Environmental Efficiency of Greenhouse Agriculture in the Coast of Granada (Spain): Towards New Planning and Management Criteria

Alberto Matarán Ruiz*

Department of Urban and Spatial Planning, University of Granada. Spain

Abstract: A successful assessment, prediction, management and planning of environmental impact (considering sustainability principles) will depend on the existence of a valid methodological approach. According to this, we have considered a set of key indicators combined with other references (reports, cartography…) as a suitable method to evaluate the environmental efficiency of greenhouse agriculture in comparison with other agricultures present in the Coast of Granada. Our main conclusion is that greenhouses are producing the most important territorial impacts and externalities related to the unplanned land occupation and to the pollutants production and discharge. The traditional management practices and planning documents are not useful to reduce the environmental conflicts caused by greenhouses in the Coast of Granada. So we have proposed new environmental planning and management criteria to improve the environmental efficiency of greenhouses and to develop a better integration of this agro-industrial use on the coastal landscapes.

INTRODUCTION

The researching developed concerning the relationship between agriculture and environmental impact is divided into two major tendencies. The first focuses on the relationship between water and agriculture as a major water-consumption activity [1-6]. According to the new statements of the EU Water Framework Directive 2000/60/EC, there is a second block of research examining the relation between water quality and land use from the point of view of improving water quality through the use of management and diverse planning instruments [7-11]. Our main interest in this article, however, lies in this second block and in a third major research tendency, which highlights the impact of important elements such as urbanization, infrastructures, and economic activities, as for example agriculture, on spatial environmental impact integrating the researching tendencies described above. This is mostly related to water quality as one of the best indicators of these impacts [12-15] and also as one of the most important issues in the mediterranean areas [16-17] like the coast of Granada, the South East of Spain [18], or other similar places as, for example, the Antalya region in Turkey [19].

In the particular case of the Coast of Granada, the extraordinary spatial expansion of greenhouses along the last thirty years is leading to the saturation of the agricultural landscapes of coastal plains [20-22]. This new change is not a new process along the convulse Mediterranean history, but we need to assess the impact that it is producing in the environment, including a broad comparison with the rest of agricultural land uses in the area.

However, we are presenting a comparative analysis of coastal agricultures based on the available information, including a broad analysis of pollutants in water, soil and wastes made by the Motril Local Council in 2002 and 2003. These data are representative of the overall situation of the coast, as most of the spatial occupation models are included inside the municipal limits.

In addition to this, we have developed a set of key factors and indicators to describe the environmental impacts related to the most representative agricultures considering the production of pollutants and other related questions such as the consumption of resources (land, water, energy, etc.). These factors will be a part of a complete set of environmental indicators developed by the author of this article [15] considered on the basis of previous descriptions [23-25].

Finally, diverse historical, political, economic and environmental circumstances have lead to a situation where natural resources are considered to have high quantitative and qualitative territorial values in the coast of Granada [26]. So, we are still on time to produce another scenario overcoming the tendencies and generating planning and management measures taking into account the important agricultural landscapes that still constitute the main identity of the Coast of Granada.

AREA OF STUDY

The Coast of Granada is a 71 Km long coast line located in the South East of Spain (Fig. **1**). There are 115.000 inhabitants all the year long, and around 220.000 during summer. It has a peculiar landscape, including several deltas and lots of hills and huge slopes leading to Sierra Nevada Mountains. The Coast of Granada has a mixture of farming (including greenhouses) and tourism development. As it can be seen in the map bellow, the geographical basis for the research project described in this article is related to the presence of greenhouses: dispersed in the case of Motril (eastern side) and more compacted in the case of Carchuna and Gualchos-Castell de Ferro (central and western side).

*Address correspondence to this author at the Department of Urban and Spatial Planning, University of Granada. Spain; E-mail: mataran@ugr.es

1876-3251/08 2008 Bentham Open

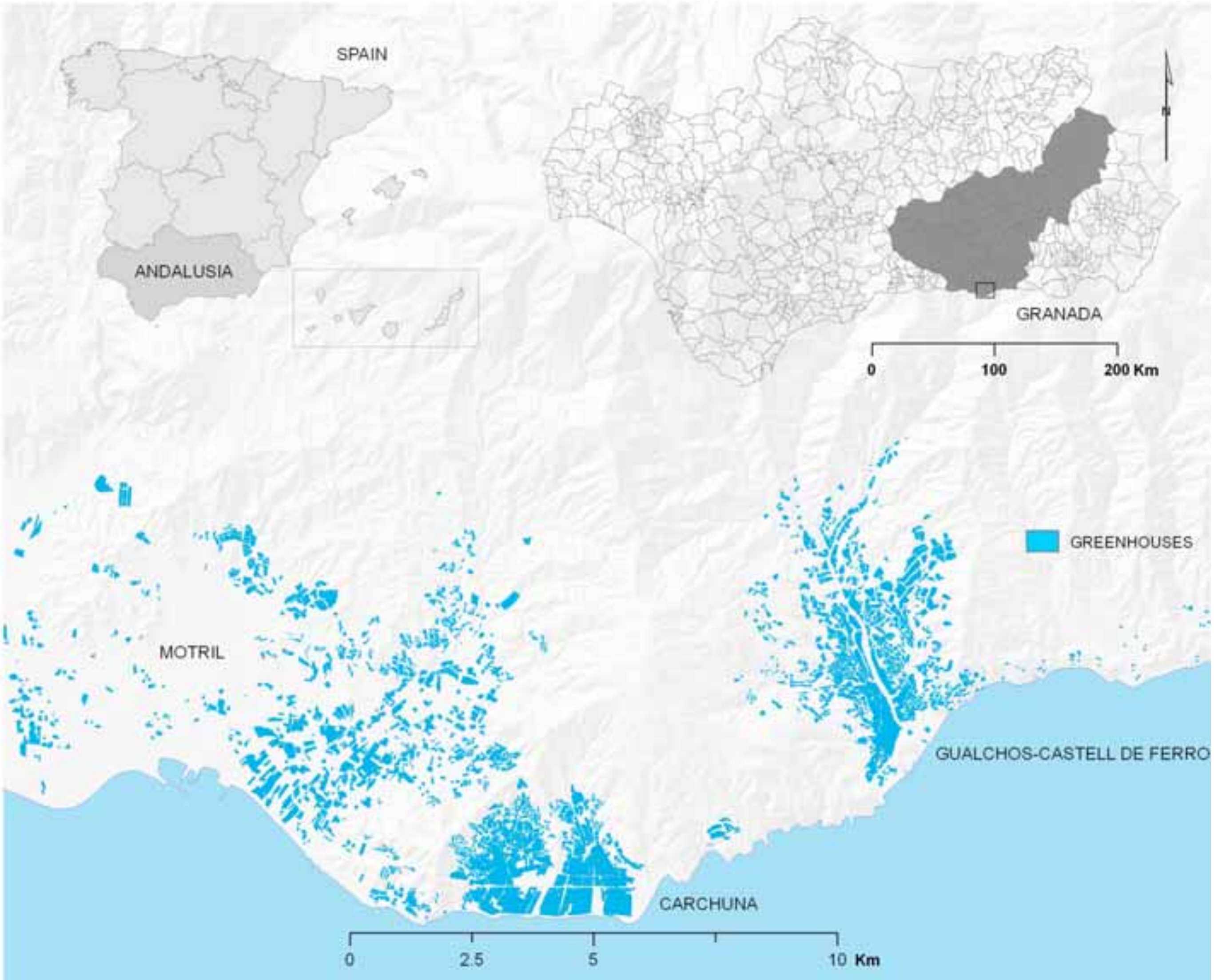

Fig. (1). The Coast of Granada: area of study (Source: Self elaborated).

3. TERRITORIAL INTERPRETATION OF THE EVOLUTION OF AGRICULTURAL LANDSCAPE AND LAND USES

As well as in the rest of the Mediterranean coast, agriculture land uses and antropization have been historically very important to build the landscape identity [27]. In order to understand the actual processes and to define a better comparison, we have resumed a historical analysis of agricultural landscape transformations produced mainly in the lowlands of the coast of Granada. In the following paragraphs we present three great steps in the agricultural development of the coast of Granada, showing the importance and diversity of the agricultural landscapes in this area [28].

The First Great Step: Increase and Decrease of Sugar Cane

It was introduced in the Xth century, and it produced the most important territorial and landscape transformation in the coast of Granada supported by a progressive reduction of water surfaces in the coastal lowlands [29]. At the middle of the XVIIth century there is an important increase in the sugar cane surface, followed by a huge decrease at the end of this century due to the introduction of American and Asian sugar. In this moment, cotton substitutes the sugar cane, but then the sugar plantations increase after the construction of the first mechanic factory to treat the sugar cane (1845) and the final reduction of the latest water ponds in the coastal lowlands. It remains as the main crop until the arrival and expansion of subtropical trees and greenhouses in the nineteen eighties. Now it is in a non-return disappearing process.

The Second Great Step: The Development of Subtropical Agriculture

At the same time as greenhouses (described bellow), rises one of the lots of attempts made by the local farmers to introduce foreign crops: the plantation of subtropical trees. Mainly avocado and cherimoya are successfully planted in the Guadalfeo Delta and in the West of the coast, occupying both the lowlands and some of the hills [30]. Including the East coast of Malaga, this is the only subtropical tree farming that still exists in Europe at commercial level. The beautiful and all year green landscape is also unique in the continent and highly valuated by tourists [31-32].

The Third Great Step: Greenhouse Development

Greenhouses appeared in few strategic points of the lowlands of the coast of Granada during the seventies, following a diffusion process of the innovations produced in the west coast of Almería [20,22]. Greenhouses are known as a kind of agro-industrial activity, which is the main economic force in the coast of Granada, much more efficient than the other farming systems, and much more defined to serve international markets (mainly central and northern Europe) [21,30]. Greenhouses have grown an average of 125,6 ha per year from 1977 to 2003, achieving a surface of 3265,9 ha. Most of the greenhouses are located in plane areas that have been saturated by plastic covers, some others, following a sprawl process, have occupied the hills bellow 500 meters. This agro-industrial activity represents only around the 25 % of the irrigated agriculture in the Coast of Granada but it is responsible of almost the 70 % of the total economic input and 75 % of the employment generated in the agriculture sector. Apart from these extraordinary data, this new activity is also producing high environmental impacts that we are going to describe bellow.

4. ENVIRONMENTAL IMPACT OF COASTAL AGRICULTURES

Our methodology is based on the use of every data and references available and its integration in a geographic information system. In addition to this, as a core of our assessment system, we have identified some key factors and indicators of the environmental efficiency of economic activities regarding the production of pollutants and other related questions such as the consumption of other resources (land, water, energy, etc.) affecting the overall environmental impact of each agricultural activity in the coast of Granada. As we noted before, these factors will be a part of a complete set of environmental indicators developed by the author of this article [15].

It needs to be considered the lack of territorial data to assess the research elements, with the exception of the still unpublished study made by the Motril Local Council, that we have analysed in a spatial context related with the agricultural land uses. In addition to this, to fulfil all the requirements for this assessment, the broad revision of the available information has been complemented by more than 50 interviews to farmers, managers, technicians, researchers, stakeholders, etc., all this support both the data and the hypothesis that we have made.

Hypothesis of Agricultural Land Use and Environmental Pollution in the Coast of Granada

The demonstration of the link between agriculture and environmental pollution in the Coast of Granada is based on the data that have been collected in Motril by the Innova Labs [33]. The data include measurements on running water, soil, sediments and agricultural wastes. There are three data series the first one that was carried out during July 2002, the second one in September 2002, and the third one in April 2003. The analytical methodology follows the standards methods established for this kind of analysis [34], and it takes into account the integrity of the samples. Finally, as described in Matarán [35], we have geographically represented the complete set of data.

Considering that the available data where too broad, in this resume, we have focused on water pollution and we have avoided the data of April as in this month it have been found very few pollutants in water.

Even this is only a previous study, we could underline some of the most important questions that we have analysed.

The presented figures, includes a large amount of pollutants that mostly cover all the territory (see sampling points in the following Fig. (**4**)), so we are studying a diffuse pollution process related with an intensive land use, which also needs an intensive use of pesticides.

According to the data and the published references [36], the most used pesticides are fungicides and insecticides; and within the last group the most important are organ-chlorines (*Endosulfan, Dicofol*…), organ-phosphorades (*Malation, Pirimifosmetil, Cloropirifos*..) and piretroids (*Bifentrin, Bufoprofezin, Ancrinatrin*...). Among all, *Endosulfan I* is the most detected pesticide as it is more persistent and it is broadly used in Spain [37-38]. Only some of the pollutants are apparently related with the type of farming present in the subwatershed related to any sampling point. As it can be seen in the following map, *Carbaril* is mostly related to greenhouses as the highest concentrations are presented in areas fulfilled by greenhouses, and there are small concentrations in some other areas where the greenhouse surface is less important. For the contrary, *Endosulfan I* has been described in almost every sampling point, which confirms that this persistent pesticide is used in almost all the farms.

Sampling Points	Carbaril	Lindano	Diazinona	Clortalonil	Clorpirifos	Endosulfan I	Endosulfan-sulfato	Tetradifon	Endosulfan II
SEPT1	0,026	0,009	0,022	0,068	0,003	0,009	0,024	0,003	
SEPT2	0,089	0,01	0,02	0,132	0,001	0,006		0,004	
SEPT3	0,033	<LOQ	0,02	0,09		0,032	0,027	0,003	0,026
SEPT4	0,02	0,01	0,019	0,034		0,004		<LOQ	
SEPT5	0,015	0,01	0,025	0,065	0,006	0,016	0,08	0,003	0,006
SEPT6	0,052	0,014	0,027	0,092	0,044	0,074	0,084	0,004	0,015
SEPT7	0,026	0,01	0,022	0,117	0,003	0,009	0,029	0,003	
SEPT8	0,041	0,007	0,021	0,085	0,003	0,014	0,034	0,003	0,004

Fig. (2). Main pollutants in water September 2002 (mg/l) (Source: Motril Local Council (2002-2003) [33]).

Sampling Points	Bromopilato	Clorpirifos	Endosulfan I	Endosulfan III	Tetradifon	Carbendazima	Imidacloprid	Ciprodinil
JAN1	0,02	0,11	0,02	<LOQ	0,02	0,39		
JAN2		0,04	0,02	<LOQ		0,16		
JAN3	0,02	0,02	0,13	0,31	<LOQ	1,5	0,35	0,07
JAN4	<LOQ	<LOQ	0,07	0,05	<LOQ	3,07	0,29	0,07
JAN5	<LOQ	0,02	0,02					
JAN6	0,02	0,04		0,08	<LOQ	0,12	0,21	0,33
JAN7	0,06	0,05	0,21	0,36		1,33	0,18	0,22

Fig. (3). Main pollutants in water January 2003 (mg/l) (Source: Motril Local Council (2002-2003) [33]).

Notes: As described bellow, the sampling points of January 2003 are included in Fig. (4). Other pollutants that have also been found: Amitraz; Hexaflumuron; Endosulfan II; Pirimifos-metil; Formetanato; Oxamilo; Imidacloprid; Carbaril; Ciprodinil; Piridaben; Malation; Procimidona; Nuarimol; Imidacloprid; Metalaxil; Pirimifos-metil; Dicofol; Buprofecin; Hexaflumuron.

The following map represents the concentrations of Carbaril and Endosulfan I in water in September 2002. We have also included in this map the sampling points of January 2003 to facilitate the spatial interpretation of the data included in Figs. (**2**) and (**3**).

Finally, the agricultural practices are related with the temporal distribution of pollutants. Analysing the Fig. (**4**) and the data included in Figs. (**2**) and (**3**) we can underline the following questions: In the greenhouse areas there are more pollutants in September (and much more in January) than in April, as their activity ends at the end of the Spring or at the beginning of the summer; In the case of Subtropicals, the most important concentrations are in September, when the plant treatments are followed; Finally, in the case of sugar cane there are almost no pollutants in April, and there are less pollutants in September, when they are harvesting, than in January, when they are in the middle of the growing process.

This temporal variation, also means that apparently, the accumulation process is very low in the analysed media.

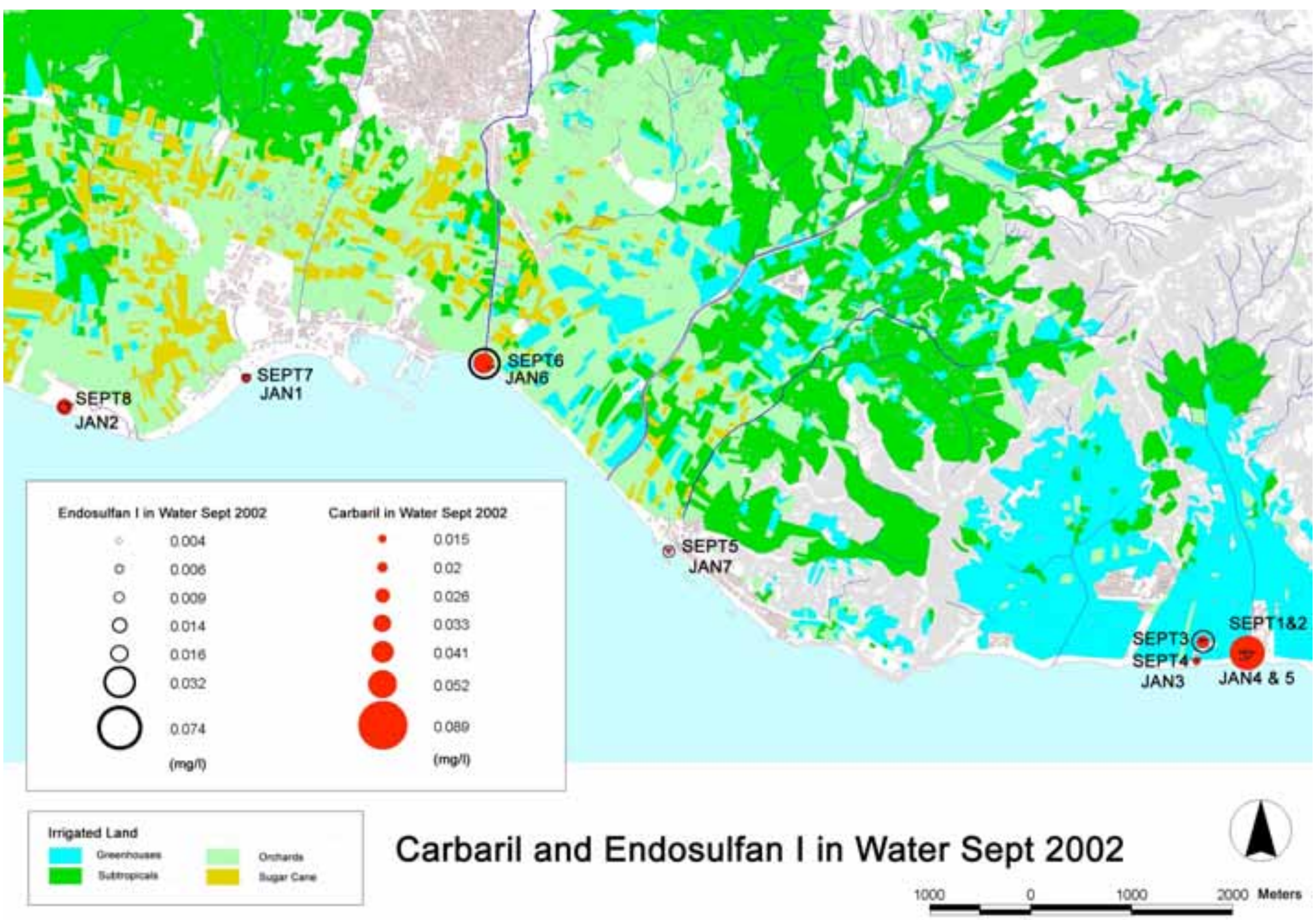

Fig. (4). Carbaril and Endosulfan I in water in September 2002 (Source: Modified from Motril Local Council (2002-2003) [33]).

Anyway, the importance of Cloropirifos [38] in the presented figures addresses us to consider this dangerous possibility.

Assessment Methodology: The Indicator System

Once we have demonstrated our hypothesis of the relationship between agriculture and pollution, we have produced a related set of indicators to assess the environmental impact of any of the farm type existing in the Coast of Granada.

The selected indicators are included in the following tables and Figs. (**5-7**) and show how greenhouses produce a much larger amount of pollutants and other environmental impacts than the avocados (most representative of subtropical) and sugar cane, but the higher productivity also reveals that the overall efficiency is better in greenhouses than in the rest of crops, because the high productive efficiency of sugar cane (Fig. **5**) is dropped by much lower prizes in the market (Fig. **7**).

Wastes

The large and diverse quantity of wastes produced by greenhouses comparing to the other agricultures (Figs. **5**, **6**). It has been producing many environmental problems in the Coast of Granada, but within few years the problem has been reduced by the application of different management measures that will be analysed in following paragraphs.

Water Quality

The worsening of water quality is one of the main problems in an area where water scarcity is crucial [15]. However, it is important to compare the different types of farming insofar as their total use of pesticides and fertilisers is concerned (Fig. **5**). As we have established in the spatial analysis of the experimental study, particularly, greenhouses use a higher quantity and a broader range of those pollutants, but their efficiency is much higher for example than in the case of avocados (Fig. **6**). Anyway, normally, the larger the use the larger the total discharge, so mainly greenhouses but also the rest of the crops have to be controlled in order to reduce this important pollution source. The actual situation is an interesting laboratory to rebuild the territory in a planning and management process addressed to reduce pollution discharge following the EU Water Framework Directive [39] and also to reduce the possibilities of an unplanned increase of the irrigated surface (mainly greenhouse surface) diminishing finally the environmental impact of agriculture and promoting the environmental values of the territory.

Other *Impacts*

Greenhouses are also leaders in other different impacts that we did not describe with numerical indicators. Landscape, biodiversity, flooding and erosion impacts are much bigger in relation to greenhouses than in other farming [21, 34, 40]. The spatial distribution and the intensive land use, is dramatically increasing those impacts. The changes produced by these industrial facilities have strong effects in the landscape, increasing also the impervious surface, which means more speedy flows, that produce more flooding and erosion risk [34]. For the contrary, the rest of the farming conform valuable landscapes, including the subtropical landscape which is the main character of this coast. The terrace method and the role of subtropical trees also reduce the flooding and erosion risk, decreasing the flows and attaching the soil.

CROPS	Productivity Tn/Ha	Water Consumption (m^3/Ha)	Fertiliser Consumption (Tn/Ha)	Pesticide Consumption (Tn/Ha)	Organic Wastes (m^3/Ha)	Organic Wastes (Kg/Ha)
AVOCADO	7	6500	1,55	0,04		
SUGAR CANE	80	9000	0,04	1,44	---	---
GREENHOUSE						
TOMATO	75	6000	2,3	0,2	140	35000
CUCUMBER	90	3500	2,3	0,2	90	22500
PEPPER	70	4700	2,3	0,2	100	25000
GREEN BEAN	22	1800	2,3	0,2	70	17500

Fig. (5). Environmental indicators of coastal agriculture (2003) (Source: Modified from Matarán (2005) [21]).

Note: We are describing the four main crops growing inside greenhouses. The efficiency rates of greenhouses are in the range of these four main crops [21].

CROPS	Water Consume Efficiency (Tn/Tn water)	Waste Production Efficiency (Tn/Tn wastes)	Fertiliser Consume Efficiency (Tn/Tn fertilisers)	Pesticide Consume Efficiency (Tn/Tn Pesticides)
AVOCADO	1.08	7	4,52	175
SUGAR CANE	8.88	----	55.55	2000
GREENHOUSE				
TOMATO	12.5	0,21	32,61	375
CUCUMBER	25.71	0,4	39,13	450
PEPPER	14.89	0,28	30,43	350
GREEN BEAN	12.22	0,13	9,56	110

Fig. (6). Environmental efficiency indicators of coastal agriculture (2003) (Source: Modified from Matarán (2005) [21]).

Water Consumption

The unique environmental impact where all the crops are above greenhouses is in the water resource direct consume (Fig. **5**). Water abstraction increases the impact produced by pollution discharge, mainly on overexploited coastal aquifers [41]. In dryness periods aquifer pollution is above legal limits for drinking water [21]. In addition to this, it is very difficult to reduce the high water consume as for example most of the subtropical farms are still consuming high water quantities even there are modern irrigation systems, and in the case of the still remaining traditional farms and sugar cane, they are just disappearing and being replaced by tourism buildings that consume much more water per hectare than agriculture [26]. For the contrary in the case of greenhouses there is a tendency to reduce water consume with hydroponics and recirculation processes. Water quality is also less important in greenhouses than in other crops, so the problems with water resources affect more to subtropical and traditional farming. In addition to this, good water quality produces better efficiency rates in greenhouses (they need less water to produce more yields). A new multifunctional scenario has to focus on the water issues, considering the different uses of water and the different demands of diverse agricultures. Anyway, even the efficiency is bigger (Fig. **6**), the increasing surface of greenhouses and the saturation of some areas [20], is producing high environmental problems according to the overall increase of water abstraction.

Economic Efficiency

Finally, if we compare the results presented above (Figs. **5** and **6**) with the results presented in the following (Fig. **7**), as well as the environmental efficiency, the economic efficiency is also lower in sugar cane and avocados, than in the case of greenhouses. We have also included the economic indicators of nurseries and organic agriculture. Considering its reduced environmental impact, and the positive results of the existing farms (very few at the moment), this is a suitable alternative to diversify the production and reduce the environmental problems related with the agriculture activities in the Coast of Granada.

All the environmental problems attached to greenhouses are the main cause of a progressive reduction of these numeric efficiencies [21]. The high quantity of environmental externalities also means that this agro-industrial production system would not be so efficient if the farmers would need to pay to recover the environmental impacts. In addition to this, as well as it is occurring in El Poniente Almeriense, in the medium term, when the ecological system will start collapsing, the greenhouse system could collapse before, so this environmental situation is increasing the uncertainties that are constraining the greenhouse system [26]. All this means that the economical system generated around greenhouses is not sustainable, because of a monofunctional and monocultural landscape system like this supposes an enormous risk. Inequalities would also grow because few farmers are accumulating high profits, and they will have the possibility to response to a predictable crisis, and the environmental costs are paid by the society and would affect both the coastal territory and the economy of a majority of farmers that could not have sufficient funds and capacities to recover from an environmental crisis. Finally, agriculture labours are in such a precarious situation (most of them are immigrants) that their capacity to respond to this crisis depends on the employment in other economic activities.

Considering the employment and the economic efficiency, it will be interesting to maintain the economic impor-

CROP	A	B	C=A/B	D	E=C-D
	Productivity Tn/Ha	Price €/Tn	Economic Income €/Ha	Cost €/Ha	Net Profit €/Ha
SUGAR CANE	80	36,29	2903,61	2.363	541
AVOCADO	7	1090	7.630	1.721	5.909
GREENHOUSES					
TOMATOE	97	290	21.750	18.030	3.720
CUCUMBER	98	330	29.700	17.730	11.970
PEPPER	70	540	37.800	16.828	20.972
GREEN BEAN	22	1090	23.980	15.626	8.354
NURSERIES (ORNAMENTALS)	10 (1000 plants/Ha)	19.718 (€/ 1000 Plants)	197.180	168.832	28.348
ORGANIC SUBTROPICALS	11.6	600	6.989	3.505	3.484
ORGANIC GREENHOUSES					
TOMATOE	74	400	29.475	12.198	17.277
CUCUMBER	53.2	600	31.901	15.650	16.251
PEPPER	13	1200	15.625	8.797	6.828
GREEN BEAN	16,1	2400	38.636	9.204	29.432

Fig. (7). Productivity and profits indicators of coastal agricultures (2003) (Source: Modified from matarán (2005) [21]).

tance of greenhouses (with some planning and management measures to reduce the externalities), but in an hypothetical growing process (following the increase of water availability due to the new Rules Dam) it will be better to increase subtropicals, organic agriculture and ornamentals as they could produce profits with less environmental impact, and it would reduce the risk of a monoculture. These agricultures are also compatibles with other uses, so, they could be developed on a multifunctional basis, for example in combination with tourism as the other economic vector of the coast of Granada.

GREENHOUSE PLANNING AND MANAGEMENT: AN IMPORTANT PROBLEM TO BE PROPERLY ADDRESSED

It has been demonstrated that greenhouses produce more environmental impacts than any other farming, affecting the stability of the littoral ecosystem, not only because the intensity of this industrial activity but also because the intensity of the land use. However, even though there are huge problems, there are only two problem solving processes running:

Concerning the solid waste production, even there are many difficulties, there are also many interesting initiatives. The selling companies and the farmers have created an integrated pesticide packaging waste management system that is running in all the coast from 2003. There is also a new plastic waste management system that is operating from 2005. And the regional government has recently built an Organic Waste Management Plant in the surroundings of Motril and is developing an Integrated Waste Management System for this organic output.

Concerning the use of subterraneous water, the new infrastructures are reducing the problem as the water pipe that is now transporting water from the Guadalfeo Delta to the east of the coast is going to cover most of the greenhouse farms of the Coast of Granada. It will reduce drastically the amount of water abstraction needed and it would maybe produce a recovery in the aquifer situation.

The landscape impact and the liquid waste generation scenario are not showing any solution. Farmers are always avoiding greenhouse integration in their surrounding environment, and the irrigation looses and the waste leachates are still disposed in the media without any treatment, generating the problems described before.

Above it the spatial planning problems of greenhouses are not being solved, so it is really possible that the problems that seem solved and the other, will increase in a close future due to the spatial disorder and the unplanned growing of the greenhouse farming. This process will not only affect to the environmental elements, but will also affect the commercialization of products because it is producing a lost on the market image and a consequent prize reduction. Some farmers and many commercial companies are dealing very well with restrictive quality assessments, and they want all the other farmers to do the same, because the environmental and commercial problems are affecting both those who produce correctly and those who do not.

Regarding the planning documents they are obsolete both in their methods and in their focus [42]. Agriculture is considered as a secondary activity in most of the documents. However, there are very few planning references to this important economic activity. In the case of local planning, the urban focus is predominant, so agriculture land is always the rest of the territory that has not got any other classification such as urban, urbanizable and protected. And in the case of regional planning, we have to add the lack of coordination and the obsolete landscape and environmental analysis.

According to this general approach, there are many problems and challenges concerning the particular case of greenhouse planning that need to be urgently addressed to reduce the environmental impact and the uncontrolled growing of greenhouses:

- Planning documents consider greenhouses as a common agricultural activity, so in addition to the general deficiencies of planning there is a misunderstanding of the real meaning of this agro-industrial activity [43-44].
- Planning documents have a restrictive focus on the territorial questions. For example, the assessments of environmental conflicts do not consider the management of diffuse pollution or the reduction of permeable surface.
- Planning documents are focused on an isotropic zoning that is not suitable to control a territorial phenomenon such as greenhouses, which produces both saturation and dispersion [20].
- Some of the planning documents are based on strict protection distances to some territorial elements without any reference to the characteristics of the territory and the activity that is producing the impact.

SPATIAL PLANNING AND MANAGEMENT CRITERIA

Considering the results presented in this article and according to previous researching [21,26,32] we are proposing here the following planning and management criteria for greenhouse agriculture as a response to those main problems described in the efficiency assessment and considering the deficiencies of the existing management practices and planning documents.

Our main objectives will be based on the reduction of landscape deterioration, diffuse pollution and spatial saturation. We propose the following criteria including two different intervention levels: spatial or regional level (that could be included in a special plan for greenhouses and in the forthcoming regional and local planning regulations) and farm level (that could be included in a special local plan and other regulations).

At Spatial Level

We have considered the ecological corridor approach and other concepts of landscape ecology in order to emphasize on the maintenance of the landscape structure and function (at local and regional scale) promoting the multifunctionality and the coexistence of land uses trough an increase in the compatibility and the territorial equilibrium [26]. The different agricultures not only have to share the space and natural resources, but also the environmental and economic risks. All this is a basic question to promote a more efficient agricultural landscape, to reduce the environmental impacts and to manage the greenhouse economic system.

- **Stop the greenhouse growing with a moratorium in the Coast of Spain** until the administrations in charge prepare a special plan for greenhouses. In order to avoid the substitution of greenhouses by urban growth, a similar measure could be applied for secondary residences as well as in the Canary Islands [45]. It is important to control the illegal growing in order to strength the planning regulations, and to reduce the impacts related to landscape transformation and pollution discharge.
- **Greenhouse excluded areas based on the description of the net of natural values.** According to Matarán and Valenzuela [26,32], the proposed methodology starts with the selection and overlaying of information shapes integrated in a GIS. Then several spatial correlations are described in order to define a spatial structure and a territorial aptitude in function of the identification of the following elements where greenhouses need to be avoided and relocated. First some areas essential for the spatial structure of the coastal ecosystems: Highly productive and/or biodiversity source areas; Articulation and diffusion corridors of the natural net; Fragile and sensible landscapes. And then some areas that are important to reduce the landscape and pollution impact: Buffer areas that filter and reduce fluxes of materials, energy and information; Sink areas for fluxes of materials, energy and information; Environmental risk areas.
- **Other greenhouse excluded areas close to the roads and the inhabited places**. Taken into account the pollution risk described in the environmental analysis we propose a minimum protection distance of 150 meters from greenhouses to urban areas following the regulations of the Motril Local Council and reducing the proposal of 300 meters for El Poniente Almeriense made by Gómez Orea [36] because it is difficult to apply in the narrow coastal space. Both references are used to determine a minimum distance to roads (50 m to high speed roads and 25 m to conventional roads).
- **Reduction of greenhouse surface in the hills.** Considering the landscape visibility and the erosion risk, it need to be established a slope limit of 30 %. In a future planning process new areas bellow this limit that are still non occupied could also be designed to compensate some of the proposed reductions. In addition to this the farms that are dispersed in the hills could be easily transformed to organic agriculture because they have better climatic conditions and they are less affected by plagues.
- **Protection of fragile areas such as aquifer vulnerable surface and agricultural planes in the lowlands**, where existing greenhouses are producing important landscape saturation [21]. Greenhouses on this areas will need to be strongly controlled with special management measures (see farm level bellow), in order to reduce the pollutant discharge.
- **Corridors through greenhouses**. Some percolation areas need to be defined between the littoral and the inland areas, trying to connect patches with high environmental value and to reduce the greenhouse saturation in some places. For example, it is important to eliminate the illegal farms close to the coastline, close to the hydrologic net, or close to the proposed percolation ways. All this will reduce the pollutant impact on important water systems.
- **Buffer areas between greenhouses**. According to previous studies [21,32], there are some areas that separate greenhouse saturated areas reducing the expansion of these farms. Some of the land uses and vegetation patches that still remain between greenhouses are also acting as a buffer area, so even the natural value is not high, the buffer function is important to be maintained, in order to reduce the impact of the pollution processes described before. It is also interesting to promote the elimination of some farms in order to increase the connectivity of the territory while filtering the pollution fluxes and the plagues. We could also reduce the density of greenhouses in the edge of the saturated areas, for example, using the interdigitation methodology [46].

At Farm Level

The multifunctional structure proposed at sub-regional and local scale need to be complemented by the strengthen of the agrarian management offices and with the participative elaboration of a code of good practice addressed to reduce the landscape impact and pollution discharge on the basis on interventions at farm level such as the following:

- The restoration of the vegetation placed in the borders of greenhouses and in the roads.

  The restoration and management of the water supply system as well as the small water courses present at this local level.
- Prepare an empty space in any farm to be used for waste management, rainwater drainage, leachate recovery, and landscape restoration.
- Reduce the use of pesticides and fertilisers, *via* the biologic methods and farmer training [47].
- Reduce the amount of waste and leachate production *via* minimisation and on-site recycling.
- Promote the environmental quality systems including certifications, as well as it has been broadly applied in the case of production quality systems.
- Promote organic agriculture and new crops through the demonstration of the viability of the researching,

development and innovation model on greenhouse agriculture.

- Improve and revise the aesthetic function of greenhouses using land art methods that include different plastic colours as it does not affect to the greenhouse productivity.

CONCLUSIONS

The presented environmental assessment, including indicators and other references, is the basis to determine the possibilities of: coexistence, coevolution, regeneration, multifunctionality, buffer/diffusion, and landscape equilibrium in the context of the agricultural landscapes in the Coast of Granada.

The presented experimental data constitute a previous study trying to produce a broad assessment of the situation. It will be the base for a better sampling distribution along the time and space. In following studies, a better understanding of the whole territory and of the land uses would be needed in order to produce better results and conclusions according to the pollutant sources and migration through different media. All this is very useful to determine a spatial hierarchy on the proposed planning and management criteria, and, if they are implemented, to assess if the application is successful or not.

According to the assessment and to the proposed criteria, the responsibility and probably the main opportunity of corporate and farmers is to follow the way to sustainability, trying to reduce the main environmental impacts through a change on their management methods. The bad example of El Poniente Almeriense, show us how there is a profit reduction throughout the years due to several causes among them the enormous environmental impact that greenhouses are producing since the nineteen eighties [18].

The flexibility of the proposed criteria is also very important as they need to be adapted to the uncertainty of environmental and social systems. The proposed planning model is also closely related to the concept of compatibility between diverse uses in a spatial context. As we have described above, agreement and compensation mechanism are useful to preserve some functions and some landscape structures without a remarkable market value at the same time as it is promoted a planned occupation of less important landscapes in order to generate economic development by market value products.

The presented researching is trying to demonstrate the existence of alternatives to the traditional methods of analysis, evaluation, management and planning. These new planning and management processes could enhance the sustainability of the Coast of Granada, as well as the rest of the Mediterranean region. In addition to this, these criteria could be very useful for the ongoing regional planning process, and also for the future revisions of local planning and sectoral plans such as: Andalusian Irrigation Plan, South Watershed Hydrologic Plan [48-49], etc.

Apart from the application and practical assessment of the proposed criteria, in following researching it will be interesting to describe the local environmental impact of future scenarios [20] to compare the actual tendencies with a possible multifunctional landscape.

REFERENCES

[1] Casabianca F. Por une politique agricole et environnementale adaptée aux zones méditerranéennes. Revue de L´Économie Méridionale 1999 ; 47: 5-17.

[2] Cox C, Mandramootoo C. Application of geographic information systems in watershed management planning in St. Lucia, Comput Electron Agric 1998; 20: 229-250.

[3] Del Moral IL, El Tratamiento del Agua en la Ordenación del Territorio en Andalucía. Andalucía Geográfica. Boletín de la Asociación de Geógrafos Profesionales de Andalucía 2002; 1: 43-55.

[4] Gardi C. Land use, agronomic management and water quality in a small Northern Italian watershed. Agriculture, Ecosyst Environ 2001; 87: 1-12.

[5] Kroll A, Ed. Agricultural water use and sectoral policies in mediterranean countries. POLAGWAT project. IPTS, Joint Research Centre, European Comisión, Sevilla, Spain 2002.

[6] Margat J. Progress towards water demand management in the mediterranean region. Contemporary trends and water demand change perspectives in the Mediterranean countries. Plan Bleu, Regional Activity Centre, Sophia Antipolis: Greece 2002.

[7] Carabias MR, Rodríguez GE, Fernández LME, Calvo SL, Sánchez San Román, F.J. Evolution over time of the agricultural pollution of waters in an area of Salamanca and Zamora. Water Research 2003; 37: 928-938.

[8] Fisher DS, Steiner JL, Endale DM, *et al*. The relationship of land use practices to surface water quality in the Upper Oconee Watershed of Georgia. For Ecol Manage 2000; 128: 39-48.

[9] Tong ST, Chen W. Modeling the relationship between land use and surface water quality. J Environ Manage 2002; 66: 377-93.

[10] Wagerhenkel M. Estimating of the impact of land use changes using the conceptual hydrological model THESEUS –a case study. Phys Chem Earth 2002; 27: 631-40.

[11] Wang X. Integrating water-quality management and land-use planning in a watershed context. J Environ Manage 2001; 61: 25-36.

[12] Bhaduri B, Harbor J, Engel B, Grove M. Assessing Wateshed –Scale, Long –Term Hydrologic Impacts of Land-Use Change Using a GIS-NPS Model. Environ Manage 2000; 26: 643-58.

[13] Kondoh A, Nishiyama J. Changes in Hydrological Cycle due to Urbanization in the Suburb of Tokyo Metropolitan Area, Japan. Adv Space Res 2000; 26: 1173-1176.

[14] Rodríguez F, Andrieu H, Zech Y. Evaluation of a distributed model for urban catchments using a 7-year continous data series. Hydrol Process 2000; 14: 899-914.

[15] Valenzuela LM, y Matarán A. Environmental indicators to evaluate spatial and water planning in the coast of Granada. Land Use Policy 2008; 25: 95-105.

[16] Bethemont J. Gestion de l´eau et conflicts sectoriells dans le cadre des pays mediterranees. Paper presented at the Seminario Europeo di Geografia dell´acqua, Ed. Pierpaolo Faggi, Monselice : Italia. 11-18 September 1994.

[17] Bressers H, Kuks S, Integrated Water Management Regimes and more Sustainable Water Resources in Europe: A Case Study comparison. EUWARENESS Project. University of Twente-CSTM Studies and Reports 2002.

[18] Contreras S. Los regadíos intensivos del Campo de Dalías (Almería). In: Martínez Fernández and Esteve Selma, Eds., Agua, regadío y sostenibilidad en el Sudeste Ibérico. Bilbao: Ed. Bakeaz. 157-192: 2002.

[19] Muhammetog˘lu H, Muhammetog˘lu A, y Soyupak S. Vulnerability of groundwater to pollution from agricultural diffuse sources: a case study. Water Sci Technol 2002; 45: 1-7.

[20] Aguilera Benavente F, Matarán Ruiz A, Pérez Campaña R, Valenzuela Montes LM. Simulating greenhouse growth in urban zoning on the Coast of Granada (Spain). In: Paegelow M. *et al*, Eds., Modelling Environmental Dynamics, Ed. Springer 2008; In press..

[21] Matarán Ruiz A. La valoración ambiental-territorial de las agriculturas de regadío en el litoral Mediterráneo: el caso de Granada. PhD Thesis. U. of Granada 2005.

[22] Matarán A, Aguilera F Valenzuela LM. Exploring new landscapes: what are the main factors affecting greenhouse expansion process in the Mediterranean coast?. In Meyer, B.C. Ed., Sustainable Land Use in Intensively Used Agricultural Regions, Landscape Europe. Wageningen: Alterra Report No.1338 2006: 105-111.

[23] Anegón Esteban MC, Coll de la Vega J. Sistema de indicadores ambientales del turismo. VI Congreso Nacional del Medio Ambiente, Madrid 2002 (CD).

[24] Ministry of Agriculture, Fisheries and Food. Towards sustainable agriculture: a pilot set of indicators. Ministry of Agriculture, Fisheries and Food. London 2000.

[25] OECD. Environmental indicators for agriculture. OECD. Paris 1997.

[26] Matarán Ruiz A, Valenzuela Montes LM. Regional planning in a Mediterranean region considering the net of natural values. Paper presented at the European IALE Congress, Faro (Portugal), March 2005.

[27] Fernández Ales R, Martín A, Ortega F, Ales EE. Recent changes in landscape structure and function un a mediterranean region of SW Spain (1950-1984). Landscape Ecol 1992; 7: 3-18.

[28] Matarán Ruiz A, Valenzuela Montes LM. The territorial model evolution of the Coast of Granada. Paper presented at the 11th International Planning History Society Conference, Barcelona, April 2004.

[29] Malpica Cuello A. Medio físico y territorio: El ejemplo de la caña de azúcar a finales de la Edad Media. In Malpica Cuello, A. Paisajes del Azúcar: Actas del Quinto Seminario Internacional sobre la Caña de Azúcar. Motril: Ed. Diputación Provincial de Granada. Granada 1993.

[30] ESECA. Estudio económico del sector hortofrutícola en la Costa de Granada. ESECA. Granada 1998.

[31] Calatrava Requena J. Contingent analysis of the scenic value of sugar cane in the subtropical coast o Granada (Spain). Some factors relates to WTP. Paper presented at the XXII International Conference of Agricultural Economists, Harare: (Zimbawe) 1994.

[32] Matarán A, Valenzuela LM. Regional planning in Granada, southeast Spain taking account the network of natural values. In: R.G.H. Bunce and R.H.G. Jongman Eds., Landscape Ecology in the Mediterranean: inside and outside approaches, Proceedings of the European IALE Conference 29 March – 2 April 2005 Faro, Portugal: IALE Publication Series 3 2006; 95-109.

[33] Motril Local Council. Estudio preliminar sobre la contaminacion por pesticidas en el termino municipal de Motril. Local Council Report Motril Unpublished (2002-2003).

[34] Alcalde F. Riesgo de inundaciones inducido por la agricultura intensiva bajo plástico. Paper presented at the V Congreso Nacional de Medio Ambiente, (CD). Madrid 2001

[35] Matarán A. Greenhouse wastes, environment and planning in the Coast of Granada, Spain. MsC Dissertation. Department of Environmental Management. University of Central Lancashire. Preston. U.K. Unpublished 2004.

[36] Gómez Orea D. Ordenacion de los invernaderos del Poniente Almeriense. Instituto de Estudios Caja Mar. Almeria 2003.

[37] Olea N, Molina MJ, García-Martin M, and Olea-Serrano MF. Modern agricultural practices: The human price. In: Endocrine disruption and Reproductive effects in Wildlife and Humans. Soto A.M., Sonnenschein C. Y Colborn T. Eds. Comments in Toxicology 1996: 455-474.

[38] Olea N. Health effects of pesticides. Paper presented at the The International Conference on Regulatory Issues in crop protection and their implications for the Food Supply. Shuman JM, Ed. Boston. 1997; 38-40.

[39] Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000 establishing a framework for Community action in the field of water policy.

[40] Alcalde F. Impactos de la agricultura de invernadero en la Costa de Granada. Paper presented at the V Congreso Nacional de Medio Ambiente. (CD). Madrid 2001.

[41] García-Aróstegui JL, Heredia J, Murillo JM, Rubio-Campos JC, González-Ramón A, y López-Geta JA. Primera aproximación mediante modelización al análisis de la influencia del embalse de Rules en el régimen hidrológico del acuífero de Motril-Salobreña (Granada). Paper presented at the V Simposio sobre el agua en Andalucía Almería, 25-28 September 2001.

[42] Priemus H, Rodenburg CA, Nijkamp P. Multifunctional urban land use: A new phenomenom? A new planning challenge? Built Environ 2004; 30: 269-273.

[43] Naredo JM. Territorio Medio Ambiente y Agricultura de Invernadero. En López Gálvez J, y Díaz Álvarez JR. Paper presented at the I Simposium Iberoamericano sobre Aplicación de los plásticos en las tecnologías agrarias El Ejido (Almería): CEPLA y FIAPA. 1995.

[44] Vattier Fuenzalida C. La explotación agrícola en invernadero y sus elementos. Paper presented at the I Congreso Europeo de Derecho Agrario. Almería: Instituto de Estudios Almerienses 1995.

[45] Cabildo Insular de Tenerife. Plan Insular de Ordenación del Territorio. Avance. Cabildo Insular de Tenerife 1994.

[46] Forman RTT. Land mosaics: the ecology of landscapes and regions. Cambridge University Press. Cambridge 2001.

[47] García AM, Gadea R, Muñoz MI, Cano I, González F. Diagnóstico de salud laboral en invernaderos agrícolas de Almería. Instituto Sindical de Trabajo, Ambiente y Salud (ISTAS), Comisiones Obreras. Madrid 2004.

[48] Confederación Hidrográfica del Sur. Plan Hidrológico de la Cuenca Sur. Ministerio de Medio Ambiente. Madrid 1999.

[49] Confederación Hidrográfica del Sur. Seguimiento y revisión del Plan Hidrológico de la cuenca Sur de España. Ministerio de Medio Ambiente. Madrid 2001.

Received: April 1, 2008 Revised: June 20, 2008 Accepted: July 24, 2008