UNIVERSITAT POLITÈCNICA DE CATALUNYA BARCELONATECH

FLOODRisk Master

DROUGHT CHARACTERIZATION FOR THE CIÉNAGA GRANDE DE SANTA MARTA (COLOMBIA) USING DROUGHT INDICES AND REMOTE SENSING

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IAHR International Association for Hydro-Environment Engineering and Research
Hosted by Spain Water and IWHR, China

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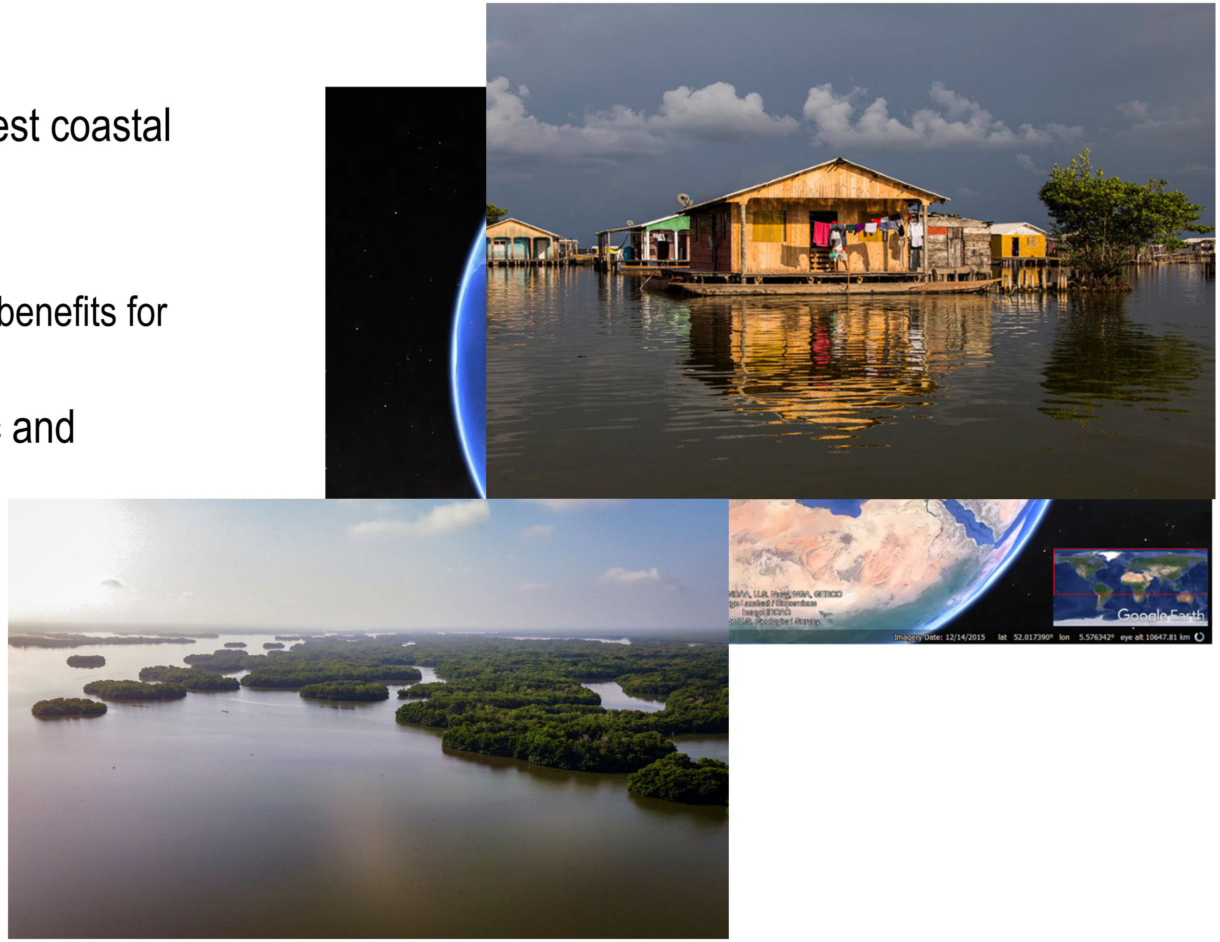
1. Introduction

- The Ciénaga Grande de Santa Marta is the largest coastal lagoon system in Colombia – 1.300 km²
- Area of big economic and ecological relevance:
  - Diversity of fauna and flora, source of economic benefits for the local communities
- Constantly under pressure due to both anthropic and natural phenomena



1. Introduction

- Main Objective: Characterize the drought events in the Ciénaga Grande de Santa Marta considering the different meteorological, hydrological, and anthropogenic factors that affect the water availability in the area using drought indices and remote sensing

1. Introduction

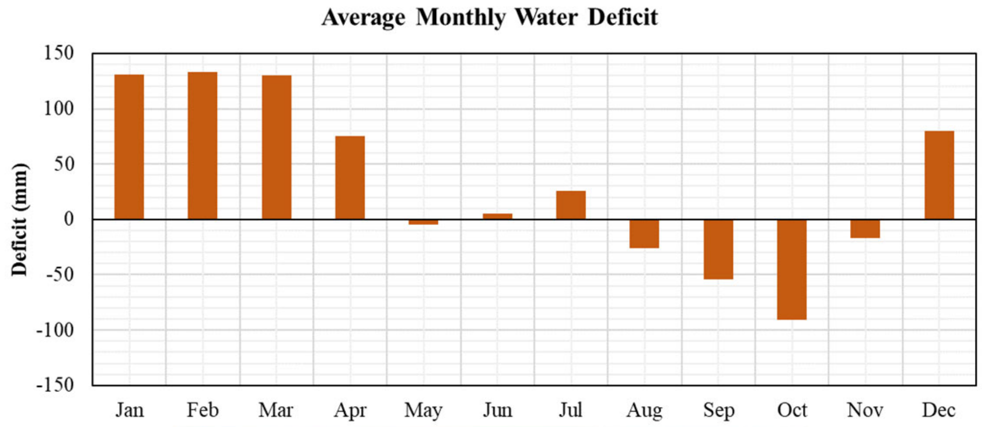
- Aspects to improve future research in the CGSM. And guidelines for the interpretation and analysis of the results of the study
- Availability and quality of the collected information
  - Limited number of hydrometeorological stations inside of the study area
  - Incomplete time series due to closure/abandonment of the infrastructure
  - High cloudiness in the area (Remote Sensing)
  - Limited analysis period and cover (Remote Sensing)
  - Different analysis period for the various sets of information
- Simplifications and assumptions for the development of the research:
  - Simplification of the water balance of the CGSM
    - Only considered the meteorological parameters and the inflow from the river.
    - Exchange of the system with the Caribbean affects mainly the main lagoon and can be neglected in a long-term analysis
    - Rivers that drain from the Sierra Nevada to the Ciénaga are used by the owners of the agricultural, almost draining the entire rivers before the water can arrive to the system
  - Calculation of the inflow from the Magdalena River to the CGSM
    - Due to the limitations of information and the need of a detailed model out of the scope of the research

2. Case Study

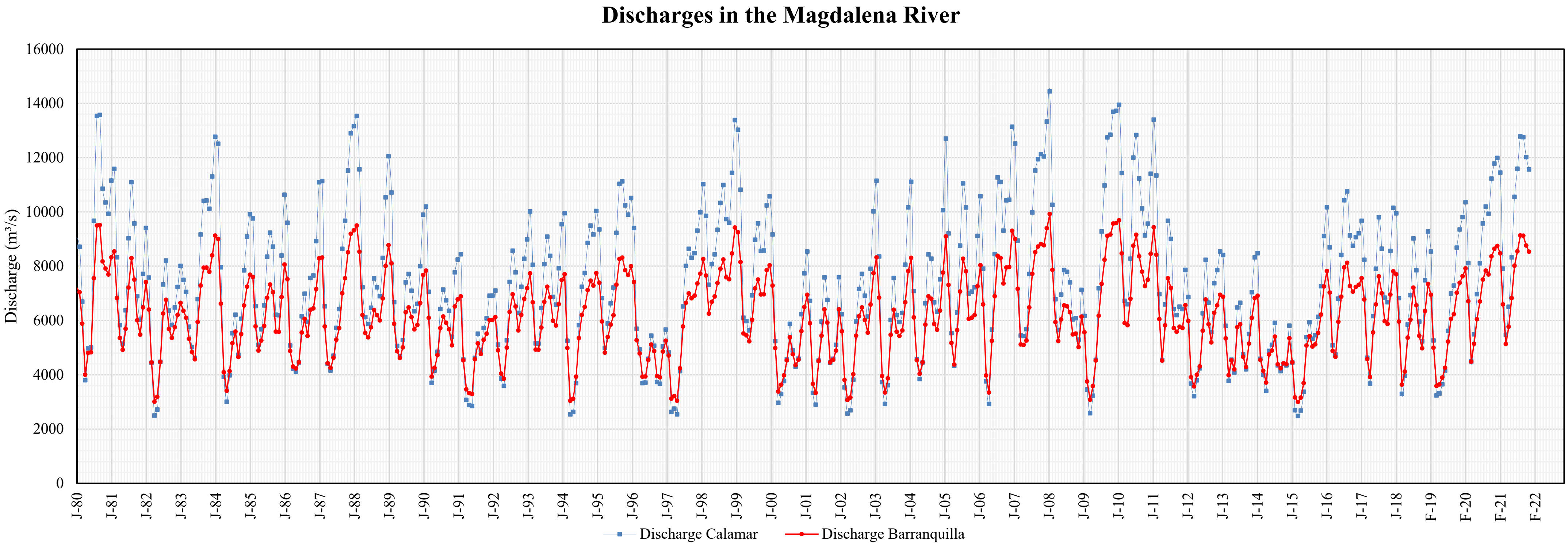
- The selected case study was the Ciénaga Grande de Santa Marta
  - Two major shallow water bodies (1-2m depth)
  - Complex system of swamps, mangrove forests and coastal lagoons
- Located in the north of the country, in the Caribbean region of Colombia, part of the Magdalena department
  - Northern boundary: Caribbean Sean and Isla de Salamanca
  - Eastern boundary: Sierra Nevada de Santa Marta =
  - Western boundary: Right bank of the Magdalena River

2. Case Study

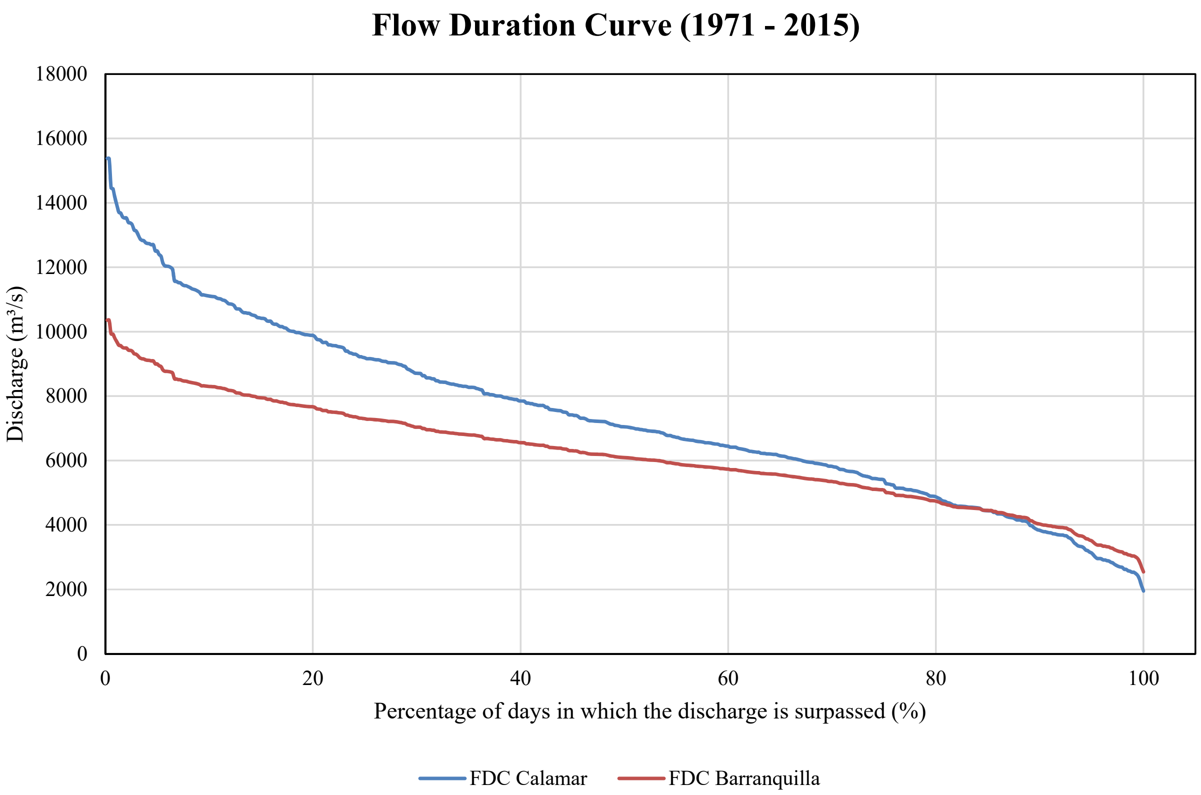
- Dry-warm climate – characterized by low mean annual precipitation, high evaporation and high relative humidity
- Precipitation range: between 1000 and 1200 mm per year
  - Unimodal regime: wet season between April and October
- Homogeneous temperature – average 27.9°C
  - Small variation along the year, the difference between the warmest and the coldest month is around 2 °C
- Average annual potential evapotranspiration between 950 and 1015 mm per year
- The area is characterized by a water deficit during dry months and a surplus of water during wet months



Discharges in the Magdalena River



Discharges in the Magdalena River



2. Case Study

- Society
  - Seven municipalities – 120.000 inhabitants
  - Three stilt towns in the biggest water body: Nueva Venecia, Trojas de Cataca and Buenavista
  - Insufficient coverage of public services, poor living conditions (inadequate housing, low income, poor education) – high vulnerability
- Economic Activities
  - Fishing, Agriculture, Agroindustry, Livestock
  - Commerce, Industry, Salt Extraction, Mangrove Felling, Mud Mines and Ecotourism
- Biodiversity
  - Land Covers: dominated by water bodies, flooded vegetation, mangroves and pasture






2. Case Study

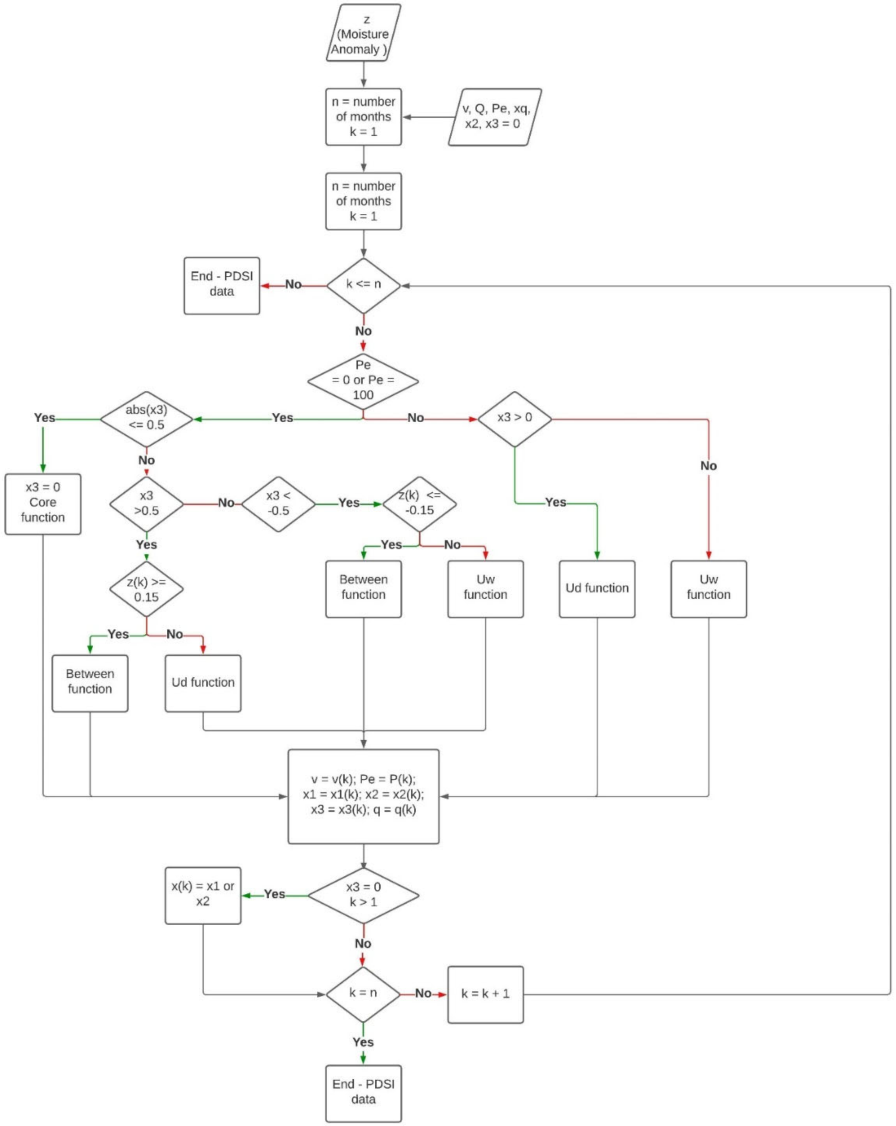
- Biodiversity
  - More than 90 species of mollusks and 120 species of fish
  - 200 species of birds, 19 species of mammals and 26 species of reptiles
  - 2 species classified as vulnerable species according to the IUCN red list
  - Mangrove forest: CO2 recycling, habitat, shelter and food for native species
- Ecosystem Services
  - Provisioning service, Cultural services & Regulation services
- Drought Impacts
  - Since 1982 ten events have been identified in the region (the information is at country level and is not extensive)
  - In the CGSM the main impacts are related to the availability of water for consumption and agricultural uses and the increment in the mortality rate of different species of fish and vegetation

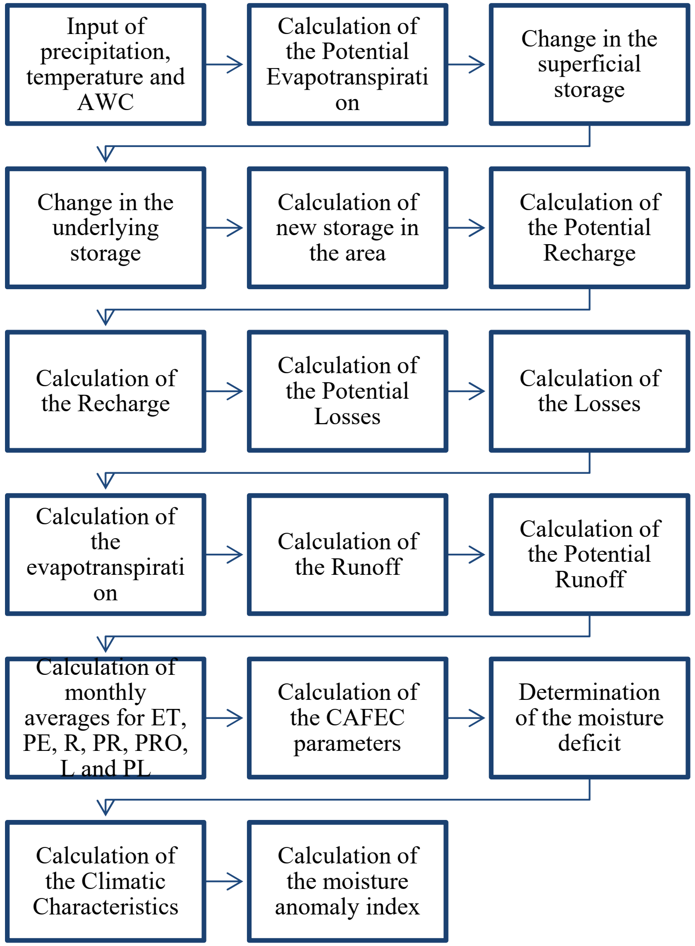
3. Research Methodology

3. Research Methodology

- Standardized Precipitation Index
  - Quantification of the deficit of precipitation – proposed to reflect the impact of the events on the availability of water
- Palmer Drought Severity Index
  - There is an amount of precipitation (water) required for the operation of a system in its near-normal conditions depending on the average climate of the area
  - Two steps procedure: Simplify water balance and Calculation of the index

Palmer Drought Severity Index



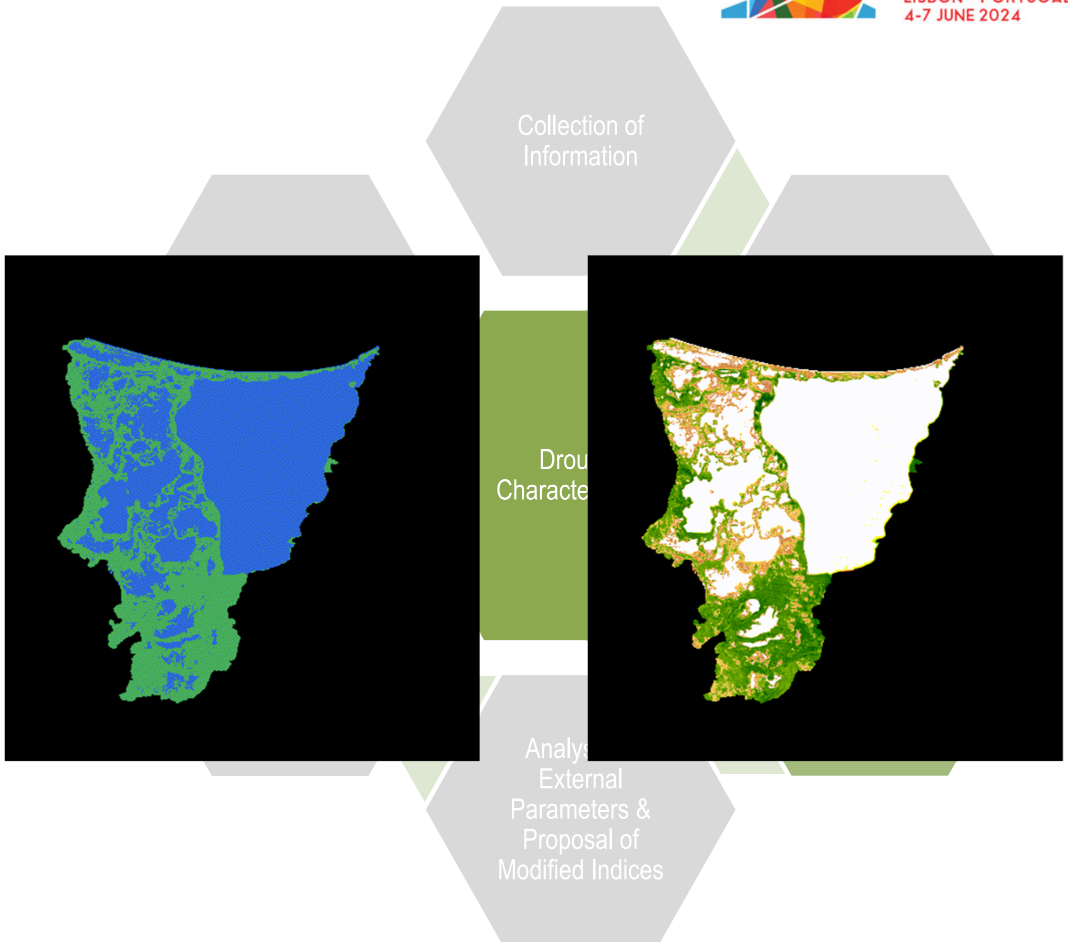


INDEX CALCULATION

WATER BALANCE

3. Research Methodology

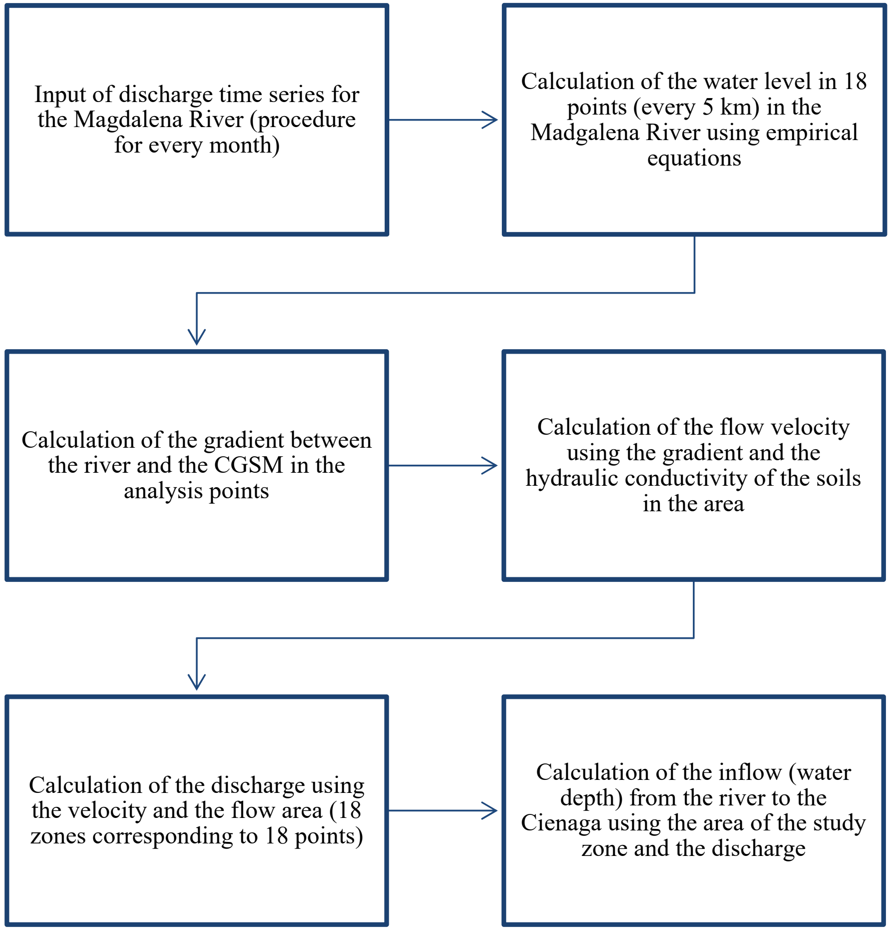
- Generation of monthly time series to analyze the relationship between the selected variables and the occurrence and characteristics of the drought events
  - Surface Water Area
  - Normalized Difference Vegetation Index
- SFA: Global Surface Water dataset – Joint Research Centre of the European Commission
  - 1984 – 2022
  - 30 x 30 m grid
  - Three categories: No observations, Not water, Water
- NDVI: Landsat 7
  - Tool for the assessment of the vegetation
  - Links the near-infrared and the red bands of the images to analyze the green spectrum of the image
  - Range between -1 to 1



3. Research Methodology

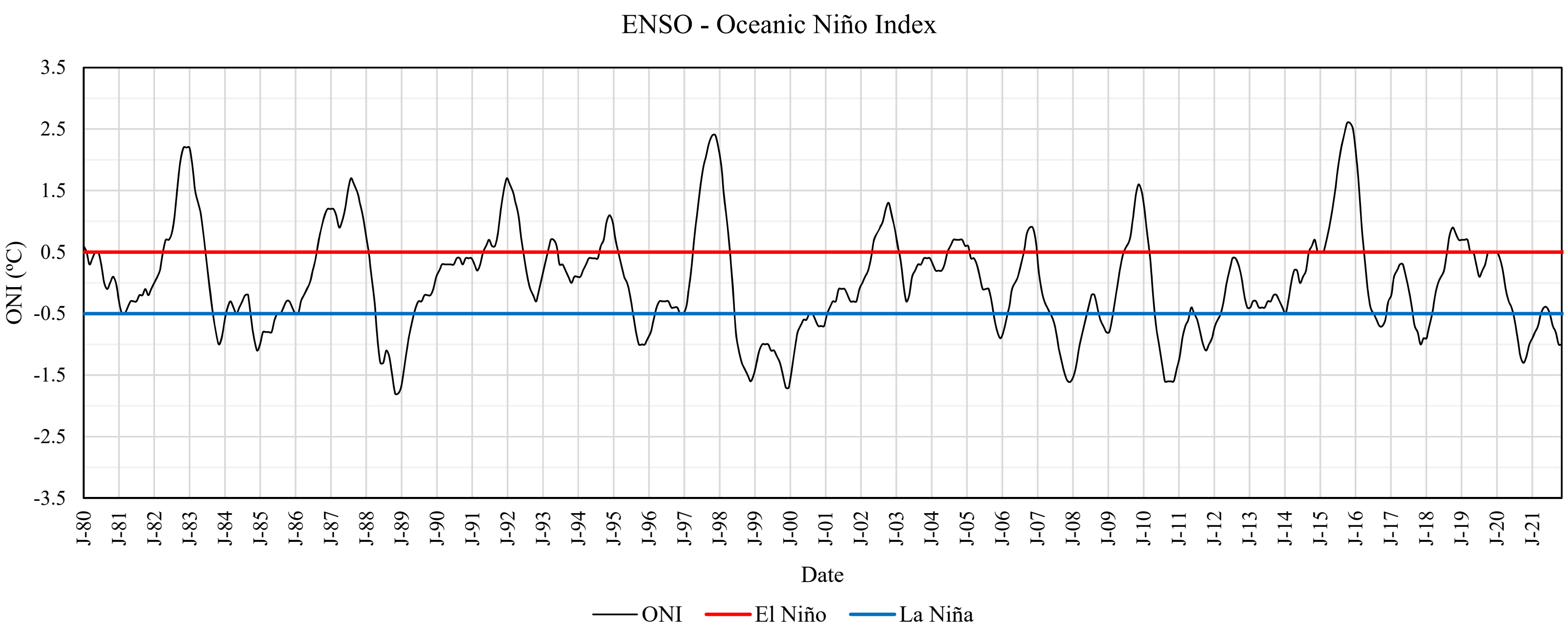
- Evaluation of non-traditional parameters
  - Salinity and inflow of water from the Magdalena River
  - Salinity obtained from measuring stations from the INVEMAR
  - Inflow calculated using a simplified approach considering the discharge and the levels of the river and the hydraulic conductivity of the soils in the study area
- Proposal of modified indices
  - The inflow can not be used directly for the drought characterization
  - Proposed to include the inflow as an additional input for the calculation of the drought indices – Precipitation + Inflow
- SWI: Standardized Water-input Index
- mPDSI: Modified Palmer Drought Severity Index

Analysis of external parameters and Modified Indices

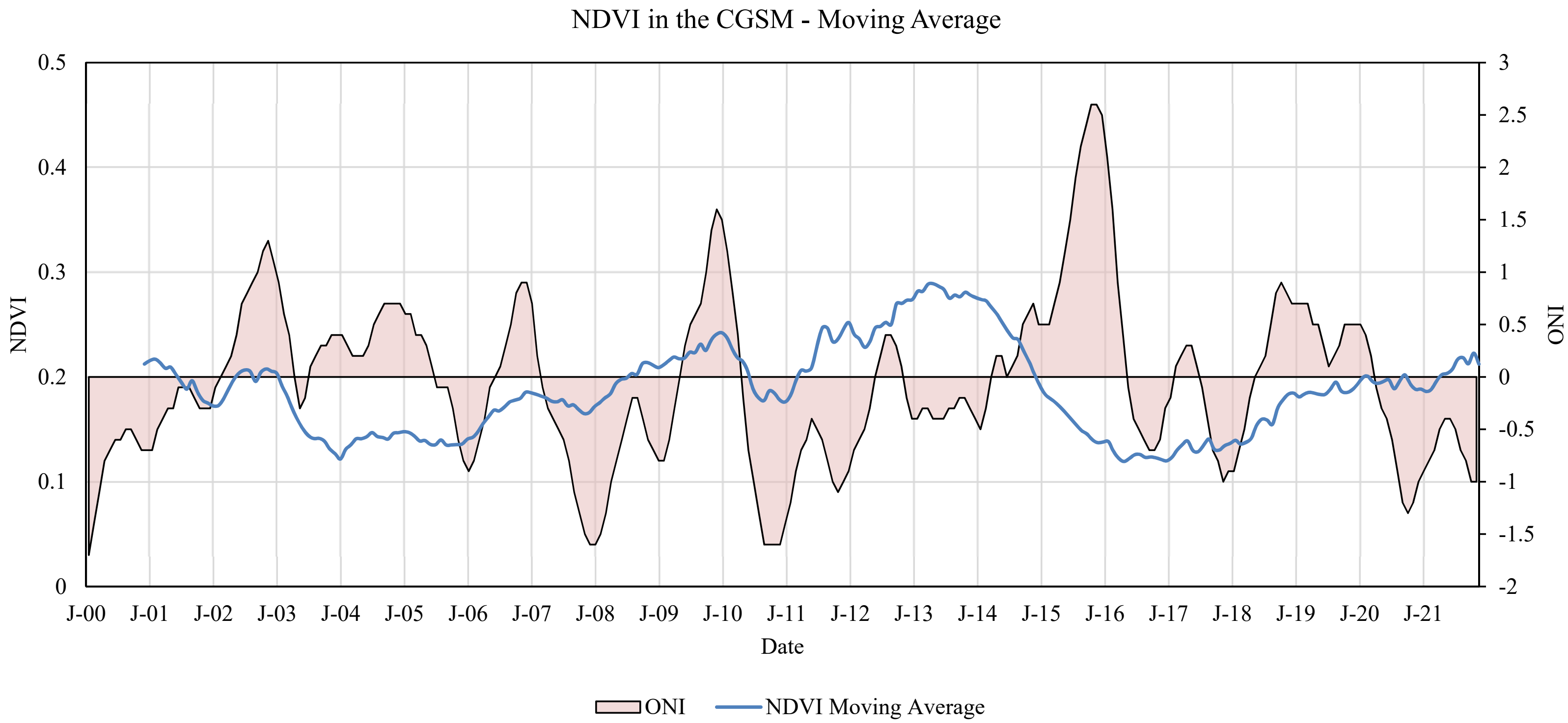


4. Results

- El Niño Southern Oscillation

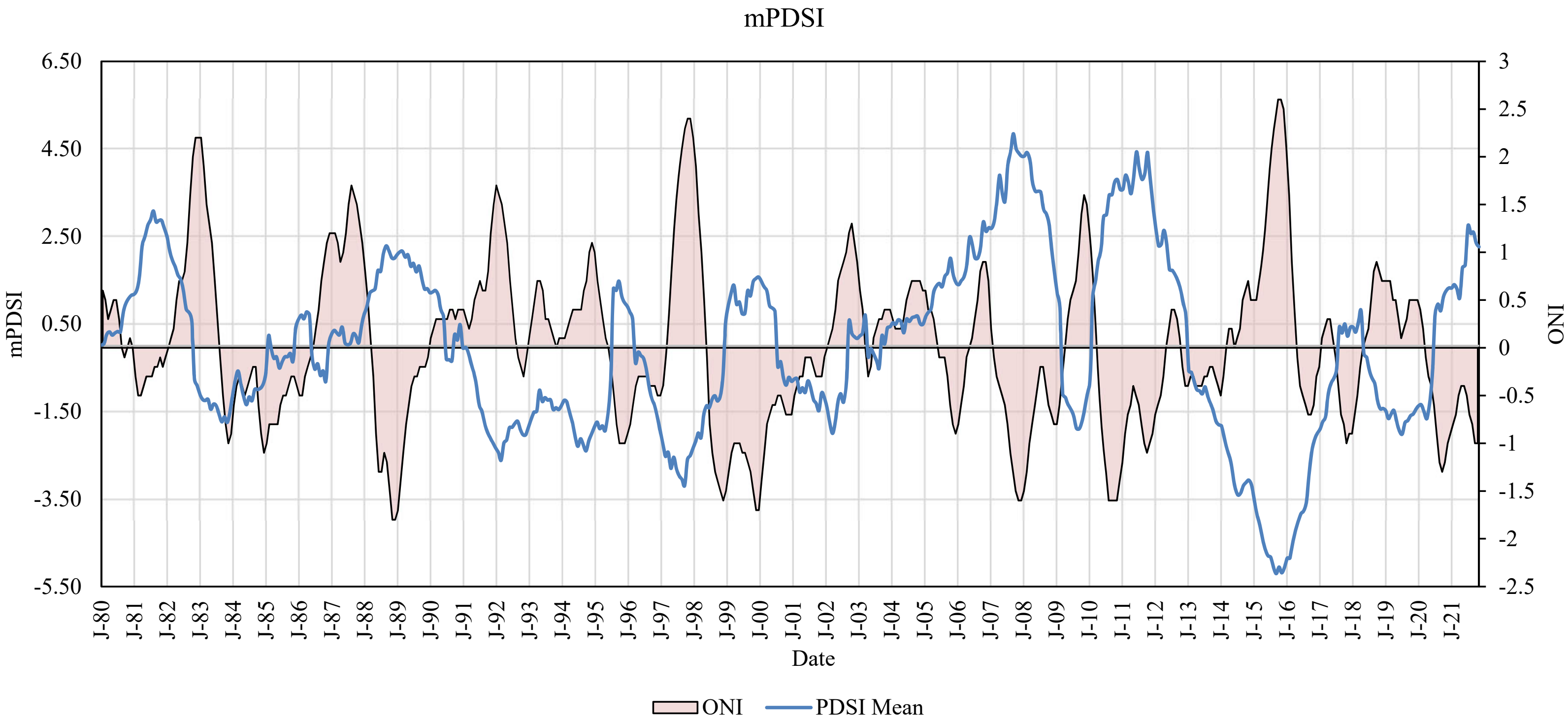


4. Results



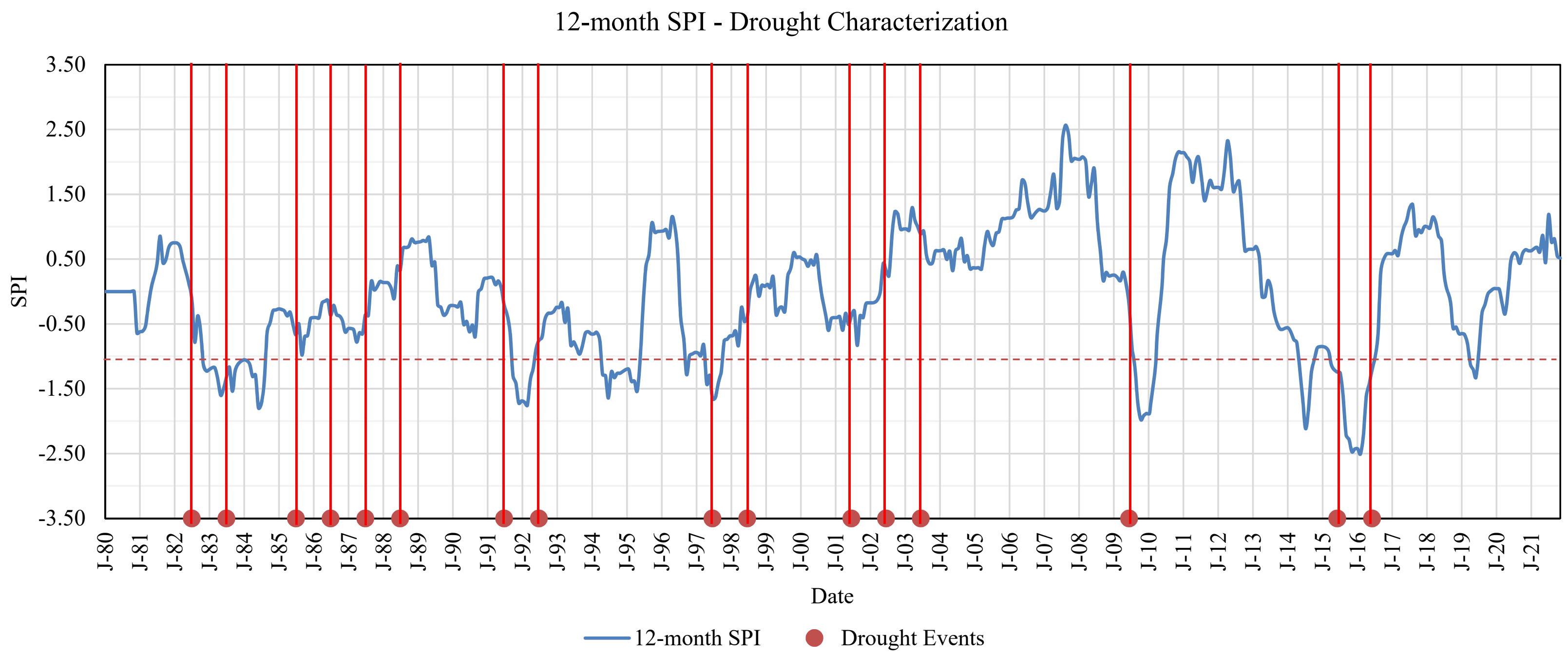
NDVI in the CGSM - Moving Average
NDVI
ONI
Date
0.5
0.4
0.3
0.2
0.1
0
3
2.5
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
J-00
J-01
J-02
J-03
J-04
J-05
J-06
J-07
J-08
J-09
J-10
J-11
J-12
J-13
J-14
J-15
J-16
J-17
J-18
J-19
J-20
J-21
ONI
NDVI Moving Average

4. Results



mPDSI
6.50
4.50
2.50
0.50
-1.50
-3.50
-5.50
mPDSI
3
2.5
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
-2.5
ONI
J-80 J-81 J-82 J-83 J-84 J-85 J-86 J-87 J-88 J-89 J-90 J-91 J-92 J-93 J-94 J-95 J-96 J-97 J-98 J-99 J-00 J-01 J-02 J-03 J-04 J-05 J-06 J-07 J-08 J-09 J-10 J-11 J-12 J-13 J-14 J-15 J-16 J-17 J-18 J-19 J-20 J-21
Date
ONI
PDSI Mean

4. Results



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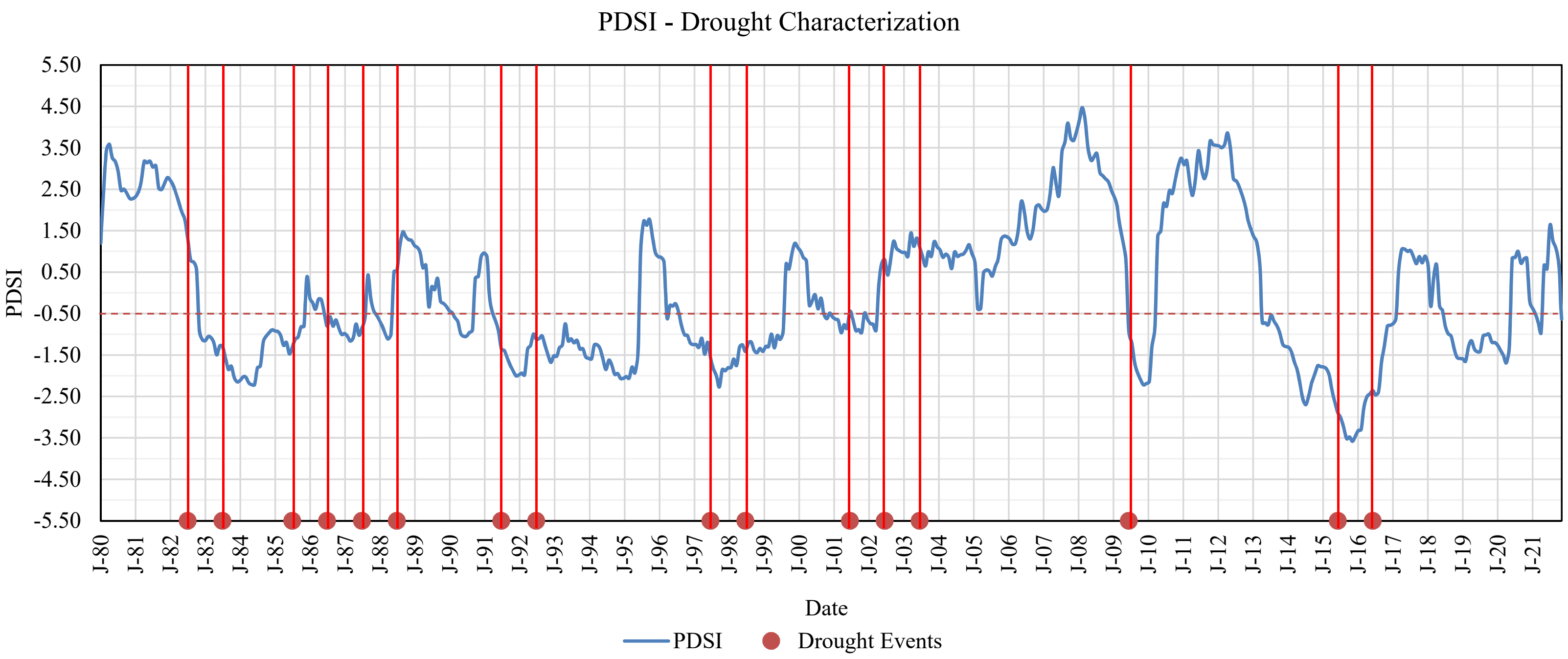
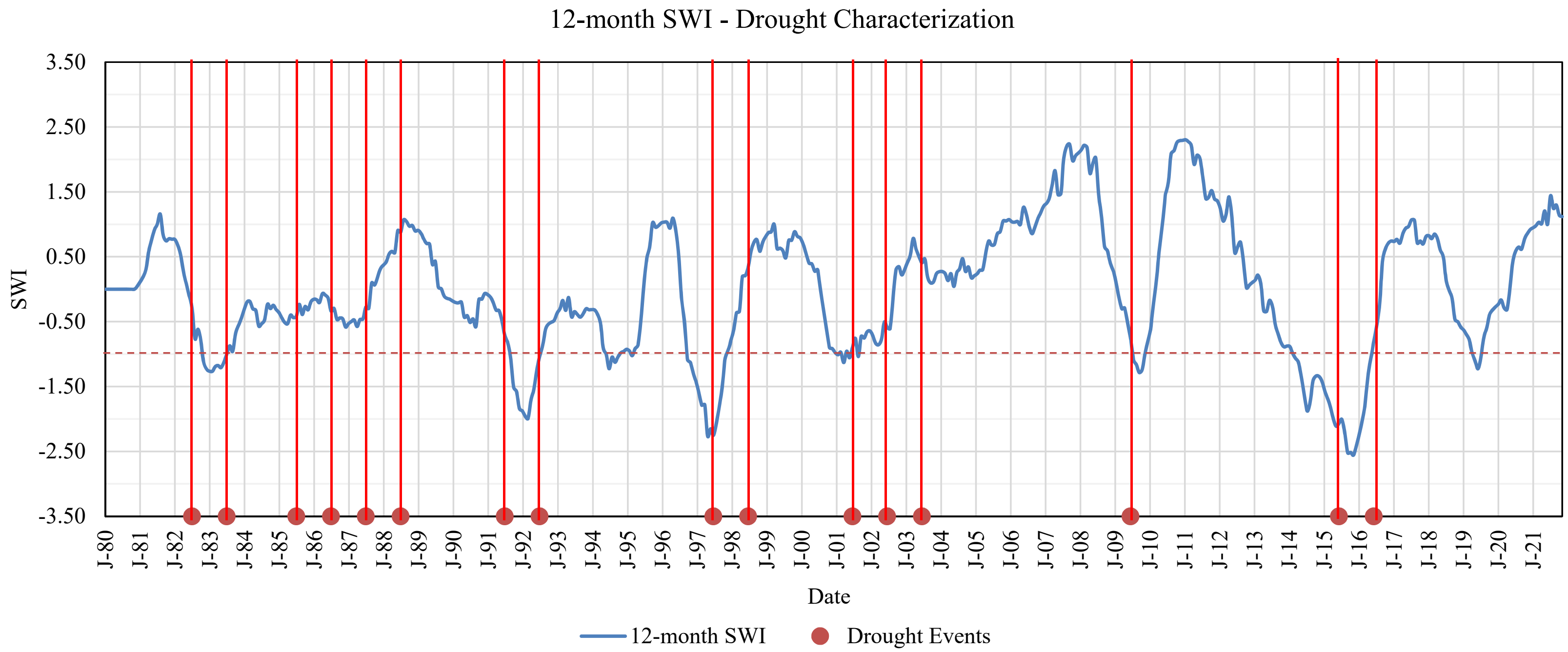
4. Results



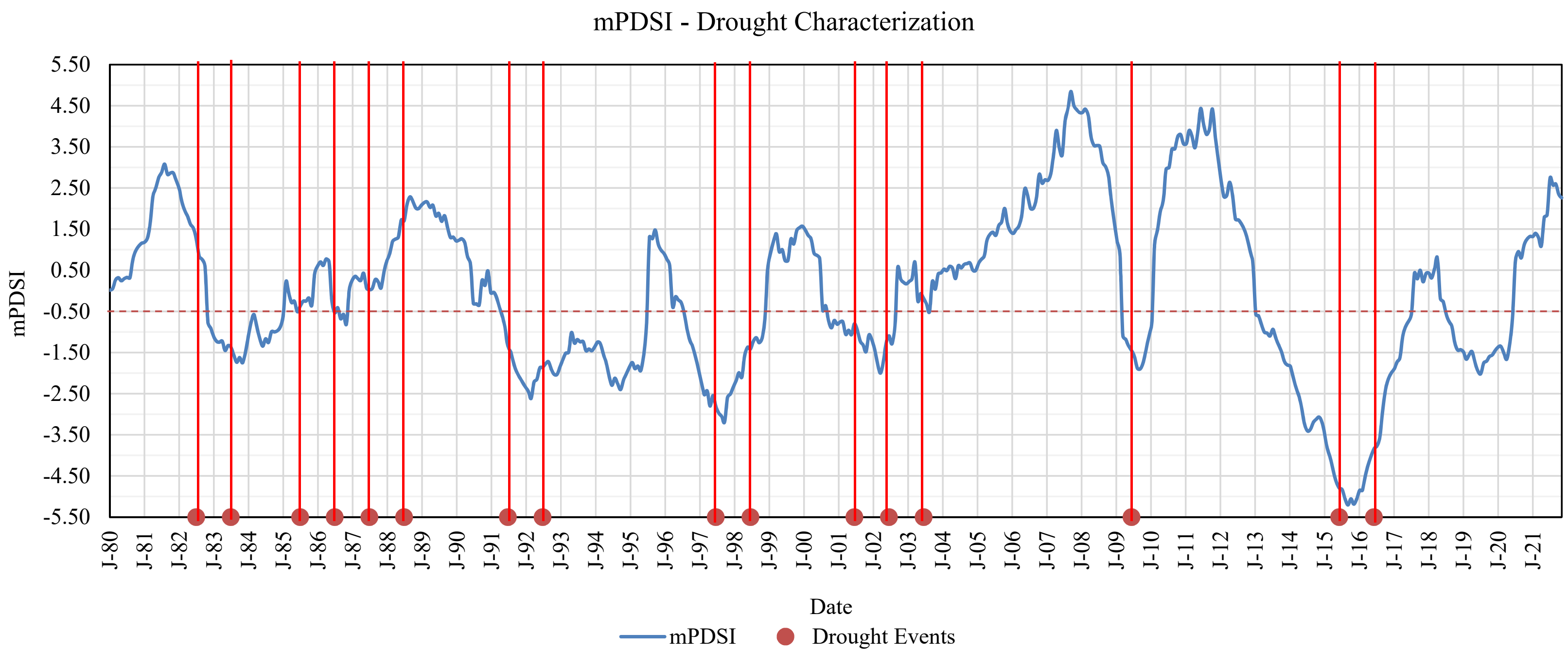
PDSI - Drought Characterization
5.50
4.50
3.50
2.50
1.50
0.50
-0.50
-1.50
-2.50
-3.50
-4.50
-5.50
PDSI
J-80 J-81 J-82 J-83 J-84 J-85 J-86 J-87 J-88 J-89 J-90 J-91 J-92 J-93 J-94 J-95 J-96 J-97 J-98 J-99 J-00 J-01 J-02 J-03 J-04 J-05 J-06 J-07 J-08 J-09 J-10 J-11 J-12 J-13 J-14 J-15 J-16 J-17 J-18 J-19 J-20 J-21
Date
PDSI
Drought Events

4. Results



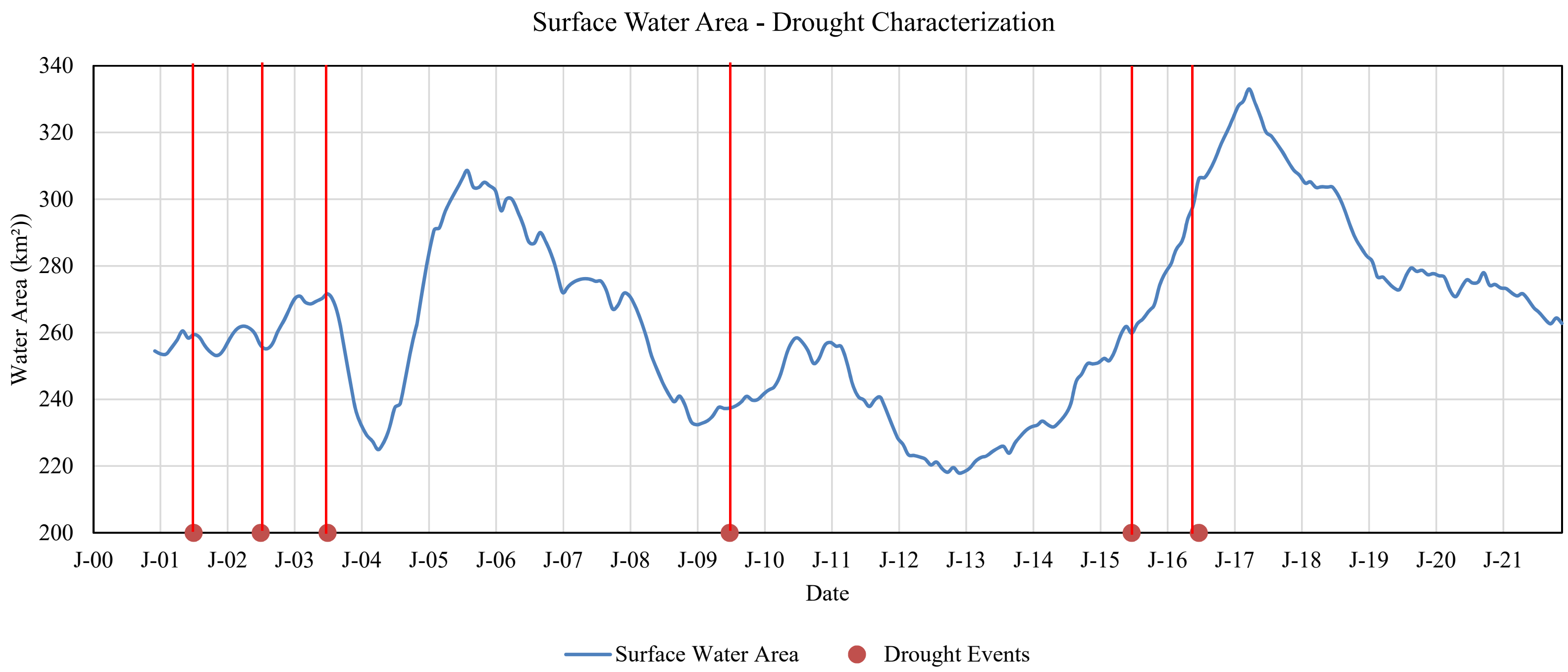
12-month SWI - Drought Characterization
SWI
3.50
2.50
1.50
0.50
-0.50
-1.50
-2.50
-3.50
J-80
J-81
J-82
J-83
J-84
J-85
J-86
J-87
J-88
J-89
J-90
J-91
J-92
J-93
J-94
J-95
J-96
J-97
J-98
J-99
J-00
J-01
J-02
J-03
J-04
J-05
J-06
J-07
J-08
J-09
J-10
J-11
J-12
J-13
J-14
J-15
J-16
J-17
J-18
J-19
J-20
J-21
Date
12-month SWI
Drought Events

4. Results



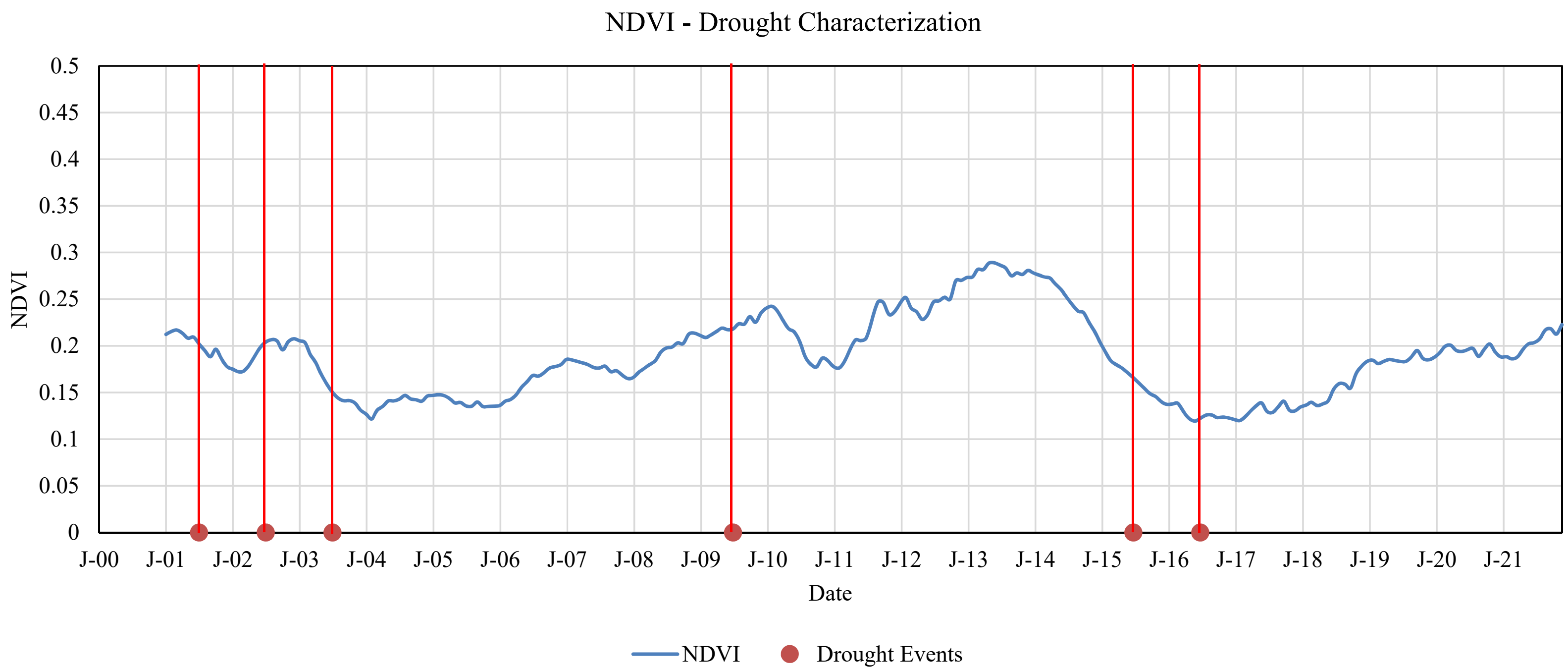
mPDSI - Drought Characterization
5.50
4.50
3.50
2.50
1.50
0.50
-0.50
-1.50
-2.50
-3.50
-4.50
-5.50
mPDSI
J-80 J-81 J-82 J-83 J-84 J-85 J-86 J-87 J-88 J-89 J-90 J-91 J-92 J-93 J-94 J-95 J-96 J-97 J-98 J-99 J-00 J-01 J-02 J-03 J-04 J-05 J-06 J-07 J-08 J-09 J-10 J-11 J-12 J-13 J-14 J-15 J-16 J-17 J-18 J-19 J-20 J-21
Date
mPDSI
Drought Events

4. Results



Surface Water Area - Drought Characterization
340
320
300
280
260
240
220
200
Water Area (km²))
J-00
J-01
J-02
J-03
J-04
J-05
J-06
J-07
J-08
J-09
J-10
J-11
J-12
J-13
J-14
J-15
J-16
J-17
J-18
J-19
J-20
J-21
Date
Surface Water Area
Drought Events

4. Results


NDVI - Drought Characterization
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
NDVI
J-00
J-01
J-02
J-03
J-04
J-05
J-06
J-07
J-08
J-09
J-10
J-11
J-12
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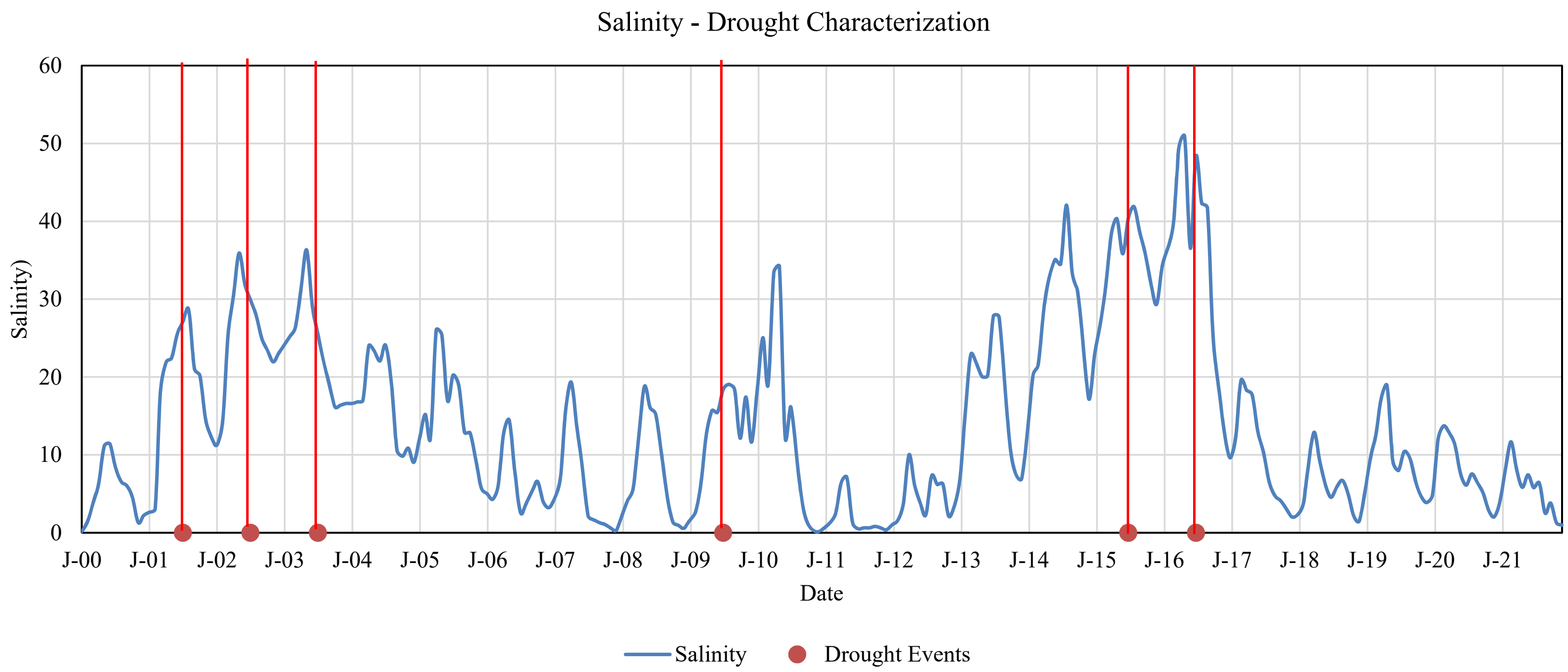
J-20
J-21
Date
NDVI
Drought Events

4. Results



Salinity - Drought Characterization
60
50
40
30
20
10
0
Salinity)
J-00
J-01
J-02
J-03
J-04
J-05
J-06
J-07
J-08
J-09
J-10
J-11
J-12
J-13
J-14
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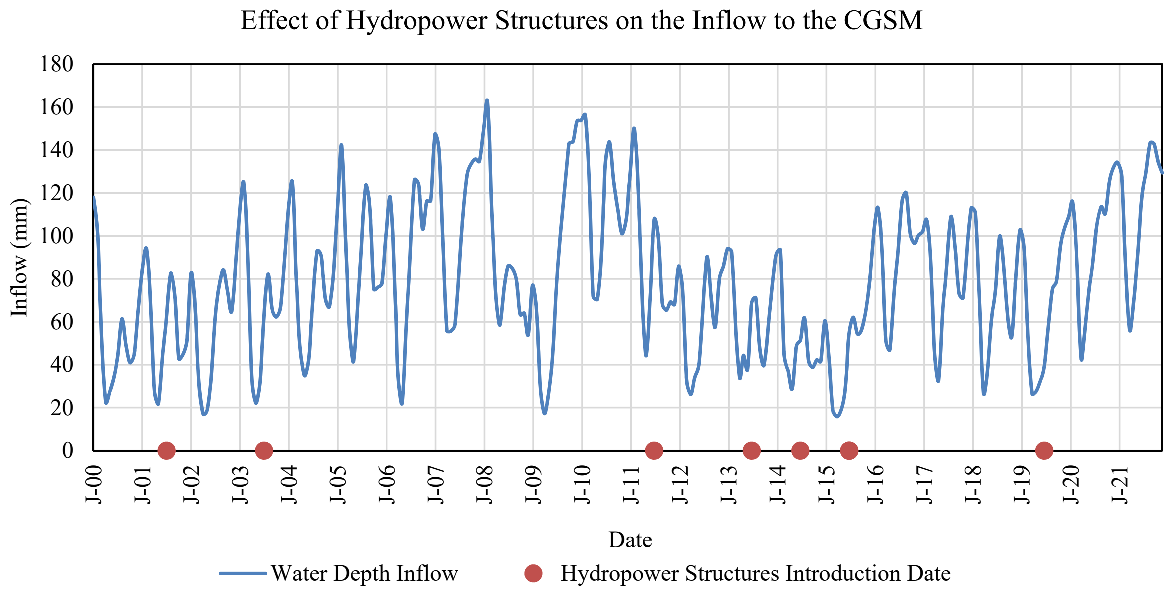
J-16
J-17
J-18
J-19
J-20
J-21
Date
Salinity
Drought Events

Effect of the hydropower



5. Conclusions and Recommendations

- Droughts in the CGSM require more attention, as until now its effects have been underestimated and more importantly overshadowed by the economic benefits that the hydroelectric energy provides for the country
- Relaying on a meteorological index for the drought assessment in the CGSM can produced misleading information and results, as it does not consider the real dynamics of the events
- The salinity (characterization) and the mPDSI (forecasting) were evaluated as the most effective methodologies for the assessment of droughts in the CGSM, despite the limitations of the information
- Building capacity around the use of remote sensing for natural risk assessments should be a priority, as it could help to overcome the limitation regarding the data availability
- The generation of a local multivariate index should be analyzed, as it could be the optimal solution for the assessment of drought events
- It is necessary to facilitate and improve the decision-making process by implementing both the IWRM and the IDM frameworks.
- The project focused only on the identification and characterization of the events, but it should be extended to evaluate the forecasting potential of the new indices and their effect in the risk management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