OLIVES AND PROTECTED CROPS: SPATIAL ANALYSIS OF OCCUPATION AZAPA VALLEY, CHILE (2003-2013)

German Sepúlveda-Chavera and Juan Leyton Carvajal

SUMMARY

The magnitude of the reduction of the olive cultivation surface and the conversion to protected horticulture is analysed over a period of 10 years (2003-2013) in the Azapa Valley, Northern Chile, an area that has been subjected to a sequence of changes in landscape and use of agricultural land. This geographical space is going through a new stage of transformation with economic, social and cultural impacts. The introduction of new cultivation technologies and the widespread growth of protected crops offer a new geographical landscape which is reflected not only in an increase of productivity but also in significant changes in farming methods and cultural patterns. The territorial, environmental and cultural impact that entails the integration of protected culture in greenhouses with production purpose, and the arrival of large seed enterprises, in the face of the reduction of traditional olive culture, emphasizes the need of planning under a territorial approach in the Azapa Valley.

Introduction

In the past 300 years humans have radically transformed the earth's surface, due to logging, overcrowding of intensive farming practices and expansion of urban centers, among others. The relationship between man, environment and processes linked to economy manifests itself as changes in coverage and land use (Ibarra *et al*., 2011). The change in land use becomes a typical phenomenon of geographical relations in today's world, and the Azapa Valley in Northern Chile is no exception to the trend followed by rural areas in Latin America. During colonial times, the bringing of olive trees into the Azapa Valley altered Andean communities and represented the settlement of the Spanish population into the valley. During the second half of the 20th century, changes in the landscape are explained by the inclusion of urban elements, rural residential properties and traditional agribusinesses. The Azapa Valley landscape is understood as a dynamic entity that has experienced changes over time as a result of the interaction among physical, biological and social components. Geographical features and climatic conditions were of great interest for transnational corporations that generated significant changes in land use and a new dynamic in the rural traditional landscapes, due to the introduction of fresh products and technologies associated to different production processes, such as protected crops (Tapia, 2009). Azapa's conditions allow growth throughout the year, obtaining high value vegetables such as maize (corn), tomato, pepper and cucumber.

By 2003 the valley was the largest tomato producer during winter, intended for consumption in Central and Southcentral Chile (Villavicencio and Tapia, 2010). Before the enforcement of a law aiming at the eradication of the fruit fly (*Ceratitis capitata*) in the province of Arica by the Agriculture and Livestock Service (SAG), in 2003, Azapa Valley was characterized by the tomato monoculture after phytosanitary treatment. The lifting of the restriction represented by this pest prompted the diversification of production in the valley, whose growth and intensification responded to the demand for agricultural products in the central region of the country (González *et al*., 2013). In this context, a significant ratio of producers with greater business capacity incorporated innovations such as fertigation and crop protection systems. However, the greatest impact was in response to the stimuli provided by the State for the installation of multiplying seed enterprises in the region of Arica and Parinacota. By the end of 2003, the first of these companies was established in the Azapa Valley, driving changes in agricultural systems. Its success attracted attention of other multinationals that considered the incentives and funding programs for innovation as an opportunity to settle in Arica. Consequently, the rural landscape of Azapa was transformed by agricultural activity, combining traditional practices with crops under greenhouses. But at the same time, the intensification of agriculture generated a series of problems, such as the loss of biodiversity and reduction of plant species.

The use given to a soil and its vegetation cover is known as 'land use'. Thus, changes or modifications in coverage and components of an area, either through natural or artificial means, can be classified under the concept of 'land use changes'. These can be defined as the impact of socio-economic activities carried out on the vegetation cover that may be causal of degradation (Braimoh, 2006). In the late 60's in Chile, the first studies about transformations of the landscape were made in the central zone of the country; later in the nineties, the Chilean government through the National Forestry Corporation (CONAF) and the National Environment Corpo-

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OLIVOS Y CULTIVOS PROTEGIDOS: ANÁLISIS ESPACIAL DE LA OCUPACIÓN DEL VALLE DE AZAPA, CHILE (2003-2013)

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RESUMEN

Se analiza la reducción de la superficie cultivada con olivo y la conversión hacia horticultura protegida en un período de 10 años (2003-2013) en el valle de Azapa, Norte de Chile, zona que se ha visto sujeta a una serie de cambios en el paisaje y en el uso de suelo agrícola. Este espacio geográfico se encuentra en una nueva etapa de transformación, con impactos en el ámbito económico, social y cultural. La introducción de nuevas tecnologías en los métodos de cultivo y la masificación de cultivos protegidos ofrece un nuevo paisaje geográfico, que se refleja no solo el incremento en la productividad, sino también en cambios significativos en los métodos agrícolas y patrones culturales. El impacto territorial, ambiental y cultural que conlleva la integración de la tecnología de cultivos protegidos bajo invernaderos con fines productivos, y la llegada de grandes empresas semilleras, frente a la reducción del cultivo tradicional del olivo, resaltan la necesidad de planificación según un enfoque territorial para el valle de Azapa.

OLIVAS E CULTURAS PROTEGIDAS: ANÁLISE ESPACIAL DA OCUPAÇÃO DO VALLE DE AZAPA, CHILE (2003-2013)

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RESUMO

A conversão da superfície da cultura da oliva em horticultura protegida é analisada em um período de 10 anhos (2003-2013). A paisagem do vale de Azapa, norte de Chile, esta sendo modificada, e atualmente esse espaço geográfico encontrasse em uma nova etapa de transformação, que impacta nos âmbitos económico, social e cultural. A introdução de novas tecnologias nos métodos de cultura e a massificação de culturas protegidas oferece uma nova paisagem geográfico, que reflete não só o incremento na produtividade, mas também mudanças significativas nos métodos agrícolas e padrões culturais. O impacto territorial, ambiental e cultural associado à integração da tecnologia de culturas protegidas em estufa com fines produtivos, frente à redução da cultura tradicional da oliva, ressaltam a necessidade da planificação segundo um enfoque territorial para o vale de Azapz.

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ration (CONAMA) quantified the existing plant resources in the country and measured changes in agricultural soil coverage (Aguayo *et al.,* 2010). The study of changes in land use and vegetation cover provide a base to understand new trends in replacement process, degradation, desertification and biodiversity decline in a given region (García *et al.,* 2011).

This paper reviews the relevant factors in changing land use, argues the spatial dimensions of the rearrangements experienced in the last decade and the implications of this transformation. Likewise, it analyzes the change of dimensions in land use and determines the territory distribution employed for olive and protected crops between 2003 and 2013.

Change in land use, territorial planning and landscape transformation

Historically, the relationship of natural and human elements is related to traditional types of occupation patterns that characterize the Azapa Valley. Erosion, climate, socioeconomic and sociocultural variations have led to landscape changes. Abandonment of some agricultural activities and the parallel development of productive intensification, and the incorporation of new technologies and conversion processes, define the dynamics of this geographical space. Human action influences on the set of landscapes and ecosystems directly or indirectly, imposing itself and increasing the occupation of spaces for agriculture, industrialization, technological development, etc. The landscape and its evolution respond to the formation of new structures and interactions which are responsible for spatial organizations. In the current landscape, it is possible to identify two specific processes: the strengthening of agriculture associated with technology and new cultivation methods, and the abandonment of traditional agriculture, both with deep consequences on the structure and functioning of the landscape. Hence, the intensification of agriculture produces a more homogeneous area with limited spatial complexity. This simplification has severe socio-cultural consequences affecting traditional and economic practices, in addition to the impact on natural resources, being one of the main causes of wildlife disappearance (López, 2002).

Olives in the Azapa Valley

The olive tree was brought into the Azapa Valley three decades after the beginning of the conquest (Hidalgo, 1993). It was introduced from Europe to the Andes after the conquest of Tawantinsuyu in 1560. Within a few years it fast spread from the central coast of Peru to the south, reaching Azapa Valley, one of the most significant geographical areas with favorable compatibility (Wormald, 1974). By mid-20th century olive occupation was centered in two areas: Las Maitas and Pago de Gómez, typifying the areas where the gradients were more abundant (Keller, 1946). To this day, olive trees grown in Azapa Valley have not only survived but became more important in terms of production, achieving high prestige at national and international level. In 2003 the estimated acreage was 1500ha, covering 50% of the agricultural area (Babárovich, 2011). Considering the slopes surface developed in recent years, the growth cultivated area in Azapa reached to 3000ha, where 649 farms with olive agricultural exploitations were documented (INE, 2007).

Worldwide, including 40 olive exporting countries, Chile represents 0.08% of the area cultivated with olive trees. In 2003 Chile and Azapa Valley experienced the last great growth, marking the end of a cycle that was followed by decline. The historical minimum production for the years 1965 and 2005 (Figure 1) was recorded in 1966 with 150t/ha olives, while the maximum production occurred in 1997 with 10,549t·ha^{-1}. The average production in the valley for the

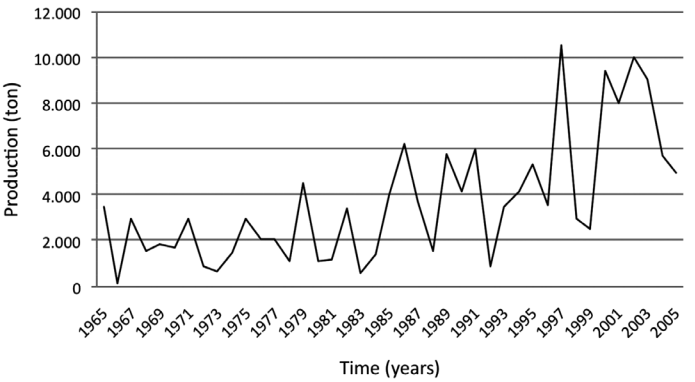

Figure 1. Olive production in the Azapa Valley (1965-2005). Source: FIC Project Code 30110565-0.

whole period was 3,940t·ha^{-1}/ year. At present and in commercial terms, the olive of Azapa is experiencing a complex situation, as international prices fell, production costs increased and the city of Tacna, Peru, has develops a large production, representing a growing competition (Sepúlveda *et al.,* 2013). Thus, farmers with investment capacity have opted for the implementation of high tech irrigation system and machinery, and have added more varieties, making improvements in quality and production efficiency. In 2011, 26.6% of the olive farmers were considered as olive growers, this being their only source of income.

Chile presents several agroclimatic zones characterized by geographical isolation, which minimizes phytosanitary complications, a remarkable condition that can be found in Azapa Valley (González *et al.,* 2013). In climate terms, the valley can be characterized as plains of continental sedimentation at the mouth of the river and ravines with normal desert climate, occasionally with clouds retained by the coastal cordillera folding screen, and moderated by the oceanic influence that breaches through the valley and plateau plain (pampa) characterized by an absolute normal desert climate. At about 2000masl it is possible to see rainfall increasing eastward with altitude, reaching 250mm/year (Torres, 1998). The prevailing climatic characteristics that allow agricultural activities in Arica are: absence of frost and extreme temperatures, moderate winds, high humidity and high direct solar radiation throughout the year; the annual average temperature of 64,4ºF and maximum annual average of 74,5ºF (Villavicencio and Tapia, 2010). This space, despite being within the subtropical climate zone during winter cycles (May to Septem-ber), presents low temperatures that cause problems in the growth of some vegetables, compromising their performance. For these cases, the use of covers allows moderate temperatures on crops, preventing damage from low temperatures (Acuña, 1974).

Methods

Study area

The full extent of Azapa Valley was considered. The valley is located at the northern end of Chile, in the Arica Commune, region of Arica and Parinacota. With a land area of 4,789ha (0.99% of the surface of the Commune), it has a variable width of 700-2200m and extends for 58km in east-west direction (18º31'2"S and 70º11' 31"W). The study area was limited to spaces of Azapa Valley that are subjected to changes in land use, from olive to protected crops. Diagnostics, field survey and analysis of information stages were organized from general to particular in order to determine changes in the agricultural landscape of the valley. Conceptually, the study corresponded to an exploratory, descriptive and cross-sectional research.

Diagnosis

The analysis included space-time dimensions, categorization and summary of the relationships between man and the environment in the studied area. The work was carried out using primary and secondary sources of information, including reviewing reports and bulletins from the National Institute for Agricultural Research (INRA), reports of the Agriculture Department, newspaper sources and diverse bibliographic material. Information in shapefiles format was accessed to start the territorial analysis using geographic information systems (GIS) provided by the integrated system of land information of the National Congress of Chile Library and the National Agricultural Research Institute, which is of public use and easy access. Also, the material in Keyhole Markup Language (KMZ format; from Google Earth archives) on protected crops in Azapa Valley allowed to complement a spatial analysis for the years of the study.

Fieldwork

Figure Technical digital limitations were minimized in the field, validating the digitized information. This activity took place every time it was required, running in parallel and in a complementary way with the rest of the stages. Coordinates and polygons were determined with a GPS (Etrex 10®, Garmin) in each target area for a supervised classification. The method involved synchronization of a digital camera (Canon PowerShot® SX30IS) with the GPS, recording the time and date values for each waypoint. The high points of the valley allowed to confirm the current heading production category and the distribution of the two studied variables.

Data processing

The information collected in the field with the use of GISs was employed. Reconstruction and location of the variables was made with the Arcgis 9.3® software, which generated polygons virtually characterizing olive trees and protected crops for the period studied, complementing the analysis between satellite images. In order to obtain digitized spatial information for the years 2003 and 2013, Google Earth archives were used, gathering a systematic set of quantitative measures in which qualitative elements were added (Chuvieco, 2008). The computer work was based on the superimposition of images scanned in Arcgis 9.3 for the respective years, taking into account mainly the spaces modified through visual interpretation and in site visits. Thus, the accuracy of the information obtained by means of GIS was determined by the quality of the data verified in the field, minimizing errors. Through Google Earth software, the spatial distribution of the productive sectors in the corresponding years were determined. Polygons were drawn following the contour of the structures of protected crops, using high-resolution satellite images provided by the software. The valley was divided into three main areas to classify the occupation and distribution of the variable under analysis. The spatial distribution of olive trees and protected crops were mapped with Arcmap® software to interpret and relate the dimensions (in hectares) for each representative polygon of the territory. To calculate the dimensions of the spaces occupied by olive trees, protected crops and those places directly replaced between the years studied, polygon layers were associated to attribute tables, calculating the area with the Field Calculator® software. Later, the table was arranged by geometric calculations.

Results and Discussion

Surface changes of olive trees in Azapa Valley between 2003 and 2013

The year 2003 was determined as a turning point in the

traditional processes of land use of Azapa Valley. This provisional definition marked significant changes in patterns of production and usage of space, being the source of deep changes after the SAG lifted the phytosanitary restrictions in 2003, observing a considerable decrease in the presence of olive trees in the studied area. The massive felling of olive trees does not go unnoticed, being a key to explain the changes experienced by the landscape element. The results of cartographic (mapped) data analysis and information processed with GIS indicate that in 2003 the Azapa Valley showed a strong olive vocation, with a lot of plots that exceeded 30ha and could reach 93.52ha (Figure 2, left), with clear predominance of olive cover in the lower and middle Azapa areas, reaching 1388ha of a total of 3000 arable hectares. In 2003, 189 farms were registered and mostly characterized with the closed field type. For 2008, the estimates were of 1323ha planted with olive trees and the remaining area destined for the cultivation of other vegetable crops. In 2013 it was estimated that 146 olive farms were in the Azapa Valley, occupying an area of 967ha, demonstrating a reduction of a 25.6% change in the period (Figure 2, left). The reduction in olive trees is directly associated with the positioning of seed companies, located in the lower and middle areas of the valley.

However, it must be noted that the reduction of olives not only responds to the systems initiated by seed companies in the area, but also to the felling process initiated by local farmers. The number of trees felled in relation to projects connected to the agricultural lands of Azapa Valley was estimated in 7,000 specimens by 2008. The Law Decree Nº 3,516 established in 1980, states rules on subdivision of agricultural property remarking that such properties, considered property of agricultural, livestock or forestry potential, located outside the city limits of regulatory plans, can be divided freely by their owners, providing the resulting batches would be >0.5ha (Babárovich, 2011). From this point of view, the design of any project should consider that the owners and/or holders are who ultimately decide with some limitations on what and how they will use the resources tied to their land, and/or their participation in planned programs (Sánchez, 2001). This largely explains the phenomenon of subdivision of plots that arose in the valley, product of new production patterns and new values linked to the soil. Lease, purchase and subdivision of land processes characterize the new dynamics of settlement; this time not linked to urban intrusion or so-called reurbanization of previous years, but to the search of greater profitability per square meter in Azapa Valley. According to the tax revaluation of the Internal Revenue Service for 2008, 2009, 2010, the commune of Arica recorded an increase in the average number of properties (Table 1), reaching the number of 8,551 for the región of Arica and Parinacota. In annual terms of property subdivisions, in the last five years, 298 subdivisions were conducted at regional level, and 178 (>60%) of them took place in the Azapa Valley.

Seed companies and crop production under greenhouses

A technological renewal is taking place in the agricultural world, linked to the use of covers, plastic constructions that seek to prevent accidents related to climate and crop pests. In the valley of Azapa this practice has expanded during the last decade to reduce losses and improve production quality. In 2008, in Azapa there were 500ha of crops protected by greenhouses. Of these, 100ha were destined for blowout seeds and biotechnological products. Globally, about ten seed enterprises control more than a third of the trade. These companies take advantage of the weather conditions in order to speed up the production processes of new hybrids for the market, achieving the reduction from five to three years in breeding times for new varieties. The main species in which hybridization was began were tomato, melon, watermelon and peppers. The arrival of the seed companies to Azapa Valley not only meant the insertion of new commercial products, but also the arrival of a new cultivation method whose practice would spread, revolutionizing production systems in the valley. Almost all new varieties of plants such as corn, rapeseed, soybean and sunflower, sold around the world stop by in at least one of the research facilities in Arica.

TABLE I
AMOUNT OF AGRICULTURAL LAND IN AZAPA VALLEY, REGION OF ARICA AND PARINACOTA

Year	Number of farms in the Region	Number of farms in Azapa Valley
2005	42	24
2006	27	14
2007	24	15
2008	56	36
2009	132	73
2010	17	16
Total	298	178

Source: Babárovich (2011).

The incentives provided by the State for the installation of such companies in the region of Arica and Parinacota, the programs to attract investment to the region and the incentives for the conversion of farms, the funding for business innovation and actions to promote production for small and medium-sized companies, all generated the setting up of several companies and, as a side effect, the use of greenhouses to protect crops has been greatly expanded. Within the institutional economic factors, it is important to consider that the arrival of multinational companies to Azapa Valley was favored by the political and social stability that the country enjoys.

It is estimated that by 2008 the spatial dimension used by seed companies in Azapa did not exceed 60ha; currently the Figure is not less than 240ha. The transition experienced in the Azapa Valley is explained by the intensive use of the soil, increasing the value per square meter of the resource, because the business practices of the seed companies and their contribution to different GDP sectors. The growing use of greenhouses in Azapa Valley incorporated different elements:

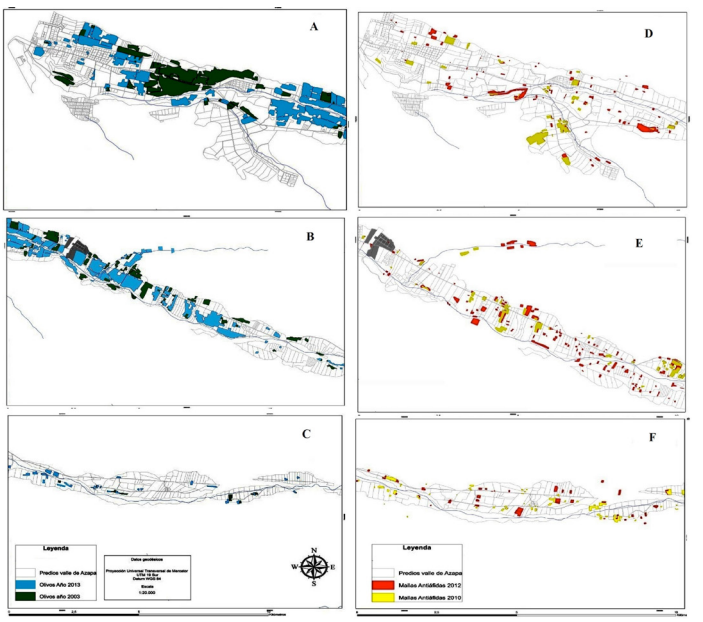

Figure 2. Evolution of land occupation in the Azapa Valley (2003-2013). Left: olive trees, right: greenhouses. A and D: low sector, B and E: medium sector, and C and F: high sector.

reduction in the use of pesticides, biological pest control and pollination by means of auxiliary insects, improved water efficiency, increased production per unit area, and greater contribution to GDP from the region of Arica and Parinacota.

Land use dimension of protected crops

GIS analysis (Table II) indicates that in the year 2003 there was an area of 144.2ha covered by greenhouses in the Azapa Valley. This area presented a disperse distribution, attributed to private commercial investment projects, with a total of 95 fenced fields, with small presence on the southern side of the valley. The same analysis performed in later years established an increase in the presence of crops under greenhouses, reaching 213.3ha over a period of seven years, continuing the pattern of occupation linked to low and middle valley zones. Compared with 2003, the number of properties taken with greenhouses rose from 95 to 292. The reality which the Azapa Valley is going through regarding the presence of large companies producing transgenic that are changing land use, does not escape the national processes observed in this area. It is estimated that the surface of the national territory in use by genetically modified seed companies covers ~0.1% of the tillable 18,473,127.9ha in Chile. The sample includes papers, certified seeds for domestic consumption and all seeds destined for export (De la Fuente, 2014). Thus, Chile is one of the leading exporters of seeds, positioned in 2012 in the fifth place worldwide and first in the southern hemisphere. The increase that has taken place in the seed industry within the national territory in recent years, to which the Azapa Valley contributes, allows to ponder this space as a new technology center, based on the climatic benefits of the territory.

With regard to the area under greenhouse cover and the floor surface specifically taken by seed companies in Azapa Valley, it is estimated that by the year 2008 about 60ha were built, while for 2012 the calculated surface was 240ha. In 2013, the presence of spaces taken by crops under greenhouses is evident in the entire valley, with some important swarms. The growth experienced by crops under this new technological approach has not been altered, reaching 525.1ha in 2013. For this period (Figure 3) important appearances of greenhouses can be found on the north side of the low sector of the valley. The type of crop is scattered with small subdivisions that match private agricultural projects such as citrus fruits, quince, guava, mango trees and productions of vegetables like peppers, tomato and cucumber. The trend is that commercial use based on new crop technologies are replacing vegetable covers of traditional use, such as olive and other fruits. From this point of view, the expansion of this cultivation method affects not only traditional agricultural production units but has moved other local consumption crops to poorer soils.

TABLE II
AREA COVERED BY GREENHOUSES

Year	Size (ha)
2003	144.2
2004	213.3
2005	321,0
2006	525,0

Conclusions

The dynamics of land use change developed in a rural area not only consumes significant amounts of territory but, at the same time, greatly transforms the natural and cultural landscape, having as one of its consequences the loss of identity of those areas. For the Azapa Valley, the decrease in the surface occupied by olives does not lie only in the presence of new seed companies, since they only impact their required space and not the totality. Another factor is the greater business capacity of local producers who, motivated by the opportunity of changing their business activities and production processes, have turned to intensive horticulture under greenhouses, influenced significantly and directly by the new landscape that the valley expresses. As a result, the valley registers impacts in the agricultural and rural spheres, including cultural, economic, environmental and traditional aspects. The absence of an instrument of self-zoned rural planning opens ways for free decisions regarding the activities developed in these areas. Such legal gaps generate, in the short and medium terms, problems associated with the lack of specialization of rural areas, regional tensions, possible extinction of natural resources such as the olive, incompatibility between neighboring activities, sectorial conflicts, and low or no participation of rural actors in building the strategies that drive the future development of their territory. The current state of Azapa Valley shows signs of new developments and insertion of elements leading to a changing land use. Territorial, environmental and cultural impacts that entail the integration of technology in protected crops under greenhouses with productive purposes and the arrival of large seed companies, *versus* the reduction of the traditional olive tree, highlights the need of planning according to a territorial approach.

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Figure 3. Azapa Valley in the medium sector. Above: 2003, without greenhouses; below: 2013, with greenhouses.

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