Changes of the coverage of three wetland areas in Cauca Valley

Cambios en coberturas de áreas y usos del suelo en tres humedales en el Valle del Cauca

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Abstract

The objective of this project was to apply geographic information system (GIS) technology, mainly ARCGIS and ERDAS software, as a methodology to identify changes in coverage and land usage of the terrain comprising the wetlands La Bolsa, Charco de Oro, and El Pital, located in the flat zone of the Andalucia municipality, in the villages of Campo Alegre and el Salto (Valle del Cauca Department, Colombia). The study employed aerial photos from 1950 and 1998, Landsat images from 2002, and base cartography of the zone. The processes within the methodology were purged. For example, the geo-referencing of photographs, and the creation of photo-mosaics to convey an image with a better visual appearance, and easier identification of the wetlands, in such a way that when making comparisons, they reveal changes in coverage in the study zone. The usage of GIS and correct processing of satellite images will be very helpful not only to evidence changes in soil usage in wetlands, but also in other areas where use of these technologies is very unusual.

Key words: Geographic Information System, wetlands, cartographic, Cauca valley, Colombia.

Resumen

El objetivo de este proyecto fue aplicar la tecnología de Sistemas de Información Geográfica (SIG), en especial los programas ARCGIS y ERDAS, como metodología para identificar los cambios de cobertura de área y uso del suelo en las zonas de los humedales la Bolsa, Charco de Oro y el Pital, localizados en la parte plana del municipio de Andalucía corregimiento de Campoalegre y El Salto (Valle del Cauca, Colombia). Para el estudio se utilizaron fotografías aéreas de 1950 y 1998, imágenes Landsat 2002 y cartografía base de la zona. Los procesos dentro de la metodología fueron depurados, un ejemplo es la georreferenciacion

de las fotografías y la creación de fotomosaicos que conllevan una imagen con mejor apariencia visual y más fácil identificación de los humedales, de manera que al hacer comparaciones, aquellos arrojen cambios de cobertura en la zona de estudio. Así, la utilización de los SIG y un correcto tratamiento de las imágenes satelitales resultan de gran ayuda no sólo en la obtención de los cambios en el uso del suelo y los humedales, sino también en diferentes áreas donde la utilización de esta tecnología es poco común.

Palabras clave: Sistema de Información Geográfica, imágenes satelitales, georreferenciación, humedales, Valle del Cauca, Colombia.

Introduction

The geographic valley of the River Cauca is a region with one of the highest indices of agricultural development in Colombia, due to its high soil fertility, strategic geographic location, a range of different climates, and the exploitation of water resources and ox-bow lakes from the river Cauca, used for irrigation in furthering the agricultural frontier. This activity has resulted in changes in the natural landscape and displacement of native vegetation (Ministry for the Environment – Research Institute for Biological Resources, Alexander Von Humboldt,1999).

Within the hydrological cycle, the wetlands play an important role in maintaining the environmental quality, and regulating the watersheds, the estuaries and the coastal waters, developing, amongst others, functions such as mitigation of flood impact, absorption of contaminants, and providing habitats for animals and plants, (Ministry for the Environment, Colombia. 2001).

In 1995 in the Cauca valley, there existed 15,286 ha of natural wetlands along the River Cauca. According to the data of the Ministry for the Environment, there currently exists 52 wetlands encompassing 2650 ha. (CVC.Madreviejas, Cali+1 videocasetes (VHS))

In the municipality of Andalucía (Department of Valle del Cauca) the wetlands of la Bolsa, Charco de Oro and el Pital are considered important, and are currently in the process of degradation. The aim of the present study was to conduct a multi-temporal analysis comparing aerial photographs and Landsat images from different timer periods (1954, 1998, 2002) With the application of Geographic Information Systems (GIS), in order to determine the changes in land coverage in the area of these wetlands. It is expected that this information will be useful for the work of the

Biodiversity Group of the Environmental Planning section of the Valle del Cauca Corporation (CVC), the body with the responsibility to manage and control the wetlands in this department, and especially those of the municipality of Andalucia (Integrated management plan for the ox-bow lakes, La Trozada, Bocas de Tuluá, Madrigal, La Herradura and Cementerio).

Materials and methods

The wetlands la Bolsa, Charco de Oro and el Pital are located in the Western sector of the municipality of Andalucía, Department of Valle del Cauca, on the right hand side of the river Cauca, between the communities of Campoalegre and Madrevieja (Environmental plan Municipality of Andalucía, 2000), and are exploited by the commercial company Asociación Granos y Granos S.A., producers of sugar cane for the factory Riopaila SA.

For this study, the units were considered differentiated by their nature, external appearance, for example, vegetation cover, and wetland area. In order to determine the classes of cover natural accidents such as forests, pastures, swamp, crops and buildings were considered. In this way the unique conditions of each type of cover were established, within which the classes were considered as: natural forest, natural intervened pasture, conflicting soil use (agriculture of low and high inputs, water bodies, and wetlands themselves) (Andrade and Baquero, 2007).

The values for the areas for the periods 1954 and 1998 were taken directly from aerial photographs using the programs ERDAS (Georeferencing and digital image analysis) and ARC-GIS (digitalization of cover areas). Information for 2002 was taken from a Landsat image, which subsequently was adjusted for 2008, with information taken directly from field observations.

Initial Phase

This phase started with the selection of the area (957 ha) of influence of the wetlands or ox-bow lakes. For the aerial photos, the selected scale was 1:30000 for 1998 and 1:20000 for 1954. The photos were taken with a focal distance of 152 mm, with the camera zeiis RMK. For the images of pixel size 30 x 30 (Landsat TM) a scale of 1:50000 to 1:100000 can be used. In this phase the following were made: (1) the cartographic and cadastral base of the study zone, including associations with the aerial photos, and the date of image capture: and (2) aerial photos and satellite images. For the analysis photos from the decades 1950 - 1998 were used, and a satellite image from 2002, representing approximately, 54 years

of differences, in which it is expected that changes in soil and coverage of the wetland areas would have occurred.

Processing of aerial photos.

The photos were scanned with an Epson-Stylus-CX 5600 and visualized using the program Photoshop modified to a high resolution of 1600 pixels/inch and with a graphic format that uses ERDAS and ARC-GIS for later processing and archived in format TIFF.

Process of geo-referencing of aerial photographs

Initially the photos were pasted into the del software ERDAS 9.21, followed by locating and identifying visible points in flat coordinates (East and North) in the three formats: aerial photographs, GPS points (‘Thales’) and mapping from 1999 provided by the CVC. The selection of points was determined according to the minimum parameters such as the number of points according to the transformation polynomial used: in this case a second grade polynomial, which requires a minimum of six or eight points in order to achieve a mean quadratic error < 1, as criterion for acceptance.

Point selection was two points in the top and bottom, left and right corners, an equal number of intermediate zones, and in the center of the photo in the south-north direction. All had the same visibility and ease of location. In some cases there was overlap between photos.

Other parameters in the geo-referencing process were of the type DATUM, which in this case was ‘Bogotá west; the transverse mercator projection type, and the international spheroid type 1924 corresponding to the study zone. The flat coordinate type was east-north.

Construction of photographic mosaic

The program ERDAS 9.21 automatically applied different steps, minimizing the effect of borders and seams between photos. Some of the most important automatic effects applied in this process were ‘Seam feathering’ whose principal function is to mix or allow color recording of the data values, and ‘Image display priority’ which controls the location priority of the photographs.

Visual analysis of the mosaic

This analysis was carried out taking into account the necessary Parameters and concepts for photo-interpretation of soils in order to interpret a photograph in grayscale including: color, tone, size, texture, pattern and form. According to these parameters variables were analyzed that intervened in the interpretation.: (1) vegetation, mainly sugar cane crops, forest in general (bamboo and typical tree species of wetlands, and other species) grasses, and other minor crops; (2) soils, uncovered and prepared for planting, occupied by anthropogenic elements of habitable type, such as the urban centers in small villages, and soil destined to be transformed to roads; (3) water bodies, including the river Cauca, and the wetlands of environmental interest, where the lake mirror is invaded by various aquatic plant species such as enea, buchón de agua and lechugilla (Andrade & Baquero, 2007).

Digitalization of areas in photographs and Landsat images

With the use of the GPS (Thales mobile mapper) the borders of the wetlands were delimited in order to identify the area in 2008, and the data were introduced into ARC-GIS. Once the wetland borders were identified in the photos from 1954 and 1998, and the Landsat image from 2002, the areas of influence of these wetlands were characterized and digitized in terms of conflict of soil use, natural representative forests, and water bodies vulnerable to desiccation through use in irrigation.

Results and discussion

Coverage and soil use

In 1954 six forms of use and vegetation cover were observed (Cuadro 1), predominantly naturalized pasture covering 588.25 ha, 61% of the total area of the pilot zone of the study (Photo 1). Low input agriculture covered a smaller proportion of the area, with 190.60 ha, 19.9% of the area, followed by the area of the wetlands or ox-bow lakes of el Pital, la Bolsa and Charco de Oro. The remaining classes of use and coverage comprised natural forest of native wetland species, and remaining water bodies. These last were formed by flooding from the river Cauca, and were favored by the surface phreatic level, which created areas of water distributed across the naturalized pasture.

Box 1. Changes in soil use and coverage type in the area under wetland influence, Municipality of Andalucia, Cauca valley, Colombia.

Cuadro 1. Cambios por épocas en el uso del suelo y tipo de cobertura en la zona de influencia de los humedales. Municipio de Andalucía, Valle del Cauca (Colombia).

Tipo de uso y cobertura	1954 (ha)	1998 (ha)	Pérdidas (ha)	1998 (ha)	2002 (ha)	Pérdidas (ha)	1954-98 (ha/año)	1998-02 (ha/año)
Cuerpos de agua	26.09	0.71	-25.38	0.70	0.52	-0.18	0.045	0.57
Pradera natural	588.25	10.75	-577.50	10.75	0	-10.75	2.67	13.12
Agricultura de altos insumos	0	621.95	621.95	621.95	850.45	228.50	57.12	14.13
Bosque natural	84.81	35.15	-49.65	35.15	30.15	-5.00	1.25	1.12
Agricultura de bajos insumos (maíz)	190.59	17.17	-173.42	17.17	37.31	20.14	5.03	3.90
Humedales	69.51	55.65	13.86	55.65	49.16	6.50	1.6	0.31

Similarly, in 1998 six classes of soil use and coverage were identified (Box 1 and Photo 2), with a predominance of high input agriculture, comprising 721.68 ha, 85.5% of the total study area, indicating a drastic change compared with the same parameters observed in 1954. The wetlands in the study covered an area of 57.5 ha, followed by natural forest (35.15 ha). In this year, it was possible to observe evidence for low input agriculture (maize crop over 17.17 ha), surrounded by sugar cane monoculture that was found in the internal part of the wetland el Pital. Also observed were grasses included in the coverage class termed naturalized pasture (10.75 ha). Water bodies occupied the most reduced area of the pilot zone, with a reservoir (0.70 ha) for the irrigation of the sugar cane monoculture (Berlanga-Robles and Ruiz-Luna).

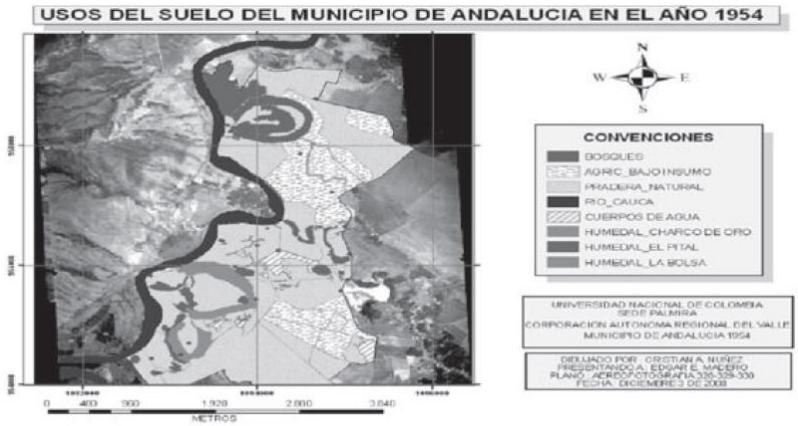

Foto 1. Aerofotografía digitalizada en el área de influencia de los humedales. 1994.

Photo 1. Digitalized aerial photo of the area of influence of the wetlands in 1954.

Foto 2. Aerofotografia digitalizada en el área de influencia de los humedales. .1998.

Photo 2. Digitalized aerial photo of the area of influence of the wetlands in 1998.

In 2002 using the Landsat satellite image, high input agriculture again predominated (850.45 ha) in 87.34% of the total area of the pilot zone of the study, followed by wetlands (57.5 ha) (Box 1 and photo 3). The rest of the zone was covered by low input agriculture (37.31ha), natural forest (30.15 ha), bamboo forest (3.34 ha), cacao crop (0.67). The most representative water body (0.52 ha) was found in the plots of the hacienda Madrevieja. For this year, the natural pasture had disappeared from the pilot zone (Pardo, M. T.; Carreño, M. F.; Esteve, M. to 2001).

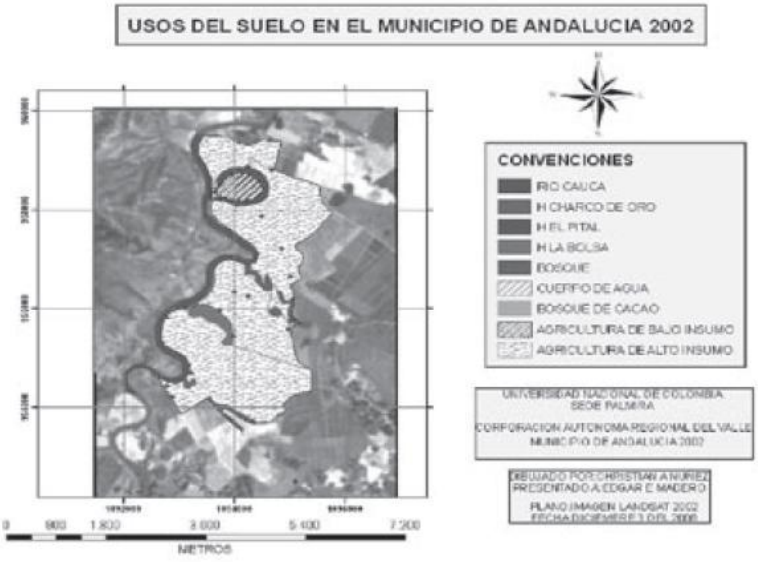

Foto 3. Imagen Landsat digitalizada del área de influencia de los humedales. 2002.

General changes in the area coverage and use

Wetland Charco de Oro. In 1954 this wetland was directly connected to the river Cauca, as well as being physically continuous with the wetland la Bolsa, showing a from of horseshoe, and a coverage with a large area of extension. In the period 1954 - 98 a considerable reduction in the area occupied by this wetland was observed, losing 12.08 ha with an annual rate of 0.27 ha. In 1991 the CVC conducted a topographical study, in which the wetland areas were identified. The ox-bow lake, Charco de Oro had 11.8 ha, allowing the deduction to be made that between 1991 and 1998 the wetland lost 8.79 ha with an annual rate of loss of 1.2 ha. In 2002 the Landsat image showed an area of 2.8 ha and in 2008, by GPS, the area was 2.5 ha (Box 2). Continuing with this tendency the wetland will disappear (Ramsar,1992).

Cuadro 2. Cambios entre 1954 y 2002 en área del humedal Charco de Oro, municipio de Andalucía, Valle del Cauca.

Año	Area (ha)
1954	15.09
1998	3.00
2002	2.80
2008	2.50

Box 2. Changes in area between 1954 and 2002 of the wetland Charco de Oro, municipality of Andalucia, Valle del Cauca.

The wetland has undergone large impacts, particularly caused by anthropogenic factors in the rush to expand the agricultural frontier. The construction of a dykes caused changes in the natural discharge and the total isolation from the river Cauca, with poor water circulation, contributing to acceleration in the process of eutrophication. Although, invasion into the water mirror is not observed, a proliferation of aquatic vegetation cannot be ruled out in earlier times, which would have removed the natural circulation and the dynamic relationship between the river Cauca and the ox-bow lake (Flórez et al., 2004).

Wetland la Bolsa. Between 1954 and 1998 this wetland lost 2.6 ha due to intervention by the sugar factory Ríopaila and the construction of a dykes to intercept the direct link with the river Cauca. In the period 1998 -2002 the reduction was 1.10 ha with an annual rate of loss of 0.27 ha. In 2008 this wetland occupied an area of 24.48 ha (Box 3).

Cuadro 3. Cambios entre 1954 y 2002 en área del humedal la Bolsa, municipio de Andalucía, Valle del Cauca.

Año	Area (ha)
1954	29.30
1998	26.70
2002	25.59
2008	24.48
2295	0

Box 3. Changes between 1954 and 2002 in the area of the wetland la Bolsa, municipality of Andalucia, Valle del Cauca, Colombia.

This wetland presents a notable change in the water regimen, in zones close to the sugar cane crops, dykes have been constructed dividing up the wetland, detaining the water and causing a significant loss of the aquatic vegetation. This causes an increase in the sedimentation, and finally leads to clogging through natural vegetative succession to bushes, and also trees in the drier zones on the perimeter. The wetland currently covers 2.5 ha in clear water, and some remnant water bodies that have escaped the bulky aquatic vegetation. The predominance of 'buchón de agua' (*Eichornia crassipes*) as an invasive aquatic species is notable, occupying the greatest surface area of the clear water, compared to other species such as enea or lechuguilla. The strong relationship between the buchón and the wetland is one of the phenomena responsible for a reduction in the level of the wetland. As a principal source of organic matter, accumulated and discomposed at the bottom of the lakes, and its facility for propagation, the Buchón is a difficult weed to eradicate, so increasing the evapotranspiration and impeding the penetration of light and the oxygen exchange (Flórez et al., 2007).

Wetland el Pital. In 1954 this wetland, similarly the others, had a direct connection with the river Cauca. Currently, it is fed by a stream el Cedrito and through an underground current from the river Cauca. In contrast to what has occurred in the wetlands of el Pital and Charco de Oro, the surface of this wetland has increased, according to measurements taken with GPS (Box 4). An increase in size in this wetland is confirmed, both in depth and extension, at the expense of floods produced by the river Cauca, breaking the dykes, and flood the sugar cane crops, reaching this wetland (Andrade, D. & Baquero, F. 2007).

Cuadro 4. Cambios entre 1954 y 2002 en área del humedal el Pital. municipio de Andalucía, Valle del Cauca.

Periodo	Area (ha)
1954	25.12
1998	27.40
2002	26.88
2008	37.84

Box 4. Changes between 1954 and 2002 in the area of the wetland el Pital. Municipality of Andalucia, Valle del Cauca.

In this wetland, the dynamic cycle of water flow with the river Cauca was also altered, causing an increase in growth in the aquatic vegetation, particularly enea. This aquatic plant is one of the principal causes of desiccation and lower water levels in dry seasons, and a main source of organic material that accumulates and discomposes at the bottom of the lakes.

Conclusions

- The improvement of land for agricultural aims and the construction of dykes have caused the alteration of water levels, and a displacement in the limits of the wetlands. This disruption frequently changes the structure, the functioning and the surface flow of the wetlands, favoring new ecological processes, although still classified amongst typical wetland processes through changes in vegetation that increase the sedimentary load or change the capacity for retention of water.
- The wetlands la Bolsa, el Pital and Charco de Oro do not possess the minimum protective zone of 30 m around its perimeter, thus infringing the decree 1449 of 1997. Additionally, the zone supposed to be the forest buffer zone is being occupied by the monoculture of sugarcane.
- The registers and periodic observations of the dynamic processes of the coverage of the area of the wetlands and their areas of influence, allow the identification of fundamental points in the evolution of the coverage and the repercussions from the actions of humans in the expansion in the agricultural frontier for the sugar cane crop.
- The use of the automated programs ARC-GIS and ERDAS allowed a quantification of changes in the area of the wetlands and measurement of the principal transformations over the period analyzed (1954-1998-2002-2008).

- These automated programs, ARC-GIS and ERDAS, also allowed a comparative analysis between the reference dates, according to the discrimination of the area of influence of the wetlands. The most significant changes were the conversion of the naturalized pasture to sugar cane monoculture, the isolation of the wetlands from the river Cauca, and the proliferation of the aquatic vegetation, in stagnant water, intense illumination, suspended organic material and an increase in the concentration of nutrients.

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