Paraná River Delta. The greatest potential for irrigated rice area from surface waters courses in Entre Rios, Argentina

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ABSTRACTS

he limitations in the growth area irrigated rice in the province of Entre Rios product of exponential growth of the areas under soybean cultivation, explained by high yields and high returns compared to other crops has been a change in the land use displacing livestock production and other grains and oilseeds, rice has limited its growth on the surface, despite the regional demand for such production. There is now a single endicada with a surface intended to rice 1540 hectares.

Parana River Delta is located at the mouth of the same in the Rio de La Plata has an area of 1.700.00 hectares. It is caused by the Parana River sediment supply. Deposits represent environmental change in the river estuary to River Plate and are between 2 m and the level of current sea. It consists of a set of islands and a complex network of waterways. The climate is temperate humid plains. The annual daily average is 16.6 ° C and varies between 24.9 degrees Celsius in January and 12 ° C in June-July. Warm winds from the NE, followed by winds from the SE, which originate in the sea, so bring cool air in summer and somewhat warmer in the winter. Frost is one of the major climatic adversities for agriculture, are common in the months of June, July and August. The annual rainfall ranges between 1000 and 1300 mm.

Geologically is a typical deltaic unit, built by the frontal advance of the deposits of the Parana River on the River Plate, at the present stage of degradation. It consists of continental calcareous silts Middle Pleistocene. The landscape shows lalbardones weakly developed, with marshy tidelands without external drainage and an active process of peat formation. Soils in the lower flood zones recent alluvial deposits are composed of a thin layer of silty clay or silty loam overlying silty franc platenses clay loams.

The potential water for irrigating rice source is surface water quality of the courses and streams in the floodplain of the Parana River. There are no limitations of area under irrigation from the point of view of water resources. the supply source; Parana River; It has average flow of 16000 m3 / s. The expected growth potential of over 100,000 hectares, representing 5% of the total area of the deltaic complex.

Finally, from an environmental point of view it is a temperate wetland with a rich fish fauna, birds and mammals. The latter the biggest determinant of growth and use of territory for irrigated rice due to potential changes to the biota, impacts on soil resources, similar to the start-value of any field with agricultural potential magnitude are anticipated addition to those provided on the socio-economic aspects. The development area will produce specific impacts of biodiversity loss by habitat destruction and modification of communities. (Millenium Ecosystem Assessment. 2005), (Zóffoli et al. 2008), et al. 2015).

• **Key words.** wetlands, sub-tropical, conversion, production, socio-economic

1 Introduction

According to the last rice census in the framework of the 2010-2011 agricultural campaign, rice cultivation covered around 103,000 hectares in the province of Entre Ríos. The average yield of 7,300 kg/ha and the harvested area led this province to become the most valuable area for national production. In the aforementioned census, 350 producers were recorded showing involvement of 95- 98% of producers in the province. When compared with the 2007-2008 campaign in which 263 producers were surveyed and the cultivated area was 69,000 ha, a 50 % growth was recorded for the land surface covered by rice and the incorporation or reincorporation of almost a hundred producers during the intercensal period (Cargñel 2011).

Most rice producers in Entre Ríos are devoted to diversified farming production while around 20% producers with lands smaller than 200 ha are exclusively rice producers or devote to rice cultivation as their only activity. It is estimated that 2,500 people work in primary production, including producers and their families involved in cultivation being 25% water carriers and 84% part of the permanent staff. A quarter of the provincial land is cultivated by rice smaller producers (<200 ha), while larger producers (>1000 ha) account for 30% of the total province land, and almost half of the province area is under rice cultivations of 200 to 1,000 hectares.

Sixty-two percent of rice cultivation surface is irrigated by water extracted from deep wells. This water extraction requires energy, which considerably impacts upon production costs. Sixteen percent of the cultivated land requires electric power for water pumping; but the energy for irrigating most of the land is obtained from fossil fuels, representing a 500 to 750-liter consumption per hectare. Almost 16% of the area is provided with water from 56 reservoirs, their volume being 3 to 16 Hm^3. In these cases, irrigated areas range from 50 to 1,350 hectares. Finally, irrigation from the two main courses, Paraná and Uruguay Rivers, with mean flows of 16,000 and 4,500 m^3/sec respectively, allowed for the development of areas that are important for farming companies that are replacing traditional producers.

Agricultural frontier expansion has led to the incorporation of a great amount of land that was first devoted to rice cultivation. Moreover, high operation costs of this kind of cultivation against those of simpler cultivation techniques have reinforced this process. The potential growth of rice cultivated lands is based on the occupation of marginal areas that are not suitable for cereals and oilseeds (mainly soya and maize).

Paraná Delta and its confluence with Uruguay River upstream Río de La Plata constitutes the greatest potential for rice expansion due to both water accessibility and quality and low pumping costs. By comparing it with Delta traditional activities such as extensive livestock implying low use of labor and technology, rice cultivation promotes regional development since it provides labor demand for field work, transportation, rice conditioning and industry.

Due to the increase in energy costs, some current systems of rice production such as those using water from deep wells may become less competitive. Low cost irrigation with surface water will certainly constitute a more profitable alternative. Traditional rainfed agriculture has not been successfully developed in those areas. Soil salinity, slow draining, and puddling limit its expansion.

The aim of this research work was the development of an area, usually subject to floods and bound to be modified by anthropic activities, to be incorporated into rice production, showing an appropriate methodology that minimizes the environmental impact on the area.

Data and Methods

The studied area, i.e. Paraná Delta, occupies a surface of 1,850,000 hectares between the provinces of Entre Ríos (84%) and Buenos Aires (16%) and presents particular characteristics in relation to its agroecological, social, and productive conditions. Paraná Delta can be considered as an intermediate zone between Mesopotamia and Pampa, where Paraná River carries its waters into Río de la Plata. It can be described as a vast area constituted by low islands, large river arms, minor creeks, occupying a considerable surface in spite of its relative narrowness between the large regions surrounding it. It is a frequently flooded plain formed by fluvial deposits. Several rivers and streams flow across this region and divide it into islands with a high border commonly called *albardón* (bank) and a central, lower, and much wider area called *bañado*, *estero*, or *pajonal* (marshland). (Figure 1)

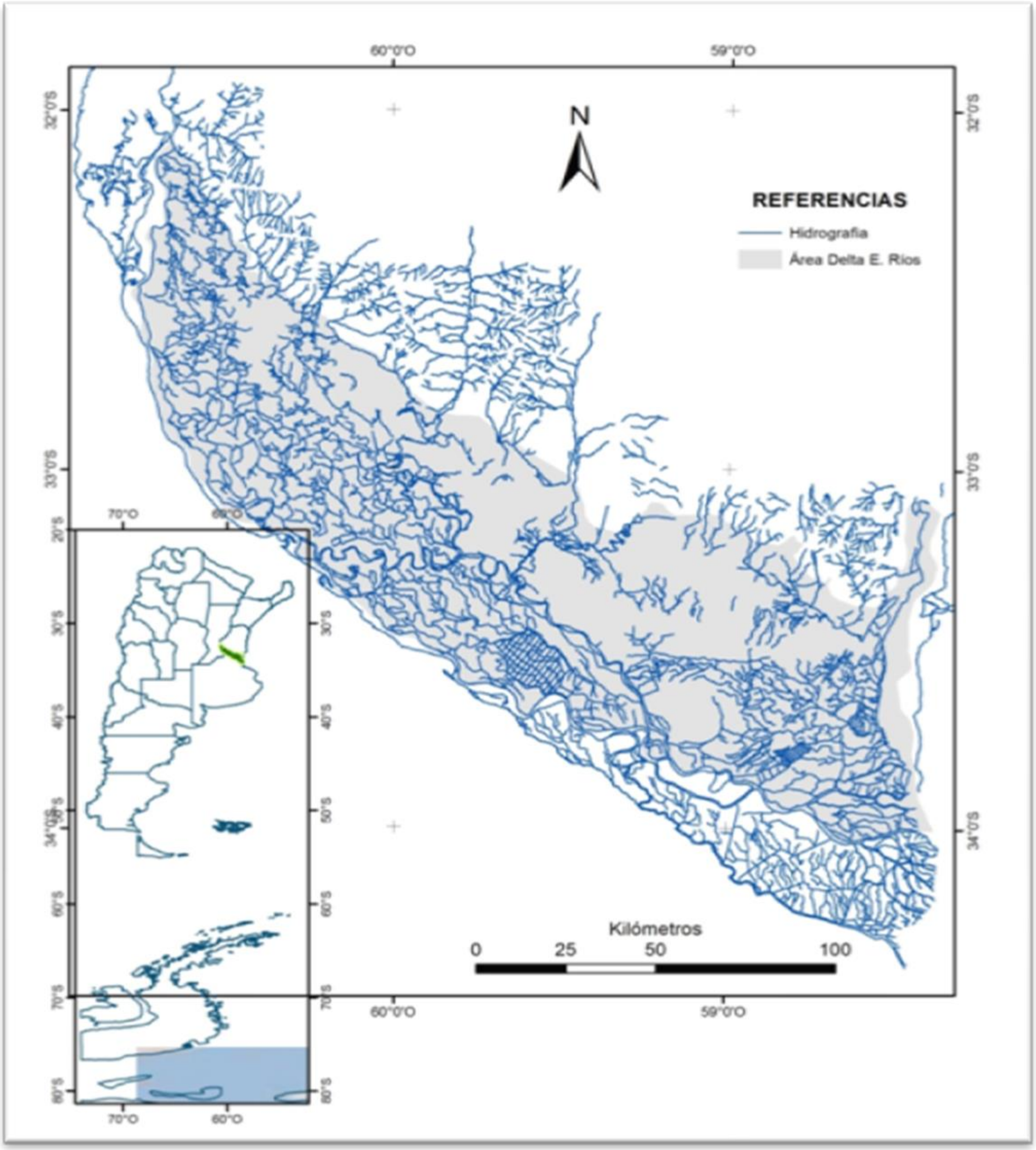

Figure 1. Parana River Delta location. Source: own elaboration.

This Delta represents the most colossal manifestation of sediment transport of the Río de La Plata basin and is highly influenced even by Uruguay River rises. One of its particular characteristics is its close proximity to densely populated zones such as the riverside areas of Gran Buenos Aires.

South Entre Ríos soils have different ages, the older ones are those in the loess plains and the younger ones are located in the area of the Paraná Delta. The age of loess plain soils is unknown, but it could be inferred that many of them are 1,000 years old or more, since it is the period required for the formation of the argillic horizon (Birkeland, 1999) present in most soils of this geomorphic unit. On the contrary, soils of the Paraná Delta are more recent than the last marine ingression (mid-Holocene), except for the higher sectors of the former lagoon (albúfera) that was not reached by the last ingression (Figure 2). Besides being young, this environment presents less geomorphic stability, since it is mostly subjected to flooding. In the region under study, several truncated soils are noticed, which implies moments of active pedogenesis during the Quaternary Period.

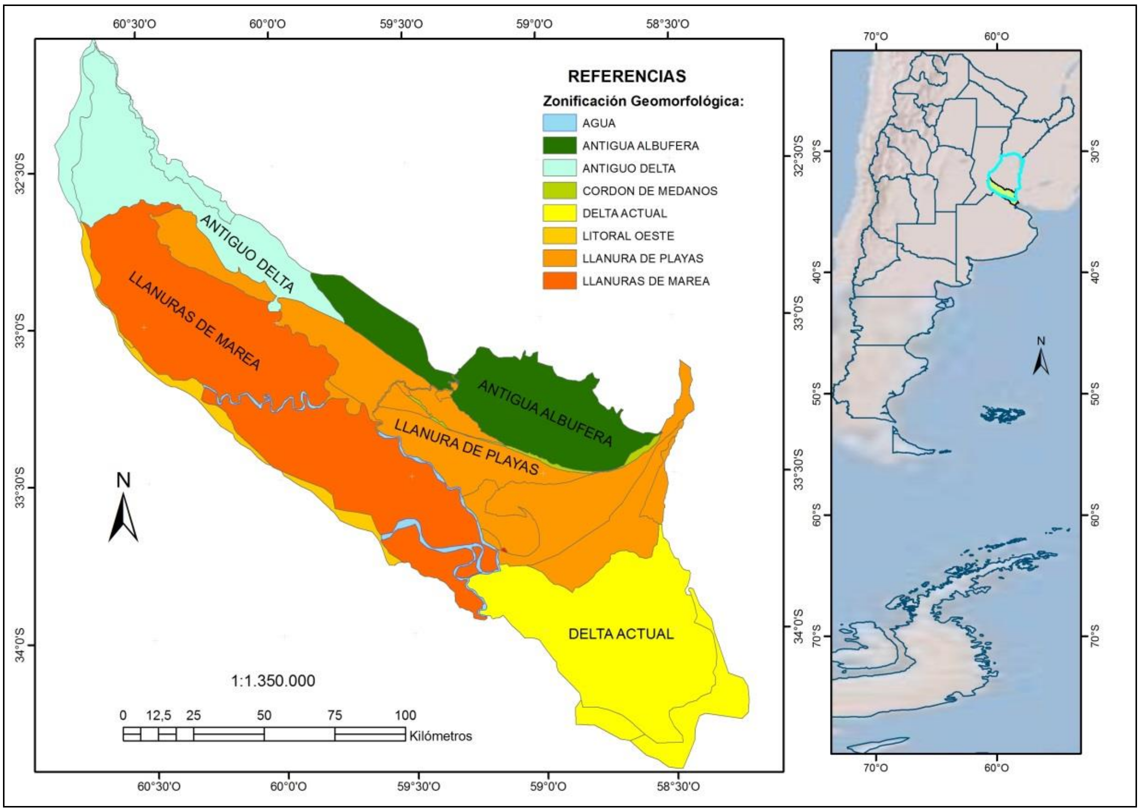

Figure 2. Geomorphologic zonification. Source: own elaboration.

The particular characteristics of the flora in the Paraná Delta are undoubtedly determined by the conjuction of species from diverse origins: subtropical, Chaquenian, Uruguayan, and Pampean. The subtropical character of the deltaic flora is easily noticed at first glance, since there is a close connection with rainforests of Misiones and the south of Brazil, as a result of the transporting action of those waters. Uruguay River provides species that settle on the albardón of the Lower Delta islands. In the Delta, the constant process of construction and destruction of islands caused by water creates a great variety of environments, each presenting particular types of plants that change over time. Prevailing plants in the Delta are aquatic and marshy. The higher sector of the islands, the albardon, is occupied by wet forests.

In the Lower Delta, a real rainforest is developed, which is called Monte Blanco(white shrubland). It presents low height, abundant lianas and epiphytes, and it is home to a great diversity of tree species. More deeply into the islands, there are plant communities

successions until the appearance of pajonales (reedlands), which occupy the central, lower, and more subjected to flooding area.
The Delta fauna, like the flora, is composed of species from various biomes. Fauna diversity in the albardón forest is wider than that of other Delta environments being its great amount of vegetation strata diverse habitats for wild animals.
This fluvial and somehow inhospitable environment, daily subject to flooding, implies a particular life style mainly related to fishing or rural activities and marked depopulation. Locally, the term “isleños” is used to denominate only those people with permanent location on the islands, and the term “ribereños” is used to denominate those residing on riverside solid lands. The “isleños” settle on the islands' albardones nearby the main water courses; and their economic activities are fishing, hunting, apiculture, and livestock breeding. Both “isleños” and “ribereños” live, mostly, in very precarious conditions. According to the Argentine Population Census of 2010, Entre Ríos Delta has 25,471 inhabitants, its rural distribution pattern being 59 % scattered and 23 % grouped, i. e. they settle in towns whose number of inhabitants does not surpass 2,000 inhabitants (Carñel et al. 2016).
As a result of the complex characteristics of this territory, the use of satellite images for identifying and quantifying current land occupation and use is a suitable tool for this kind of studies. Landsat Multispectral Optical Images were used, which collect the energy reflected from the observed surfaces with a 30 m spatial resolution. Reflectance characterizes the state of natural surfaces. Multispectral characteristics of images were used to distinguish between water, vegetation, and land (Carñel et al. 2009), since in the visible red (0,63-0,69 μm) and infrared band (0,76-0,90 μm) the energy is both highly absorbed by water and reflected by vegetation. Specific GIS image processing software was used: ArcGis v. 10 and Idrisi Taiga.
Soils are originated from the suspended material carried by the river water, which becomes sediment as a result of a reduction in velocity when reaching the mouth of Río de la Plata. Two main types of soils are distinguished: alluvial and hydromorphic. By means of soil sampling, laboratory analyses, infiltration assays, and physical and chemical characteristics tests, the possible aptitude-conditioning factors were determined. Also, water samples were collected so as to characterize physical and chemical conditions for irrigation.
The process of systematization or transformation of low areas comprises, in the first place, the construction of an embankment as a defense against floods. This construction should be high and large enough so as to bear the levels and force of the rises of the involved rivers’ rises. In this sense, both extreme hydrometric levels and rainfall regime and intensity are studied. From the hydrological and hydraulic point of view, the drainage regime of Paraná and Uruguay rivers was characterized with the aim of specifying mean, maximum, and minimum flows per month.
The recorded series of daily, monthly, and annual rainfalls was analyzed with the aim of identifying the recurrence of maximum rains for 24 and 48 hours and recurrences in 5, 10, and 20 years . Adjustments were made using statistical techniques of extreme value distribution such as Pearson, Log Pearson, and/or Gumbel. According to the recurrence adopted for both water courses’ levels and maximum rainfalls, defensive embankment height and draining flow were determined, and the pumping system was thus designed for the identified areas. Drainage flow was calculated by combining a maximum rainfall in 24 or 48 hours for the adopted Recurrence Time (5, 10, or 20 years), the surface to be drained, the filtered layer and the submersion time required for draining exceeding rain water.
Lastly, projects must also contemplate 20 to 25% of the total surface for buffer and reservation zones for wild life. These areas provide environmental benefits and can be devoted to tourism, amusement, or production activities such as apiculture. The outer embankment defines a protected area or zone for a more safely farming exploitation. In that zone, works must be accomplished to level the land and systematize water drainage and collection from rains or phreatic aquifers. In other words, the required system must prevent river and stream waters from entering the farming area but allows exceeding water to drain out. This implies a necessary network of channels, lock and sluicegates, and pumps. On the other hand, rice

cultivation requires the construction of irrigation channels and water capture and pumping systems.

Results

The proposed methodology was validated along the development of a project that was carried out in the mouth of Gualeguaychu River, at its confluence with Uruguay River. The surface was characterized by using satellite and topographic images collection (Figure 3).

Surface horizons of the analyzed soils presented a high content of organic material as a prevailing characteristic, which varied between 10 and 25%. Surface and subsurface soil horizon pH was slightly acid. The available phosphorous showed variable values, medium to high values were observed on the surface, indicating that it had received phosphorous-rich sediments, while deep layers were highly phosphorous-deficient. Soil salinity was evaluated according to its electric conductivity and showed to be moderate to low. In marshlands, values were lower than 4 dS/m. As expected due to the characteristic saline vegetation, a higher value (19 µS/m) was observed on the surface. Salinity is more highly present in superficial layers, indicating that there has been a capillary ascent and salt concentration on surface after draining and under conditions related to a dry year (with scarce rainfalls) before sampling.

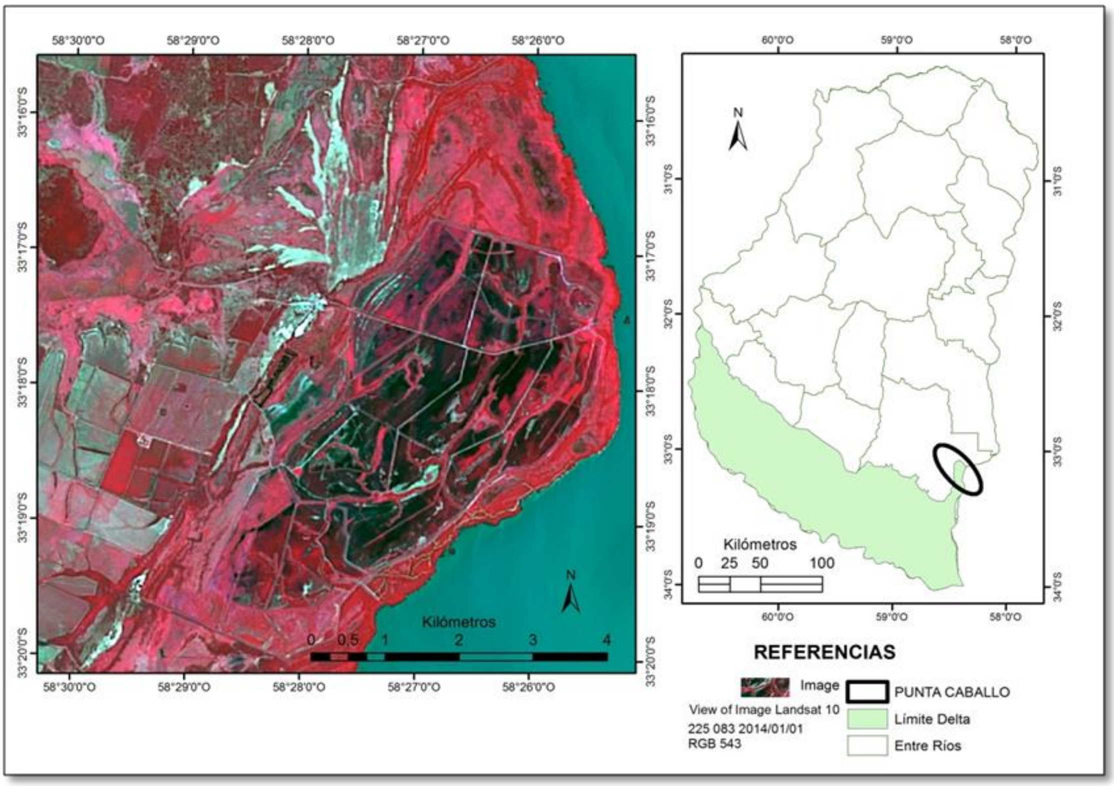

Figure 3. Validation area for the proposed methodology.
Source: own elaboration.

The historical series used for evaluating river rise recurrence is that Uruguay River in the Gualeguaychu mouth operated by Argentine Naval Prefecture. The considered series extended from January 1905 to date, so that 105 year records were processed. The daily maximum per month was selected for each month; and the daily maximum per year was determined for each year.

Maximum values were recorded in 1872 with 5,09 meters, followed by those in 1992 with a level peak of 4,96 meters. In the 1959 rise, a height of 4,80 meters was reached; and in 1922 hydrometric levels reached a height of 4,70 meters. By applying Gumbel distribution to the aforementioned series, hydrometric levels for different recurrences vary among 3,85, 4,35, 4,63 and 4,89 meters for 10, 20, 50, and 100 years, respectively. Data were conveniently arranged by their hydrometric levels in decreasing order and were processed by adjusting them to Gumbel distribution (Figure 4).

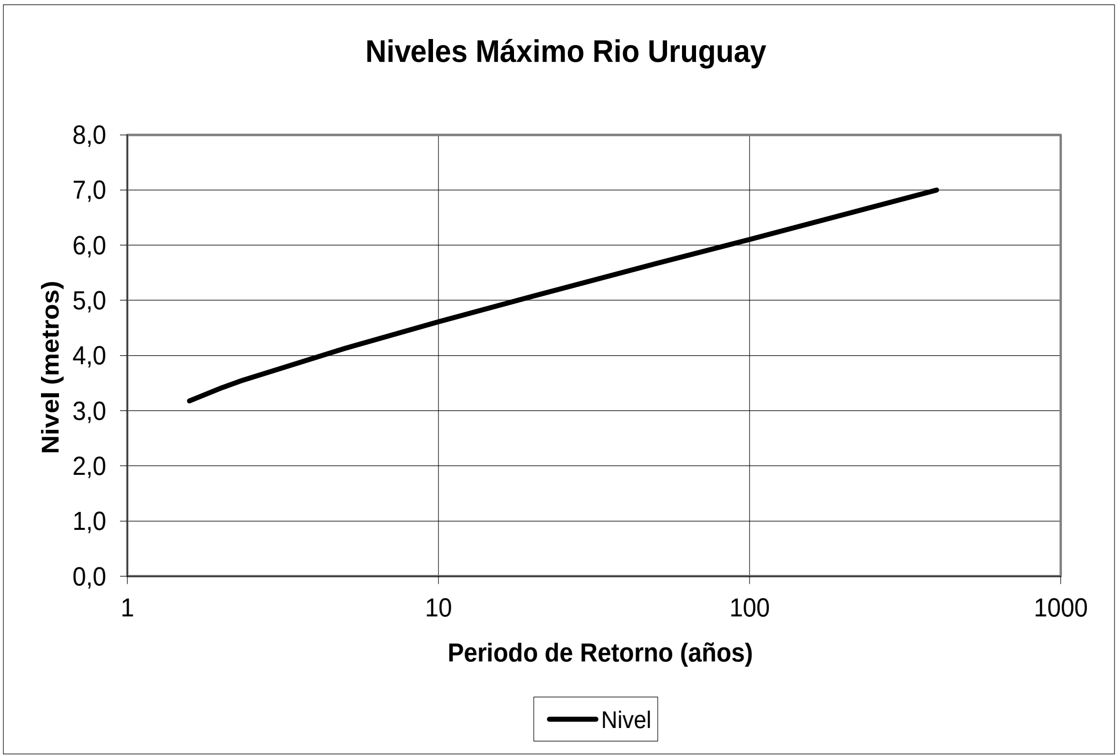

Figure 4. Aplication of extreme laws to hydrometric levels. Source: own elaboration.

The historical series used for evaluating rainfall recurrence is that of Perdices, a town in Gualeguaychú Department. The considered series has a 69-year record: from 1921 to 2006, all available daily records were processed. The daily maximum per month was selected for each month; and the daily maximum per year was determined for each year.

Maximum daily 24-hour rainfalls occurred in 1925 with 175 mm, followed by those in 1973 with 175 mm. In 1938, a 171 mm precipitation was reached in 24 hours; and in 1963, daily maximum precipitation climbed up to 152 mm. As regards 48-hour duration, accumulated rainfalls reached a 233 mm layer in 1938, 221 mm in 1984, 195 mm in 1930, and 180 mm in 48 h in 1937. Figure 5 presents the obtained adjustments for different recurrence times for 24-hour rainfalls.

This draining flow implied the installation of eleven pumping devices of 1 m^3/sec. It should be highlighted that the most unfavorable conditions are assumed for this analysis, i.e. Uruguay River level over 2 meters of hydrometric height and a 10-year recurrence for a 48-hour rainfall.

The protection design involved the construction of embankments of 11,340 meters approximately, consisting the construction method of land excavation on both sides of the embankment (deposit area) and the incorporation of this land onto the embankment. Involved embankments were Uruguay River 7,200-meter embankment; the northern embankment along the 1740-meter settlement, whose deposit used for construction has an upstream draining action for the hydrological basin of Chilcas stream; and the southern 2,400-meter

embankment from the coastal embankment of Uruguay River until reaching the crest elevation of the natural land, which is shown in Figure 4. This embankment will have a crest elevation of 5,50 meters in relation to Zero in the Uruguay River Hydrometer of Boca Gualeguaychú.
This methodology allowed to incorporate 1516 ha from Punta Caballos S.A. Establishment to farming production that was formerly an extensive livestock producer.

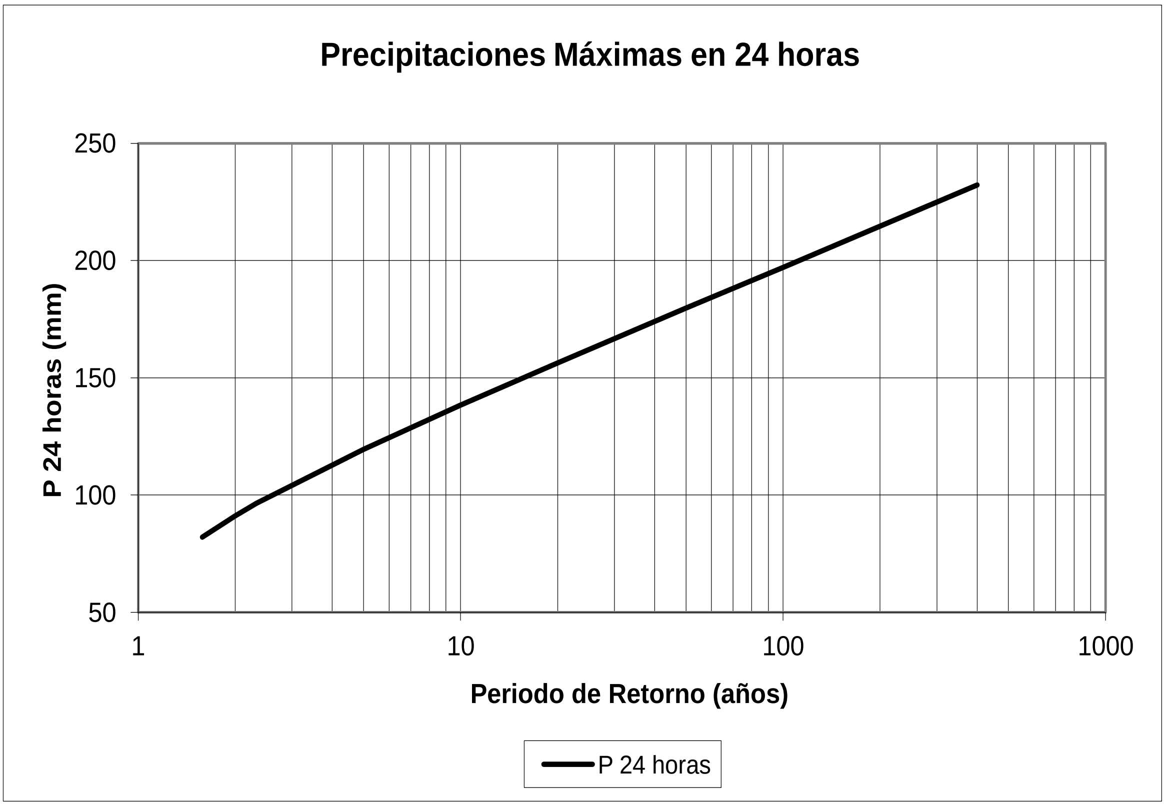

Figure 5. Rainfall analysis. Source: own elaboration.

Table 1 presented for different times of recurrence and precipitation maximum, the drainage flow to be consider for the design of the surface studied (1516 has).

DISEÑO DEL CAUDAL DE DRENAJE ESTABLECIMIENTO PUNTA CABALLOS						
Duración del Evento (horas)	**Tiempo Recurrencia (años)**	**Precipitación Máxima (mm)**	**Superficie (ha)**	**Lámina Infiltrada (mm)**	**Precipitación en Exceso (mm)**	**Caudal de Drenaje (m^3/seg)**
24 horas	5	123	1516	54	69	6,1
	10	141	1516	54	87	7,6
	20	158	1516	54	104	9,1
48 horas	5	150	1516	54	96	8,4
	10	174	1516	54	120	10,5
	20	198	1516	54	144	12,6

Table 1. Design of draining flow. Punta Caballos S.A. Establishment

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- **Discussion**

It is noteworthy that the area, unlike other deltaic environments, has a dense network of hydrometric stations with a series of daily data records that reach up to 100 years along the Parana and Uruguay rivers. Also a sufficient distribution of rainfall stations is available for analysis and adjustment to the statistical extreme techniques, product of the importance of that Parana River has as waterway and the proximity to the port of Buenos Aires.
The construction of impoundings has already been used in the area for forestry and extensive livestock establishments. Such development will produce an improvement in the quality of life of the inhabitants of the Parana River Delta, as well as prevent migration of the farm population to areas of greater employment opportunities.

- **Conclusions**

Is of highlight that the area to difference of other environments deltaic, has with a dense network of stations hydrometric with a series of data daily that reach records of up to 100 years along them riorios Paraná and Uruguay. Also, there is a distribution of stations rainfall sufficient for the analysis and adjustment to the technical statistics of ends. This product of the importance of the Rio Paraná as via River and its proximity to the port of Buenos Aires. The enclosed construction, has already been used in the area by forest settlements and ranching (Boschetti, N. g., 2013). The development will produce an improvement in the quality of life of the inhabitants of the Delta of the Rio Paraná, as well as also prevent the migration of residents to areas of greatest labour potential.It is important to highlight the relevance of medium resolution satellite images in studying heterogeneous regions that are not easily accessible such as the Paraná Delta. In the same way, data systematization and georeferentiation enable analysis and decision making at the occurrence of known and/or predictable events.
imilarly, the systematization of data and geo-referencing them, facilitate analysis and decision making to the occurrence of events known or predictable. The proposed methodology has made it possible to successfully incorporate a surface of 1516 has the productive process of rice irrigated in the Delta of the Rio Parana.la same can be replicated in the system Delta, reaching a surface of up to one hundred thousand acres without a foreseeable impact that alters their natural conditions.

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2 References

Baumann V., Altinier V., FerrerJ. y Tchilinguirian P. (2004). Génesis de suelos y evolución del paisaje en el Delta del Río Paraná. Revista de la Asociación Geológica Argentina, 59 (2): 229-242 Birkeland, P, 1999. Soils and Geomorphology. Oxford University Press, 430 pp.
Boschetti N.; Dìaz, E.; Duarte O.; Garcìa N. y G. Carñel. Anàlisis Hidrológico-Ambiental de los endicamientos en el Delta de Entre Rìos. Argentina. XXIV Congreso Nacional del Agua. Comitè Permente de los Congresos NAcionales del Agua. San Juan. ISSN 1853-7685. Pp 223. Extended CD. October, 2013.
Carñel, G. E., Varisco M. y Caplan D., 2016. Poblamiento y escolaridad en el delta del río Paraná, en la provincia de Entre Ríos. En IV JORNADAS NACIONALES DE INVESTIGACIÓN EN GEOGRAFÍA ARGENTINA. Tandil, Argentina. May 2016
Millenium Ecosystem Assessment. 2005. Ecosystems and Human Well-Being: Wetlands and water. Synthesis. 80pp. (http://www.millenniumassessment. org/en/index.aspx).Pereyra F. X.
Zóffoli, L., P. Kandus, N. Madanes y D. Calvo. 2008. Seasonal and interannual analysis of wetlands in South America using NOAA AVHRR-NDVI time series: The case of the Parana Delta Region. Landscape Ecology 23(7): 833-848.