Revista Científica Interdisciplinaria Investigación y Saberes
2022, Vol. 12, No. 3 e-ISSN: 1390-8146
Published by: Universidad Técnica Luis Vargas Torres

Hydrological degradation due to the effect of banana and cocoa monocultures in the canton of Valencia, Ecuador

Degradación hidrológica por efecto de los monocultivos de banano y cacao en el cantón Valencia, Ecuador

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Received 2022-02-02
Revised 2022-04-22
Accepted 2022- 05-03
Published 2022-09-04
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Pages: 12-31

Abstract

Anthropic pressure to irrigate extensive monoculture banana and cocoa plantations from the surface hydrographic network of the canton of Valencia has substantially diminished the flow and water mirrors of the main surface water bodies of the canton. The need to generate foreign exchange to maintain the socioeconomic functioning of the country must address both internal and external factors such as rapid population growth and increasing international demand for tropical agricultural products. The present investigation involved extensive field inventory work of the global study area to select a specific sampling area that is representative of the central problem of the present investigation, and involved the collection of extensive digital geoinformation for subsequent processing in a GIS environment, The digital spatial treatment of the main agricultural coverages of the canton of Valencia dominated by banana and cocoa monocultures to determine their territorial expansion in time and space, as well as the temporo-spatial analysis of the variation of the

water mirrors of the San Pablo and Quindigua rivers and the modeling of the flow of the micro-watershed of the Quindigua river located in the sampling area.
Key words: Monocultures, Banana, Cocoa, Hydrographic network, GIS, Sampling.

Resumen

La presión antrópica para la dotación de riego de extensos monocultivos de banano y cacao a partir de la red hidrográfica superficial del cantón Valencia ha disminuido sustancialmente el caudal y los espejos de agua de los principales cuerpos superficiales de agua del cantón. La necesidad de la generación de divisas para mantener el funcionamiento socioeconómico del país debe encarar factores tanto interno y externos como el rápido crecimiento demográfico y la creciente demanda internacional de productos agrícolas tropicales. La presente investigación conllevó un amplio trabajo de inventario en campo del área global de estudio para seleccionar un área específica de muestreo que sea representativa del problema central de la presente investigación, conllevó la recopilación de amplia geoinformación digital para su posterior procesamiento en un entorno de SIG, destacándose el tratamiento digital espacial de las coberturas agrícolas principales del cantón Valencia dominadas por los monocultivos de banano y cacao para determinar su expansión territorial en el tiempo y espacio, así como el análisis temporo-espacial de la variación de los espejos de agua de los ríos San Pablo y Quindigua y la modelación del caudal de la microcuenca hidrográfica del río Quindigua que se encuentran en el área de muestreo.
Palabras clave: Monocultivos, Banano, Cacao, Red hidrográfica, SIG, Muestreo

Introduction

Water is vital to human survival, health and dignity and is a fundamental resource for development. The world's freshwater resources are under increasing pressure and many people still lack

adequate water supplies to meet their basic needs. Population growth, increased economic activity and rising living standards have led to increased competition and conflict over limited freshwater resources.

The expansion of monoculture for export in Latin American countries is an example of the "extractive activities" or "extractivism" promoted by neoliberalism since the 1990s (Gudynas, 2013; Seoane, 2013). In this way, transnational corporations received multiple incentives from the State under the assumption that they are the fastest way to economic progress (Svampa, 2008). In practice, this led to the commodification and private appropriation of natural resources in territories with deficient environmental legislation (Silvetti, Soto, Cáceres & Cabrol, 2013).

In Ecuador, agricultural production in the 1920s and 1930s was dominated by cocoa, and from the 1950s to the present, bananas have been the most important agricultural export product. The area dedicated to these export crops has been increasing, so that between 1980 and 2000 the harvested area has increased, reaching 165,000 hectares in banana and 433,00 hectares for cocoa (MAGAP, 2012). Agricultural diversification as the basis for change in the productive process at the provincial level is very complex to carry out, mainly due to the exhaustive use of production factors such as labor, land and capital and basic agricultural technology Pacheco, Ochoa-Moreno, Ordoñez, & Izquierdo-Montoya (2018).

When the soil in Canton Valencia is converted from rainfed to irrigated conditions, crop yield will increase due to a constant application of water throughout crop development. Espinosa & Rivera (2016) indicate that not following a proper soil water balance and applying an adequate irrigation dose at a given time can lead to shortage or excess irrigation. To date, there is still inadequate irrigation water management in Ecuador. Farmers in Cantón Valencia produce largely for domestic consumption and exports, as in the case of rice and bananas, which are monocultures that bring together agricultural producer associations that give them greater access to national and international markets (Gaybor, Ramos, Tamayo & Arroyo, 2008).

From the acute process of concentration of water from wells that among the 20 companies (of the 47) of Reybanpac and 3 companies of the Noboa Group (of which we have information) monopolize 73%

of the concessioned flow, located mainly in the province of Los Rios. According to key informants involved in banana production, one hectare of banana crop in production requires irrigation by subfoliar sprinklers three times a week for two hours each time. The subfoliar sprinklers reach a flow rate of 680.21 L/hour being the spacing between them 12 m x 14 m, with application efficiency of 90 % (Caicedo et al., 2016).

Methodology

The method constitutes the series of steps that the researcher follows in the process of knowledge production, including a series of operations, rules and procedures established voluntarily and reflexively, to achieve a certain objective. Thus, the qualitative techniques were essentially based on the reading and analysis of various bibliographic sources, critical analysis of regulations and government documents. Field work deserves an important mention in order to contrast the results of the analysis of alternative sources with those generated in the concrete reality. Particularly important were the interviews with a qualitative approach carried out with officials and managers, economic agents and users of the Vinces river basin in a hierarchical context, focusing on the institutions that have a more direct action on the basin.

The following methodological steps were followed to achieve the objectives of this research:

To develop the conceptual framework, the bibliography and institutional documents related to the pressure of monocultures on water resources were analyzed.

To carry out the physical-natural characterization of the canton of Valencia, basic and thematic cartographic information at 1:100,000, 1:50,000 and 1:25,000 scale provided by the Military Geographic Institute (IGM), the Ecuadorian Space Institute (IEE) and the Ministry of Agriculture and Livestock (MAGAP) was used. The aforementioned cartographic information was processed in the Geographic Information Systems (GIS) program ArcGIS Desktop 10.1.4.

In order to determine the specific study area within the canton of Valencia, a sampling area was defined to address the fundamental problems of this study.

In order to establish the evolution of the water mirror of the main surface watercourses in the canton of Valencia, remote sensing and remote detection processes were carried out in the study area considering the summer months to avoid bias in the results due to the comparison between summer and winter months.

The determination of the change in the extent of agricultural cover of banana and cocoa monocultures in the canton of Valencia was made from the compilation of land use cover studies generated by the Ministry of Agriculture and Livestock (MAG) and the Ministry of Agriculture, Livestock, Aquaculture and Fisheries (MAGAP) for the years 1990 and 2014, complemented with the digital processing of Landsat satellite images from October 1990 and November 2014. For each of the dates analyzed, a differential processing was carried out in the Geographic Information Systems (GIS) environment using ArcGIS 10.4.1 software:

- Year 1990: The analog land cover made by MAGAP was used as a basis, which was subjected to a digitalization and conversion process to the official Datum in force in Ecuador, WGS84. Subsequently, it was improved by performing an overlay with images for the year 1990 with the Google Earth Pro program and a supervised classification using an image from the Landsat 5 satellite.

- Year 2014: Based on the digital land cover carried out by MAGAP - SENPLADES, which was complemented with quantitative information from the banana and cocoa censuses carried out by MAGAP in 2013 and field verification of banana and cocoa crops.

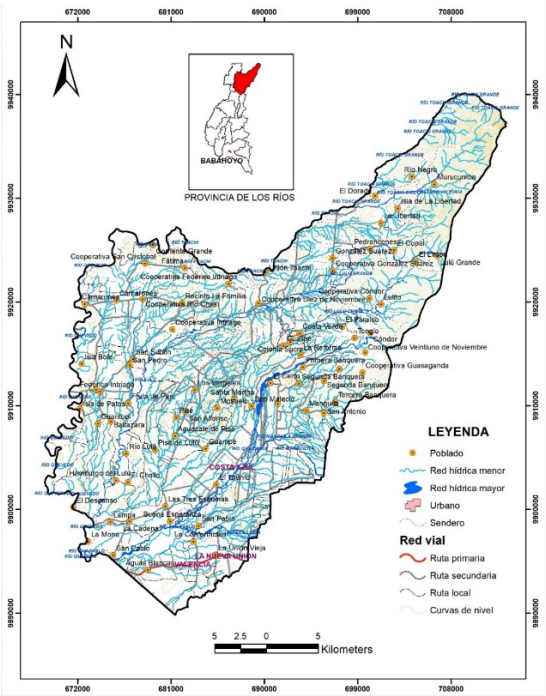
To determine the volume of irrigation water demanded by the banana and cocoa monocultures in the summer months, the area planted within the Quindigua River micro-watershed was considered, where the liters of water consumed by each plant per day were related to the total population present per hectare unit in each monoculture.

To show the decrease in the flow of the Quindigua River, hydrological modeling of the flow in summer (October) was carried out using the HEC-HMS hydrological modeler.

HEC-HMS® is used to obtain, by means of simulation, the hydrological flows in a hydrographic basin (Silva et al., 2005). To do this, the program requires the specification of basin models, meteorological models, control specifications and input data, to create precipitation or flow ratio runs. Its application is very broad, and the hydrographs generated can be used directly or with other programs for the study of water availability, flood-related problems, calculation of urban drainage, flow forecasts, impact of future urbanization, design of spillways for dams, flood prediction, flood damage reduction, among others.

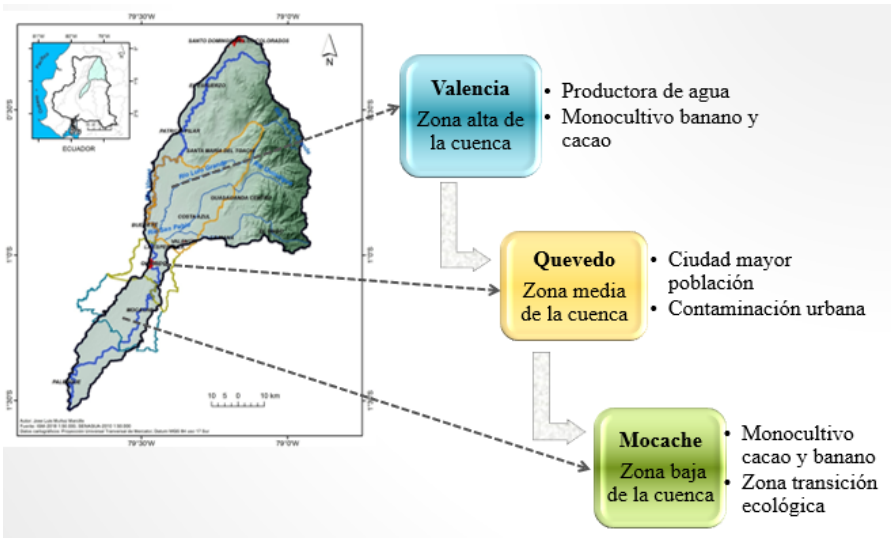
The Valencia canton is located at 0°32'0" south latitude and 79°29'00" west longitude, covering an area of 978.21 km2 (Fig. 2). Valencia is located in the northern part of Los Ríos province and in the northeastern part of the Vinces river basin (Fig. 3). It has a wide network of surface watercourses, including the Lulo, Quindigua, and San Pablo rivers and a wide network of estuaries.

Figure 2. Canton Valencia



Source: Own elaboration

Figure 3. Canton Valencia in relation to the Vinces River Basin.



Source: Own elaboration

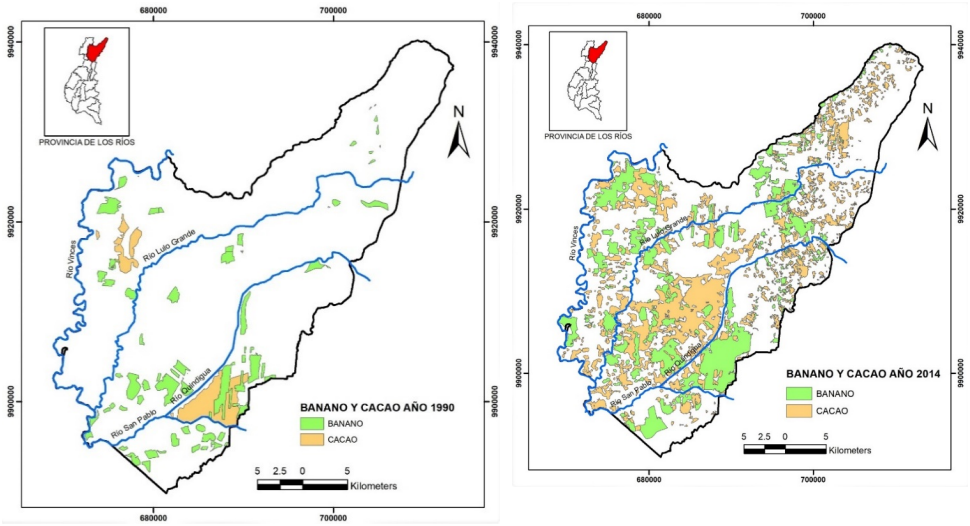
Results

Land use is mainly agricultural (highly technical intensive agricultural systems), the main activities are bananas, rice, coffee, cocoa, corn, African palm, tropical fruits such as mango, oranges, melon, sugar cane, among others. The Daule River sub-basin is one of the areas with the highest concentration of agricultural production in Ecuador. More than 68% of crop production originates in irrigated lowland areas on the central Ecuadorian coast (Borbor-Cordova, Boyer, McDowell & Hall, 2006).

Banana and cocoa cultivation in the Valencia canton

The analysis of the agricultural coverage of banana and cocoa monocultures in the canton of Valencia for the years 1990 and 2014 can be seen in Figures 4 and 5.

Figures 4 and 5. Area of banana and cocoa monocultures in 1990 and 2014.



Source: Prepared by the author

It can be seen that the area of banana and cocoa monocultures in the canton of Valencia increased by 291% and 663%, respectively (Table 1).

Table 1. *Area under banana and cocoa monocultures*

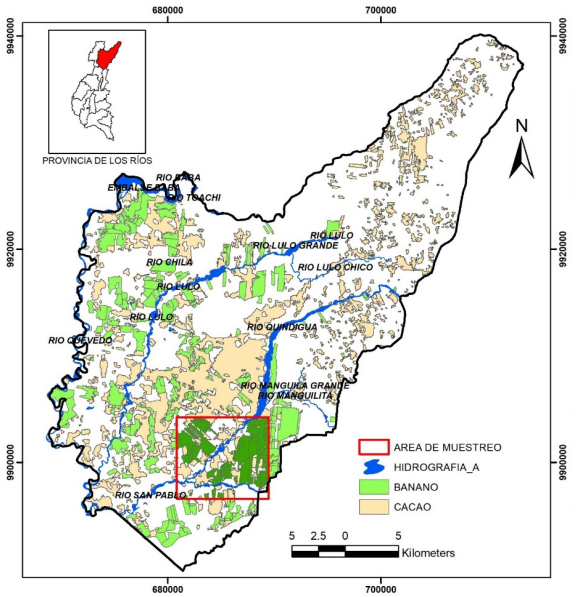
MONOCULTURE	YEAR 1990 AREA (HA)	YEAR 2014 AREA (HA)	% Increase
BANANA	5335.05	15559.71	291
CACAO	2911.42	19306.07	663

Source: Own elaboration

Sampling area

Since the total area of the canton of Valencia is considered to be very large, extending over 978.21 km2 , a sample area of 66.12 km2 was selected in which the San Pablo and Quindigua rivers are present and in whose area of influence there are extensive banana and cocoa monocultures (Fig. 6).

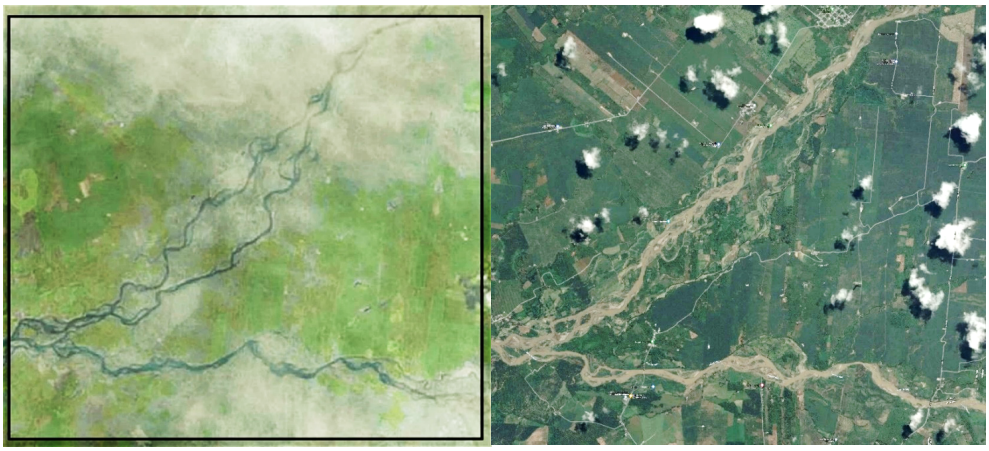
Figure. Determination of sample area



Source: Own elaboration

The determination of the variation of the water mirrors of the San Pablo and Quindigua rivers in the specific study area was made from two orthophotos corresponding to the months of October 2005 and 2014, respectively, dates that correspond to the summer season in Ecuador, Figures 7 and 8.

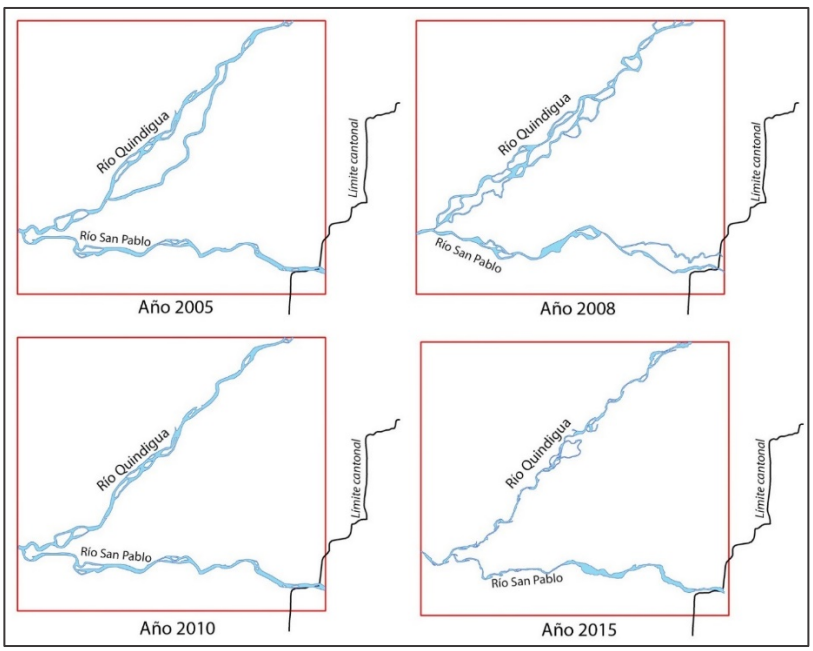
Figures 7 and 8. 2005 and 2014 orthophotos.



Source: Ecuadorian Space Institute

Figure 9 shows the physical degradation of the San Pablo and Quindigua rivers expressed in the decrease of their water mirrors in the months of October (summer) in 2005, 2008, 2010 and 2015.

Figure 9. Physical degradation of the San Pablo and Quindigua rivers.



Source: Own elaboration

Irrigation pressure for banana and cocoa monocultures during the eight months of summer has caused a decrease in the water bodies of the San Pablo and Quindigua rivers, Table 2.

The banana crop in the long summer period requires an average of 26 liters of water per plant per day to maintain its productivity, reaching a hectare to have 1800 plants while cocoa with 1000 plants per ha consumes 40% less than the amount of water demanded by bananas.

Table 2. *Physical degradation of the San Pablo and Quindigua rivers.*

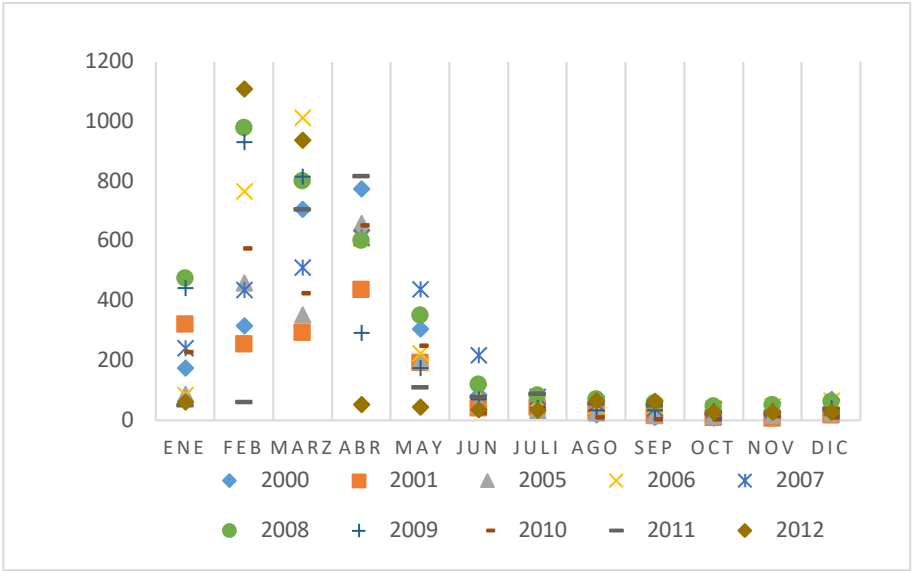
RIOS	*YEAR 2005 WATER MIRROR AREA (HA)*	*YEAR 2008 WATER MIRROR AREA (HA)*	*YEAR 2010 WATER MIRROR AREA (HA)*	*YEAR 2015 WATER MIRROR AREA (HA)*
QUINDIGUA SAN PABLO	229,59	213,59	192.02	125,50
Decrease of water mirror in %.		7,00 %	16,36 %	45,33 %

Source: Own elaboration

The Quevedo River, which is fed by the waters of the San Pablo and Quindigua rivers, shows flow variations that are related to the winter and summer periods, as shown in Fig. 10. The average flow for the years 2000 - 2012 for the months of January - April corresponding to the winter months is 500 m3/sec, while for the low water months from May - December it is 66 m3/sec.

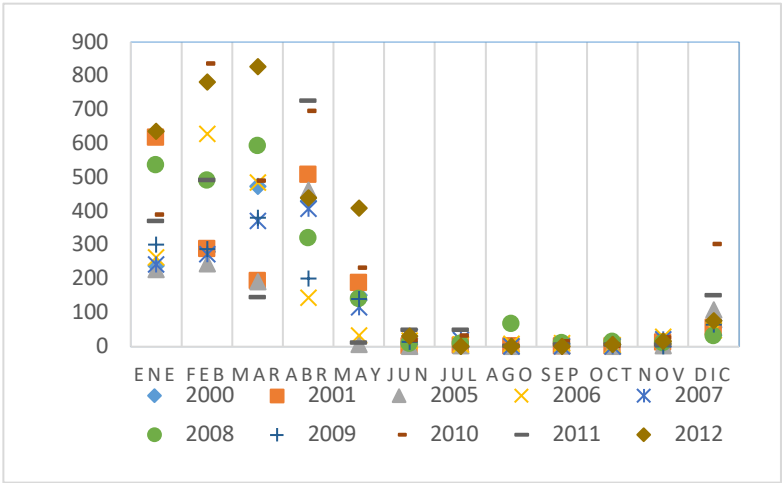
The precipitation regime in the canton of Valencia is distributed according to the climatic seasons of winter with four months of duration and summer with a duration of eight months. Fig. 11 shows that the average winter precipitation in the period from 2007 to 2016 is 422 mm, while in summer the precipitation for the same period of years is 75 mm.

Figure 10. Average flows (m3/sec.) year 2000-2012 in Quevedo River.



Source: Own elaboration based on INHAMI, 2016.

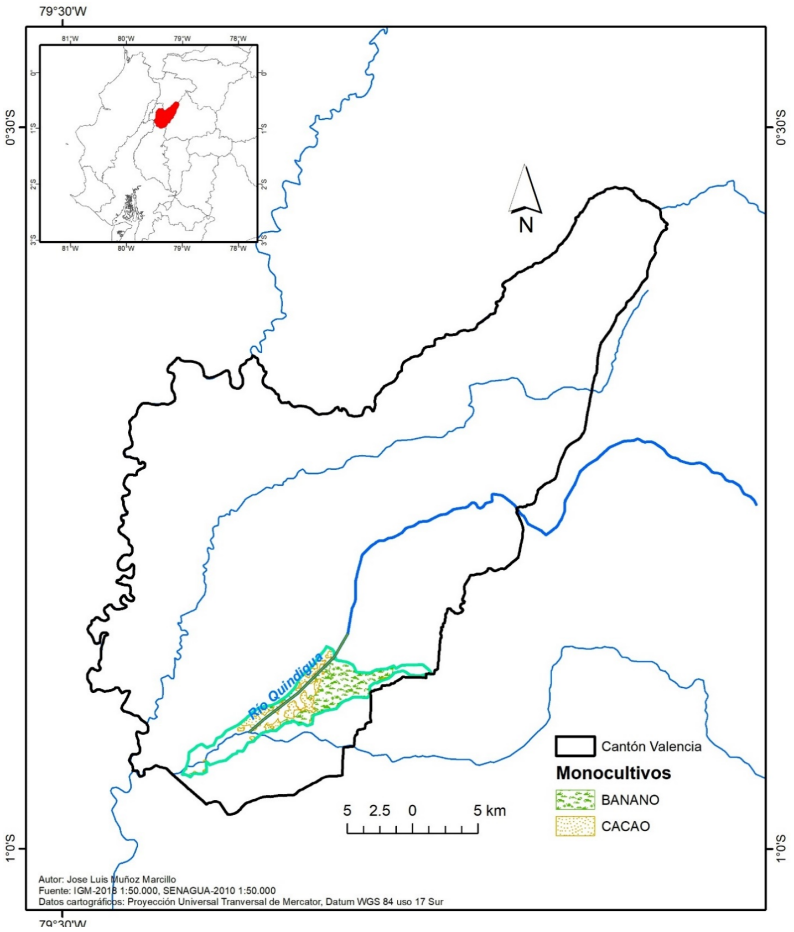
Figure 11. Average precipitation (mm) years 2007-2016 in Quevedo river.



Source: Own elaboration based on INHAMI, 2016.

Table 3 shows the water consumption per hectare for irrigation during the 8 summer months by banana and cocoa monocultures in the Quindigua river basin, Figure 12.

Figure 12. Quindigua River micro-hydrological basin.



Source: Own elaboration

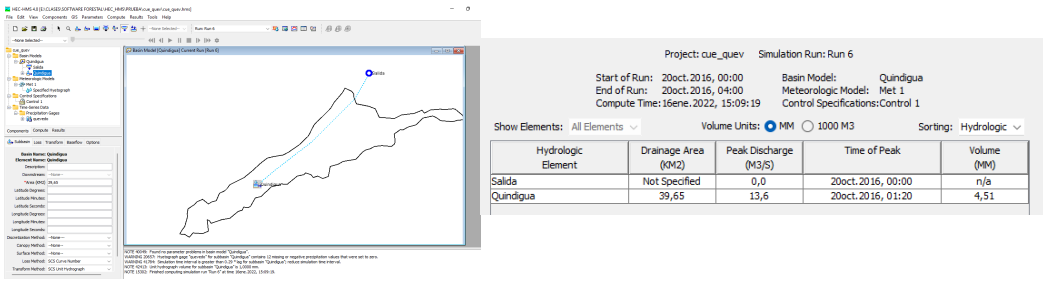
The banana and cocoa monocultures present in the Quindigua river basin exert pressure for irrigation water during the 8 months of summer, when they are most productive and require permanent irrigation, requiring daily irrigation rates per plant of 20 liters and 8 liters, respectively.

Table 3. Water consumption of banana and cocoa monoculture plantations

Crops	*Surface area (ha)*	*Plants (ha)*	*Water consumption in summer (m^3)*
Banana	1492		11'458,560
Cocoa	682	1000	1'636,800

The simulation of the Quindigua river flow from the application of the hydrological modeler HEC - HMS in the microbasin of the aforementioned river allowed us to appreciate the significant decrease in the Quindigua river flow during the summer season, Figure 13.

Figure 13. Hydrological modeling of the Quindigua river basin in HEC - HMS software.



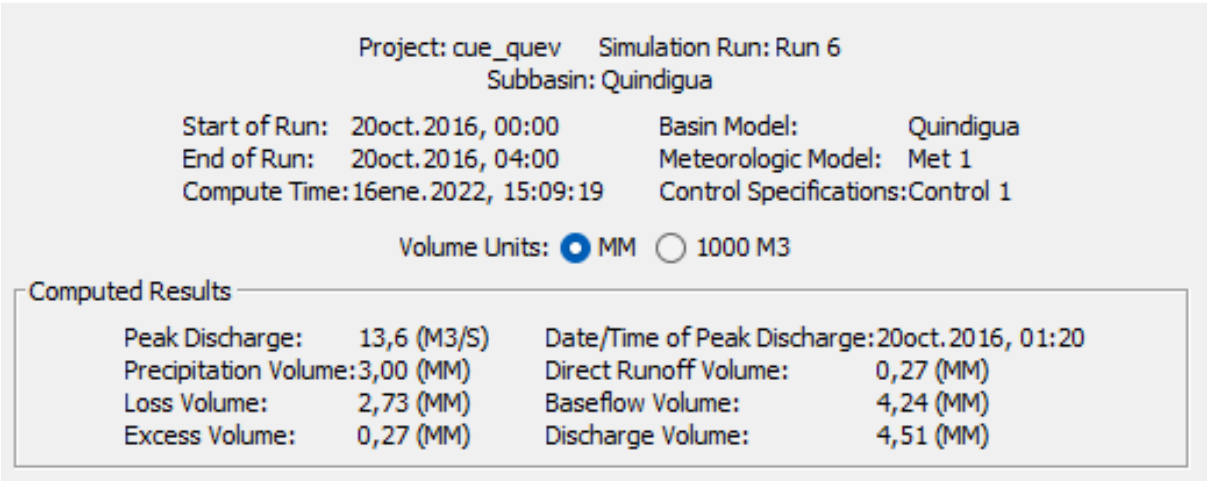
Project: cue_quev Simulation Run: Run 6

Start of Run: 20oct.2016, 00:00
End of Run: 20oct.2016, 04:00
Compute Time: 16ene.2022, 15:09:19

Basin Model: Quindigua
Meteorologic Model: Met 1
Control Specifications: Control 1

Show Elements: All Elements Volume Units: MM 1000 M3 Sorting: Hydrologic

Hydrologic Element	Drainage Area (KM2)	Peak Discharge (M3/S)	Time of Peak	Volume (MM)
Salida	Not Specified	0,0	20oct.2016, 00:00	n/a
Quindigua	39,65	13,6	20oct.2016, 01:20	4,51



Project: cue_quev Simulation Run: Run 6
Subbasin: Quindigua

Start of Run: 20oct.2016, 00:00
End of Run: 20oct.2016, 04:00
Compute Time: 16ene.2022, 15:09:19

Basin Model: Quindigua
Meteorologic Model: Met 1
Control Specifications: Control 1

Volume Units: MM 1000 M3

Computed Results

Peak Discharge: 13,6 (M3/S)
Precipitation Volume: 3,00 (MM)
Loss Volume: 2,73 (MM)
Excess Volume: 0,27 (MM)

Date/Time of Peak Discharge: 20oct.2016, 01:20
Direct Runoff Volume: 0,27 (MM)
Baseflow Volume: 4,24 (MM)
Discharge Volume: 4,51 (MM)

Project: cue_quev Simulation Run: Run 6
Subbasin: Quindigua

Start of Run: 20oct.2016, 00:00 Basin Model: Quindigua
End of Run: 20oct.2016, 04:00 Meteorologic Model: Met 1
Compute Time: 16ene.2022, 15:09:19 Control Specifications: Control 1

Time	Date	Precip (MM)	Loss (MM)	Excess (MM)	Direct Flow (M3/S)	Baseflow (M3/S)	Total Flow (M3/S)
00:00	20oct.2016				0,0	12,0	12,0
00:05	20oct.2016	0,00	0,00	0,00	0,0	12,0	12,0
00:10	20oct.2016	0,00	0,00	0,00	0,0	12,0	12,0
00:15	20oct.2016	0,00	0,00	0,00	0,0	11,9	11,9
00:20	20oct.2016	0,00	0,00	0,00	0,0	11,9	11,9
00:25	20oct.2016	0,00	0,00	0,00	0,0	11,9	11,9
00:30	20oct.2016	0,00	0,00	0,00	0,0	11,9	11,9
00:35	20oct.2016	0,00	0,00	0,00	0,0	11,9	11,9
00:40	20oct.2016	0,00	0,00	0,00	0,0	11,8	11,8
00:45	20oct.2016	0,00	0,00	0,00	0,0	11,8	11,8
00:50	20oct.2016	0,00	0,00	0,00	0,0	11,8	11,8
00:55	20oct.2016	0,00	0,00	0,00	0,0	11,8	11,8
01:00	20oct.2016	0,00	0,00	0,00	0,0	11,7	11,7
01:05	20oct.2016	0,17	0,15	0,01	1,2	11,7	13,0
01:10	20oct.2016	0,17	0,15	0,01	1,8	11,7	13,5
01:15	20oct.2016	0,17	0,15	0,01	1,9	11,7	13,6
01:20	20oct.2016	0,17	0,15	0,01	2,0	11,7	13,6
01:25	20oct.2016	0,17	0,15	0,01	2,0	11,6	13,6
01:30	20oct.2016	0,17	0,15	0,01	2,0	11,6	13,6
01:35	20oct.2016	0,17	0,15	0,01	2,0	11,6	13,6
01:40	20oct.2016	0,17	0,15	0,01	2,0	11,6	13,6
01:45	20oct.2016	0,17	0,15	0,01	2,0	11,6	13,5
01:50	20oct.2016	0,17	0,15	0,01	2,0	11,5	13,5
01:55	20oct.2016	0,17	0,15	0,01	2,0	11,5	13,5
02:00	20oct.2016	0,17	0,15	0,01	2,0	11,5	13,5
02:05	20oct.2016	0,08	0,08	0,01	1,4	11,5	12,8
02:10	20oct.2016	0,08	0,08	0,01	1,1	11,5	12,5
02:15	20oct.2016	0,08	0,08	0,01	1,0	11,4	12,5
02:20	20oct.2016	0,08	0,08	0,01	1,0	11,4	12,4
02:25	20oct.2016	0,08	0,08	0,01	1,0	11,4	12,4
02:30	20oct.2016	0,08	0,08	0,01	1,0	11,4	12,4
02:35	20oct.2016	0,08	0,08	0,01	1,0	11,4	12,3
02:40	20oct.2016	0,08	0,08	0,01	1,0	11,3	12,3
02:45	20oct.2016	0,08	0,08	0,01	1,0	11,3	12,3
02:50	20oct.2016	0,08	0,08	0,01	1,0	11,3	12,3
02:55	20oct.2016	0,08	0,08	0,01	1,0	11,3	12,3
03:00	20oct.2016	0,08	0,08	0,01	1,0	11,3	12,2
03:05	20oct.2016	0,00	0,00	0,00	0,4	11,6	12,0
03:10	20oct.2016	0,00	0,00	0,00	0,1	11,9	12,0
03:15	20oct.2016	0,00	0,00	0,00	0,0	11,9	11,9
03:20	20oct.2016	0,00	0,00	0,00	0,0	11,9	11,9
03:25	20oct.2016	0,00	0,00	0,00	0,0	11,9	11,9
03:30	20oct.2016	0,00	0,00	0,00	0,0	11,9	11,9
03:35	20oct.2016	0,00	0,00	0,00	0,0	11,9	11,9
03:40	20oct.2016	0,00	0,00	0,00	0,0	11,8	11,8
03:45	20oct.2016	0,00	0,00	0,00	0,0	11,8	11,8
03:50	20oct.2016	0,00	0,00	0,00	0,0	11,8	11,8
03:55	20oct.2016	0,00	0,00	0,00	0,0	11,8	11,8
04:00	20oct.2016	0,00	0,00	0,00	0,0	11,8	11,8

It can be seen that the flow of the Quindigua River for October 20, 2016 remains between 11.8 to 13.6 m3/sec, which is a decrease below the 28.493 m3/sec recorded by the Quindigua River hydrological station in that same month in 2012.

Intensive banana monoculture has been expanded mainly by powerful economic groups whose plots exceed 100 hectares, which generates a very high pressure on the basin's water resources for irrigation. It is frequently observed that they do not respect the flows granted by the environmental authority and in many cases they have been sanctioned economically, but they pay their fines and continue to clandestinely use water for irrigation in the canton of Valencia. This reality experienced in the basin is not very different from what is happening in the rural area of Bogotá, where the expansion of the agricultural frontier has led to the almost total disappearance of the páramo's buffer areas, this is related to the forms of economic use of the land, due to several large estates that have been leased to third parties, precipitating the ecosystem and water deterioration of the basin (Hernández, Rojas & Sánchez, 2013).

The results of the temporal-spatial study of the agricultural cover of the canton Valencia allowed the identification of recent trends in land use patterns. Morales, Carrillo, Farfán & Cornejo (2016) indicate that the quantitative spatial analysis on changes in vegetation cover and land use between 1979-2013 in the region of Bahía de Banderas, Mexico, generated valuable information for monitoring natural resources with implications on the hydrological cycle, biodiversity, soil erosion and local climate, among other relevant aspects. Likewise, Florez-Yepes, Rincon-Santamaría, Cardona & Alzate-Alvarez (2017) state that the application of multitemporal analysis allows determining the most significant environmental changes and impacts over time allowing knowing the interrelationships between the elements that compose it and the anthropogenic activities

Conclusions

The power and dubious practices that are often carried out in the country facilitate large production and export companies to grant

large flows for irrigation without effective control of their use with the consent and certain complicity of the state due to its dependence on foreign exchange earnings from exports generated precisely by crops for agricultural export production, CPAE over crops that guarantee food sovereignty, CGSA, a distinction that has to do with the emergence of the concept of family farming and beyond transitions and mixed cases, lock the state in a dilemma impossible to solve, unbalancing the political system and impacting the quality of life and good living.

Water resource management in the canton of Valencia suffers from fragmentation due to the varied number of entities that have certain levels of competencies for the management of irrigation projects, such as MAGAP, MAE, provincial GAD's and cantonal GAD's, resulting in a deficient management of water resources, which can be seen in the reality of the countryside where conflicts over the use of water for irrigation are recurrent, especially with small producers.

The Ministry of Environment of Ecuador is aware of the damage caused by intensive banana plantations for export to surface water courses in the canton of Valencia, however, the only thing that has been done so far is the enactment of the "Law to stimulate and control the production and marketing of bananas, plantain (barraganete) and other related musaseas, for export" which mentions in Art. 25 "New banana plantations are prohibited". Banana plantations qualified as organic shall be registered with the planted area and shall not be subject to any sanction". Note that the intention of this restriction only obeys to an economic interest that seeks to control the production of bananas for export in order to avoid the fall of the commercialization price of the banana box due to overproduction. This article of the law has not worked in practice, since the power groups continue planting new banana plantations for export.

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