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Changes in land use in the Region of Doñana from POTAD to 2009

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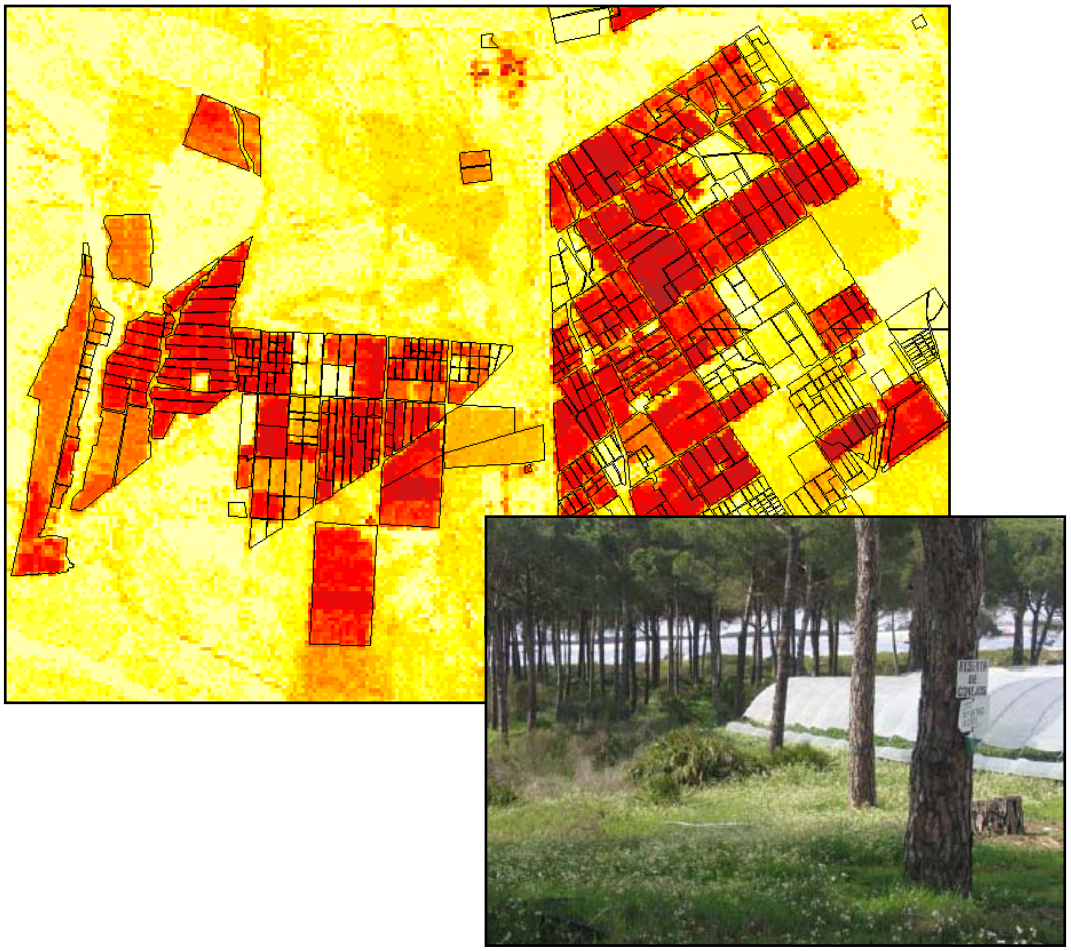

Changes in land use in the Region of Doñana from POTAD to 2009

GEOSYS S.L. and WWF-Spain

PICTURE ON THE COVER:
Example of map for the detection of plastics, GEOSYS S.L.
Photograph of an exploitation of strawberries under plastic. WWF/Felipe Fuentelsaz

June 2009

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1.- INTRODUCTION

1.1.- Background

From the 80s, crops under plastic have increased around Doñana. The strawberry has become one of the main crops regarding not only the surface and the economy of the area, but also some environmental aspects. It has had a great impact on the quality and quantity of water available for the wetlands of the National Park, and, specially, on the occupation of areas which connect Doñana to other valuable areas inland.

Among all the initiatives concerning the arrangement of soil arisen in the last years, we must highlight POTAD*,* standing for *Plan de Ordenación Territorial del Ámbito de Doñana* (land use planning in Doñana), approved in 2003. One of the purposes of this plan was to establish a legal framework for the arrangement and the sustainable development around Doñana in order to ensure compatibility between the preservation of environmental and territorial resources and the socio-economic progress together with improved living conditions for its citizens (Andalusia Government, 2003). In this plan there is information about the location of crops under plastic in 2003. The information is based on aerial photographs taken in 2001-2002 and on the work of technicians who, in 2003, obtained parameters and recommendations in order to improve the rural development.

However, after the approval of POTAD, the irrigation surface around Doñana has highly increased, sometimes even at the expense of the loss of forest lands, breaking thus important articles of POTAD and the environmental law in force.

Consequently, in December 2007, the Andalusia Government signed the drafting of a special plan for the rural rearrangement (a new land-use planning) of the strawberry area in Doñana and the creation of ecological corridors. Its main purpose are to relocate the farms that are placed in corridors or in areas considered sensitive from an environmental point of view; to remove those that had broken the basic environmental law, especially the farms that have been transformed after POTAD; and to legalise the ones that can conform to the current law.

Having into account the evolution of crops under plastic around Doñana and the different initiatives to arrange and plan that crop, the techniques for Earth Observation provide data that allow an adequate knowledge of the extent, distribution and evolution of the areas covered by crops under plastic. Therefore, this kind of remote detection has been regularly proposed.

1.2. - Purpose of the report

This study aims to identify and quantify the surface of the crops under plastic in the region of Doñana studied at different dates:

- POTAD (December 2003)
- Campaign 2008-2009

For this study, it has been defined a baseline that shows the distribution of the crop at the time in which the cartography of POTAD was made. From these data and using satellite images for different later campaigns, it seeks to identify all the areas that have been transformed into crops under plastic from another land use, highlighting the number of hectares converted from dry to irrigated land, and from forest to agricultural use.

To achieve an adequate monitoring of the evolution of areas converted to crops under plastic and their territorial distribution, some updates in the cartography of the baseline have been carried out, joining, in that way, new areas transformed into crops under plastic which were studied in the different campaigns.

1.3. POTAD Rules

Regarding the use of soil, different articles are specified in POTAD

Article 45. Area A. Area of protection of natural resources. In area A the transformation of forest use and the introduction of new agricultural uses are forbidden.

Article 46. Area B. Area of specific restrictions to the changes of uses

Article 47. Area C. Area of general restrictions to the changes of uses.

Regarding the use of water, the following articles are specified:

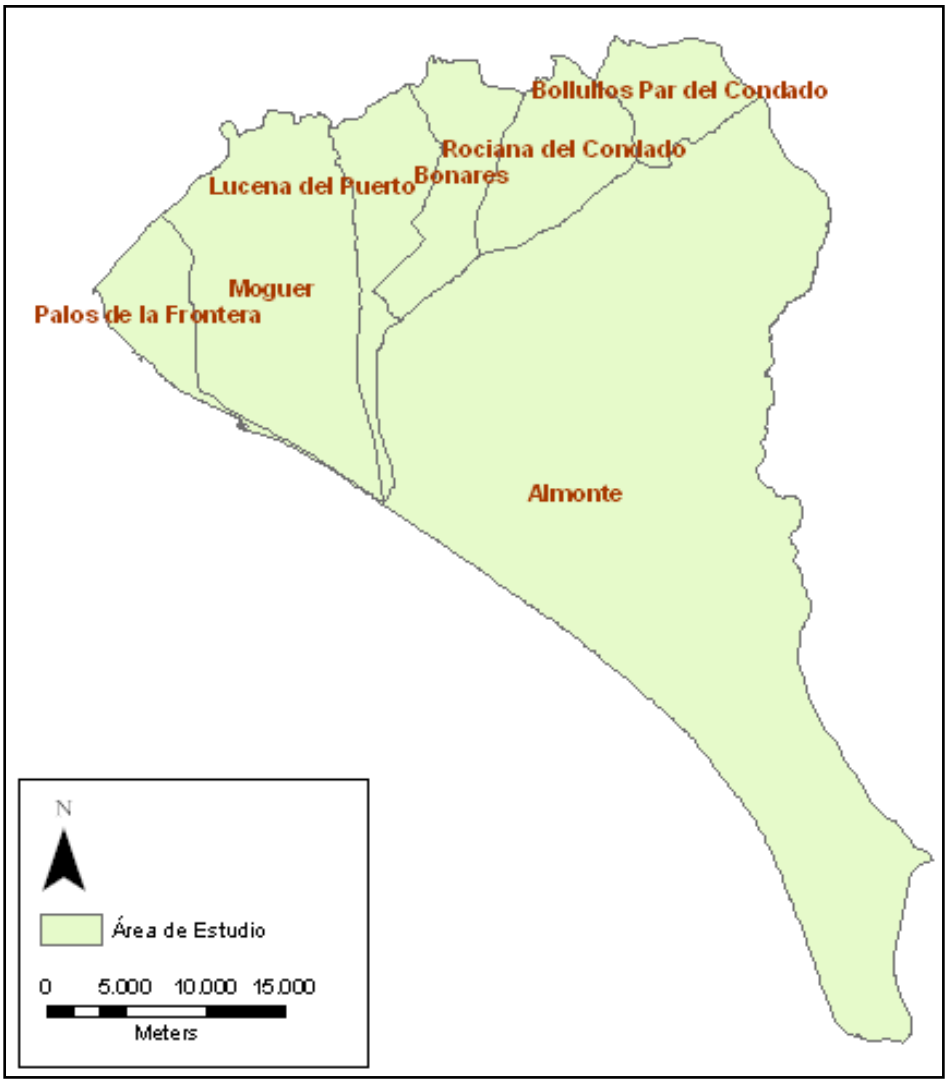
Article 73. Prohibition of irrigation in Area I. In Area I, delimited in the map about resources and risks, the introduction of new irrigation surfaces will not be allowed.

Article 86. Area I. Area of prohibition to extract underground water resources. In Area I, delimited in the map about resources and risks, water extractions will not be allowed,

Article 87. Area II. Area of restrictions to extract underground water resources. Area II will be subject to the rules established by the Guadalquivir Hydrological Plan for the so-called zone without specific restrictions of the Hydro geological Unit Almonte-Marismas.

1.4.- Researched Area

The researched area includes the District of Doñana, which covers the municipalities of Almonte, Bollullos Par del Condado, Bonares, Lucena del Puerto, Moguer, Palos de la Frontera and Rociana del Condado.



In this studied area, the techniques for crops under plastic are quite different from those of the conventional greenhouses that are abundant in other areas like Almería. Here they represent a very small percentage of the whole agricultural area. The techniques used here are padding, which is a first coating of black plastic on the ridges at ground level; and/ or microtunnel and macrotunnel, which are larger or smaller tunnels of white plastic that provide air to the plants.

1.5.- Data sources

Landsat satellite images from different years have been acquired, as well as digital cartography provided by different public administrations and digital orthophotos by Andalusia Government.

1.5.1 Landsat images

Among the different satellites for the observation of the available natural resources, Landsat satellite has been chosen as it is considered the most suitable for the research, because its characteristics allow the study of large areas and the differenciation of crops under plastic from other uses of soil.

Once the availability of images is known, the following selection criteria have been taken into account:

- *Date criteria: considering the phenological characteristics of crops under plastic. Winter is considered the best time to acquire images to distinguish them from other covered areas.*
- *Quality criteria: in any case, it was intended that the studied area did not present any cloud cover.*
- The description of the acquired images are the following::

ID	Orbit	Date	Sensor
IMG1	202-34	07-01-2002	Landsat 7 ETM+
IMG3	202-34	18-01-2009	Landsat 5 TM

According to the phenology of strawberries, Landsat images have been acquired coinciding with the period in which plastics have been totally installed.

1.5.2.- Supporting Digital Cartography

For this research, different vector layers have been considered. These layers have supported the stages of display, digitization and analysis. For each one, it has been determined the scale of work in which they were produced, the dates on which they were generated and the thematic information contained in their databases in order to ensure their proper integration in the stage of analysis

The cartographic information has been used as follows:

A. Boundaries of the municipalities

B. Kilometer grid U.T.M

C. Cadastral map SIGPAC

D. Soil uses in POTAD: thematic cartography of land use distribution, developed by the Andalusia Government by means of photo interpretation in POTAD

E. Cartography of the distribution of intensive crops under plastic of POTAD

F. Cartography about areas with special environmental concerns. It refers to areas of Natura 2000 network (updated in September 2004), to public forests according to the Regional Ministry of Environment, and WWF proposals of corridors in Doñana (updated in September 2007)

1.5.3.- Digital Orthophotos

The digital orthophotos used belong to the years 2002 and 2006 and have been provided by the Andalusia Government.

2. - METHODOLOGY TO IDENTIFY AREAS TRANSFORMED INTO CROPS UNDER PLASTIC

The methodology for the distinction of plots occupied by crops under plastic has been based on the extraction of thematic information from different data sources.

The spectral information of Landsat images has been used to detect areas occupied by crops under plastic, while the more detailed spatial information of the digital orthophotos has been used to define the agricultural plots to a larger scale of work.

Besides this documentation, an intensive work in the field has been done, verifying the information in the document and analysing new changes.

2.1. - Cartography of plots transformed into crops under plastic at the baseline (date of the elaboration of POTAD cartography).

POTAD includes maps of areas occupied by crops under plastic. However, for the production of this report, it was considered necessary to revise and update this information due to the following factors:

- POTAD cartography was made with data from 2001 and visits in the field made in 2003, so that all the transformed surfaces before the approval of the plan are not necessarily included.
- The layer of intensive cultivation of POTAD was generated as a class within a general map of land uses. Within this class, plots under plastic cover the largest surface, but it also includes roads, irrigation pools or reservoirs, non- productive areas and buildings.

In order to obtain a detailed cartography updated at the time of the approval of POTAD, a review process has been undertaken in two phases:

a) Development of maps adjusted to the crops under plastic within the boundaries defined by POTAD cartography

   It has been used to include additional parcels adjacent to POTAD areas, which have been clearly identified as areas covered by plastic. These areas were not included in the first cartography either by lack of precision in the scale of digitization or by a defect inherent in the cartography.

b) Use of LANDSAT satellite images to the inclusion of transformed areas which were not included in the POTAD cartography. It has been viewed the cartography from the previous phase on the false colour composition for 2002. At the same time it has been done a process of photointerpretation to locate all the areas with crops under plastic in the LANDSAT image which were not included in the provisional cartography.

   Once these areas have been located, they have been included in the cartography, identifying their limits on the orthophoto of 2002.

Figure: Example of the review and updating of the cartography carried out by POTAD. In lined green, we can find the baseline cartography, whereas yellow represents the current maps

2.2. - Delimitation of areas transformed into crops under plastic from the baseline to 2009

In the next phase of the work, it has been determined the areas transformed into crops under plastic after the baseline (POTAD).

For this purpose there have been used the compositions in false colour of Landsat images and the processes of visual interpretation to determine the areas transformed from POTAD to 2009

In this way, having studied different images, we have defined the areas that are covered by plastic and that did not appear as such in the maps of the baseline.

As a result of the global process, a detailed cartography of areas covered by plastic has been obtained, after having studied different dates.

2.3. - Location of other interesting changes in the studied period

In this phase of the work, areas that have suffered deforestation processes (regardless their grade) have not been considered. On the other hand, areas occupied by other intensive cultivations within Area A of POTAD were located.

To locate the areas that had suffered deforestation processes, a comparative study was made. It compared the images available for the location of areas that could potentially turn into crops under plastic in future campaigns. For this purpose, a detailed visual review of 2009 images was made in order to detect areas of land with some degree of deforestation.

Once these areas were detected, it was determined the type of soil they belonged to according to POTAD and the surface was quantified.

2.4.- Validation Campaign

On May 2009 it was made a campaign in the field to collect data for the validation of the digital map of crops under plastic in the studied period, within the researched area and visiting areas with special interest, like areas in process of deforestation or intensive cultivations in Area A of POTAD

The number of farms visited and their surface is in the following chart:

Validation Campaign	
Visited Farms	243
Surface of Visited Farms	1370 hectares

3.- SUMMARY AND RESULTS

Within this section, the obtained results are presented after having applied the developed methodological process to obtain the surface transformed into both, intensive crops under plastic and other crops or uses.

The **transformed surface** provides data on the surface that, during the studied dates, has been given the adequate infrastructure and conditions for the cultivation under plastic, and that has been put into production. This block is divided into the following sections:

- **Definition of the baseline situation.** This section frames the situation of the surface transformed into crop under plastic at the time of the elaboration of POTAD cartography (2003)

- **Transformations into intensive crops under plastic from the baseline situation to 2009.** In this section new data about the surface changed into CUP (crops under plastic) are given. They cover the period between the development of POTAD cartography and 2009.

For each one of the analysed periods, it is presented an analysis of changes in relation to land use according to POTAD and an analysis in relation to other cartographies, such as that of Public Forest Land and Nature 2000 Network areas.

In this paragraph other **changes** in the researched area are considered, like those related to deforestation processes that are currently in agricultural production or not.

Finally, the results of the **validation campaign in the field** are shown.

3.1. - Estimation of the surface transformed into crops under plastic and analysis of the changes in land uses

3.1.1 Definition of the baseline situation

There are quantitative differences when comparing the surface defined by the vector layer of POTAD and the digitised vector layer in the first phase of the development of this project (digitization of plots transformed for cultivation under plastic within the boundaries of POTAD cartography).

As it can be observed in the following chart, the total area which covers both layers differs by about 1747 hectares. There are two different reasons:

- Both layers have been developed considering different scales of work.
- The revised cartography only defines the areas covered by intensive crops under plastic without introducing some elements which belong to other categories such as buildings, water pools, roads, and so on.

Cartography	Surface (hectares)
POTAD	10304
Revised cartography in the research (first phase)	8557

In the second stage of the review, the cartography has been updated including plots under plastic which had been discriminated by analysing data from Earth observation in 2002. This process has digitized a surface of 561 hectares divided into 521 plots outside the boundaries established by POTAD.

Relation to initial cartography	Surface (hectares)
Within the boundaries of POTAD	8557
Outside the boundaries of POTAD	561
TOTAL	9118

The following chart shows the results of the surface at the baseline in relation to the municipalities:

MUNICIPALITY	Surface (hectares)
Almonte	2653
Bollullos	71
Bonares	773
Lucena del Puerto	1059
Moguer	3182
Palos de la Frontera	1083
Rociana del Condado	296
TOTAL	**9118**

3.1.2 Transformations into intensive crops under plastic from the baseline situation until 2009

A) Estimation of area transformed into CUP in the researched period

It is reckoned that the surface transformed into intensive crops under plastic in the region of Doñana from the baseline situation (date of the elaboration of POTAD cartography) to 2009 is of **1688 hectares**. The surface transformed in this period represents an increase of 18.5% with respect to the surface at the date of reference (POTAD)

Period	Transformed surface (hectares)
Baseline	9118
Baseline - 2009	1688
TOTAL	10806

The following chart shows the results of the new surface transformed from the baseline to 2009 in terms of municipalities.

MUNICIPALITY	Transformed area (hectares)
Almonte	736
Bollullos	15
Bonares	174

Lucena del Puerto	334
Moguer	324
Palos de la Frontera	29
Rociana del Condado	76
TOTAL	**1688**

Regarding the distribution of the transformed area in terms of municipalities, the towns of Moguer and Almonte are highlighted, as they count with percentages around 43% and 19% respectively from the total transformed area.

***B)* Analysis of changes in land uses**

Once the surface transformed within the territory has been quantified, it is highly interesting to identify the changes produced in the distribution of land uses.

Land use	Surface (hectares)
Extensive dry farming	351
Vineyard	42
Olive	24
Olive-vineyard	35
Citric and fruit trees	49
Extensive irrigated land	78
Intensive irrigated land	17
Unproductive farm	361
Forest In transformation	116
Wooded lands	375
Bush/Scrub woodland	95
Reafforested mounts	5
Grasslandl/wooded grassland	102
Others	38
TOTAL	1688

Although all the changes in land use are of great interest, the changes in relation to forest uses must be emphasized. Besides being the transformation that most strikingly modifies the landscape structure, it is considered the most critical, as it means the loss, not only of forest land in terms of quantity, but also of the quality of the ecosystems in the region. These forest areas undoubtedly play a vital role as ecological corridors which connect Doñana to other natural areas in Andalusia.

This chart highlights that **693 hectares** of forest use have been transformed according to POTAD, many of them private forest farms. It also points out that:

- 375 hectares have been transformed from wooded lands into CUP.
- 1313 hectares have been transformed from other uses (according to POTAD) to CUP, 102 of which are pasture (grassland and wooded grassland). Furthermore, it is stressed the quantity of surface transformed from unproductive farm into CUP (about 360 hectares) and from extensive dry farming into CUP (about 351 hectares).

Regarding the classification of uses in POTAD, the 1688 transformed hectares have the following classification:

MUNICIPALITY	A (hectares)	B (hectares)	C (hectares)
Almonte	124.50	527.30	84.90
Bollullos			15.20
Bonares	128.00		45.50
Lucena del Puerto	173.70		159.80
Moguer	158.50	0.6	165.20
Palos de la Frontera	6.80		22.00
Rociana	4.2		72.20
TOTAL	**595.70**	**527.90**	**564.80**

It must be highlighted that **595.70 hectares classified in Area A** have been transformed, so that the article 45 of POTAD has not been fulfilled. This article prohibits the transformation from forest use and the introduction of new agricultural uses, as Area A is an area of protection of natural resources.

Within this line, a most detailed analysis about the areas listed as Public Forest has been done. As a result, it has been observed that a total of 2436 hectares identified as total transformed surface are located within the boundaries of Public Forest. It is interesting to

note that 2019 hectares are plots integrated within the limits set by POTAD as intensive cultivation.

MUNICIPALITY	Surface within Public Forest (hectares)
Almonte	919
Bollullos	0
Bonares	77
Lucena del Puerto	1221
Moguer	217
Palos de la Frontera	1
TOTAL	2436

From this total, some **417 hectares** have been transformed between the period of the elaboration of POTAD cartography and 2009

MUNICIPALITY	Surface within Public Forest (hectares)
Almonte	60
Bonares	31
Lucena del Puerto	312
Moguer	14
TOTAL	417

C) Analysis of changes in areas of special environmental interest

It is of great interest to identify how much of the surface transformed from the baseline until 2009 is within some protection areas like Natura 2000 Network and WWF proposals of ecological corridors.

The following results have been obtained from the integration of the map on areas transformed from the baseline until 2009 and the map that includes areas of the Natura 2000 Network:

MUNICIPALITY	Surface Within Natura 2000 Network (hectares)
Dehesa del Estero y montes de Moguer	11

Doñana	93
North and West Doñana	90
Lagunas de Palos y las Madres	1
TOTAL	195

This chart emphasizes that about 90 hectares have been transformed within the space known as Doñana and North and West Doñana.

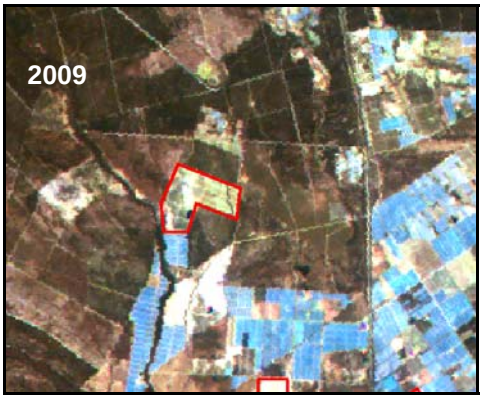
3.2. - Other changes of interest in the studied period (POTAD cartography- 2009)

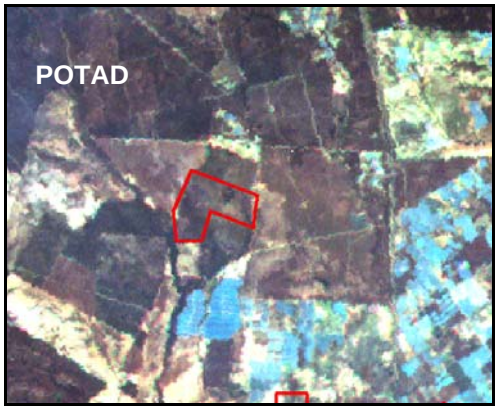
During the visits in the field, it was discovered the existence of a number of plots in transition of transformation in areas of intensive cultivation where a process of deforestation was clearly observed. This fact has implied the preparation of the cartography about such areas for future analysis and research.

The first kind of analysed changes are related to deforestation processes that, though they are not currently crops under plastic, they could be transformed into this type of cultivation in future campaigns.

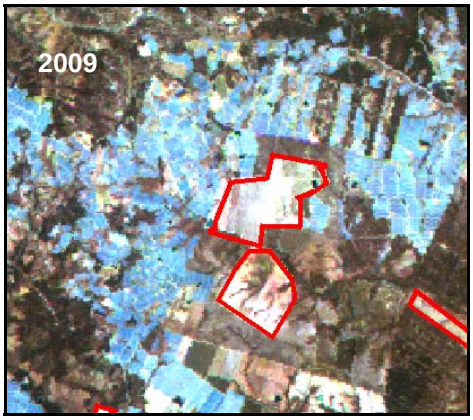
3.3.1. - Location of potential areas in transformation into CUP

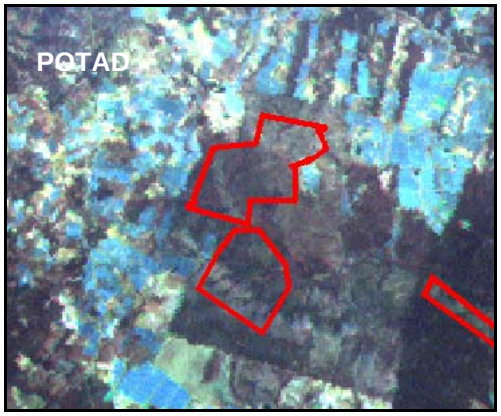
When comparing POTAD images to 2009, some areas with different degrees of deforestation have been located:



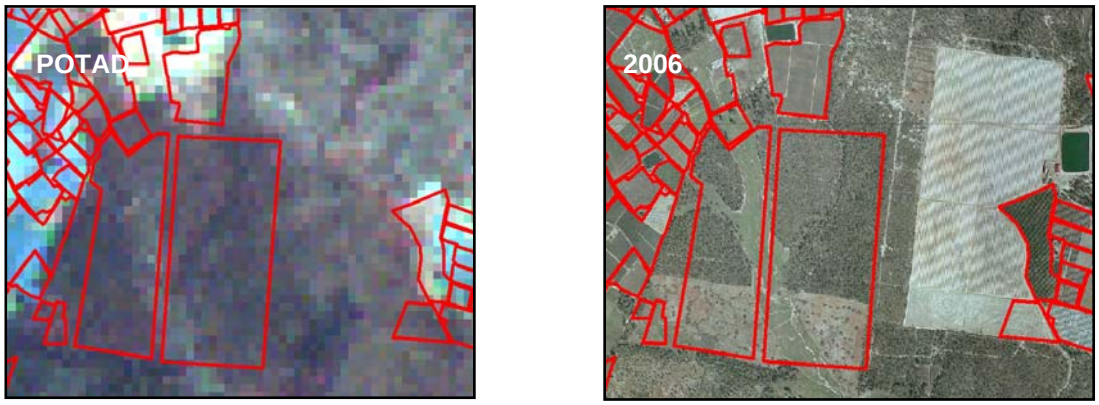


Example of deforested plot, where the visit in the field proved that the existing forest area had been converted to agricultural crops

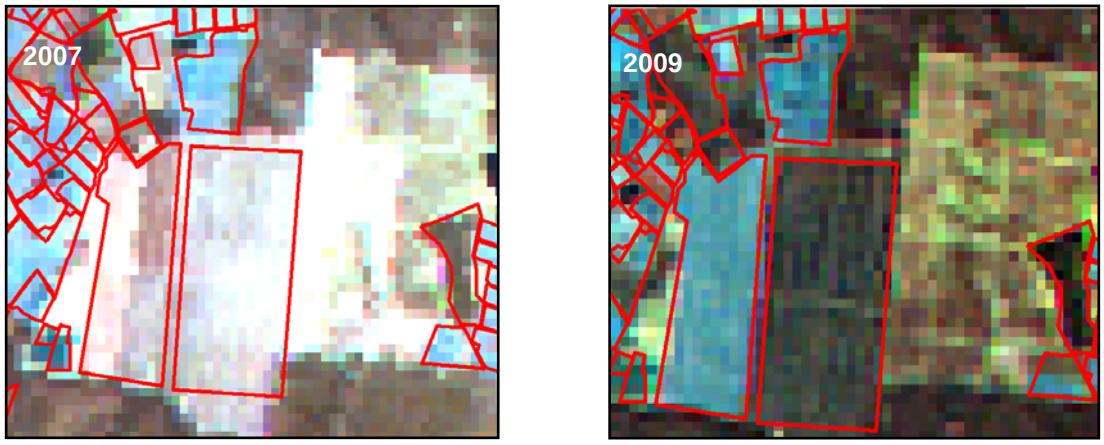




Example of partially deforested plot where the visit in the field proved that the soil was being conditioned for the intensive cultivation of blueberries.



Example of plots before undertaking the transformation (image at the left). In the image on the right, on orthophoto from 2006, the beginning of the transformation processes can be seen.



Example of plots in transformation (image on the left) which have lost their original forestry cover. The image on the right reveals that some of the identified area has been covered with plastic and some is being cultivated with blueberries (according to field data).

3.3.2- Location of other intensive cultivation in Area A of POTAD

Given the restrictions established by POTAD in Area A, it has been considered of interest to identify other areas transformed into another type of intensive cultivation without plastic in such area in the researched period.

4. CONCLUSIONS IN RELATION TO THE OBTAINED RESULTS

This report tries to answer some questions related to the transformation of the territory with a high degree of reliability:

- What was the distribution of the plots transformed into crops under plastic at the time of the elaboration of POTAD cartography?
- What has been the area transformed into crops under plastic in the region of Doñana after the elaboration of such cartography up to today? And after signing the plan known as POTAD on December 2007? Where have new transformations appeared in the different studied periods?
- What types of surfaces are those that have changed?

The data in this report belong to farms turned into crops under plastic in different periods from the approval of POTAD. WWF has not checked if these farms have the necessary permits, both for water and for soil.

Finally, the main conclusions from the results are highlighted:

4.1. - Conclusions in relation to the estimation of surface transformed into CUP in the studied period

A) Definition of the Baseline situation

The review process carried out made clear the differences between a type within a general map on the use of soil (layer of intensive crops of POTAD) and a map of plots cultivated under plastic which does not consider elements such as roads, irrigation pools and buildings (revised map of the area transformed at the time of the elaboration of POTAD cartography). This fact has allowed working and offering results more adjusted to reality.

Thus, the total area transformed into plots covered by plastic **at the time of the approval of POTAD amounts to 9118 hectares**, although there is some additional area for associated infrastructure, which is not included in this amount, that is part of the consumption of land resulting from intensive agricultural practices.

B) Estimation of the surface transformed into CUP and analysis of changes in land uses from the baseline to 2009

In the period from the elaboration of POTAD cartography until 2009, **1668 hectares have been transformed into crops under plastic**, which represents 18.5% of the amount established as reference data from POTAD cartography.

From the analysis of the distribution of transformed areas, it is observed that the process of changes in land uses are not concentrated on specific focuses, but quite dispersed within the researched area. The size of the new exploitations is also quite variable.

The total area occupied by plots with infrastructure for cultivation under plastic amounts to 10806 hectares.

The process of agricultural intensification that it is still produced in the region of Doñana implies **a significant change in relation to land uses**. These changes are reflected when comparing the cartography of areas transformed into intensive crops under plastic from the elaboration of POTAD and the 2008-2009 campaign to the POTAD cartography of land uses.

In this sense, the following changes to CUP should be noted:

- 361 hectares have been transformed from unproductive farming (according to POTAD uses).

- 375 hectares have been transformed from scrub woodland (POTAD uses, Area A).

- 351 hectares have been transformed from extensive dry farming (POTAD uses)

Regarding the classification of uses by POTAD, it should be highlighted that **595.70 hectares are in Area A of POTAD**, area of protection of natural resources where the change of land use is forbidden. In the same way, **527.90 hectares are in Area B**, with specific limitations for the change of land uses.

On the other hand, it has been analysed the loss of Public Forest Land due to processes of agricultural intensification, reaching the amount of 2436 hectares. When we consider the total area transformed and the category of soil in Public Forestry Land before the baseline situation, the most worrying data is that 2019 hectares of Public Forest are transformed at the time of the elaboration of POTAD cartography. In the period after the reference date of December 2003, **417 hectares have been transformed within the area declared as Public Forest.**

When analysing the data in relation to municipalities, it is observed that Almonte and Lucena del Puerto are the municipalities where the largest percentage of surface with forest use before the approval of POTAD has been transformed.

The Region of Doñana contains areas of high environmental interest, and it is also interesting to analyse the changes taking place in these areas. In the case of the division of areas established by Natura 2000 Network, it is important to mention:

- There are about 90 hectares within the area designated as North and West Doñana and other 93 hectares within the area of Doñana.

In addition, in relation to WWF proposals of corridors presented in 2007, it should be noted the transformations occurred within these areas in Lucena (about 151 hectares) and Moguer (about 150 hectares).

4.2. - Conclusions in relation to other transformed areas

The areas where a deforestation process was detected, regardless their degree of severity, and that could potentially be transformed into Crops under Plastic, occupy a significant territory (828 hectares), so it is recommended to follow up with field visits and image analysis for future campaigns.

There is also a territory of 456 hectares that has been identified as intensively cultivated areas within Area A of POTAD where a detailed observation is recommended, given the constrictions for such area.

4.3. - Conclusions in relation to the validation campaign

In general, we can say that the cartography conforms precisely to reality. The date in which the validation in the field was made was the adequate one to detect all CUP. Of all the visited farms, only a case that had already removed the plastic was detected.

For other visited areas, in the categories of deforested and possibly deforested, we may say that while they may be an indicator of future transformations into crops under plastic as those seen in previous researches, it is necessary to undertake annual monitoring. In this regard, it was found that in some cases the transformation had finally derived into crops under plastic, although in other cases, they were not put into production or were the subject of forestry work (reforestation, wood thinning …).

In relation to the discriminated surface of new transformation in the period 2007-2009 and according to the sampling done, we can see that there has been a level of accuracy of 100% for the category of new transformation in the period 2007-2009, which shows a high degree of reliability as to the obtained results.