar is a grant-aided grower cooperative in El Ejido that formed in 1976 with over 100 members and over 700 acres of agriculture under plastic (Tout 1990). Ejidomar members must sell all of their produce within the co-op and like other co-op farmers, they meet before growing seasons and make decisions regarding who grows what, and how much. The co-op claims to have brought "a greater awareness of quality and grading standards than the *alhondigas*" and exports eighty-five percent of produce internationally, a substantially higher percentage compared to the sixty percent average (ibid, 309). The marketing of higher quality produce and entrance into international markets paid off, and the company doubled its capacity of installations in two years (ibid). Ejidomar paved the way for present day competition for better tasting and assured quality of products than competitor's cooperatives or *alhondigas*. An additional cooperative worth mentioning is the El Grupo Cooperativo Mercosur*,* SA who in 1988 was created with the merger of several cooperatives from Almería, Granada, and Málaga to make up more than one thousand growers (ibid). The growers selling their produce directly to the supermarkets via cooperative contract agreements avoid the auction system of the *alhondigas* (Castilla and Hernandez 2005). This new marketing scheme was effective in supplying European markets with greenhouse vegetables. The combination of cooperatives and corresponding increase in growers, acreage, and produce, allows for more influence when talking with perspective companies about total tonnage and variety of possible crops. Carrefour, the second largest retail group in the world in terms of revenue, Mercadona, the largest retailer in Spain, Aldi and Lidl, the two largest retailers in Germany and amongst two of the biggest world retailers, and Tesco, the UK's largest and the worlds third biggest retailer, are the biggest buyers of Almería produce.

New presentations of established products rather than new crops are the current trend for Almería produce. Presentations include "variations of the color, shape or size of crops already cultivated, as well as quality labels" with examples like cherry and cluster tomatoes in contrast to the Daniella tomato (see figure 10) or baby vegetables (Castilla and Hernandez 2005, 18). Traceability of produce is becoming an essential requirement for production, and has introduced new technologies to the industry (ibid). The pesticide scare mentioned earlier was traced back to thirty-seven specific greenhouses in Almería accredited to these technologies. Traceability allows growers producing high-quality products cultivated in environmentally conscious, labor-safe, and hygienic ways, to assure buyers of their products credibility. The Integrated Management System mentioned earlier is fast becoming a necessary step in assuring the quality that markets foresee as a requirement for Almería to remain competitive in a global market. Growers now provide production details as a common practice in supplies to supermarkets (ibid). Labeling and quality certified products are "winning the confidence and sustaining consumer fidelity" (ibid, 18).

FIGURE 10 Three different varieties of tomatoes starting from the upper left, the long-life Daniella tomato, Pear tomato and Raf tomato. (Source: R.T. Wolosin 2007)

Related Industries

The heightened interest in Almería produce from national and international produce companies has brought additional changes to the greenhouse region. Industries related to the construction, maintenance, and destruction of greenhouses, as well as distribution, packaging, seeding, and recycling of produce, now exist throughout the greenhouse coastal agricultural corridors. Greenhouses in Almería produce 30,000 tons of plastic and one million tons of organic waste per year (The Olive Press 2007b; Webster 2001). To deal with the amount of waste produced an ambitious moneymaking industry; specialty-recycling plants for both plastic and organic waste were constructed in the last ten years. Plastic plants, in addition to constructing the covering for greenhouses, accept used or old plastic covering for recycling purposes. This gives farmers the opportunity to recycle and the possibility of making a small amount of additional money, and for the production company it reduces production cost. Figure 11 shows an example of what a plastic industrial building looks like. Organic waste is composed of old plants after a growing season, vegetables or fruit not considered the right size, quality or rotten, used substrate materials, and sometimes soil from the sand plot. A farmer takes these various items to the recycling plant, where they are piled in compost mounds, eventually packed, and then distributed as fertilizer soil. Touring the greenhouse region of the Campo de Dalias, near El Ejido, my guide and I drove past an organic waste recycling plant, giving a passersby an idea of its industry by the enormous heaps of produce pilled in front. Other plant debris is sent to the landfill, controlled burning, or used in “biofumigation”, a form of pest control using fungus (Castilla and Hernandez 2005).

FIGURE 11 Plastic producing and recycling center near El Ejido, Spain. (Source: R.T. Wolosin 2007)

Industries related to the construction, like those for the integrated, multitunnel, and climate controlled greenhouse and destruction, like parallel greenhouses, are becoming common throughout the province as farmers switch to new greenhouses. Most of the major vegetable seed companies of the world now have experimental stations in the Almería region (Cantliffe and Vansickle 2003). The availability of seeds from local producing, but still mostly large corporate foreign owned seed factories, reduces the cost of importing from the Netherlands and produces jobs for locals or migrants. The seed facilities have brought research money to the region to explore seeds that yield higher levels and produce better tasting crops for the Almería climate. Industries related to the Integrated Pest Management systems, have built facilities for the development of management items for these systems. Specialization in management of pests specific to the Almería, gives the industry a selling point for their product. Furthermore, any industry that is required for the greenhouse industry has taken steps to build facilities in or around the Almería growing areas.

With the growth in importance of quality assurance through labeling, packaging and distribution centers importance as an industry has also increased (Castilla and Hernandez 2005). Enormous state of the art packing facilities, running on conveyor belts that push the produce along a computerized controlled track, litter the province, labeling the produce with the markings of all the big supermarkets of Western Europe (See figure 11 for an example of a pepper packaging plant in Almería). Boxes of tomatoes "bearing Sainsbury's 'sweet and juicy' stickers" and Tesco's certificates of quality assurance are pasted on before making their way to the distribution center and supermarket shelves" (Tremlett 2005, 1). By labeling and sorting the crops in Almería, international and national buyers can package the produce while fresh, ensuring or increasing the chance of superior quality at the grocery store.

FIGURE 12 A pepper packaging facility in Almería with various choices in color. (Source: http://www.pepperstoday.com).

Summary

One of the purposes of this chapter was to explore the greenhouse industry various systems of production. Spain's greenhouse sector is the second largest after China and Almería has the greatest concentration of greenhouses in the world. The systems of Almería greenhouse production are important because of their successes and uniqueness. The development of not only the greenhouse structure but of the systems involved in the making, marketing, and recycling was discussed. This overview is necessary to understand the complexities that make up the province's greenhouse industry. Only forty years ago greenhouses were simply plastic protecting crops grown in sand plots. Today integrated systems recycle water, introduce necessary nutrients, and provide integrated pest management to thwart off invasive insects. The majority of farmers seem to change only when demand from customers rises and prices for these changes drops. As quality certifications and packaging become relevant, the Almería greenhouses will change. As northern European demand for agriculture produce, produced with biological alternatives, increases, farmers of Almería will continue to make the shift to these new forms of growing. This is another example of how the international market forces changes at the local level. The new technologies that use less water, pesticides, and herbicides in combination with recycling of plastic offer possibly more sustainable alternatives to the older greenhouse systems of growing.

The last thirty years have transformed the landscape once again by the addition of a plastic sea built over the arid landscape. As demand for winter produce has grown within and outside of Spanish borders, the plastic has spread to new areas, sometimes at the expense of a hillside or dry river. Politicians typically look the other way when it comes to environmental issues, unless they influence the greenhouse or tourism sector, because the population of Almería depends on the agriculture to remain economically successful. The regional and national governments have introduced policies for new water sources, particularly from desalination, showing the importance of the region. Advocates of the greenhouse agriculture point to the wealth it has created and the poverty it has alleviated, having turning the poorest region in Spain into one of the most economically successful. There have been both advantages and disadvantages to greenhouse agriculture in Almería. These advantages and disadvantages are social and environmental in nature. The next chapter aims to examine these aspects with particular attention to water.

Chapter V

Political Ecology of Almería's Greenhouse Agricultural Sector

Introduction

The purpose of this chapter is to use the theoretical framework of political ecology to examine the water issues associated with the greenhouse agricultural sector in Almería. Considered the driest area in Europe, Almería is subject to minimal average annual precipitation, low water availability, and a high rate of evapotranspiration. The development of greenhouse agriculture in the last thirty years in this corner of southern Spain has been spurred by local, regional, and global agricultural policies. These agricultural policies which operate at various scales of government have a direct impact on agricultural practices as well as the management of land and water. Water in particular is the most important resource in the Almería area without which the continuation of large-scale agricultural production would be impossible. With the growth in the greenhouse sector and concomitant demands for produce from other European Union member countries, new challenges have arisen that are associated with impacts on water use and management, including, but not limited to, the following: salination; water shortages, over-use of low-lying aquifers, competition from increased population and tourism, and pesticide and herbicide water contamination. In response, innovations in water conservation and watering systems have been adopted within the greenhouse sector.

Water is the key to the success of greenhouse agriculture in Almería. Since the 1950s when the Spanish government drilled the first water wells in the greenhouse growing area of Almería, Almería's dependency on water has remained an imperative. Without various policies and practices to secure a source of viable water for farmers and residents, Almería would have most likely continued to be a dry uninhabitable desert of Europe. The Spanish government's national AGUA plan in 2000 and more recent policies and water politics (i.e., hydropolitics) further underscore the critical importance of this resource to a whole industry and the growth trajectory of the province. The lessons learned from an analysis of the Almería situation may perhaps be applied to understand similar water issues worldwide. The analysis of this case study will draw upon the findings from both an empirical investigation and an extensive analysis of the scientific literature.

This chapter begins with a background on Almería's current environmental state providing information regarding precipitation and temperatures. A theoretical background on political ecology, degradation, and water resources research follows. This section of the chapter provides a background on the topics and research by others, and relates it to water issues in Almería. The chapter then moves into a section that provides a history of water for Almería greenhouses. The section covers the beginning stages of development of the Campo de Dalias, and the transformation of the Campo's water systems to provide for a growing agriculture industry. The next sections cover recent water politics plans of retaining enough water for greenhouse production and a booming population, while combating water shortages and salinated water. The summary discuses the processes that contribute to perceived benefits and costs of water related issues in Almería's greenhouse sector.

Almería's Environment

Almería has seen substantial growth both economically and agriculturally in the last thirty years. Almería deals with benefits of an economic boom via the rise in greenhouse agriculture and the problems that arise from large-scale agriculture in an arid climate. See Figure 13 for information on average temperatures and precipitation in Almería.

Monthly averages				°F | °C
January	Avg Low: 48°	Avg High: 63°	Avg Precipitation: 0.54 in	
February	Avg Low: 49°	Avg High: 64°	Avg Precipitation: 0.81 in	
March	Avg Low: 52°	Avg High: 67°	Avg Precipitation: 0.56 in	
April	Avg Low: 54°	Avg High: 70°	Avg Precipitation: 0.5 in	
May	Avg Low: 59°	Avg High: 75°	Avg Precipitation: 0.39 in	
June	Avg Low: 66°	Avg High: 82°	Avg Precipitation: 0.16 in	
July	Avg Low: 71°	Avg High: 87°	Avg Precipitation: 0.03 in	
August	Avg Low: 72°	Avg High: 87°	Avg Precipitation: 0.02 in	
September	Avg Low: 68°	Avg High: 83°	Avg Precipitation: 0.34 in	
October	Avg Low: 62°	Avg High: 76°	Avg Precipitation: 0.81 in	
November	Avg Low: 54°	Avg High: 69°	Avg Precipitation: 0.64 in	
December	Avg Low: 50°	Avg High: 64°	Avg Precipitation: 0.88 in	

FIGURE 13 Monthly averages for Almería temperature and precipitation. (Source: http://www.msn.com).

Drought is the major environmental condition affecting southeastern Spain today. Drought is defined as surface and subsurface water supplies that are below normal and the effect of physical water shortages on people. In the past twenty years, areas of Spain, including Almería, have shown a marked decrease in precipitation and an increase in the number of drought-related conditions (Lana et al. 2001, Vicente-Serrano et al. 2004). According to the Spanish Meteorological Institute, Spain is presently experiencing the lowest rainfall levels in 60 years. The precipitation records, which date back to the 1940s, indicate that not only is Spain in the worst drought in recorded history, but the drought has been a sustained drought for the past ten years. High temperatures exacerbate the drought conditions. Many areas expect to have a 4 degree Celsius increase (7 degree Fahrenheit) in temperature in the next 70 years (Euroresidents 2005).

According to the Spanish Meteorological Institute, the regions most affected by the drought include east Andalucía, Murcia, and Castilla La Mancha (Euroresidents 2005). The small-scale agricultural sectors in these areas have experienced the greatest damage to their livelihood because the drought has made it hard to compete with large-scale agriculture. Drought research into water shortages, crop failures, decreased river flows, groundwater mining, shrinking reservoirs, and negative economic impacts have well-documented statistics for many of these regions in southern Spain (International

Herald Tribune, 2002; Reuters 2006; ThinkSpain 2005). An exception to the unfortunate economic picture is the province of Almería in the region of Andalucía that has seen a steady economic boom, shifting in economic rank from being one of the poorest to the fifth wealthiest among over fifty provinces.

The demand for produce has led to a continuation of intensive agriculture in the region even though the area is stricken with a drought and is desperate for water. The regional and international market has pressured the region to continue its expansion of greenhouse agriculture despite the problems encountered by water shortages. Southern Spain's produce supply market to northern Europe is analogous to Mexico and southern California's year round produce supply to much of the U.S. and Canada. The *International Herald Tribune* published an article by James (2002, 1) summarizing drought related issues throughout the world. James concluded with a statement about Almería's greenhouse agricultural sector:

> "use of vast amounts of water for hydroponic cultivation…has severely depleted the region's underground water supply, thus degrading the soil by increasing its salinity…turned Almería into a vivid illustration of desertification…The battle against desertification has been undercut because environmental concerns get pushed to one side by enthusiasm over the economic boom."

Political Ecology, Degradation, Resource Control

To study the transformations and history of water issues and systems in the Almería greenhouse sector, I employ a political ecology framework. As previously mentioned I use Watts's (2000, 257) definition of political ecology. Through research into historical decisions regarding water by local and non-local entities, and an outsider perspective of the Almerían agricultural sector, I attempt to build an understanding of the various factors and processes of the GA sector's water. Local insights and perceptions gathered through fieldwork are used to underscore the complexity of the situation surrounding Almería's water and give a localized opinion on water issues. Research from geographers and other allied social scientists have addressed questions of water. A few of these research topics will be discussed in this section of the chapter. The political ecology framework will lay the foundation for understanding how policies and an economic boom, fueled by produce demand, have transformed the water system of Almería.

According to Karl Marx, the "degradation of the environment is fundamental to capitalism" (cited in Robbins 2004, 46). A key to capitalist production is the "extraction of surpluses from labor and nature" which is needed to feed an always-growing economy (ibid). Thus, capitalistic governments must find a source of surplus to continue growth no matter the outcome. Land is expected to produce and to keep the economy running. For any environmental industry, the rate of extraction always outpaces the restoration (ibid, 51). These ideas correlate with Almería's water shortages, salination of water, attempted water pipes from northern Europe, and now the construction of a massive desalination plant to keep the economy and agricultural industry growing no matter the environmental outcomes.

Robbins's (2004, 14) degradation and marginalization thesis shows how "otherwise environmentally innocuous local production system undergo transition to overexploitation of natural resources on which they depend as a response to state development intervention and/or increasing integration in regional and global markets." State intervention in the Almería water system, and Almería's integration into providing cheap winter produce for a regional and global market, have overexploited and transformed the water system of Almería. Political ecology "recognizes that resource use patterns may be ecologically degrading while being socially profitable or functional, at least in the short term," for farmers (Ferguson and Derman 2005, 62). While Almería has depleted and damaged its water source (resources degraded), the region and farmers have been economically successful (social profits). In addition to continuing the scale of greenhouse agriculture in Almería, new methods of providing water were and are necessary.

Issues of privatization of water, water management policies, and cross border water conflicts and decisions make up the majority of political ecology studies on water (Budds 2004; Loftus and McDonald 2001; Walsh 2004). In these analyses political ecology "serves to re-embed water politics in daily practice through its focus on management questions and the articulation of these questions with the changing context of state and market roles" (Dubash 2004, 218). Dubash's essay explores rural groundwater use and systems of exchange for ground water in western India and concludes that markets are "ultimately social institutions that are shaped by local circumstance and ecological context" (ibid, 219 and 239). While Dubash centers on privatization and the process of selling of groundwater and differs from the context described, the papers share the similarity of water and the roles of various actors in management methods. The alterations in the Almería water supply are influenced by ecological changes in the Almería climate, but I argue in addition that these changes in the water system are the result of foreign and local management request. Questions of water management in Almería must be looked at in the framework of local, regional, state, and international policies. The policies of these various scales each have an important role in past and future decisions regarding Almería's water system.

Concerns about privatization also relate to issues regarding the supply of water from privately owned desalination plants and the effect desalination has on the price of water for farmers. In 2003, a few powerful corporations controlled ten percent of the world's water supply, but within the next ten years "the top three" corporations could have "control of over seventy percent of water systems in North America and Europe (Barlow 2003, 29). The private sector can "bring expertise in both technology and management, and can organize financing for water infrastructures and services" which would be beneficial to more cost effective desalination plants and distribution of water to farmers (Catley-Carlson 2003, 71). In the past Spain has been skeptical of private energy and resource industries opening businesses within Spanish borders, but as part of membership in the European Union, fair competition for foreign European industries opposed to private Spanish industries is necessary. Regardless of foreign or Spanish ownership, private desalination is part of the future and will alter yet again the Almería greenhouse agricultural sector. This chapter does not look into the detailed issues of privatized water via desalination because of how new the technique is to the area and the lack of information regarding future ownership of the desalination plants.

Brown's essay (2003), "The Effect of Emerging Water Shortages on the World's Food" brings up other examples of aquifer shortages leading to changes in water systems and sources. Brown points to a 2003 Chinese aquifer shortage under the North China Plain in the wheat and corn growing area, that depleted groundwater to a level that only rainwater could replenish, forcing farmers to drill into the deeper and non-replenishable aquifers. According to Brown (2003, 79), "half of the world's population live in countries where aquifer depletion threatens to reduce food supplies." Where one would think that water issues would just be a regional or national issue, water scarcity issues have crossed international borders via international food trade and markets in Almería. Brown argues that "farmers who lose their irrigation water supply entirely have the option of returning to lower-yield dry-land farming" or in desert areas "loss of irrigation means the end of agriculture" (ibid, 81). Unfortunately, Brown leaves out any possibilities or descriptions of alternative water supplies like desalination or wastewater.

Briscoe's essay (2002, 181-190), "Water-The Overtapped Resource", describes agriculture's use of water throughout the world. Briscoe (ibid, 183) writes that "the most immediate and obvious problem associated with unnatural irrigation-based farming is that it requires a steady source of water but does nothing to replenish this source." The depletion of underground aquifers due to drip irrigation in Almería far exceeds the natural rate of renewal. In addition to Spain, the United States, India, China, North Africa, and Saudi Arabia have seen substantial depletion of aquifers due to agriculture irrigation. "Depending on local characteristics and the extent of the depletion, declining groundwater sources can bring the utter collapse of communities and farms" (ibid, 184). As Brisoe (2002, 184) and others point out, the overuse of underground water sources has severe consequences. When the price to pump water increases, "small farmers with tight operating cost are squeezed out… large, wealthy operations that can afford the technology to pump water remain in business" and buy out the smaller farmer. In Almería, small acreage family owned greenhouse farms, usually three acres still make up the great majority of the industry and Almería, but slowly foreign owned companies with money are moving into the region. With the introduction of desalination and new forms of recycling agricultural water, prices for water will rise and small farmers will have to pay. Water shortages have become an ever-important issue in Almería and will lead to a transformation and transition in water use for farmers.

Water for Agriculture in Arid Almería

In the early to mid 20th century, Spain established government programs to "raise the rural standard of living nationally by providing water for irrigation" (Wilvert 1993). The majority of Spanish provinces dealt with providing water by building hundreds of dams throughout the country, so that today Spain has over "1000 dams and reservoirs that cover more than five percent of the country's surface area"(Downward and Taylor 2005, 278). In Almería, the lack of groundwater or rain but available land led to the government looking below the surface to the then abundant shallow aquifers of the Campo de Dalias. In 1941, the Spanish Ministry of Agriculture (*Ministerio de Medio Ambiente y Medio Rural y Marino*), working through the National Institute for Colonization (*Instituto Nacional para la Colonización*), became responsible for the introduction of the irrigation system that has transformed Almería and in particular the growing region of the Campo de Dalias ten miles west of the province capital, Almería (IEEP, 2000). Water pumped from the aquifers was dispensed by way of "gravity systems from irrigation systems and utilized in the agricultural plots with surface or flood irrigation" (ibid, 69). Until 1950, dry land crops were grown. The first substantial wells were dug 115-130 feet by hand, and water was pumped to an irrigation channel for distribution to nearby fields.

In1953 the Spanish government with the General Plan for the Colonization of the Irrigation Sector at Aguadulce (a town in the Campo de Dalias) offered 3,845 acres of land, with 1,850 fit for irrigation, to mountain villagers in return for their relocation into the agricultural sector of Almería (IEEP 2000). The parcels of land were then subdivided by the government into three-acre plots, sold cheaply, or offered to farmers at very good terms, or sometimes sold along with new houses in planned villages (Wilvert 1993). At the end of the 1950s, greenhouse agriculture was introduced to the region but substantial expansion in the greenhouse agricultural sector did not begin until the 1970s. Spray lines and electric pump-fed irrigation, which provides water at required volumes and times with limited labor or economic cost, superseded furrow irrigation in the late 1960s and early 70s. The availability of water in the Almería aquifers and new technologies meant "that water was inexpensive and, over the short timescale in which growers expected economic return on their investment, seemingly inexhaustible" (Downward and Taylor

2007, 261). In 1971, trickle irrigation (drip irrigation) was introduced from Israel. However drip irrigation would not gain in popularity until restrictions on water were consigned in the 1980s. In 1973 with only 2250 acres under plastic horticulture, the Spanish government added an additional 5,000 acres of irrigated land (IEEP 2000). Subsequently the over-exploitation caused a drop in the water table and deterioration of the quality of water from the Campo de Dalias aquifer. Instead of using water exclusively from water wells, water irrigation was partially supplemented by the Beninar reservoir. By 1975, the irrigated area of Almería was approximately 16,580 acres with total greenhouse acreage at 7500 acres. In 1977, an additional chapter of irrigated land was added using regulated water from the reservoir.

In 1980, the Spanish Geological and Mining Institute (now the Technological and Geomining Institute or Instituto Geológico y Minero de España) began a series of studies intended to identify possible marine intrusion (salination) into the Campo de Dalias aquifer (IEEP 2000). Greenhouse acreage by 1980 was nearing 18,000 acres and rising rapidly along with concerns of water shortages and salt-water intrusion. About this time, farmers realized that greenhouses "were essential technological and productive bases, allowing a much earlier ripening," thus a better price for out of season crops, and "an increase in production" with lower investment cost (ibid, 71). In 1984, with evidence of the over-exploitation of the aquifers and marine intrusion, The Junta de Andalucía (Autonomous Government of Andalucía) froze the expansion of irrigated greenhouses, implementing legal restrictions on water extraction (ibid). However this only limited the aquifer pumping in various growing sectors of the Campo de Dalias, while pumping, both legal and illegal, continued in others. In 1984, an additional measure banned the building of new or expansion of old greenhouses because of lack of suitable or sufficient amounts of aquifer water. Professor Juan at the Universidad de Almería alleged that "it was hard to make this measure accepted socially as there were many people in need" of water, and "the landowners within a liberal economy wanted to enforce their rights to do whatever they wanted with their lands." The measure was never followed through on because there was "no interest to make people follow it." From 1985-1986, between 1200 to 2700 acres of new greenhouses were implemented regardless of restrictions.

After 1986, in response to water shortages and farmers' demand, the Andalucía government took several steps to alleviate shortage issues. Between 1986 and 1990, millions were spent on deeper wells, water supply lines, and new irrigation pipes. A dam was built on the Rio Adra at Beninar, about thirty-five miles from the Campo de Dalias, and water brought by canal and tunnel to the greenhouse growing area (Tout 1990). In 1986 a grand scheme to supply Almería with water from the Rio Trevelez, in the adjoining province of Granada, was squashed by protestors (ibid). The biggest and most important endeavor at this juncture to facilitate water demands was when the government dug a community well 700 meters (2000 feet) deep in the mountains to the north of the Campo de Dalias. The water is pumped from the mountains and through pipes to artificial holding reservoirs where another series of pumps and pipes send water to the greenhouses. Because the well is used for not only agricultural purposes but also urban/rural populations, the government regulates the amount of water farmers receive per day. The regulation of water made drip irrigation a necessity for any greenhouse farmer wishing to maintain high production and low water input. The government's intervention in Almería's salination issue shows the early importance of the agricultural sector to the economy, not only of Almería but also to the region of Andalucía and country of Spain. By the late 1980s, drip irrigation was a requirement for the approval of loans for new greenhouse development (Tout 1990). Downward and Taylor (2007, 284) conclude that:

> while regulation has undoubtedly improved the irrigation communities, in practice there has been a lack of reliable information on exactly how much water, where and at what rate it was being abstracted and recharged, and what the long term environmental implication might be.

Restrictions or a lack of an adequate water supply kept greenhouse growth relatively slow from 1985 through 1990, growing at about 2500 acres per year. However by 1990, there was still an astonishing 41,000 acres of greenhouse agriculture in the province of Almería. See Figures 14 and 15 for information on mean annual groundwater abstraction and discharge/recharge percentages from the shallow aquifers. In Almería, there are two different types of aquifers, shallow unconfined aquifers and deep confined fossil aquifers. The shallow aquifers can be replenished by rainfall but are susceptible to saltwater intrusion while the deep aquifers are a closed system. Most pumping in Almería has been in the shallow aquifers but the deep water well in the mountains uses the deep aquifer. For figure 14, note that the highest levels of groundwater abstraction are located in the Campo de Dalias (hydrogeological unit 6.14) and Nijar (hydrogeological unit 6.11) greenhouse growing areas. In Figure 15 areas with high overdrafts (total discharge exceeds recharge) of aquifers are coincident again to the two irrigated greenhouse growing areas.

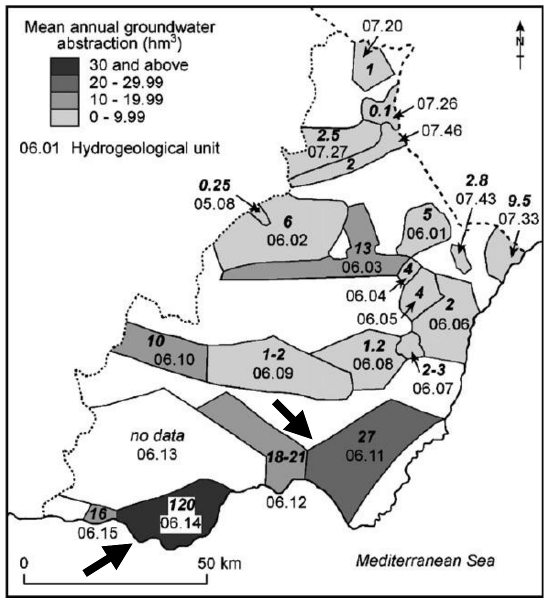

FIGURE 14 Mean annual groundwater abstraction for each of Almería's hydrogeological units. Note (large arrows) the highest amounts of extraction come from the greenhouse growing areas of Campo de Dalias and Nijar. (Source: Downward and Taylor 2007).

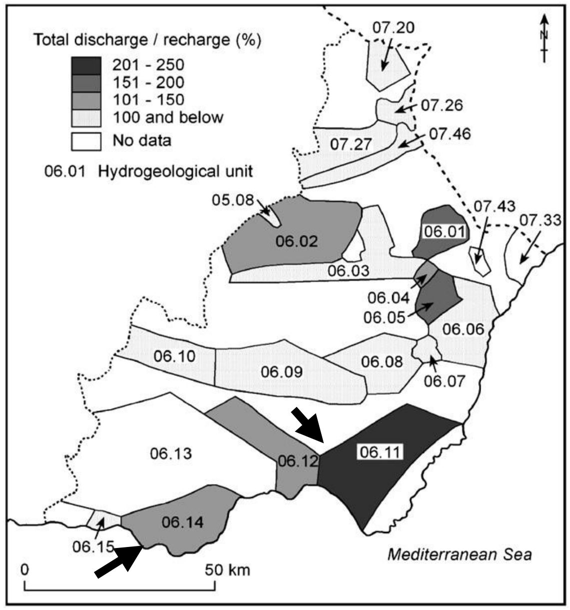

FIGURE 15 Mean annual ratio of total discharge/recharge percentages for each of Almería's hydrogeological units. Note (large arrows) the two greenhouse growing sectors. (Source: Downward and Taylor 2007).

New Policies and Markets

On January 1, 1986, after the transition to a democratic political system was completed, Spain entered the European Union by signing the *Tratado de Adhesión* (Treaty of Adhesion or Union). This implied a "total liberalization of trade with the members of the Union and the adoption of all the trade agreements" instituted by the European Union and other countries (Boldrin and Prieto 1997, 23). It required the elimination in the space of three to four years of the "residual quantity restrictions on imports and exports" as well as the "abolition of tariffs" (ibid). The liberalization of trade with other European countries that resulted from Spain's entrance into the European Union introduced the Almería greenhouse horticulture sector to a new market for the sale of produce and a justification for more growth in greenhouses. New institutions and policies led to new markets and thus the expansion of the greenhouse growth and water demands. The prospect of dealing with watering crops for a growing market with high demands placed new pressures on Almería's water sources. In addition to introducing a new market for produce, joining the European Union meant compliance with environmental instructions, maintaining good ecological status in sensitive areas, and following the European Union's water framework directives and policies. By 1994, the total greenhouse acreage of greenhouses in Almería had grown to 62,000 acres.

In a conjunction with greenhouse growth, the early 1990s brought a serious drought affecting the Mediterranean Europe for five years (Reuters 2006). Greenhouse growers continued to irrigate using water from shallow ground water wells using aquifer mining. The mining of shallow aquifers inflicted serious depletion of most of the coastal aquifers. Water mining shallow aquifers that needed less pumping is another example of the lack of political action taken to restrict greenhouse growth or water withdrawal. The lack of action is due to locals who see only the short-term economic gains possible in the produce market and government officials who saw a growing economic industry for the region of Andalucía.

Almería's aquifers are seldom "exhausted but overexploitation by pump abstraction" causes significant changes in the water chemistry by way of salinisation or salt-water intrusion (Downward and Taylor 2007). The development of salinisation occurs in several ways. The aquifers themselves may include salt-rich rocks; water drilling might tap pockets of water from former sea levels, and excessive pumping and associated drawdown can encourage salt-water intrusion into the aquifer (Downward and Taylor 2007). Technological advances have altered irrigation systems and brought improved efficiencies (ibid). Growers have adopted their crops through selection and specialist seeds to better suit water with higher salinity levels when aquifer levels drop. Dependency on the limited variety of salt resistant crops, like tomatoes, is problematic for an industry that demands a greater variety and reduces the "growers' ability to command higher prices than their global competitors" (ibid, 284). By the mid 1990s, the majority of greenhouses in both the Campo de Dalias and Campo de Nijar growing areas had switched to drip irrigation-watering systems. The 1990s introduced computer-controlled fertilizer and irrigation systems that control and optimize the water and nutrients levels to the preferred levels for the life cycle of the plants. Although new technologies have reduced the amount of necessary water, the continued expansion of the greenhouse sector and growth in other industries place demands that exceed the natural recharge rate from precipitation to replenish the water drawn from the aquifers.

Conflicting Industries

The 1990s have brought growth in population and two additional industries demanding water: the arboriculture industry with a particular emphasis on olives, and tourism. Unlike greenhouse crops, the growth of olive plantations in Almería was stimulated by European Union subsidies that have provided a major incentive for farmers' interest in oil production. The area under irrigated arboriculture in Almería doubled from 1997-2003 to 74,000 acres with 25,000 acres for olive production (Downward and Taylor 2007). In contrast to the greenhouse industry, the majority of arboriculture operations irrigate through gravity irrigation (surface flooding or ditches) instead of drip (IEEP 2000). Competition between the greenhouse and arboriculture industries for both available land suitable for agricultural growth and water resources has not been an issue in the province. Different requests in appropriate land for the two industries (climate, soil, wind, etc.) and the necessary water resources keep conflicts at bay. Based on field data and current trends we can expect to see heightened issues of aquifer water contamination and the reduction in the natural replenishing rate, in correlation with higher water cost from future desalination resources, may ignite a battle for water between the two booming industries.

Conflicts do exist between greenhouse agriculture and tourism. Spain remains one of the top tourist attractions in the world with just fewer than 60 million visitors in 2006 and rising, compared to 40 million only three years prior (World Tourism Organization 2007). The growth in tourism is centered on the coastal regions of Spain's Mediterranean coast and stretches in patches from Barcelona in the northeast to Cadiz and Huelva in the southwest. The Costa del Sol in the southwest and Costa Dorada in the northwest now embody sky scraper hotels, ex-pat apartment blocks, golf course resorts, yacht clubs, and Spanish and foreigner condos and second homes. The Costa de Almería, the Mediterranean coast of the Almería province, was until recently relatively unknown to foreign tourists and remained a mostly "Spanish" weekend or vacation getaway. The availability of cheap land, a rising population, and the booming agricultural industry helped to put Almería on "the map" for new tourism development endeavors. A Spanish government allotted natural park on the east side of the province provides tourists with undeveloped and scarcely visited beaches, and the coastal fringe of the Campo de Dalias, including the cities of Aguadulce and Roquetas, encompasses all the necessary amenities for tourists. The town of Almerimar even has a professionally designed golf course and a four-star clubhouse/hotel. Almería is now a popular destination for British, German, and Scandinavian retirees searching for cheap land and sunny weather. The widely read Lonely Planet (2007,397) introduces the province of Almería as having "3000 hours of sunlight" that bring beach, golf, and sun lovers to the coastal resorts.

The areas near the coast with climates better suited for agriculture are lined with vacation developments. Farmers with land on the fringe of the Campo de Dalias, adjoining or near the Mediterranean, find it more profitable to sell out to developers than to continue in the agricultural trade. In agreement, one interviewee, Santiago said, "Building houses is more profitable than agriculture, so they [farmers] are building houses, and they are selling their greenhouses because these are becoming less profitable on a daily basis." Although this would normally result in the reduction of greenhouses, instead new farmers seek out land in the Campo de Nijar or the valleys stretching north into the mountains from the Campo de Dalias for new greenhouses. Consequently, tourism development continues to grow along the coast as the greenhouse industry grows inland. Santiago thinks that "more and more tourists are coming, and fewer and fewer greenhouses are being built," meaning that the pendulum of importance is switching over to tourism.

Competition between tourism and the agricultural sector regarding issues of water have emerged in the past ten years. Farmers who have been on the land since the original greenhouses, find it unfair that tourism is sucking water out of aquifers that have provided the greenhouses with the sustenance to exist in the arid climate of Almería. Developers argue their right to build as long as there is demand from the tourism industries and the government allows it. Typically, in other provinces:

> Agricultural production has become less economically viable compared to tourism given that thirteen hundred liters of water are required in order to produce a dollar's worth of agricultural produce, while only twenty-three liters are needed to produce a dollar in the tourism sector (Auernheimer and Gonzalez 2003, 179).

In Almería, greenhouse agriculture reduces the amount of water necessary per dollar made, but that is still above the tourism ratio. Aquifers that struggle to provide for just the growing population and immense horticulture industry now have to provide for tourist developments, expat housing, and golf courses. Solutions to the problem include reduction in water use, desalination, and gray water treatment of sewage water. The three farmers interviewed in my research had no qualms with the tourist industry, and instead viewed it as an important aspect in making the Almería economic makeup more well rounded. "So this [tourism], along with businesses and the distribution of agricultural products, have produced other activities in the province, so that today's economy is more balanced" (Pedro). They regarded the greenhouse industry as too important to the province, region, and nation to let tourism subsume agriculture. They viewed a future that allowed the two industries to exist side-by-side using water from alternative sources and reduced amounts of aquifer water. Animosities exist between farmers and tourist developments, but as long as suitable, relatively cheap water exists for greenhouse farmers, little will be done to change the continued growth and importance of the two industries.

Pipe Dreams and Politics

To combat issues of water shortages in the 1990s, the Spanish government passed the Spanish National Hydrological Plan (SNHP) in 1998. The National Parliament approved the plan in 2001, and the plan immediately became a heated issue in Spanish politics and news (Downward and Taylor 2005). The SNHP's transbasin dispersions would transfer water from water basins considered to have an abundant or excess amount of water to basins with a lack or deficiency of water. The plan detailed the construction of a series of dams throughout Spain, and a series of water transfer pipelines starting from the northwestern Spanish Ebro river basin and stretching as far as Almería (over 700 kilometers or 435 miles away) to the southeast of Spain, and transfer pipelines from the Rhone River to Barcelona. The main receiver of the transferred water would have been the irrigated agricultural sectors of Murcia, Alicante, and Almería receiving fifty-six percent of the total, followed by cities, industries, and tourist developments on the eastern coastline receiving the remaining forty-four percent (Auernheimer and Gonzalez 2003).

Serious environmental concerns were highlighted by opponents, particularly with respect to compliance with European Union environmental directives such as the habitat and water framework directives that require Spain to maintain good ecological status on the Ebro River (Downward and Taylor 2007). With the European Union offering to front forty percent of the bill for the SNHP, opponents felt the Union was funding a project that went against its own directives. Opponents additionally pointed to the fact that agriculture in the Ebro River basin would suffer, so that unsustainable development in the south could continue.

The Almería government believed that while the SNHP water transfer would be helpful, the transfer would not be enough to combat water deficits. The greenhouse sector and money produced from the industry were enough for the government to plan for the transfer of water from the Ebro. The Spanish government and European Union were willing to decimate and alter the Ebro river basin for the benefit of industries, growing populations including expatriates, and agriculture up to 700 kilometers away from the source. Almería and the rest of Spain would never see the results or conflicts created from the SNHP because in 2004 the newly elected socialist government, with President Jose Zapatero's approval, cancelled the National Hydrological Plan. The new government launched the Progama AGUA, *Actuaciones para la Gestión y la Utilización del Agua*, or Actions for the Management and Use of Water (Downward and Taylor 2007). The cancellation of the Ebro water transfer is widely applauded as a "triumph of environmental consciousness and autonomous liberty over the perceived water greed of the southern Mediterranean provinces" (ibid, 278).

In his 2004 inauguration speech President Zapatero (MMA 2005, 1) declared his plans for AGUA:

> I want to announce a new politics of water, a politics that will take into consideration the economic, social, and environmental value of water with the objective of guaranteeing its availability and its quality, optimizing its use, and restoring the associated ecosystems.

AGUA emphasizes desalination as the means to guarantee water availability and quality on the eastern cost of Spain. Ten provinces are included in the AGUA program at an estimated cost of around 4 billion Euros, or about 6 billion dollars, with one thousand hectometers of water (over one million acre-feet) added to the provinces. Twenty-one desalination facilities, including upgrades and construction of new ones, are included in the plan. Spain has more than fifteen hundred kilometers of seashore and plentiful coastal aquifers for desalting briny groundwater (Downward and Taylor 2005). Unlike the water transfers of the SNHP, supplies of desalinated water may be available regardless of climate changes or drought, and possibly give the coastal regions an endless supply of water. The Spanish government believes that the revenues from the agricultural, service, and tourism industries will offset any financial limitations to the cost of desalinating water (ibid). One hundred eighty nine hectometers or 230 thousand acre-feet of water from five desalination at a cost of 352 million Euros have been allocated to the province of Almería from the national government. The manufacturing of desalinated water in Spain doubled from 2000 to 2004. The Spanish government predicts that production will double again in another five years, particularly with the passing of AGUA. Today, Spain is the fourth largest user of desalinated water, and Spanish companies make up the "largest percentage of competitors on the international market for the design, engineering, construction, and operation of new desalination plants around the world" (Technology 2006).

Desalination as the Solution?

Before the cancellation of the SNHP, Almería politicians and water planners recognized that they could not wait until the 2015 completion date for the Ebro basin water pipeline as a solution to water shortages. Shortages were heighted in the 1990s with a long-term drought, booming urban population in the cities of El Ejido and Almería, a high capacity for the development in tourism, and the continued growth and importance of the greenhouse agricultural sector. Downward and Taylor (2005) point to the possibility that Almería may have wanted to remain independent of the right-of-center national government's SNHP because of the province's affiliation to the socialist government of Andalucía which had voiced its opposition to the plan's sustainability. Almería commissioned the building of two desalination plants as a logical and quick solution to shortages before the passing of the SNHP in 2001. Almería accentuated the vital necessity for domestic water to divert attention away from any "perceived agricultural profligacy (wastefulness)" in hopes of attracting European Union financial support for the construction of the desalination plants (ibid, 285). The plan worked and the European Union funded half of the 121 million Euros for the construction of the biggest desalination plant in Europe at Carboneras (see figure 16), a small town in the eastern part of the province. The estimated cost for the reverse osmosis desalinated water, in conjunction with water reuse treatments, could be provided at .45 Euros per cubic meter, compared to the estimated .75 from the SNHP planned transferred water (Uche et al 2001).

The Carboneras plant opened in 2002 and the initial output per day stood at 10,000 cubic meters (2.6 million gallons), supplying 120,000 homes with domestic water. At full capability, the plant can desalinate up to 120,000 cubic meters (31.7 million gallons) per day. Carboneras already produces enough water for irrigation of 7,000 hectares (17,297 acres) of greenhouse farmland in the Campo de Nijar growing area (United World 2008). The second plant converts brackish water, which is typical of the low-lying aquifers that have more salt then fresh water but less than the sea, into drinkable water for the city of Almería. The plant will provide 76 thousand cubic meters of water per day to the capital. Unstructured interviews and conversations with individuals living in the capital suggest that the brackish water facility has experienced multiple problems and has yet to operate at a substantial production rate. The AGUA program lays the foundation for four new desalination plants in Almería and a second phase addition to the Carboneras facility.

FIGURE 16 Europe's biggest desalination plant located near Carboneras, Almería. The red circles identify two large tanker boats docked at the facility to offer a scale comparison. (Source: http://maps.google.com)

If water savings and the possible acquisition of desalinated water improve water quantity and quality, greenhouse growers can increase their productivity through increased yields, better quality produce, and possibly a greater variety of produce. Santiago, in response to how desalination would affect local agriculture, put it this way:

> Well, all solutions have an impact on the environment. We have to try to make that impact as small as possible. The agriculture would be affected in that prices would surely rise. The construction of these plants [desalination] entail big investments and big labor and a lot of time, which in turn will make water more expensive and then the crops grown with that water will obviously be more expensive. We are doomed to live with that! I, for one, think that this is a very good idea because it is based on a natural atmospheric process. The problem is environmental impact, which is what we have to try and solve. Even if the produce becomes more expensive, I think this is the best solution.

Farmers who have maximized their productivity efficiency yet still operate at limited profitability would be susceptible to bankruptcy in the event of an increase in water prices. Downward and Taylor (2005, 287) believe that "aquifer recovery will only be possible with effective pricing to ensure that desalinated water is affordable relative to conventional resources." As long as desalinated water stays more expensive than conventional water resources, growers will combine poor quality aquifer water with high-quality desalinated water to achieve a desired quality. This could mean that aquifers would not be given the chance to recover and possibly could lead to illegal drilling of aquifer water to compensate for rising water prices. Professor Herrarez at the Universidad de Almería concludes that future water supplies for Almería agriculture "lay in the massive use of the desalination plants."

Impacts of desalination include brine build-up, increased greenhouse gas emissions, high-energy dependencies, destruction of prized coastal areas, and reduced emphasis on conservation of rivers and wetlands (World Wildlife Fund 2007). Electrical costs are the second highest after construction and make up sixteen to twenty percent of desalted water cost (Downward and Taylor 2005). The Carboneras desalination plant consumes one third of Almería's electricity with 500 thousand kilohertz per day. The desalination plants are set up to run on carbon-based energy sources, like natural gas, which creates additional environmental impacts. Spain and Almería have taken steps to introduce alternative energy sources. Recently, Spain has taken steps to reduce their carbon footprint using wind power. Heavy winds allowed Spanish wind power to generate forty-one percent of the total energy for consumption in Spain, with twenty-eight percent the average (AFP 2008). The abundant amount of sun and wind in Almería make it a prime region for exploration into new techniques of solar and wind powered desalination plants. European Union field trials are under way in Almería, using technology from the Spanish Canary Islands, to develop solar powered plants. Desalination plants built in the sea are being developed that would use only wind and ocean based power sources. Uses of initially higher cost alternative energy sources may raise the price of water and energy to higher levels than farmers are willing to pay. Brine, concentrated salt build up, emitted from the plants pose a potential threat to soils and aquatic sea life near these massive plants. From interviews and conversations it seems the people and farmers of Almería think desalination is the best (or only) choice for the current water shortages.

Summary

The purpose of this chapter was to discuss the policies, drawing attention to those affecting water use and management, that have contributed to the emergence of the greenhouse agricultural sector in Almería. Both perceived benefits and costs are attributed to recent and future social and environmental issues. Different rounds of policies passed by governments to either suppress or expand greenhouse growth or water extraction highlight the varying ideologies in the past forty years of Almería's history. Concerns about maintaining the growth of the greenhouse sector have superseded those focused on environmental issues because of the sector's economic importance to the province and the national economy. The benefits of economic success for the province, farmers, and people of Almería, compared to the environmental cost related to growth, were talk about in this chapter. The key to the provinces success in agriculture and one of the most important resources affected by the success is water.

Almería's importance as an agriculture hub for greenhouse winter produce, the expanding growth in population and industries, as well as the recent tourism boom, put pressure on different levels of government to articulate water policies for Almería. Early on in the economic and agricultural boom of Almería, issues with over exploitation of the province's aquifers pushed governmental intervention through a series of policies. The regional policies of the Andalucía government set up zones where aquifer extractions were acceptable and other areas where it was illegal. The policies proved impossible to enforce, because growing populations of ambitious farmers, with hopes of making money, constructed greenhouses and drilled wells. The policies of the 1980s did limit growth in the greenhouse sector compared to the 1990s. The slowing down of growth gave various levels of government time to strategize additional ways to supplement water for the greenhouse sector. Spain's introduction into the European Union in the mid 1980s provided Almería with rules from international bodies to comply with the extraction and use of water. The European Union and liberal trade policies gave Almería a completely new market in which to sell produce.

The farmers of Almería have been instrumental in forcing the development of new technologies that reduced water use, pesticide and fertilizer contamination of water and soil, and the amount of waste produced. Substrate systems of growing produce reduced water use and now recycling water technologies offer a possible sustainable alternative for greenhouse agriculture. An interviewee even suggested that rising water costs would encourage farmers to switch to integrated systems of greenhouses with recycling water capabilities. Farmers' ambitions, along with market adaptations to environmental problems and customer concerns and demands regardless of government decisions, are another interesting aspect to changes in the horticulture of Almería.

Desalination is seen as the solution to water woes in the province even as water prices increase. Regardless, agriculture remains an important industry at multiple levels, and if rising water prices are hurting farmers, governments will step in to help. Based on field observations and local opinions, the overpumping of the aquifer is expected to diminish with the introduction of desalination. Partial recovery from three decades of intensive groundwater mining may be possible.

Chapter VI

Synthesis and Conclusion

Chapter VI begins with a discussion regarding the positive and negative impacts of greenhouse agriculture. Summarizing information from the previous chapters, the synthesis discusses the economic, technological, and social benefits of the greenhouse agriculture sector to the province of Almería. With the benefits come negative impacts resulting from transformations of the landscape and water supply, dependence on foreign customers, public health, and issues with immigration. The concluding section emphasizes the major points and/or findings from this study, summarizes limitations to this study, and provides suggestions for future research.

Positive Impacts of Greenhouse Agriculture

The principal advantage of the greenhouse industry is the economic success that has come to the province. Once the poorest province in all of Spain in terms of per capita income, Almería is now the most affluent province in the region of Andalucía, the region with the largest population in Spain, and fifth most prosperous in the whole country (Martin 1999; INE 2008). Ambitious industries, farmers, and services accompanied a growing population that replaced a stagnating and declining population downtrodden by failures in the mining and grape industries. According to Professor Juan from the Universidad de Almería, the economic structure of Almería has experienced major shifts. As he stated, the "service sector was scarcely represented, unable to produce any wealth", but due to the protected agriculture in greenhouses, "farms began to capitalize." Many industries that provide supplies for the greenhouses flourished, such as plastics, seeds, irrigation systems, chemicals, biological, fertilizers, and so forth. The service sector that supported this kind of agriculture and a growing tourist industry helped to transform the economy as well. Along with these industries, new business and the distribution industries for agricultural produce, helped to make the economy more balanced than before.

With the success of agriculture and concomitant rise of the region's economic importance to the country of Spain and European Union, Almería has received millions of Euros to improve transportation networks and construction of new buildings for growing populations. Almería has come a long way in transportation from being compared to a third world country road wise. Regional transportation was barely adequate for the increased semi-truck, tourism, and population traffic (Tout 1990). In 1988, the international journal *Economica* said that the future of success for the Almería horticulture industry was in development of the highway system of Almería and water saving technologies (ibid). Nowadays, four to six lane highways link Almería to Granada to the west and as far as France if not beyond to the east. In the Austrian documentary film *We Feed the World* (2005), the camera shows an Almería semi-truck driver leaving Almería with greenhouse produce one day, and arriving for shipment the next day in Wien (Vienna), Austria. An airport that was considered incompatible for the traffic generated by the agriculture, and more recently, tourism industries, has been upgraded with additional distribution space and a new ticketing area. However, my observations and field data suggest that the limitation of one runway and little growing room without displacement of populations, limits any additional growth. The high-tech port of Almería recently reported the addition of cranes, distribution space, and more room for docking in response to increased transportation activity for future projects (Puerto de Almería 2008). The development of the port is closely connected with the growth in the greenhouse industry, tourism, the Morocco-Spain ferry via Melilla, Spain (a Spanish enclave province in Africa and entry point to Morocco), and a petrol distribution center. Even with a potentially capable port, the majority of transportation for produce is completed through semi-trucks and European highways. Recently Almería has been in talks with the North American Free Trade Agreement countries (USA, Canada, and less so Mexico) to increase crop sales (Martin 1999). This agreement would heighten the necessity for an adequate airport to sustain the traffic, or as an alternative, transportation in refrigerated boats.

Establishing itself as the plastic greenhouse horticulture center of Europe, if not the world, has given Almería additional benefits to both the city and province. The shortcomings of water shortages and salination have allowed Almería to establish crops resistant to higher levels or salt, through research into cross breeding, and technologies that reduce the amount of water necessary for crops. The Universidad de Almería was established in 1993 to help teach future generations about agricultural technologies including greenhouse agriculture. The University boasts a department for the production of vegetables or Producción Vegetal, with a focused emphasis on greenhouse produce production, and that includes various research opportunities for students. The growth in industries related to agriculture has meant University programs in fertilizer chemistry, hydrology studies, and entomology for greenhouses. Countries with similar climates look to Almería greenhouse professionals for information regarding greenhouse development. One of my interviewees, Jose, talked about the work he was doing in Morocco setting up drip irrigation systems and introducing the substrate growing method (see Chapter 2). Jose said that within the next year a business trip to Mexico was planned with similar objectives.

One of the biggest advancements in water saving technologies that led to growth in the greenhouse sector was drip irrigation technology. The ability to use less water by adding a drip irrigation system allowed for greater yields in the same greenhouse and made greenhouses an even more popular enterprise because of low cost systems and high payback. To make sure that drip irrigation became the norm, the government made drip irrigation necessary for the approval of loans. Plants tolerable to higher levels of salt, like certain types of tomatoes and peppers, were developed and grown when water quality became worse from the aquifer depletion.

Tourism in Almería has introduced a new industry to the landscape and a competition to agriculture for some of the best agrarian land and water for greenhouses. The study of tourism in Almería is not covered in detail here, but is an important aspect of Almería's changing landscape. Almería is a popular destination for British, German, and Scandinavian retirees searching for cheap land and sunny weather. Almería's two biggest economic contributors are agriculture and tourism; with "3000 hours of sunlight" bringing beach, golf, and sun lovers to the beach resorts and oasis golf developments. The areas near the coast with climates better suited for agriculture are lined with vacation developments. Some farmers with greenhouses near or on the coast in the Campo de

Dalias have sold to developers, but for every displacement another greenhouse is started in the Campo de Nijar; hence, greenhouse numbers remain relatively steady. Rising competition between development and agriculture arose in response to water shortages, but seems to have settled down with the newly elected Spanish government passing AGUA. All interviewees responded that the development of the tourism industry would not affect the agricultural sector of Almería because of its importance to Spain and the European agriculture system.

The sunny and windy weather of Almería has brought a new change to the landscape in the form of solar panel farms and wind generator farms. Spain has taken the lead in wind and solar power related energy sources in the world, and Almería has become an important province for these industries. With the growth in demand for alternatives to carbon based fuels and solutions to combat climate change, solar and wind power have grown immensely important. The cities of Almería, Aguadulce, and El Ejido now include energy industry businesses from Spain and international companies. To highlight Almería's importance for Spain and Europe, the 2005 Mediterranean Games were held in Almería. The event hosted twenty-one different nations and over three thousand athletes participated (Almería 2005). Years before the event massive, new construction projects, backed by the Spanish government, included athlete housing, road networks, stadium, and city beautification. Almería's soccer (*futbol)* club recently joined the top league, *la Liga*, a feat considered very important to Spaniards. To think that Almería was known and described as a depleted, lifeless, and uninhabitable wasteland only fifty to sixty years ago, almost makes the local saying "el milagro de Almería" ring true. The economic success story of Almería and the complete transformation of the province in the last forty years is incredible, but does not come without negative aspects concerning landscape transformation, issues with low paid immigrants, and water.

Negative Impacts of Greenhouse Agriculture

Several negative impacts stand out from this study of the Almería greenhouse sector. The first negative impact is the pure amount of plastic covering the ground, at around 80,000 acres or 94 square miles. Almería's landscape has been in a semi-constant state of transformation since the Copper Age with some saying even enough to have forced a climatic shift to a more arid landscape. Latorre (2001, 1) writes: "Archaeological remains, as well as historical documents and place-names, prove that forests played an important role in this territory up to the nineteenth century, and that a great diversity of fauna, including forest species roamed the area up to the early modern period." Any temptation to call the current environment, landscape, or ground "natural" would be incorrect because "the current landscape was formed primarily in modern times as an inadvertent effect of economic activities" (Latorre 2001, 2). A continued demand for produce in a globalized market has meant the further alteration of landscapes, particularly in the rustic, unspoiled valley areas to the north of El Ejido, to accompany more plastic regardless of the severity. Giles Tremlett (2005) in *The Guardian* quotes an environmentalist saying that new greenhouses "block up dry riverbeds and destroy mountainsides" to allow more growing space, with no government officials taking action regardless of complaints.

These changes in the landscape can cause serious environmental issues in the case of heavy rains. The greenhouses heighten the "risk of flooding as their thousands of acres of impermeable plastic greenhouses interrupt the natural flow of the coastal hydrological cycle" (The Olive Press 2007c, 2). Field observations of the dry riverbeds showed plastic and other trash evident of flooding. The natural hydrological cycle of the coastal regions would allow flow through interconnected pathways to the sea, using flood pains adapted to compensate for the amounts of water. In areas were the geology allowed, water would seep into the aquifers, replenishing the shallow groundwater, and eventually make its way to the sea where evaporation lifts moisture into the atmosphere (ibid). The greenhouse growing areas have an "effect similar to opening a giant umbrella" by denying natural drainages and consequentially overwhelming gullies and dry riverbeds (ibid). Although rainfall is rare in the region, typically it comes in downpours.

Another issue is the amount of plastic used for construction of the greenhouses, and how the plastic is manufactured, disposed of, or recycled. Greenhouses in Almería produce 30,000 tons of plastic and organic waste per year (The Olive Press 2007b). To deal with the amount of waste produced, specialty-recycling plants for both plastic and organic waste were constructed but seldom used or required for plastic. Typically, greenhouses require new plastic sheeting every two years. The old plastic is often deposited by leaving the trash beside the road, tossed into a nearby dry riverbed, or taken to a recycling plant. Several things might happen to plastic placed along the roadside. It may be picked up by a passing semi truck making a trip to the recycling center, taken by an immigrant worker to use the plastic for housing, a farmer with less money who needs to patch a greenhouse, the wind might push any remaining to open space or *ramblas* (dry riverbed) or the plastic sits in a heap waiting. Plastic deposited in the *ramblas* awaits the rainstorm of the year, which will push the plastic through the *ramblas* blocking culverts and leaving plastic distributed along the riverbed once the flooding subsides. In addition to plastic's slow biodegradable rate, pesticide residue still on used plastic creates additional problems for the environment, aquifers, and humans. There is evidence that farmers burn used plastic contaminated with pesticide deposits, which releases dangerous dioxins into the air that are potentially harmful to the 200,000 residents living in or near the Campo de Dalias and Nijar (The Olive Press 2007b). As far as organic material is concerned, the majority of farmers take the material to the recycling center where it is turned into fertilizer that is used in the sand plot growing method. Farmers receive a discount for providing the center with organic material. It remains to be seen if pesticide residue left on organic material was contaminating the fertilizer.

Immigration to Almería from northern Africa and Latin America has increased immensely with the growth in the agricultural sector and heightened demand from international markets. Farmers unable to farm the greenhouses with family alone, or wanting to expand, welcomed cheap labor. Immigrants from North Africa are typically looked down on by Spaniards, and forced to congregate together, in either minimal rundown housing where they sleep and live in very cramped quarters, or in old greenhouse skeletons. In *We Feed the World*, the documentary shows a group of Muslim North Africans living in what used to be a greenhouse, using old plastic to make shanty houses with no running water or bathrooms. The similarity of racial tensions and exclusion that exists for Latin American workers in the United States agriculture and industrial sectors comes to mind. In February of 2000, race riots broke out after the death of a young woman by a suspected Moroccan immigrant worker (BBC 2000). This year, 2008, race riots broke out yet again in Almería after a young woman was killed and an immigrant Moroccan suspect arrested. Hundreds of Spaniards took to the streets yelling racial slogans, burning Moroccan owned shops and vehicles, and threatening to torch immigrant slums (BBC 2008). A resolution must come between demand and necessity for cheap labor and animosities that exist towards immigrant workers in Almería.

A physical constraint is an insufficient supply of the coarse sand needed for the top layer of the sand plot (Wilvert 1993). Ecologists and the more influential tourist industry, have protested the removal of sand from beaches because of a limited supply. Today sand must be trucked in from other regions, adding additional cost to production. The introduction and slow transformation to a substrate growing system throughout the Almería greenhouse sector is one way to combat this issue. The cost of a substrate system requires money that farmers often do not have. Substrate systems require additional industries to construct the necessary products and thus require room to build on, electricity to power the plant, and water.

Overexploitation of aquifer water has led to shortages and salt-water intrusion, forcing and/or persuading the regional and Spanish government to introduce money to fund new technologies of water production, like desalination and deep-water wells. Approximations of up to eighty-eight pounds of pesticides per three acres in greenhouses, brings the issue of pesticides leaching and inevitably contaminating aquifers to the forefront (The Olive Press 2007c). Research at the University of Granada detected links between some pesticides used in Almería greenhouses and increased breast cancer in women and testicular cancer in men (ibid). It may be too early to tell, but years of pesticide use and watering from low aquifers could have eventual health effects on the public living near or on the Campos.

Finally, I want to focus on the negative impacts associated with growing a monoculture of high-demand vegetables for distant national and global food markets. The ban on Almería produce, initiated after a pepper tested positive to illegal pesticides, shows the vulnerability of Almería's agricultural sector to decisions or policies from outside sources. The *alhondigas* and co-ops now sign contracts with large international and national supermarkets to provide particular crops, in certain amounts, at assured dates, for an agreed upon price. Although this guarantees a price for farmers, it additionally locks farmers into growing a particular crop at a set date, versus basing that decision on their own experience or local demands. With success in greenhouse agriculture, the region's employment, industry, and prosperity are essentially dependent on the success of the plastic covered growing season. Rises in water prices due to shortages in water have introduced the drip irrigation method (used by nearly 100%), and expensive water recycling systems. These new technologies only encourage the continued growth or use of greenhouse agriculture instead of looking at the possible negatives to the industry. Any failure in the greenhouse systems, climatic shift, or diseases attacking the vegetables would be detrimental to the industry. In a globalized world, Almería has benefited from shipping crops internationally. Globalization brings competition from regions with similar climates (North Africa, Turkey, Mexico, and Israel) and could alter the market Almería has grown accustom to filling. Vandana Shiva (2000, 1), discuses the impacts of "globalized, corporate agriculture on small farmers, the environment, and the quality of the food we eat." She shows how a sustainable rural and local agriculture system changed into a global food industry. An economic crash, reducing the amount of available money for imports, or a change in politics, like one against a globalized produce industry in Europe, could possibly alter the greenhouse industry of Almería. In the end, "Overspecialization and overdependence have always been environmentally and economically dangerous games to play" (The Olive Press 2007c, 13).

The eastern coast of Spain and the province of Almería have changed immensely in the last forty years. The eastern cost of Spain is now a metropolis of tourist development and businesses that are fueled by a regional policy to encourage or promote the growth. This has transformed arid environments into booming golf communities and high-rise block apartments and hotels for tourists seeking warmer climates and pretty beaches. Almería differs in the situation arising on the eastern coast because of the addition of a substantially important greenhouse agricultural sector that limits urban growth to the coast. From local, provisional, regional, national, to international, Almería's greenhouse sector is an important moneymaking winter (and summer) vegetable and fruit production center. The key aspect to all of these regions, provinces, industries, and services continued success is the availability of water, and in most cases, quality water.

Conclusion

The purpose of this thesis was to investigate changes in the landscape of Almería's greenhouse sector. The research focused on local-global scale and environmental history analysis within a political ecology framework. The point of the thesis was to try to determine why the province of Almería has the largest concentration of greenhouses in the world. Specifically, the thesis addresses how and why the landscape has changed; what factors, both environmental and social, have led to the continued boom in greenhouse agriculture since David Tout undertook research in the late 1980s; how the province and government have dealt with sustaining 80,000 acres of greenhouse agriculture with serious constraints on water availability in an arid province. Analyzing these various factors through a political ecology framework helped to build a deeper understanding of why Almería's landscape is extensively covered in plastic.

Using the framework of political ecology contributed to the processes of analysis for the research. Focusing through the lens of political ecology on the current situation of landscape change in Almería and connecting that with the environmental history of Almería helped to make historical links of landscape transformations. Throughout the environmental history of Almería various societies/powers, both foreign and local, have been interested in the landscape of Almería. These various societies have each taken a part in transforming the landscape either physically or visually. Greenhouse agriculture is the latest endeavor of alteration to the Almería landscape fueled by a globalized demand of produce during winter months.

From this study, it can be concluded that one of the biggest change since Tout's 1990 article is in the new technologies that have been employed in the past twenty years. The pesticide scare with Almería produce that recently occurred in Germany is another possible point of change in the industry. Pesticide use has been the popular method to combat invasive insects and diseases in the past but with demand for pesticide free produce increasing from northern European consumers, farmers have begun the change to integrated pest management systems. Substrate systems have slowly begun to replace sand plot systems because of higher quality and productivity. The low cost and acceptable outputs from the sand plot system mean that the change to the substrate system will be slow. Recycling water systems along with the integrated pest management (IPM) will most likely play a major role in the future for the Almería greenhouse sector. The IPM is becoming a substantial alternative to pesticides while recycled water systems make up only two percent of total greenhouses. The recycled water systems along with a necessary substrate-growing medium may rise in popularity as the price of water increases due to the addition of desalinated water and reduction in the availability of cheap aquifer water.

The disadvantage of moving into an IPM is the companies that develop these management systems are part of powerful international agribusinesses from outside of the local area that are driven by the profit motive of reaping maximum profits with little or no concern for the local social and environmental impacts. The Swiss company *Syngenta*®, the third largest seed company in the world and one of the biggest agribusiness companies in the world with 9.2 billion dollars worth of sales in 2007, has taken a vested interest in Almería greenhouse agriculture. *Syngenta Bioline*® is the division specializing in biological controls using and selling IPM in Almería. The other companies selling IPM systems in Almería come from large foreign agribusiness. *Monsanto*® the world's largest seed company and supporter of genetically modified (GM) crops recently cited greenhouse agriculture as the fastest growing agriculture industry just before news was released of their purchase of a Dutch tomato seed producer specializing in greenhouse seeds (Reuters 2008). Almería growers buy the majority of their seeds from Dutch companies, while remaining confident that GM crops would not be grown in Almería. The movement of large corporations into the Almería agriculture system threatens to unbalance a system built upon family owned farms. Large transnational corporations taking interest in international agriculture sectors are done solely because a niche to make money is discovered. These companies seem to care more about short term marketing strategies and economic gains for their shareholders and CEOs, then for long term effects on the environment or human well being. IPM is currently a solution to pesticide and herbicide use, and allows these companies to argue that they are fully engaged in products that are good for the earth. The problem lies in issues of access and control and not the technology.

Local and Spanish government support for new technologies along with incentives for adaptation of these technologies is a necessary step. In 2007 the Junta de Andalucía invested 4.5 million Euros into IPM technologies, a good sign of investments to come (S&G peppers Today 2007). The IPM systems cost is relatively similar to pesticides and only needs an incentive for farmers to begin using it. Instead of private foreign corporations controlling the IPM systems, the Spanish government should incite local business endeavors or public universities to open IPM production facilities. This idea runs into problems with European Union laws on fair opportunities for foreign European companies seeking establishment in Almería but competition from local business would be a good addition. Making sure foreign companies put money back into these communities and assuring that the foreign companies are educated on local matters is important. The truth of the situation in Almería regarding IPM is that the international businesses have solidified their placement as provider of these systems for local farmers. An interviewee mentioned that sometimes we have to take negative issues when the advantages overpower prior practices. The use of pesticides and herbicides is outdated and only leads to contamination of water and food, with possibilities of human health side effects. IPM would eliminate the necessity of using pesticides and herbicides, which is an advantage that extends past the negative of corporate control of these systems.

Landscape change in Almería is the most visible transformation in the region. Countless acres of greenhouses now cover the Almería landscape after only thirty to forty years of agriculture growth. The current rapid transformation of the province turns out to be part of an environmental history of changing industries and landscapes. Fueled by international demands for various resources and products, the Almería landscape has been subjected to environmental modification and degradation since Roman occupation. Foreign powers controlling the province or locals profiting from international market arrangements, extracted resources and/or utilized the land with little obvious anticipation of long-term consequences. The historical transformations prior to greenhouse introduction led to a complete environmental shift from a semi-arid forested landscape with flowing streams, to an arid treeless landscape with dry streams beds flooded only during infrequent rains. Lessons learned from prior mistakes seem not to be an issue with the latest money making industries in Almería, greenhouse agriculture and tourism.

Production of 2.7 million tons of produce in Almería would have been impossible without the introduction of greenhouses, the early discovery of abundant, high quality, low-lying aquifers, refrigeration, subsidized transportation, and a cheap supply of labor.

What began as a solution to populate an uninhabitable and inhospitable land by offering cheap land to mountain villagers in the two growing areas of the Campo de Nijar and Campo de Dalias, has resulted in the complete transformation of this area into a large-scale agricultural operation in twenty years. The landscape became engulfed by plastic horticulture by the 1980s and only issues of salt-water intrusion in the aquifers pushed government officials to attempt limits on greenhouse construction. When limits on construction proved unsuccessful, the government turned to ways of sustaining continued growth of the agriculture sector via new water sources. As land for greenhouse growth in the Campo de Dalias has become limited and even gone down somewhat because of tourism developments encroachment on greenhouse land, growth into the north valleys and Campo de Nijar has risen. The landscape of the valleys to the north has begun to be dismantled by bulldozers as hills are taken down and dry riverbeds filled in to make room for greenhouse growth. In the Campo de Nijar, greenhouse growth threatens to encroach on the pristine *Cabo de Gato* natural park. Farmers search for viable areas for the continuation of greenhouse agriculture regardless of the landscape in question. Environmentalists cry foul at the ongoing degradation of the landscape, but most politicians wear environmental blinders. The amount of money the greenhouse industry has brought to the province keeps politicians' decision-making limited regarding negative issues surrounding the greenhouses. Politicians know that an economy built on greenhouses means a voting block for greenhouse agriculture.

Instead of building more greenhouses by altering the landscape, the government and farmers should look into technologies that will increase quality and yields using the same space. Developing systems of greenhouse agriculture that are self-sustaining with recycled water, IPM systems, and renewable sources of energy must be the future for Almería. The province has developed a legacy of a lack of political action taken to restrict greenhouse growth or water withdrawal because of pressures by locals who saw only the short-term economic gains possible in the produce market and by government officials who saw a growing economic industry for the region of Andalucía that would also line the pockets of Spain. The government must incite farmers to change and farmers must be willing to adapt more sustainable methods.

The most influential and substantial key to the continued existence of Almería's greenhouse sector is the control and manipulation of water, especially groundwater. The introduction of drip irrigation gave farmers a tool to water plants in a greenhouse more efficiently and cheaper. With the original low-lying aquifers suffering from over exploitation and government initiatives to subdue drilling failing, actions were taken to dig a mountain well for watering the province. As drought, population increase, tourism, and greenhouse growth continued, water shortages again became an issue. As Spanish government plans to pipe water to Almería from northeast Spain went into effect, the Almería government established two desalination plants in the province. The cancelation of the pipe and passing of a Spanish plan to use desalination to solve water shortage problems have introduced the next stage in Almería's history of water systems. As new plants are built and the two older ones updated and added on to, new issues arise. For now, desalination remains an expensive and energy intensive source of water compared to the cheap aquifer water Almería farmers are used to. The prospect of increased water prices for farmers will surely bring changes like the negatives of illegal drilling or aquifer pumping and advantageous new technologies like recycling water and substrate farming. The high-energy use necessary for desalination plants may be offset by using energy from solar and wind, which Spain is doing, and doing quite successfully. The brine and waste that desalination produces is a negative, but a positive compared to the continued exploitation of ground aquifers.

Pesticide and fertilizer use remains a serious issue in regards to water contamination of the low-level aquifers, and three decades of drinking water coming from the same aquifers could have serious health repercussions for generations. New technologies, specifically the integrated systems with recycling water capabilities, are the best solution to many of the issues facing Almería. The demand for winter produce nationally and internationally is unlikely to disappear and more likely to increase, thus farmers must switch to new water saving and limited or no pesticide use methods. The price for integrated systems is high, but with government help and higher priced but better quality produce, the transformation is possible.

International and Spanish market demand for fresh vegetables and fruits during winter months is the key to greenhouse development in Almería. Almería produces the "necessities" (i.e., tomatoes, peppers, cucumbers, etc.) that northern Europeans crave during the cold months. Almería shares a similarity with California and Mexico that also produce vegetables year round for North American consumers. Without greenhouses Almería would not be a viable location for such mass scale agriculture. Establishing a commodity that is dependent on international markets is a dangerous path for Almería agriculture. Estimates are that sixty percent of produce is shipped internationally and with new markets like the USA and Canada being introduced, this percentage is expected to increase. Fluctuations in international economics or politics that cut off produce imports would be detrimental to Almería. The effects of a possible stop in exporting were plainly visible during the pesticide scare in Germany when imports of Almería produce were halted by northern European countries. Markets were only reopened because of Spanish and Andalucía government assurances that produce was safe and contamination limited to a few greenhouses. In a world of climate change, population growth, and shrinking resources, greenhouse agriculture could be a viable solution to providing food at high yields. Or the collapse of the greenhouse systems "may leave us with a legacy of a environmental catastrophe in the shape of a desert of abandoned greenhouses, with tattered plastic blowing across a land stripped of its soil and bled of its ground water" (The Olive Press 2007c, 13).

Several other factors in combination with overdependence on foreign markets combine to make a portion of Diamond's (2005) theory of a society moving toward collapse a plausible outcome in Almeria. Almeria's dependence on fossil fuels for the manufacturing of plastic, water pumping, refrigeration, and transportation of the produce is problematic with the rise in petrol cost. The overexploitations of aquifers in combination with the environmental history of landscape alterations show the unsustainable path of Almeria endeavors. The dependence on the fossil fuels and Almeria resources are environmentally unsustainable and could prove problematic for the province in the future.

Future Research

Limitations to this research largely stem from several constraints. Before my arrival in Spain, I had assumed that conversational Spanish skills would be enough to facilitate in-depth semi-structured interviews. My inability to speak Spanish fluently limited my ability to ask good follow up questions to interviewees, and instead I focused on my template of questions. A lack of transportation restricted my access to field sites and opportunities to meet study participants who were located away from the capital. A budget limited to personal savings restricted the amount of money I could put towards covering costs associated with the field research. Political ecologists look at local scale in-depth fieldwork as a major part of conducting thorough research. While fieldwork was undertaken for this study, more time would have allowed me to capture more perspectives from a greater diversity of stakeholders and to conduct a survey of family farmers in the area. Secondary research after my return to the United States brought up issues I would have been interested in including in the interviews. More hard data regarding water supplies, groundwater extractions, anticipated water uses, and detailed climatic data would have been beneficial.

There are a number of ways to build upon and extend this study. The issue of the role of immigrant workers in the greenhouse agriculture sector in Almería needs research and is relevant to current debates regarding European Union immigration policies. The demand for cheap labor not filled by Spanish workers brings thousands of Africans across the Mediterranean Sea who are hoping for employment and a better life. A population decline in Europe is subsiding, in part, because foreign migrants are settling in a number of these countries. The hostilities that exist against immigrants are similar to those pointed at Latin American workers in the United States who are accused of taking jobs away from locals residents, engaging in crimes, and foreign language intrusions.

In addition to the topic of migrant labor, water resource management and desalination in Spain along the eastern arid cost will be interesting to study. As pointed out earlier, the success or failure of Almería's growth trajectory is largely dependent upon securing a water supply. A greenhouse sector that could produce enough food for the entire Iberian Peninsula on only 80,000 acres is an interesting research direction. Greenhouse agriculture as a future agricultural industry in a changing world makes Almería's situation vital for future research. More in-depth interviews with a much larger population would bring interesting results regarding opinions on greenhouse agriculture. Research of the high-energy cost associated with desalination and new Almeria's attempts to power the plants with wind and solar power to combat these high cost, offer an interesting topic. The future interconnections and possible conflicts that arise between tourism and agriculture in southern Spain offer an additional research direction. As the eastern coast of Spain becomes ever more popular with tourists, how will local farmers and policy makers respond to shifting priorities? In-depth research into how European Union policies are either hurting or helping the Almeria agriculture sector and province is another possible direction of research. Comparing and contrasting Almería's system of agriculture to other agricultural areas around the world would be beneficial to future research. These questions on greenhouse as a solution or distraction, along with comparisons of other world regions with large-scale agriculture, immigration, and research into the new technologies of greenhouse agriculture offer a plethora of research opportunities for the greenhouse sector of Almería

Climate change, human population increases, and rising food prices threaten to alter landscapes and environments in ways not known to modern humans. The future of agriculture in a changing world is an important issue for geographers to examine. Will we become dependent on large seed corporations that promise genetically modified plants to combat changing climates? Will we switch to a civic agriculture system where local farmers produce food for their community? Will greenhouse agriculture be a solution to meeting the world's food needs? On the other hand, could greenhouse agriculture be a short-term fix? Regardless of the future, Almería's greenhouse industry has left an incredible visionary change on the landscape and transformed a entire provinces economy.

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Appendices

I

Chronology of the Environmental History of Landscape Change in Almería

Event Name	Start Date	End Date	Category	Notes
Copper and Bronze Age	4000 BCE	1000 BCE	Firewood	First known historical landscape changes by humans
Roman Empire	0200 BCE	0500	Multiple	Dry farming. exportation of minerals such as lead and silver. Reports of enormous wooded surfaces and forest vegetation
Recovery Period	0500	0711	NA	Environment experiences a recovery period
Moorish Occupation	0711	1492	Agriculture	Citrus fruits and almonds based on an extensive system of irrigation
Reconquista	1492	1850	Multiple	Terraced farming, wool and silk, intensive mining. Reports of no trees in lowlands. Possible climatic shift.
Table Grapes	1860	1950	Agriculture	Dry farming with limited irrigated farming.
Greenhouses	1950	2008	Agriculture	80,000 acres of greenhouses
Tourism	1990	2008	Construction	Competition for coastal lands and water between greenhouse agriculture and tourism developers
Solar and Wind Power	1998	2008	Energy	

II

Interview Information

Pseudonyms are used for all interview participants to protect their identity. The first seven interviews were semi-structures while the eighth interview was unstructured.

Interview I, professor's office: Dr. Juan

Dr. Juan is a professor for the Universidad de Almería's Ingenieros Agrónomos department. He is responsible for research on production regarding greenhouse agriculture and recently specializing in tropical region covered agriculture.

Interview II, café in El Ejido: José

Jose is a greenhouse agriculture technician and chemist that has worked in the industry for ten years. He currently does work in both Almería and Morocco regarding development of nutrient solutions for crops based on environment and crop type.

Interview III, café in city of Almería: Santiago

Santiago is a recent graduate from the Universidad de Almería. He has been working in the greenhouse agriculture business for seven months.

Interview IV, class room Universidad de Almería: Gustavo

Gustavo is a quality control technician in a tomato warehouse in the Campo de Nijar. He has been working with tomatoes for 4 years and with greenhouse quality control for eleven years.

Interview V, café in city of Almería: Maria

Owner of greenhouse specializing in integrated pest management systems, recycling water, an experimental station for University students, and a tourist attraction for visitors interested in new greenhouse technologies. Maria was born into a farm not using greenhouse but at two years old, her father switched to greenhouse agriculture.

Interview VI, professor's office: Dr. Rafael

Dr. Rafael is a professor at the Universidad de Almería with concentration in the chemistry of soil used for greenhouse agriculture. Dr. Pasqual researches substrate growing systems and integrated growing systems that recycle water.

Interview VII, friend's vehicle: Rafi

Rafi is a current student at the Universidad de Almería studying greenhouse agriculture. Rafi's family has been farming in the Campo de Dalias region for three generations, beginning with uncovered agriculture by his grandparents in the early 1930s and switching to greenhouse agriculture in the 1970s.

Interview VIII, greenhouse: Pedro

Pedro is a worker and owner of two greenhouses in the Campo de Dalias. His crops depend on what is in demand by the co-op he belongs.

III

Selected Statistical Information on Almería

Population
1960: 360,464
1981: 405,019
1996: 501,761
2006: 635,850 (27th in Spain)

Major Cities: Population
Almería
1960: 86,000
2000: 169,000
2007: 189,798

El Ejido
1960: 1000
2000: 53,000
2005: 68,828
2008: est. 100,000

Total Land Area: 8,774 km^2
Irrigated outdoor vegetables: 15,000 acres (1999)
Almond agriculture irrigated and unirrigated: 173,000 acres (1999)

Greenhouse Area
1968: 1349 acres
1975: 7350
1980: 18,000
1990: 41,000
1994: 62,000
2007: 80,000 (50% of protected cropping in Spain)

1999 Main Greenhouse Crops

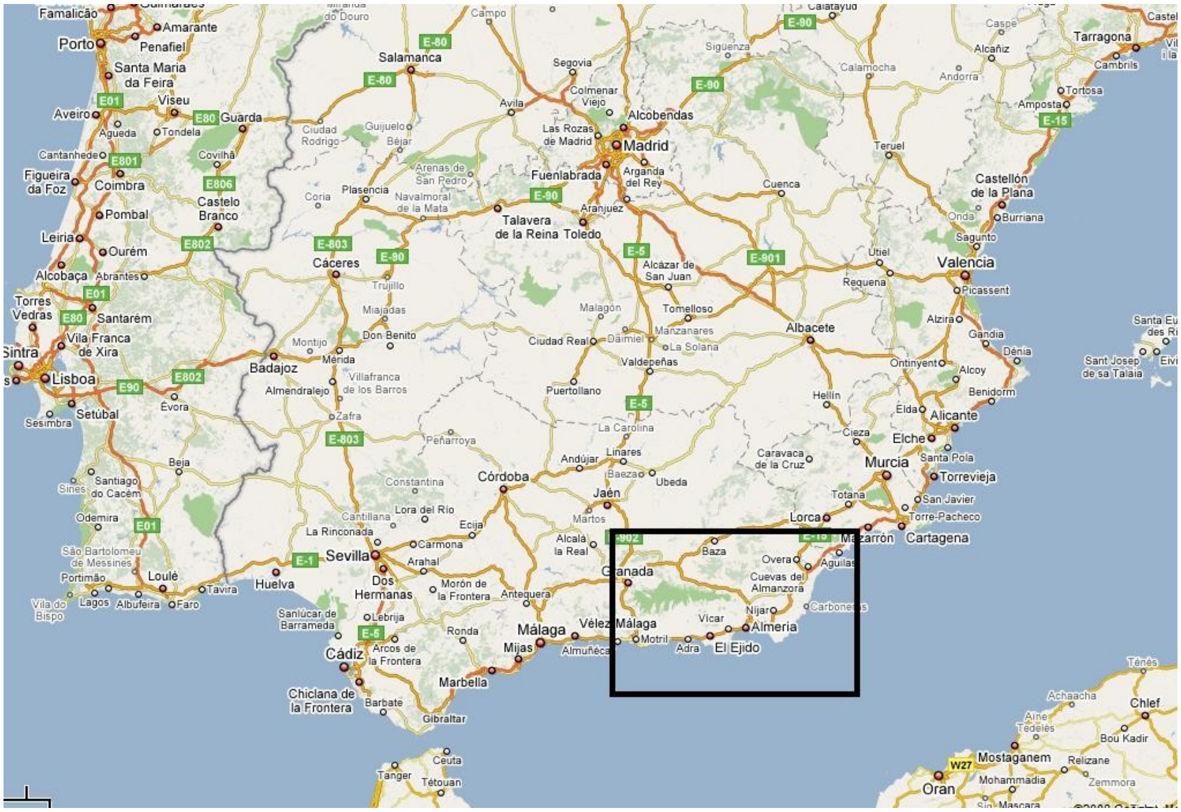
Peppers: 17,600 acres
Watermelons: 13,400
Melons: 13,000
Green beans: 11,600
Tomatoes: 11,000

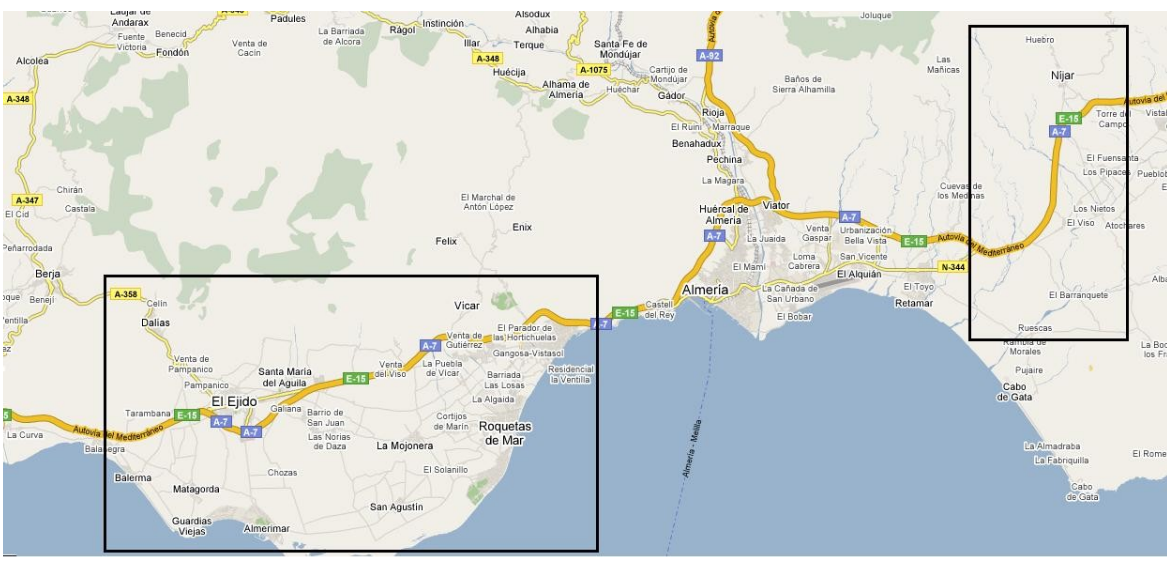
Zucchini: 6,450
Cucumbers: 5,700
Egg Plant: 2,250

(Sources: INE, IEEP, Martin 1999, Tout 1990)

IV

Location Maps





(The first map indicates the approximate area of the province of Almería, while the second picture shows the two greenhouse growing sectors of Almería. Source: http://maps.google.com)