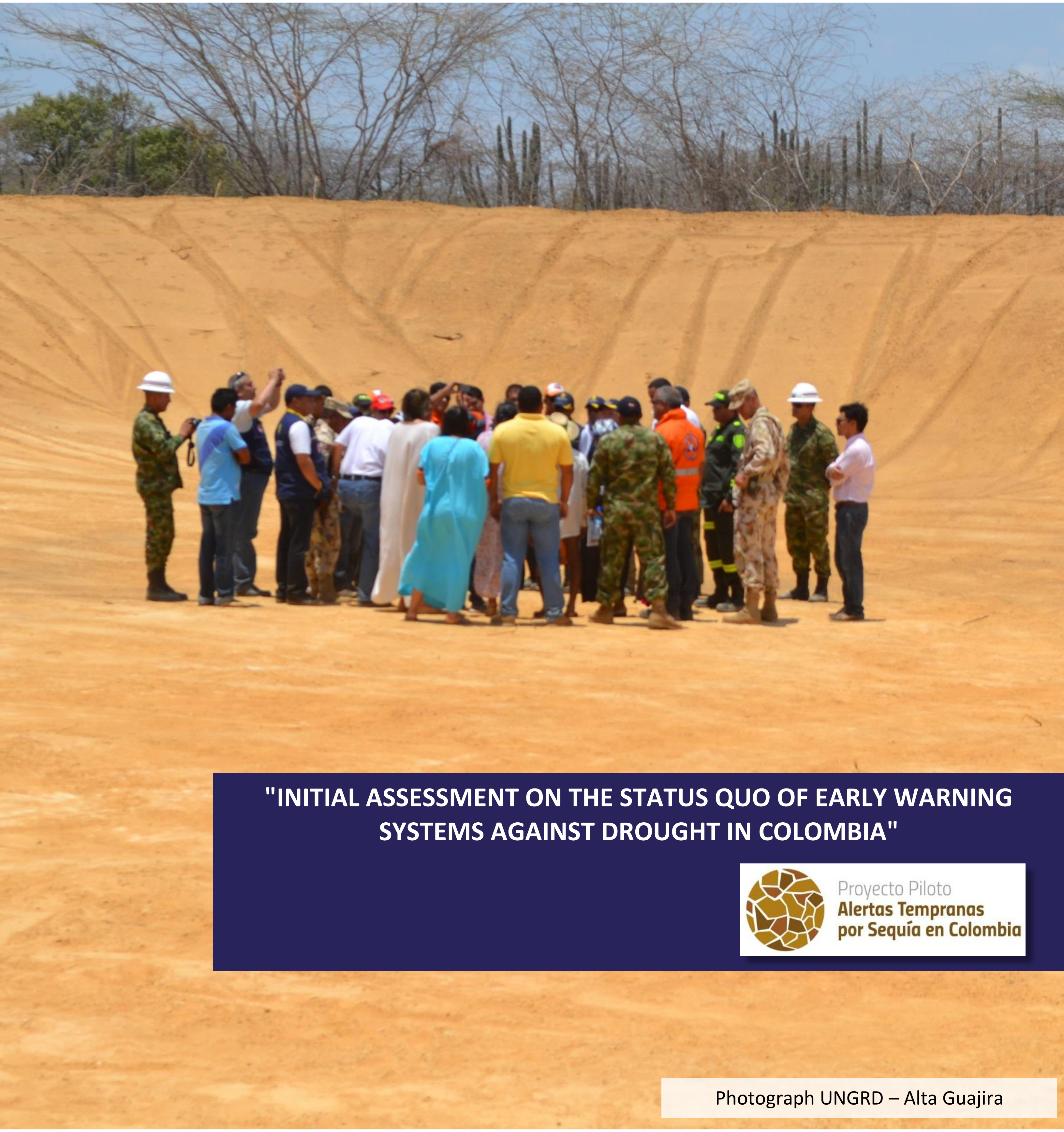

"INITIAL ASSESSMENT ON THE STATUS QUO OF EARLY WARNING SYSTEMS AGAINST DROUGHT IN COLOMBIA"

Proyecto Piloto
Alertas Tempranas por Sequía en Colombia

Photograph UNGRD – Alta Guajira

UNGRD
Unidad Nacional para la Gestión del Riesgo de Desastres - Colombia
Sistema Nacional de Gestión del Riesgo de Desastres

GOBIERNO DE COLOMBIA

United Nations
Convention to Combat Desertification

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

ACRONYMS AND ABBREVIATIONS

UNGRD: National Unit for Disaster Risk Management
SNGRD: National System for Disaster Risk Management
GRD: Disaster Risk Management
UNCCD: United Nations Convention to Combat Desertification and Drought.
IDEAM: Hydrology, Meteorology and Environmental Studies Institute
DIMAR: Maritime General Directorate.
IGAC: Agustín Codazzi Geographical Institute
SGC: Colombian Geological Survey
DNP: National Planning Department.
INS: National Health Institute
MADR: Ministry of Agriculture and Rural Development
MADS: Ministry of the Environment and Sustainable Development.
MINVIVIENDA: Ministry of Housing, City and Territory
MINMINAS: Ministry of Mines and Energy
SIATA: Valle de Aburrá Early Alert System
IDIGER: District Institute for risk Management and Climate Change
CCO: Colombian Ocean Commission
ERFEN: Regional Study of the El Niño Phenomenon
CIIFEN: International Research Center on El Niño Phenomenon.
WMO: World Meteorological Organization
UNISDR: United Nations International Strategy for Disaster Reduction

IRI: International Research Institute for Climate and Society
NOAA: National Oceanic and Atmospheric Administration of the United States
CAR: Regional Autonomous Corporation of Cundinamarca
CENICAFÉ: National Research Center on Coffee
CENICAÑA: Colombian Sugar Cane Research Center
CHEC: Caldas Hydroelectric Power Plant
CORPOCHIVOR Regional Autonomous Corporation of Chivor
CORPOGUAJIRA: Regional Autonomous Corporation of La Guajira
CORPOICA Colombian Agriculture Research Corporation
CORPONOR: Regional Autonomous Corporation of the Northeastern Border
CVC: Regional Autonomous Corporation of Valle del Cauca
EAB: Bogotá Aqueduct Company
EMPOPASTO: Water Works Company of Pasto
EPM: Public Companies of Medellín
FEDEARROZ: National Rice Growers Federation
INVEMAR: Marine Research Institute
PNNC: National Natural Parks of Colombia

PRESENTATION

The lessons learned in the past few years with the effect of climate variability in the country, and particularly those related to the rainfall deficit associated with the El Niño phenomenon, with serious consequences in agriculture, water, health, energy, environment, among others, are showing us the path to follow where we should conduct our efforts to reduce the impact caused by these risk factors in the Colombian economy.

Through the UNGRD and during the past six years, the new National Policy on Disaster Risk Management has changed its strategy of allocating resources under a transversal scheme of risk management in development plans. We went from concentrating disaster management resources (over 90% in the last decade) to prioritizing disaster risk reduction (currently over 60%).

The National Disaster Risk Management Plan 2015-2025 has established that "improving the knowledge on disaster risk in the national territory" should not only be the first of the five strategic objectives, but should be materialized through various strategies that constitute the decision-making base on safe investment, incorporation of sustainability criteria in development planning, land use planning and environmental planning processes.

One of the elements that are part of the knowledge are the EWSs, and the drought alert systems have become a fundamental tool to anticipate the probability of occurrence of this threat, which is considered one of the most complex due to its difficulty of forecast. In Colombia, climate diversity allows perception to be different and its impact is very specific to each region and to each sector sensitive to drought. This is why it is necessary to build systems that integrate all the drought indicators used for specific monitoring, that can show us what its effects on the community and its activities are, , and therefore include in the contingency plans which sectors should receive more attention.

Thinking about creating awareness on the sectors that are affected in one way or another by water deficit, the UNGRD promotes workshops to share experiences, knowledge, interdisciplinary groups that allow them to manage the wide flow of information in a comprehensive and interdisciplinary way in order to incorporate it into their risk reduction plans in the face of the effects of drought, which has caused them so many socioeconomic losses.

This research and technical effort is based on an initiative of a document prepared by the UNGRD and the Ministry of Foreign Affairs, where Colombia’s needs were raised based on the discussions from the ERFEN Committee, on the follow-up and monitoring of the “El Niño” phenomenon and the need to strengthen communication between all entities involved, from a "Pilot Project on Drought Early-Warning Systems in Colombia", with the aim of promoting, among all sectors, the drafting of “Seasonal Drought Outlook Strategies for Colombia" as a mechanism of institutional action in the country for decision-makers. This project was accepted by the Secretariat of the of the United Nations Convention to Combat Desertification and Drought – UNCCD and a Memorandum of Understanding was signed with the National Risk Disaster Management Fund of the Republic of Colombia

This task was undertaken with the conviction of providing useful information to society, allowing for risk reduction, facilitating disaster management and the implementation of development plans. This document is one of the outputs with a multidisciplinary, interdisciplinary, participatory, and open approach, drafted in pursuit of sustainable development from the interpretation of the contributions made by the experts who participated in working groups.

I appreciate the support offered by the Secretariat of the United Nations Convention to Combat Desertification - UNCCD for the trust placed in the professionals that lead this project.

I want to thank the group of professionals from the Ministry of Agriculture and Rural Development, Ministry of the Environment and Sustainable Development; Ministry of Housing, City and Territory; Ministry of Mines and Energy, IDEAM, DIMAR, SGC, CORPOGUAJIRA, UPME, DNP, EPM, ISAGEN, CIAT, CORPOICA, CAR, FEDEARROZ, FENALCE, FAO, FINAGRO, ECOSAGA, ASOHOFRUCOL, the Superintendent of Public Services, for their inputs and contributions, who with their expertise and lessons learned from the point of view of affectation in their sectors, made the necessary recommendations on the weaknesses and possible solutions to consolidate recommendations for an Early Warning System for Drought in Colombia, which have resulted in this document.

CARLOS IVÁN MÁRQUEZ PÉREZ
Managing Director

INTRODUCTION

In the past decades, Colombia has felt the influence of climate variability phenomena with greater severity. The most documented ones due to their effects and impact are the events of "El Niño" and "La Niña". Others like the tropical waves of the east, the hurricanes, the Madden & Julian intraseasonal waves[1] also cause anomalous behaviors in precipitation in different regions of the country, and are subject of study that are being included in the weekly forecasts and the monthly trends, for being events that appear within the seasonality in tropical areas and that have influence in the rainy and less rainy seasons.

Likewise, it has been possible to establish that the frequency and intensity of these events continue to increase, and that their impact on the national economy has been strong. It is necessary to be prepared with contingency plans that implement surveillance and monitoring systems to support the generation of more effective early warnings and alerts that reduce their vulnerability and risk in the face of current impact scenarios.

One of the concerns of the members of the entities that make up the National Technical Committee for the study of the "El Niño" phenomenon - CTN ERFEN (IDEAM, DIMAR, SGC, DNP, MINISTRY OF FOREIGN AFFAIRS) which is part of the Permanent Commission for the South Pacific - CPPS, operating since 1977, is the need to predict with sufficient anticipation the oceanic-atmospheric changes associated with the possible occurrence of the El Niño-La Niña phenomena. This allows, at a given moment, the reduction of the risk in the face of climate effects (rain increase or deficit) and reduces the impact that these phenomena cause in the different productive sectors (agriculture, energy, industry, transport and health, among others).

This possible early prediction is, in turn, extremely important for the entities of the National Disaster Risk Management System (SNGRD), each of them within their roles, functions and competencies, including the territorial entities that manage the risk headed by the municipality and department authorities, and of course for the Regional Autonomous Corporations, as the main regional environmental entities.

Normally, generalized drought events are associated with the occurrence of El Niño phenomenon, considering that they have an impact especially when they occur with a moderate or strong intensity, causing rainfall deficits in the Andean, Caribbean and central and northern regions of the Pacific. It is noteworthy that in this last region, being an area of intense rainfall throughout the year, although there may be a significant decrease in rainfall, this situation does not indicate records with low amounts of rain that imply a markedly dry condition.

[1] The Madden & Julian Oscillation (MJO for its abbreviation in English) is a wave or intraseasonal fluctuation that propagates from west to east along the equatorial region in all the planet, with a cycle in the order of 30 to 60 days, as part of a natural component of the ocean-atmosphere coupled system. The MJO is responsible for much of the climate variability on intra-seasonal level (every week) in the equatorial region, causing variations in important Oceanic and atmospheric parameters, such as: speed and direction of the wind at low levels and high in the atmosphere, clouds, precipitation, surface temperature (SSTS) sea and surface evaporation in the ocean. Source: IDEAM

The most recent drought experience was related to the occurrence of the last El Niño phenomenon in 2014-2015-2016, whose influence in Colombia was manifested precisely by a rain deficit in the rainy seasons, especially in the Caribbean and Andean regions, accentuating the dry seasons. Its climate effects and impact were felt in the productive, environmental and all other sectors in the country, due to the fact that these sectors' yields depend not only on technological and economic factors, but on the climate resource.

Despite the fact that the warnings were given with enough time in advance, the execution of the contingency plan coordinated by the UNGRD cost the country 1.6 trillion pesos (COP), with the agricultural sector being one of the most affected in times of drought. According to data from the Ministry of Agriculture and Rural Development for the year 2015 during the El Niño season 2014-2016, there was an agricultural impact in 1,185,763 ha in 20 departments in the country, with the greatest impact in Atlántico (403,365 ha), Córdoba (243,677 ha), Nariño (108,250 ha), Antioquia (92,344 ha) and Casanare (67,575 ha). Among them, the most affected crops were: cassava, palm, barley, rice, potatoes, corn, cotton, panela cane, plantain, cocoa, beans, tobacco, sorghum, banana, sugar cane and soybeans.

With regard to the livestock sector, it suffered the effect of a loss of 3,421,590 livestock units in 15 departments in 2015, including cattle, swine, poultry, horses, among others. Córdoba with 2,389,769 livestock units, followed by Antioquia (465,157 units) and Boyacá (188,818 units) were the departments which suffered the greatest effects. According to the National Livestock Breeders Association (FNG, for its acronym in Spanish), in the period between May 2015 - January 2016, the partial losses in the livestock sector reached $632 billion pesos. Looking at these figures is enough to infer that Colombia is highly vulnerable to extreme weather events.

Under these scenarios, the Ministry of Foreign Affairs presented in the Session of the Convention to Combat Desertification in New York held in 2016, the possibility of making a "Pilot Project on Early Warning for Drought in Colombia", in order to promote among all sectors the drafting of seasonal drought outlook strategies, which would serve as an institutional action mechanism in the country for decision-makers. This document was prepared by the UNGRD based on the discussions in the ERFEN Committee.

In a Collaboration Framework, a Memorandum of Understanding was signed between the Secretariat of the United Nations Convention to Combat Desertification - UNCCD and the National Fund for Disaster Risk Management of the Republic of Colombia to develop the Pilot Project on Early Warning Systems for Droughts in Colombia, considered very useful in risk management in lieu of future drought periods, seeking to reduce the negative impact generated by the deficit of water resources on the different sectors of the Colombian economy.

This document corresponds to a first report that constitutes the baseline and starting point for interdisciplinary work with experts in meteorology, hydrology, etc., who are linked to public and private entities of the agricultural, energy, water and environmental sectors.

The conclusions and basic concepts on drought and warning systems in general that were drawn from the first Workshop on "Drafting Seasonal Drought Outlook Strategies in Colombia", where experts from the entities participated, are part of this document. Likewise, the National Catalog of Hydrometeorological Stations of IDEAM and the catalog of other private institutions provided by IDEAM are included, supplemented with information provided by said entities.

It also presents inputs or reviews of some early warning systems from the point of view of monitoring at the national level and some worldwide as contributions to the knowledge on a topic as important as drought.

We hope that this work contributes to achieving the project’s first objective: "To strengthen monitoring systems and models for seasonal prediction in Colombia", with inputs that serve in the preparation of the baseline to update and coordinate hydrometeorological, soils and vegetation cover monitoring instruments and tools as components of the Drought Early Warning System.

1. CONCEPTUAL FRAMEWORK

Photograph UNGRD – Alta Guajira

1. CONCEPTUAL FRAMEWORK

1.1. Concepts

In order to establish a reference level that allows unifying the different concepts related to drought in a certain way, some of them are included below:

1.1.1. Weather

There are different ways to describe the definition weather. Perhaps the most basic of them establishes that it is the state of the atmosphere in a specific moment and place through the measurement of the behavior of the different elements of climate, namely: precipitation, temperature, relative humidity, pressure, solar radiation among others. Sometimes, in some of the definitions, the atmospheric phenomena that occur in very short term, such as fog, mist and rays, are involved, but always emphasizing that they are registered in term of hours. Instrumental and sensory or visual observations are taken into account to determine weather. Aspects such as visibility, cloud types and others stand out.

It should be noted that the weather can be forecasted from the analysis of various data and from information processed from them. Examples of this process are synoptic maps or time maps.

1.1.2. Climate

On many occasions, climate is usually defined as the average state of the atmosphere. Thus, they are the set of conditions that characterize the average state of the atmosphere (observations of long periods of time, usually not less than 30 years, known as Climate Standards). That is to say, in order to get to know the climate of a certain area, it is necessary to have a good record of climate variables with which it is possible to establish the average behavior of each of them throughout the year, which is known in many areas as the annual cycle. Likewise, from the data of different stations on a certain area, it is possible to establish the spatial behavior of each one of the variables.

Due to the above, the weather conditions, which in various scenarios and situations is only recognized as "weather", determines the activity of the phenomena present in the atmosphere in a lapse of hours or very few days. When analysis of data of extended periods is carried out, the determination of the averages allows talking about climate.

1.1.3. Climate Variability

Refers to the fluctuations in climate observed during relatively short periods of time. There are different scales within climate variability, which are largely defined by the chronological time scale in which they present themselves: seasonal, which corresponds to the fluctuations between seasons of greater and lower rainfall; intraseasonal refers to those fluctuations that occur between seasons, in periods that can range between 30 and 60 days, interanual, which occurs between years and where El Niño Oscillation of the South (ENSO) Phenomenon stands out; and interdecadal which determines fluctuations that occur between decades. Phenomena associated to these scales affect the country’s climate, so it is possible to find wetter and drier years. This situation allows determining that climate one year is different from any other, and that it is influenced not only by the "normal" transit of the Intertropical Confluence Zone (from south to north during the first semester of the year and vice versa during the second semester), but also in turn, by the ocean atmospheric dynamics in the Atlantic and the Pacific, seen in a global context.

El Niño Phenomenon:

Although some climate variability phenomena can be recognized and distinguished that in one way or another support or inhibit rainfall in the national territory, emphasis is placed on the occurrence of El Niño, due to its impact associated with rainfall deficits in a large part of the country. This generates droughts, especially when its duration is prolonged and its intensity is significant.

ENSO phenomena are formed in the tropical Pacific Ocean, and in their warm phase they are known as El Niño. In order for it to form, the surface is required to present a weakening of trade winds that normally blow from the east. In this situation winds begin to predominate in the west, bringing warm waters from the west to the center and east of the Pacific basin. When the coupling between the ocean and the atmosphere is evident, that is to say, when the warming of waters is clear (positive anomalies in surface temperature of the sea in a good part of the tropical Pacific) and there is an evident predominance of westerly winds, it is said that the phenomenon has been consolidated (figures 1 and 2).

In the study of the dynamics and evolution towards a possible El Niño event, the term anomaly is involved. It is calculated based on the difference between the variable's registered value and its average. In this context, not only the anomalies of the surface and subsurface temperatures of the sea (as main oceanic indicators) are evaluated, but also the anomalies of the winds in surface and in height and another series of indicators of the ocean and the atmosphere. These determine the coupling of the atmosphere and the ocean. In addition, some indexes and indicators are evaluated to determine the possible development of an El Niño phenomenon.

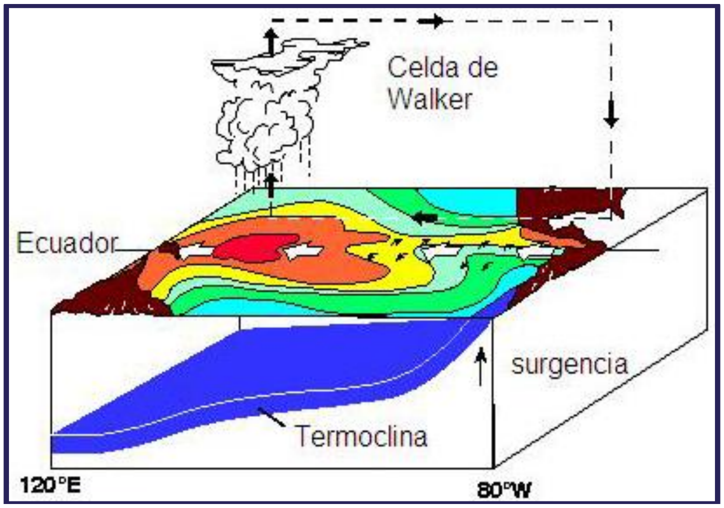

Figure 1. Scheme where the ocean-atmosphere conditions are visualized under a neutral scenario. The surface winds flowing from the East (white arrows); warmer waters on the surface to the west (red-orange colors) and cooler to the east (green-blue); the thermocline, which corresponds to the line that joins points where the water temperature is equal to 23°C, with an inclination that allows to have fresh waters close to the surface in the eastern tropical Pacific. Source: edited from NOAA/PMEL/TAO

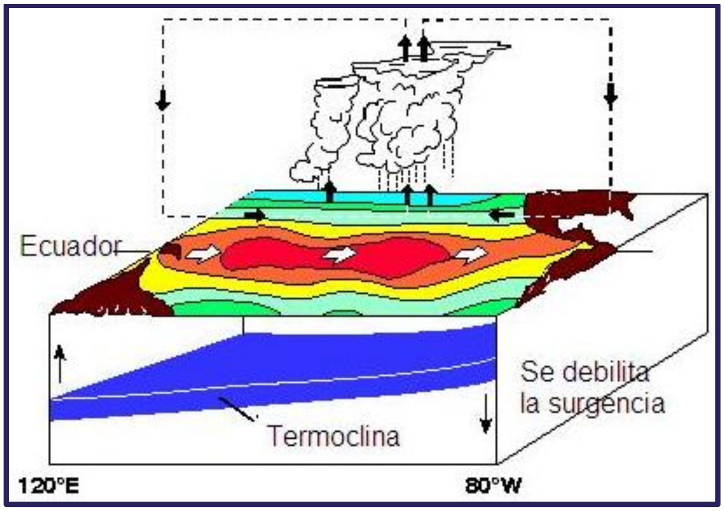

Figure 2. Scheme where the ocean-atmosphere conditions are visualized under an EL NIÑO scenario. The winds on the surface change direction and begin to flow from the West (white arrows); Warmer waters on the surface expand along the tropical Pacific (red-orange colors); The thermocline, which corresponds to the line joining points where the water temperature is equal to 23°C, is deepened especially in the center-east of the tropical Pacific, resulting in the deepening of the fresh water in the east. Source: edited from NOAA/PMEL/TAO

Within these indicators, the National Oceanic and Atmospheric Administration (NOAA) of the United States has developed the Oceanic El Niño Index (ONI), which is the international indicator that is most recognized and used to determine the beginning, duration and intensity of an El Niño Phenomenon. Its calculation is based the behavior of sea surface temperature anomalies in the Niño 3.4 region (Figure 3), with the need to have at least five (5) consecutive months with anomaly values greater or equal to 0.5°C. To the extent that the duration under these conditions is greater and the values significantly distance themselves from the threshold, the El Niño event can be cataloged as intense.

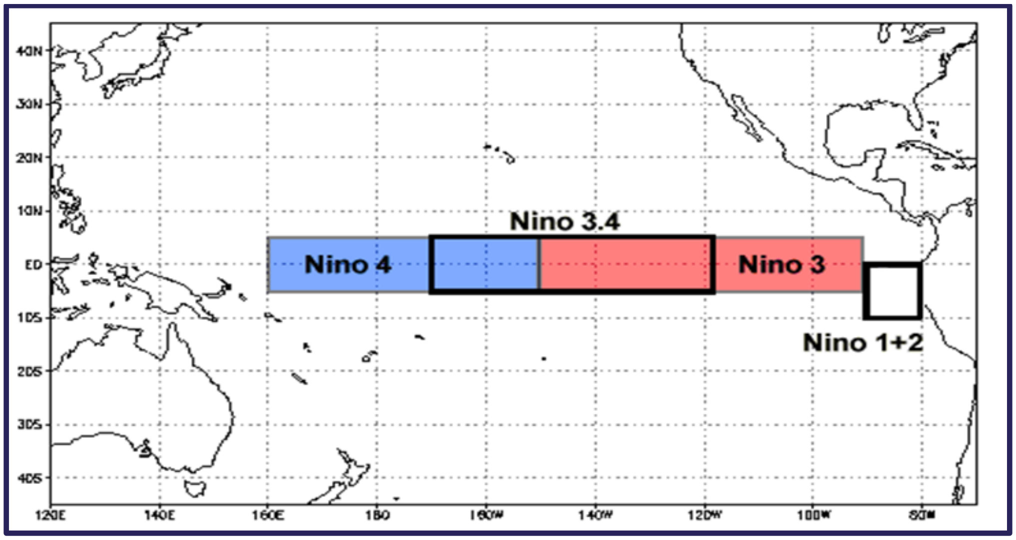

Figure 3. For various operational and investigative purposes, the tropical Pacific Ocean has been divided into 4 regions; Within them, Region 1 + 2 is the closest to the South American continent, the Niño 3 contiguous to the previous one, Niño4 over the Western Pacific and Niño 3.4 over the central zone with a portion of each of the Regions 3 and 4. Graphic source: NCDC/NOAA.

In that order of ideas, the magnitude of the climate effects of an El Niño phenomenon responds largely to the intensity of the event. It is worth mentioning that, in the presence of an El Niño, rainfall amounts are usually below the monthly averages of the historical series, especially in the Caribbean, Andean and Pacific regions. However, as IDEAM has pointed out in various scenarios before Risk Management entities, the SINA, productive sectors and media, among others, an El Niño phenomenon does not suppress rainy seasons, but tends to weaken them.

Its climate effect not only results in a deficit of precipitation. A considerable increase in air temperature is also notorious, with higher levels of solar radiation and therefore notorious increases in evapotranspiration. Additionally, it is important to emphasize that El Niño phenomena reach their greatest intensity towards the end and beginning of the year, just when the dry season (less rainfall) occurs in most of the country, making droughts more critical in many areas of the Caribbean and Andean regions. This suggests that the magnitude of the climate effect also depends on the time of year. Emphasis is also placed on the fact that the Pacific region (an area in which rainfall volumes are significant throughout the year), beyond being able to have a deficit effect due to the presence of an El Niño, fails to be impacted so that a drought process in that region can be glimpsed.

Now, it is important to clarify that climate effect another the impact are two different things. The latter is more associated with the vulnerability of each socioeconomic sector and the ecosystem itself.

Given this panorama, an inquiry is usually posed on the periodicity or frequency with which the ENSO phenomena take place. Most of the literature indicates that they can appear between every 2 and 7 years, which suggests a significant uncertainty in relation to the prediction of an El Niño event associated with the referred frequency. On average, the warm El Nino phase usually lasts approximately between 8-10 months. However, it is still under study given that the duration and frequency with which it happens is not fixed.

1.1.4. Climate Change

The Earth's climate has not been static or permanent. In the planet's history through paleoclimate studies, it has been possible to establish cold (glacial) and warm (interglacial) periods, linked to changes in the energy received from the sun, known as solar radiation. The above is known in the field of science as natural climate change. Another perspective of the concept is associated with anthropic activities. The close relationship between the increase in greenhouse gases and the increase in air temperature worldwide is notorious. This situation has been more evident since the 1940s in the immediately preceding century, that is, almost 80 years ago, just coinciding with the industrial revolution.

To be able to establish climate trends and therefore climate change, there must be series of records of at least 30 years. When we talk about shorter climate variations in the time scale we can be referring to climate variability in one of its different scales, or to meteorological phenomena in the scale of hours or few days.

At a national level, the analyses and research carried out by Professor Thomas Van der Hammen in some sectors of the Cundiboyacense Highlands, allowed verifying the occurrence of other glaciations prior to the last, but there is still no absolute chronology of them. There is a chronology of climate changes and variations in vegetation.

This climate change, more significant now that in the recent past, is given mainly by changes in variables such as temperature, precipitation and humidity mainly. Studies and more recent analyses show that the temperature trend around the world is rising, while the behavior in terms of rain is differential. There are areas where there is a trend towards less rain, and there are others which show that rain has tended to increase. In addition, in regards to rain, it has been established that it is now more common to have short periods of rainfall, in popular slang known as ”pouring”. This condition allows estimating greater scenarios of erosion and sedimentation, with the aggravating and growing increase of deforestation in some areas of the country.

The relationship indicated between the increase in the emission and accumulation of greenhouse gases in the atmosphere such as carbon dioxide (CO2), methane (CH4), sulfur dioxide (SO2) and nitrous oxides (NOx), the increase in temperature has been generating relevant regional changes. In this context, in various situations, especially when extreme events occur, there is a tendency to associate climate change with events of another scale such as tropical cyclones (meteorological phenomena) or as ENSO phenomena (climate variability), among others. Basically, the aforementioned association has reached conclusions related to a greater frequency of strong events. This way, an influence of climate change on the El Niño phenomena has been considered, with the consequences already mentioned associated with drought.

1.1.5. Drought

The most basic definition of drought is related to the lack of rain for a significant period of time, during which the demand for water, given by the needs and requirements of plants, animals and human beings, exceeds the availability of water resources.

In order to better contextualize drought, some definitions will be mentioned:

Normal and recurrent climate characteristic. It occurs practically in all climate zones. It is originated by a deficiency in precipitation for a long period of time considering the area´s normal characteristics, and consequently brings a water shortage that affects both human beings and nature. (Moreno, M., 2004)

Temporary absence or shortage of water in a region compared to the usual conditions within water availability of soils. A drought is a period of unusually dry weather that persists long enough to cause economic, environmental or social problems. (Terminology on Disaster Risk Management and Threatening Phenomena, UNGRD, 2017)

A phenomenon that occurs naturally when rains have been considerably lower than the normal levels recorded, causing an acute water imbalance that harms the production systems of land resources. (United Nations Convention Against Desertification in Countries Affected by Severe Drought and Desertification, 2004)

Drought is a harmful and silent phenomenon that occurs as a result of levels of precipitation being lower than expected or than normal, and that, when it lasts for a season or for longer periods, causes rainfall to be insufficient to meet with society's and the environment's demands. (World Meteorological Organization, 2006)

A drought is such when the phenomenon has adverse effects on man. This way, if there is a period of zero or scarce precipitation compared to the normal rainfall records for a given area that affects local ecosystems but does not have consequences for human beings and their activities, it should not be considered as a drought. However, if the same conditions are present and consequences are observed on man or his activities, a drought should be considered. (National Drought Mitigation Center, 2003).

In the workshop held on October 19th as part of the project in question, work was done with experts that were divided into five working groups according to the sector (environment, energy, agriculture (2) and water). The methodology consisted in making them aware of all the previous definitions as well as the types of droughts, so that they elaborated on one or assumed one of these definitions for each working group, according to their subject matter and effect. In the end, by consensus, only one definition was obtained. (See table 1)

Some groups defined drought in their own words. Others, such as the water sector working group and one of the agricultural sector working groups, took into account the definitions of hydrological drought and agricultural drought respectively, taken from the document (Drought in Colombia technical note, IDEAM, 2006). These definitions were also socialized in the workshop. In the end, by consensus, the definition of the energy sector was adopted.

Although sudden water level increases and landslides are often recognized as extreme events that generate the most disasters in many areas, droughts associated with the "upsurge" of a dry season can be devastating, being as they disturb food's production processes, making them stop entirely at times. Of course, in this situation causes a setback in the socioeconomic activities of the region that suffers the effects of the drought, sometimes having an impact on the national economy. Not only is its negative impact notorious in agriculture, but the decrease in the water supply also causes pastures to die and, in extreme cases, there is the death not only of flora, but also fauna.

In Colombia, drought events have a high impact in different municipalities of the country. Thus, in the presence of moderate to strong intensity of El Niño phenomena, water shortages are recorded in various sources that supply rural and municipal aqueducts.

Another important aspect is the impact that the changes that have been taking place in the rain patterns have on drought, especially because their distribution over a month is now more heterogeneous than in the past. This situation means that drought events can occur and increase in dry seasons (with less rainfall), especially between December and March, when in many strategic areas of the country there is fewer or no rainfall.

1.1.6. Types of Drought

As it was possible to observe in the technical working groups in the aforementioned workshop, depending on the context of each sector there are usually different definitions that, beyond being very close conceptually, have some difference related basically to the impact that a drought event has in each of them. Additionally, it is important to mention that there are several the approaches to the different types of drought, mainly considering meteorological, climatological, hydrological and edaphological variables.

Meteorological Drought:

This drought is based on a single parameter, the amount of precipitation recorded due to given atmospheric conditions compared to the historical record of average rainfall for an area or region; if there is reduction of precipitation, there was meteorological drought. (Drought in Colombia. Technical note, IDEAM, 2006)

Table 1. Definition of Drought by sectors

SECTOR	DEFINITION
Environment Sector	Deficiency in water availability during a given period of time that is outside the normal thresholds, whose impacts depend on the particular conditions of each territory such as: environmental offer (water and ecosystem), capacity and land use, and resilience of communities and the ecosystems.
Energy Sector	An anomalous decrease in rainfall with respect to historical averages, which affects the natural hydrological cycles as well as production systems and other environmental and socio-economic activities in the country or region in particular.
Agriculture Sector -Working Group 1. This sector agreed with the definition of agricultural drought of the document (Drought in Colombia, technical note, IDEAM, 2006)	Agricultural Drought: Agricultural drought occurs when the water expected either by precipitation or storage in the soil or in the different bodies of water is not enough for the crops to grow and develop properly. Its impact is limited to the state of the crops and does not take into account any other consequences that a drought may cause.
Agriculture Sector -Working Group 2.	Atypical hydro-meteorological event characterized by the deficit of the water resource that is not enough to satisfy the environmental, social and economic system’s demand, causing a negative impact on the ecosystem and livelihoods in the population.
Water Sector This sector agreed with the definition of hydrological drought of the document (Drought in Colombia, technical note, IDEAM, 2006)	Hydrological Drought: Associated with the effects of low precipitation periods on the supply of surface or groundwater. The frequency and severity of this drought is often defined by the level of the rivers or other scales. In addition, this drought is usually different from the occurrence of meteorological or agricultural drought. This is due to the fact that it takes more time for precipitation deficiencies in the components of the water system to be evident, such as soil moisture, river levels, lakes, reservoirs and groundwater. Although climate is the main contributor to hydrological drought, other factors such as changes in land use, soil degradation and construction of dams, among others, affect and area’s hydrological characteristics.
GENERAL DEFINITION BY CONSENSUS	Abnormal decrease in rainfall with respect to historical averages which affects natural hydrological cycles and affects production systems and other environmental and socioeconomic activities in the country or ina particular region.

It is usually defined from a threshold of precipitation deficit that is reached during a predetermined period of time. The chosen threshold (for example, 75% of normal precipitation) and the duration (for example, six months) will vary depending on the location and depending on the users' needs and activities (World Meteorological Organization, 2006).

According to its definition, meteorological drought is the origin of the other types of drought. In turn, the origin of the scarcity in rainfall can be attributed to an "exacerbation" of dry conditions or less rainfall due to alterations in the ocean-atmosphere system, as a result of natural climate variability processes or others caused by man.

Meteorological drought may refer in Colombia to the seasonality of dry seasons (or less rainy seasons), especially in sectors of the Caribbean, Andean and Orinoquía regions. Here it is important to mention the clear differences that occur all over the country in terms of these seasons. While in some areas of the Caribbean coast it is normal to have fewer or null rainfall (from January and until much of April), in many sectors of the Orinoquía and the Andean departments, these seasons (regularly between January and March) usually have small amounts of precipitation, logically decreasing their intensity and frequency in relation to the rainy months.

Therefore, in order to analyze meteorological drought in Colombia, one should not only consider the seasonality of dry seasons (or seasons of less rainfall), but also the climate variability linked largely to the occurrence of the El Niño phenomenon and the trends in weather patterns as a result of climate change. Finally, it is important to mention that this type of drought does not only involve precipitation. The anomalous behavior of other climate variables in the aforementioned seasons may mean an increase in temperature as well as important changes in winds, solar radiation and humidity that result in an increase in evapotranspiration. This suggests reductions in the infiltration of water to the soil, lower runoff rates, and therefore a decrease in the normal storage of groundwater.

Agricultural Drought:

Agricultural drought occurs when the water that exists either from precipitation or from storage in the soil or in the different bodies of water is not enough for crops to grow and develop properly. Its impact is limited to the state of the crops and does not consider any other consequences that a drought may cause. (Drought in Colombia. Technical note, IDEAM, 2006)

It is usually defined in terms of the availability of water in the soils for crop support and for the growth of the forage species, and depends on the capacity of water filtration in the soil, as some soils have a high water retention capacity and some others do not. The latter are more prone to agricultural droughts. (World Meteorological Organization, 2006)

Hydrological Drought:

Associated to the effects of low precipitation periods on the supply of surface or groundwater. The frequency and severity of this drought is often defined by the level of the rivers or other scales. In addition, this drought is usually far from the occurrence of a meteorological or an agricultural drought. This is due to the fact that it takes more time for precipitation deficiencies in the components of the water system to be evident, such as soil moisture, river levels, lakes, reservoirs and groundwater. Although climate is the main contributor to hydrological drought, other factors such as changes in land *use, soil degradation and construction of dams, among others, affect the hydrological characteristics of an area. (Drought in Colombia. Technical note, IDEAM, 2006)*

Socio-economic Drought:

The socio-economic drought differs markedly from other types of drought because it reflects the relationship between the supply and demand of basic commodities, such as water, animal feed or hydroelectric energy, which depend on rainfall. The offer varies annually depending on rainfall or water availability. Demand also fluctuates and tends to rise due to the increase in population or development, among other factors. Source: WMO Document #1006.

An example of how socioeconomic drought affects Colombia can be the situation faced during the months of December, January, February and March, being the months with lowest rainfall in the Caribbean and Andean regions. The great influx of people towards these regions during these months, which coincide with the holiday season, makes the demand for water and energy the highest of the year, and when it is under the influence of an El Niño event, it is even more severe. According to the report by the National Planning Department, the last El Niño phenomenon cost the country 0.6% of its GDP.

To speak of socioeconomic drought it is not necessary to have a restriction in water supply, but it is enough to have any economic sector affected by the water shortage with unfavorable economic consequences. The increasing pressure of human activity on water resources means that the incidence of socioeconomic drought is growing, with increasing economic losses (Taken from: http://www.mapama.gob.es Source: Ministry of Agriculture and Fishing, Food and Environment - Government of Spain).

The experts at the workshop made some notes to keep in mind when talking about drought, such as:

- The definition must be differentiated by sector, however, there must be a homogeneous indicator.
- Starting from definitions that include drought per each sector to learn about thresholds of impact; not a definition per sector but a definition of indicators per sector (water balance) for example.
- Always starting from the definition of meteorological drought.
- Keep in mind that drought is a threat, depending on the productive activity or system, it must have variables to be monitored by the system.

1.1.7. Early Warning System - EWS

Early Warning Systems have become fundamental tools that are part of the Risk Management process in its risk knowledge component. National strategies for sustainable development must have programs for risk reduction and mitigation for natural disasters, with planning, early warning and emergency response as a fundamental part of these processes.

To put this in context, some definitions are presented below:

Early Warning Systems are tools that provide timely and effective information through identified technical, scientific and community institutions, through tools and elements that allow individuals exposed to a latent threat to make decisions to avoid or reduce being at risk and their preparation so that they can provide an adequate response taking their capacities into account UNGRD, 2015)

The ISDR[2] speaks of the "set of capabilities necessary to generate and disseminate, in a timely and effective manner, warning information that allows threatened individuals, communities and organizations to prepare and act appropriately and with enough time to reduce the possibility of damage or loss."

An EWS is a set of coordinated procedures through which information on predictable threats is collected and processed, in order to alert the population to a natural phenomenon that may cause disasters, improve emergency response to minimize damage and social impacts, helping to reduce the vulnerability of the population. (IDIGER[3])

As can be seen, an optimal conceptualization of an early warning system leads to tools, coordination, procedures and timely and effective communication so that the community can prepare in advance to reduce or minimize damage or loss.

From an operational point of view, an EWS seeks to alert with due priority by using diverse mechanisms and analysis tools, through sound, visual and other alarms, on the need to transition towards such a state (threshold), that indicates a high probability of occurrence of a given phenomenon that can generate a disaster with the consequences that it entails.

This information issued through alarms must quickly reach the disaster risk reduction and management entities and the municipal and departmental Coordinators, to set forth all the prevention actions with the purpose of safeguarding lives and reducing the negative impact at all levels, before the possible occurrence of a disastrous event. Therefore, as far as possible, the EWS must include processes that range from community participation to the inclusion of a technology that makes the system efficient, timely and effective.

As a basis for any Early Warning System, it is necessary to establish and have the susceptibility information for a given event, which is the result of physical-geographical, socioeconomic and environmental conditions, among others, that allow determining those areas where the first level of observation must be established within the EWS. Based on this susceptibility, historical information must be collected in order to determine both the triggers and the thresholds that "give rise" to an event, which ultimately allows the threat to be fine-tuned. It must be constantly followed up and monitored. With this historical information, vulnerability scenarios are also built, establishing the risk of a certain area or region in a high percentage.

This way, an EWS requires decision-makers to be aware of their risk with a high commitment and understanding of the system’s integrality, the actors involved in it, and the functions and scope of each of them.

[2] United Nations International Strategy for Disaster Reduction.
[3] http://www.sire.gov.co/web/guest/sat

Likewise, important logistics aspects must be taken. There must be adequate coordination between different risk management organisms, as well as the coordination and organization thereof, with clear functions and roles within the Early Warning System.

It is essential to gather information from thematic bases based on the recognition of the susceptibility to a given event, as well as the territory's social, economic and environmental vulnerability analysis, among others. This added to the risk to a certain type of event, which must be known, recognized, assessed and dimensioned not only by sectorial and territorial organizations, but also by the common citizen through socialization processes focused on the recognition of their risk.

Therefore, it is imperative for the population to recognize its risk and the responsibilities it must bear within the early warning system.

The current early warning systems literature involves a response capacity, as we will see in the next item.

1.1.8. Early Warning System Components - EWS

One of the exercises in the first workshop that was part of this project was the conceptualization of a drought early warning system, taking the four components outlined in the platform for the promotion of UN/ISDR Early Warning (see Figure 4) as a basis.

Being a) risk knowledge; (b) monitoring, data processing, product development and issuance of alerts; c) communication and dissemination of alerts; and d) institutional and community responsiveness.

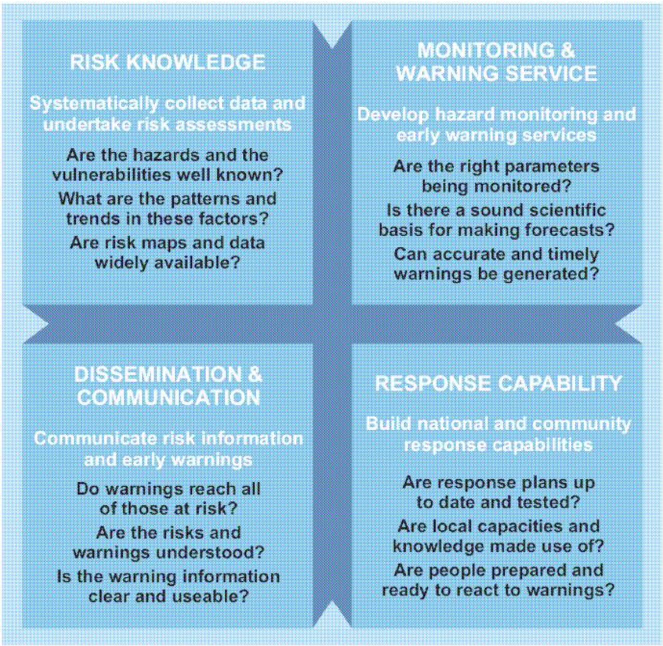

Figure 4. Source: Platform for the promotion of an ISDR/UN Early Warning System

5 working groups were organized, distributed by sectors: agriculture sector (2), environment sector, water sector and energy sector. Paper cards with names of different parameters or characteristics that were part of each of the four components of the early warning system that would be taken as a reference were randomly distributed (See figure 5).

Figure 5. Expert participants in the workshop.

After the agreements, each working group was located according to their criteria, with the cards with the names under each component. After discussions with the group in general, we relocated the names of the parameters that belonged to each component (See figure 6).

Figure 6. Group Work on construction of EWS by drought

This exercise gave us the criteria to prepare an outline of an early warning system for drought in Colombia (See figure 7).

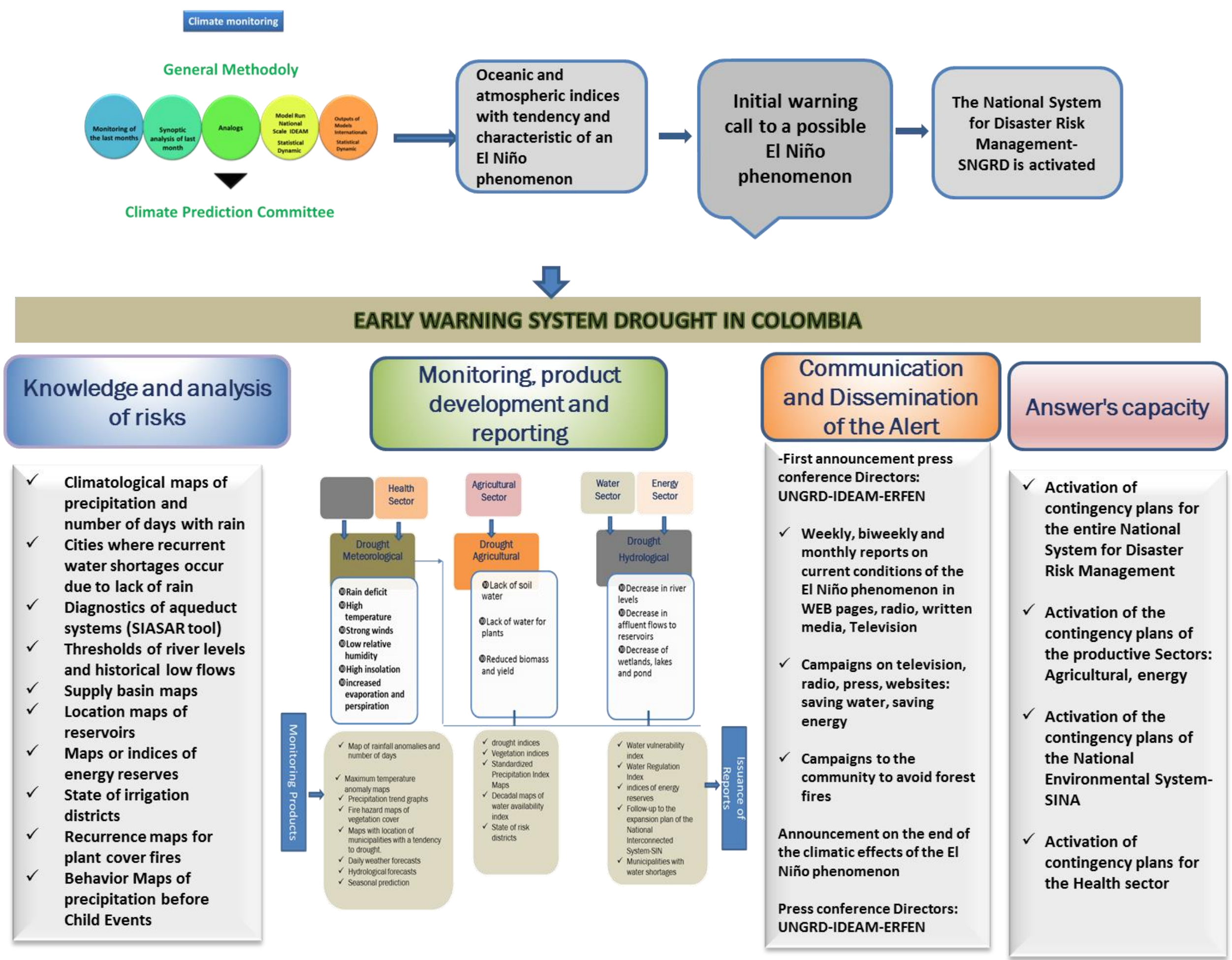

Figure 7. Early Warning System due to drought in Colombia Scheme
(authors' own development).

This starts from the Climate Surveillance made by the IDEAM as one of the functions of the meteorological services, and which is the official entity that is part of the Disaster Risk National System - SNGRD as a technical body that supports the system.

It is continuously monitoring the climate variability phenomena, including El Niño - La Niña ENSO phenomena, and particularly on drought the threat, El Nino becomes relevant. With its own analyses and reports of international entities such as NOAA, IRI, CIIFEN, world climate centers, it performs follow-ups on ocean-atmospheric indicators, runs dynamic and statistical climate prediction models, analyzes international models among many other products and issues monthly bulletins on climate forecasts as part of this process. If the analyses of the ocean and atmosphere indices are manifested with a trend of characteristics proper of an El Niño phenomenon (see section 2.1.3, Climate Variability, El Niño Phenomenon), the monitoring of these variables in order to make a first announcement of the probability of the formation of an El Niño phenomenon is intensified and as of this moment the Disaster

Risk Management National System- SNGRD is activated. This is the starting point of the Early Warning System due to Drought process in Colombia.

As the diagram shows, this system has been based on four main components: a) risk knowledge and analysis; b) monitoring, product development and reporting; c) communication and dissemination of the alert, and d) response capacity.

An Early Warning System is not only comprised of Monitoring, product development and reporting; it must also be effective and timely in the communication and dissemination of the alert as a component and in the response capacity.

2. LEGAL FRAMEWORK

Photograph UNGRD – Alta Guajira

2. LEGAL FRAMEWORK

International benchmarks such as the Sendai Framework for Disaster Risk Reduction 2015-2030 that was approved at the Third United Nations World Conference on Disaster Risk Reduction, held from March 14th to 18th, 2015 in Sendai, Miyagi (Japan) mentioned in its Priority 4: "Increase disaster preparedness in order to give an effective response and better rebuild the areas of recovery, rehabilitation and reconstruction" and in paragraph 33 in its part (b) it states: b) develop, maintain and strengthen multiple warning and multi-threatening prediction systems that are multisectorial and people-centered, communication mechanisms for emergencies and disaster risks, social technologies and telecommunications systems for threat monitoring, and invest in them; develop those systems through a participatory process; adapt them to the needs of users, taking into account social and cultural particularities, especially gender; promote the use of simple and low-cost early warning equipment and facilities; and expand the channels of dissemination of early warning information on natural disasters.

Other international bodies such as the United Nations Convention to Combat Desertification (UNCCD, UNCCD) were approved on June 17th, 1994 in Paris and opened for signature on October 14th, 1994. It became effective on December 26th, 1996. The Colombian Government, concerned about the continuous and profound processes of land degradation and its negative impact on environmental, economic and social conditions, ratified it through Law 461 of August 4th, 1998, becoming part of it as of September 8th, 1999. Source: Third National Report on the Implementation of the United Nations Convention to Combat Desertification and Drought. Bogota, D.C. Colombia, Ministry of Environment, Housing and Territorial Development/UNCCD Secretariat, 2007.

In compliance with the international commitments acquired by Colombia as a UNCCD country, it has delivered to the UNCCD Secretariat three national reports on the implementation of the Convention in April 2000, April 2002 and the third report in 2007, especially those related to the development of the National Action Plan to Combat Desertification and Drought in Colombia (PAN).

The regulations that govern Colombia in relation to the components of the early warning system and drought are listed below.

Table 2. Legal Framework

ENTITY	NORMATIVITY
Presidency of the Republic of Colombia	Law 99, 1993 "Whereby the Ministry of the Environment is created, the Public Sector in charge of the management and conservation of the environment and renewable natural resources is reorganized, the National Environmental System, SINA is organized, and other provisions are dictated" Art. 16. The IDEAM is created as the entity in charge of establishing and operating national oceanographic, tide-measuring, meteorological and hydrological infrastructures to provide information, predictions, warnings and advisory services to the community.
Presidency of the Republic of Colombia	DECREE 2811, 1974 "Whereby the National Code of Renewable Natural Resources and Protection of the Environment is issued." MINISTRY OF AGRICULTURE.

Ministry of the Environment and Sustainable Development	LAW 373, 1997 "Whereby the program for the efficient use and saving of water is established".
Presidency of the Republic of Colombia	Decree 308, 2016 "Whereby the National Disaster Risk Management Plan is adopted". Law 1523, 2012. "Whereby the national disaster risk management policy is adopted and the National Disaster Risk Management System is established and other provisions are issued" Law 1523, 2012 Chapter I (Article 3) 2. Protection principle: Residents in Colombia must be protected by the authorities in their life and physical and mental integrity, in their property and in their collective rights to public security, tranquility and health and to enjoy a healthy environment, in the face of possible disasters or dangerous phenomena that threaten or inflict damage to the values enunciated. (Article 4: Definitions) Warning: State that is declared prior to the manifestation of a dangerous event, based on the monitoring of the behavior of the respective phenomenon, so that the entities and the population involved activate previously established action procedures. Law 1575, 2012. "Whereby the general law of firefighters of Colombia is established" Law 1753, 2015. "Whereby the National Development Plan 2014-2018 "Todos por un Nuevo país" is issued (Chapter VI Green Growth - monitoring).
Ministry of National Defense	Decree Law 2324, 1984, reorganizes the DIMAR and gives it the following functions: - To regulate, authorize and control the construction and use of artificial islands and structures in the areas of its jurisdiction. Decree 5057, 2009. By which the structure of the National Ministry of Defense - General Maritime Directorate is partially modified and other provisions are dictated. Article 6. The function of the CIOH is: To study and execute research projects and evaluation of oceanographic, hydrographic and marine pollution phenomena, in accordance with the programs of the General Maritime Directorate.
Ministry of Housing, City and Territory	Resolution 0154, 2014. "Whereby the guidelines for the drafting of Emergency and Contingency Plans for disasters and emergency management associated with the provision of public services of home water, sewage and sanitation are adopted and other provisions are issued" Decree 1077, 2015, book 2 Regulatory regime of the housing, city and territory sector, part 2 Structure of the territorial development sector, Title 2 Planning for territorial zoning, chapter 1 territorial zoning instruments, Section 3 "Incorporation of Risk Management in Territorial Zoning Plans".
Presidency of the Republic of Colombia	DECREE 1600, 1994 "Whereby the National Environmental System -SINA is partially regulated in relation to the National Systems of Environmental Research and Environmental Information".

Presidency of the Republic of Colombia	DECREE 1729, 2002 "Whereby Part XIII, Title 2, Chapter III of Decree-law 2811, 1974 on hydrographic basins is regulated, partially point 12 of article 5 of Law 99, 1993 and other provisions are dictated".
Ministry of the Environment, Housing and Territorial Development.	DECREE 3100, 2003 "Whereby the remuneration rates are regulated by the direct use of water as recipient of the punctual discharges and other determinations are made".
Ministry of the Environment, Housing and Territorial Development.	DECREE 4742, 2005 "Whereby article 12 of Decree 155, 2004, is modified by means of which article 43 of Law 99 of 1993 on rates by utilization of waters" is regulated.
Ministry for Social Protection	DECREE 1575, 2007 "Whereby the System for the Protection and Control of Water Quality for Human Consumption is established."
Ministry of the Environment, Housing and Territorial Development.	DECREE 1480, 2007, "Whereby the zoning and intervention of some hydrographic basins is prioritized at a national level and other provisions are dictated".
Ministry of the Environment, Housing and Territorial Development.	DECREE 1323, 2007 "Whereby the Water Resource Information System -SIRH is created".
Ministry of the Environment, Housing and Territorial Development.	DECREE 3930, 2010 "Whereby partially Title I of Law 9, 1979, as well as the Chapter 11 of Title VI-Part 11I- Book 11 of the Decree - Law 2811, 1974, is regulated regarding the uses of the water and liquid residues and other provisions are dictated."
Ministry of the Environment and Sustainable Development	DECREE 1640, 2012, "Whereby the instruments for the planning, zoning and management of the river basins and aquifers are regulated and other dispositions are dictated".
Ministry of the Environment, Housing and Territorial Developent	DECREE 1076, 2015, compilation of Decree 1277, 1994, whereby the Institute of Hydrology, Meteorology and Environmental Studies-IDEAM is organized and established, and the entity is assigned in numeral 6 of article 2.2.8.8.1.15 the function of providing, to the extent of its technical capacity, the services of forecasts, warnings and alerts of a hydrometeorological nature for the National System of Disaster Prevention and Attention, air, maritime, fluvial and terrestrial transport, agricultural, energy, industrial sectors and those that require it, in accordance with the aforementioned article 2.2.8.8.1.29 of the mentioned decree, indicates that IDEAM is the official source of scientific information in hydrology and meteorology of the country.

Source: Own development.

3. BACKGROUND OF DROUGHT IN COLOMBIA

Photograph UNGRD – Alta Guajira

3. BACKGROUND OF DROUGHT IN COLOMBIA

Colombia has regions of little rain, and when it comes to zoning dry regions it is done by climatic factors, although there are other indicators which should be taken into account such as the geomorphological indicator.

Colombia has 245,342 km2 in dry areas, that is to say approximately 21.5% of the country. The Orinoquía and Caribbean regions have the greatest extension of these areas, with 94,096 and 91,522 km2 respectively. In the Andean region the distribution of dry areas is related to the valleys and canyons in rain shadow. In the Orinoquía region, the savannas of Vichada, Casanare and Arauca are affected. In the Caribbean region, 72,81% is found in savannas, swamps, gallery forests and mangroves, while the much of the mountainous region of the Sierra Nevada of Santa Marta is different from this[4].

The most concerning situation in the country is when there is a significant decrease in rainfall in those dry areas which has an impact on agricultural production, livestock, electric power generation, and water supply, among others. This leads to a socioeconomic impact with serious repercussions for the Colombian population.

From the beginning of this document we have been mentioning the great influence that the El Niño phenomenon exerts on the rainfall deficit conditions in the country. The most complete studies on climate variability phenomena are the ones referring to this event. From the lesson learned from the El Niño phenomenon in 1991-1992, when Colombia was forced to have a blackout (power cut) in 1992, some productive sectors have been more attentive to the follow-up of this event. This has happened particularly the energy sector, that despite the fact that the El Niño phenomena of 1997-1998 and 2014-2015-2016 have had ocean-atmospheric characteristics and stronger climate effects, this sector has emerged well. Other sectors such as agriculture and water and environment sectors have had greater impact. According to the report of the National Planning Department, the national economic loss in 2015 caused by the effect of forest fires was approximately $476 billion pesos, equivalent to 0,063% of GDP in 2015. By regions, the Andean region in the Center-East (Cundinamarca, Boyacá, Santander and Bogotá) is the most affected one, with losses of $112,438 million, represented in 6,498 hectares, followed by the Caribbean, Plains, Pacific, South Central, and Coffee Growing regions.

3.1. Characterization of Droughts

Droughts can be categorized according to their intensity, duration, and affected area. When talking about intensity, it refers to the deficit of precipitation and effects associated with this drop. Its magnitude is determined depending on the monthly values that are below the ranges that normally occur. For example, rains have abnormalities of 30% below normal or the river level is 2 meters below historical records. Also, the magnitude of the drought can refer to the normalized precipitation index.

The duration is also part of the characterization of the drought. For example in Colombia, under the influence of the El Niño Phenomenon that has its maximum phase at the end of the year and the beginning of the following year, and considering that this situation coincides with the season with lowest

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[4] Source: "Diagnosis elements and recommendations of action to be included in the national action plan in the fight against desertification and management of dryland ecosystems in Colombia. (PAN) phase 1. IDEAM 2003 "

rainfall in the year, more surveillance should be activated in order to determine if this season goes beyond the months in which seasonality normally occurs. The magnitude of the effects depends on the time of year in which the rainfall reduction begins. In some cases the reduction begins during the months of October and November, which are the wettest months of the year in the Caribbean and Andean regions, and that aggravates the situation due to the deficit in the months of lower rainfall.

In Colombia, the entire country is not affected by precipitation deficit; however, the exposed areas correspond to the most populated areas which demand the resources of the productive sectors.

3.2. Difficulties posed by surveillance and early warning issuance for drought in Colombia

Climate monitoring (different to the daily monitoring of hydrometeorological conditions) involves a weekly and monthly monitoring of climate variability events that could alter the normal conditions in each region. For Colombia, the rainy or less rainy seasons that mainly are modulated by the Intertropical Convergence Zone-ITCZ in their displacement from North to South and South to North throughout the year could be altered (Intraseasonal), or when there are continuous periods close to a year or more with irregularities that can be characterized by dry years or (interannual) rainy years.

The monthly analysis of the anomalies in precipitation always present zones with behaviors above or below normal without this meaning that a drought alert can be issued (for the case of rainfall deficit).There are other factors that influence the behavior of rainfall in Colombia, such as tropical waves from the east, cold fronts, Madden & Julian intraseasonal waves, which cause more or less rain throughout the year. This is why drought surveillance is done particularly on the probability of occurrence of an El Niño phenomenon.

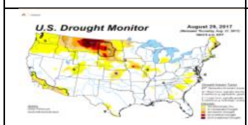
There are difficulties in the issuance of these alerts because they depend a lot on the time of year when El Niño begins, as well as its intensity and duration. In addition to each region's vulnerability, it is not the same to have an "El Niño" event in La Guajira, which is one of the driest regions of Colombia, beginning to affect mid-year, which is the period in which rains normally occur, than at the beginning of the year, where rainfall is almost null. The experience in Colombia has shown us that it is very difficult to determine when a drought begins or when it ends, and we cannot relate it to the beginning or end of an El Niño phenomenon. This goes further, and more drought indicators must be worked on so that decision-makers can have this information in a timely manner to reduce the consequences.

When the experts in the workshops on drought warning systems were consulted, they considered that it was very important to integrate rain behavior with normalized rainfall indices (SPI) with other water-type parameters such as flow rate index, storage level of reservoirs, or vegetation indexes (NDVI), soil moisture, among others. This way changes are gradually identified as the drought consolidates in order to be able to issue the early warning.

3.3. Early Warning Systems - Drought EWSs worldwide

All meteorological services in the world monitor drought, but some countries have developed platforms for specific products and indices that allow them to determine the trend towards water deficit that can lead to a meteorological, hydrological, agricultural drought, etc. They have very particular objectives, where even several countries have joined and have implemented Early Warning Systems due to drought. Below is a table with the information of some EWSs.

Table 3. Drought EWSs in the world.

Early Warning System	Regions	Monitoring	Products	Website
	Colombia, Peru, Ecuador, Chile and Bolivia	El Niño Phenomenon	Newsletters, climate monitoring	http://www.ciifen.org/index.php
	Latin America	Drought	It provides data, information, and tools needed for a comprehensive analysis of the drought phenomenon Seasonal forecasts	http://edo.jrc.ec.europa.eu/scado/php/index.php?id
FEWS NET Famine early warning systems	Some countries of Central America and the Caribbean, Central Asia and Africa.	Drought	Monthly newsletters, maps and special reports in each country, analysis of food insecurity.	https://www.fews.net/?l=es
	United States	Drought	Interactive drought monitoring maps based on data analysis at the regional level.	http://droughtmonitor.unl.edu/
Observatorio Agroclimático	Chile	Drought	Maps and figures on drought conditions	http://www.climatedatalibrary.cl/UNEA/maproom/
JOINT RESEARCH CENTRE EDO - European Drought Observatory	Europe	Drought	Maps and figures on drought conditions	http://edo.jrc.ec.europa.eu/edov2/php/index.php?id=1000
	China	Drought	Daily drought monitoring maps , available in the main website of the Center on Climate of Beijing since February of 2003 standardized precipitation index, in periods of 30 and 90 days,	http://cmdp.ncc.cma.gov.cn/pred/en_cs.php
	Great Horn of Africa: encompassed 24 countries in the southern and eastern	Drought	Drought monitoring maps by means of remote sensing Surveillance map of humidity in the top 20 cm of the soil layer, weather bulletins for 10-	http://www.icpac.net/

	sub-region of Africa		day, monthly and seasonal periods.	

3.4. Early Warning System for Drought in Colombia

IDEAM, as Colombia's meteorological authority, has monitoring networks, data processing, follow-up of the behavior of hydrometeorological variables, drafting of reports and a large amount of data and information that is generated daily, weekly, monthly etc., as part of its functions. It monitors all threats of hydro-meteorological origin such as landslides, floods, flash floods, forest fires, extreme events (hailstorms, heavy rains, etc.) and monitors the rain deficit during the dryer season. IDEAM, as technical support to the SNGRD[5], is in charge of issuing reports on threats due to rainfall deficit, and together with the UNGRD[6] they provide communication and dissemination of the warning as a third component. The fourth component in this response capacity process is coordinated by the UNGRD based on the National Contingency Plan for the EL NIÑO Phenomenon.

Given these circumstances, it could be said that the Early Warning System for drought in its first two components is done by IDEAM and components 2 and 3 are part of the entire National System for Disaster Risk Management - SNGRD. See example for El Niño 2014-2016 (see Figure 8).

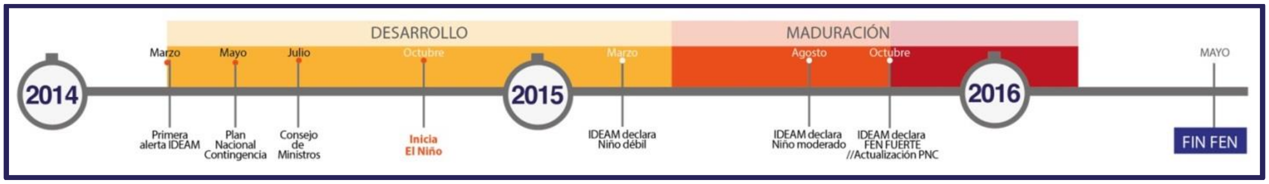


Figure 8. How the Early Warning System for El Niño 2014-2016 operated

Below are the products that are currently being developed between the IDEAM and UNGRD for drought monitoring.

Table 4. Early warning system for drought in Colombia

EARLY WARNING SYSTEM FOR DROUGHT IN COLOMBIA	All the country	Drought	Behavior of the drought index in the last six months, drought index maps for periods of 1, 3, 6 and 12 months, newsletters, maps, forecasts, warnings, contingency plans.	http://www.pronosticosyalertas.gov.co/ portal.gestiondelriesgo.gov.co/

[5] National System for Disaster Risk Management
[6] National Unit for Disaster Risk Management Coordinating Entity of the SNGRD.

4. CURRENT SITUATION OF DROUGHT MONITORING IN COLOMBIA

Photograph UNGRD – Bogotá

4. CURRENT SITUATION OF DROUGHT MONITORING IN COLOMBIA

To have an idea of the current situation of drought monitoring in Colombia, we asked what State and private entities perform monitoring of meteorological and hydrological variables behavior to determine all the hydrometeorological threats. The following table presents some entities with monitoring and drought follow-up products:

4.1. Input Catalog

Table 5. Input Catalog

Early Warning System	Regions	Monitoring	Products	Website
Bogotá Capital District Warning System	Bogotá	Hydrometeorological Variables	Rain in real time, daily rain and accumulated last days, areas prone to vegetation cover fires, monitoring of river levels.	http://www.sire.gov.co/web/sab
Valle de Aburrá Early Alert System	Medellin and the Metropolitan Area of Valle de Aburrá	Hydrometeorological Variables	Real time access to information generated by weather stations, monitoring the levels of rivers, hydro-meteorological forecast models.	http://siata.gov.co
Early Warning System of La Guajira	Guajira	Hydrometeorological variables; Its objective is floods and landslides	Description of weather conditions for the department and municipalities through daily bulletins that are published on the website	http://www.corpoguajira.gov.co
Network of hydrometeorological stations of Manizales, operated by the National University at Manizales	Caldas	Hydrometeorological Variables	IInteractive map of weather and alerts	http://idea.manizales.unal.edu.co/index.php/estado-tiempo-manizales
CAR Cundinamarca	Cundinamarca	Hydrometeorological Variables	Levels of rivers, warning bulletins for hydrometeorological conditions,	https://www.car.gov.co/?idcategoria=10545

Early Warning System	Regions	Monitoring	Products	Website
	Valle del Cauca	Hydrometeorological Variables	River levels, hydrometeorological conditions warning bulletins, forecasts for Valle del Cauca	https://www.cvc.gov.co/
Cenicafé 	Coffee growing areas	Hydrometeorological Variables	Agrometeorological bulletins, monitoring of climate variables	http://agroclima.cenicafe.org/web/guest/condiciones-actuales
Cenicaña 	Valle del Cauca	Hydrometeorological Variables	Agrometeorological bulletins, monitoring of climate variables	http://www.cenicana.org/clima_/index.php

Note: See Annex: Input Catalog.

4.2. National Hydrometeorological Stations Catalog

IDEAM's role is to provide, within its technical capacity, hydro-meteorological forecasting, warnings and alert services for the National Disaster Risk Management System, air, maritime, fluvial and terrestrial transport, agricultural, energy and industrial sectors and those that require the service, and is the official source of scientific information in hydrology and meteorology in the country (Decree 1076, 2015, compilation of Decree 1277, 1994). Likewise, it is in charge of establishing and operating meteorological and hydrological infrastructures to provide information, prediction, warnings and advisory services to the community. Similarly, it monitors the nation's biophysical resources, especially in relation to pollution and degradation for the decision-making of environmental authorities.

For follow-up and monitoring, IDEAM has a total of 2,637 active stations, 344 of which are automatic, 52 automatic without transmission and 2,241 conventional. Of the automatic stations, 50 are hydrological, 86 hydrometeorological and 208 meteorological. Of the conventional, 523 are hydrological, 7 hydrometeorological and 1,711 meteorological (See figure 9).

Figure 9. Location of IDEAM Meteorological and hydrological stations. Source: IDEAM

According to other entities' catalog of stations, there are a total of 2,513 active stations; 344 of which are automatic, 22 automatic without transmission and 2,147 are conventional. Of the automatic stations, 81 are hydrological, 41 hydrometeorological, 222 meteorological and of the conventional stations, 771 are hydrological, 41 hydrometeorological and 1,374 meteorological (see figure 10).

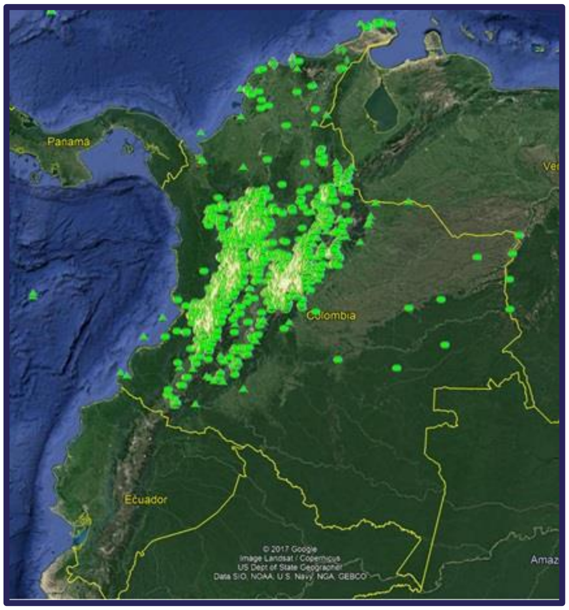


Figure 10. Location of meteorological and hydrological stations of other entities. Source: IDEAM

Other entities such as the CAR, CENICAÑA, CHEC, CORPOCHIVOR, CORPOGUAJIRA, CORPONOR, CVC, EAB, EMGESA, EMPOPASTO, EPM, FEDEARROZ, PPNC and INVEMAR sent information on the catalog of their stations (see Figure 11).

Figure 11. Location of meteorological and hydrological stations of other entities. Source: Entities mentioned

5. CHARACTERIZATION BY VULNERABLE REGIONS IN COLOMBIA

Photograph UNGRD – Alta Guajira

5. CHARACTERIZATION BY VULNERABLE REGIONS IN COLOMBIA

To characterize the regions that are vulnerable to drought in Colombia, we started by determining the history of drought events, which coincided with the influence of the El Niño phenomenon. According to IDEAM's historical analyses, the years in which drought events have occurred correspond to the periods between June/71-October / 72, June / 74-August / 75, May / 76-May / 78, September / 82-September / 84, January / 89-October / 90, March / 91-April / 93, December / 93-June / 95, April / 97-May / 98, August / 2009- May / 2010, February 2015 - June 2016.

For the analysis of the most vulnerable areas to drought in Colombia, parameters such as the economic impact on agricultural activities, the number of hectares sown per department and GDP[7] per department were taken into account, based on the hypothesis that regions with greater commercial and industrial activity are seriously affected by the scarcity of water resources, in order to measure the degree of impact due to drought that may occur in a region.

On the other hand, the drought frequency in a region was analyzed according to IDEAM's Climatological Atlas maps, and the supply versus demand ration of surface water resources and a territory's capacity to maintain its supply in dry times determined in the Water Vulnerability Index[8].

Finally, it was observed in the regions where there are sources of groundwater if this resource is used as the main source of supply or as an alternate source in periods of reduction in surface supply and the degree of exploitation of the aquifers. The regions where this resource is used as an alternate source are less vulnerable to drought due to their ability to adapt and exploit groundwater in periods of scarcity of surface resources than those where this resource is over-exploited or the only source of supply (See figure 12).

Finally, since the information available for all the parameters mentioned in numerical form was not available, a statistical analysis could not be carried out. A qualitative analysis was done according to the available information extracted from the National Water Study (IDEAM), Third national agricultural census (DANE), departmental accounts (DANE)[9], volume of water licensed by departments (IDEAM), climatological atlas (IDEAM) and El Niño Phenomenon Comparative analysis 1997-1998 v. 2014-2016 document (UNGRD).

5.1. Caribbean Region

Sectors affected by drought events

Droughts in the Caribbean Region affect all sectors dependent on water resources., The level of effect and the sectors that are most affected depend on the intensity of the drought. According to the UNGRD (2016), the most affected sectors in this region during the drought of the El Niño phenomenon 2014 - 2016 were:

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[7] Gross Domestic Product.
[8] National Study on Water. IDEAM, 2014
[9] National Department of Statistics.

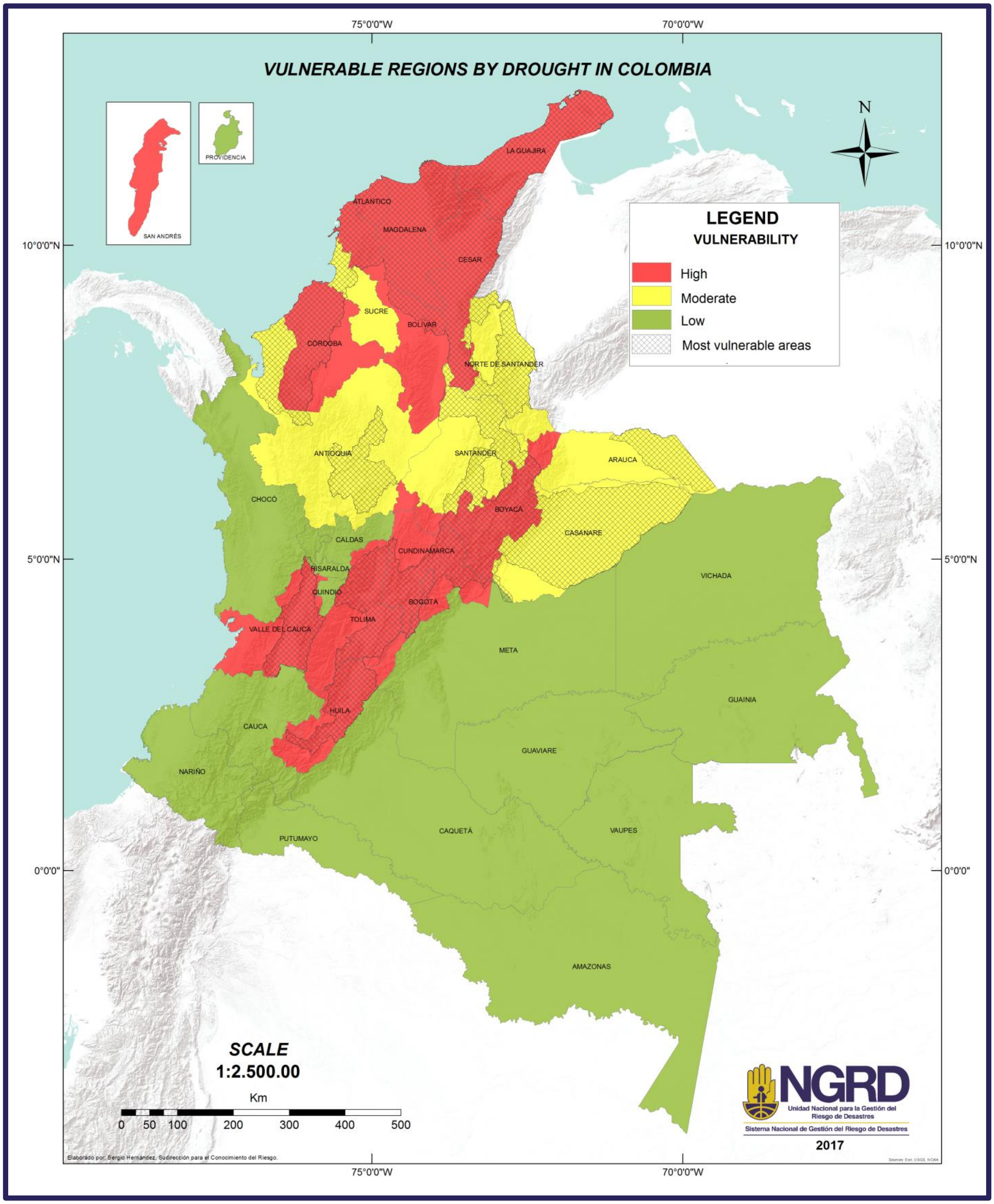

Figure 12. Vulnerable regions by drought in Colombia.

- Drinking water sector due to shortages, mainly the departments of La Guajira, Cesar and Magdalena as the most affected ones, with 93%, 92% and 87% of the municipalities in the territory with water shortages.

- The agricultural sector was also strongly affected during this event, being the departments of Atlantico and Cordoba the most affected ones with 403,365 hectares and 243,677 hectares respectively, only in 2015.

- The livestock sector also suffered important damages, being Cordoba, Atlantico, Bolivar, Magdalena and La Guajira, the most affected departments. According to reports of the National Livestock Fund (FNG), the total number of cattle that died as a result of the El Niño phenomenon for the fourth quarter of 2015 was 36,016.

- The environment sector was also affected by forest fires, being Magdalena the most affected department with 11,767 hectares.

- In the transport sector, the volume of cargo on the Magdalena river was affected by the restriction of navigation because of low levels.

- The energy sector was affected by low levels of the Urra 1 reservoir in Cordoba, which significantly decreased its electric power generation.

- Regarding the health sector, hydroclimate conditions generated during the occurrence of the El Niño Phenomenon favored the outbreak of vector-borne diseases such as Dengue, Chikungunya and Zika.

Vulnerable areas

- The precipitation deficit in phenomena such as El Niño affects the subzones of the Caribbean with reductions in river flow between 10% and 46%, particularly highlighting the anomalies in the León River and direct effects on the Mulatos River in the Antioquia Urabá and in the area of Cesar in the Ariguaní, Jobo and Mariangola Rivers, where reductions between 18% and 46% are estimated (IDEAM, 2010).

- According to the analysis of parameters, the departments with the greatest vulnerability to drought are:

- La Guajira: This department has a high vulnerability due to its climate condition. It is the Colombian department where it rains the least, registering an average annual precipitation between 0 - 1000 mm (IDEAM, 2014b). It has hydrographic subzones in high vulnerability according to the Water Vulnerability Index, mainly due to the low water supply. Groundwater is the main source of supply, with a high exploitation level of the resource extracted from the aquifer systems of the Middle Guajira, High Guajira and ranchería (IDEAM, 2014a). According to the National Water Study (ENA for its name in Spanish) 2010, the municipalities of Urumita, Villanueva, El Molino, Hatonuevo and Maicao in Guajira are the most vulnerable to water shortages. However, the last El Niño Phenomenon that occurred showed the vulnerability of the municipalities of Uribia and Manaure.

- Cesar: This department has high vulnerability given that it has a low to moderate mean annual precipitation between 1000 - 2000 mm (IDEAM, 2014b). The northern zone of the department is the most vulnerable, presenting high water vulnerability indexes (IVH, for its acronym in Spanish) in the subzones of the Ariguaní River, low, middle and high Cesar, due to the low water retention capacity of these basins, which makes it difficult to maintain the supply in drought periods. Groundwater is the main source of water in some areas, and the resource exploitation level extracted from the Cesar aquifer system is high (IDEAM, 2014). According to ENA 2010, in Cesar, the municipalities of Valledupar, El Copey and La Jagua de Ibirico are the most vulnerable to water shortages.

- Magdalena: This department has high vulnerability given that it has a low to moderate mean annual precipitation between 500 - 1500 mm (IDEAM, 2014b). Most of the hydrographic subzones have a high water vulnerability index (HVI) due mainly to the low water regulation of the area and the high demand of the resource in the region. Groundwater is mainly extracted in this department for economic activities, the Ciénaga - Fundación aquifer system being the most exploited for African palm and banana crops (IDEAM, 2014a, IDEAM, 2013). According to ENA 2010, the municipal capital of Santa Marta is highly vulnerable to water shortages.

- Atlantico: This department has high vulnerability given that it has a low mean annual precipitation between 1000 - 1500 mm (IDEAM, 2014b). All the hydrographic subzones have very high water vulnerability indexes (IVH) due mainly to the low water regulation of the area and the high demand of the resource in the region. When there are drought events, the agricultural sector in this department is among the most affected in the country. This department concentrates 98% of its demand for water resources in surface water (Hoyos & Noguera, 2014), this perhaps being the reason why it is so affected in periods when the surface water supply decreases substantially. According to ENA 2010, Luruaco and Malambo are the municipal capitals with the greatest vulnerability to water shortages.

- Bolivar: This department has high vulnerability in its northern part to the subzones of lower Magdalena, Dique Canal and direct streams to the Caribbean. The average annual rainfall in this area is low (1000 -2000 mm) (IDEAM, 2014b). The Water Vulnerability Index (HVI) is high and very high, due to the very high demand for water resources in this area. Groundwater is the main source of supply, and the degree of exploitation of the resource extracted from the Arroyo Grande, Turbaco and Maco aquifer systems (IDEAM, 2014) is high. According to ENA 2010, Arjona, Santa Rosa, Turbaco, Turbaná and Villanueva are the municipal capitals with the greatest vulnerability to water shortages.

- Cordoba: This department has a high vulnerability. The most vulnerable areas are those of the Canalete River, middle and low Sinú in the north of the department, because the total average annual rainfall in these areas is low (1000-2000 mm) (IDEAM, 2014b), and the ratio of supply vs. demand for water is critical. The agricultural sector is the one that requires more water resources in the department and is strongly affected in dry periods. The surface waters of the Montería - Ciénaga de Oro and Arenas Monas aquifer systems are exploited as an alternative supply source (IDEAM, 2014a).

- Sucre: This department has a vulnerability. The average annual total precipitation is low with values between 1000 - 2000 mm (IDEAM, 2014b), the water regulation index is low and the demand for the resource is moderate. The low water regulation makes the resource scarce in times of drought. Groundwater is the main source of supply, and the level of exploitation of the resource extracted from the Morrosquillo Gulf, Tolú Viejo, Morroa and La Mojana aquifer systems (IDEAM, 2014a) is high.

- San Andres: It presents a high vulnerability because the HVI is very high, since the supply of surface water is very low, with groundwater being the main source of supply for this island, water is extracted from the aquifers of the San Andrés and San Luis formation.

- According to IDEAM (2015) a deficit in precipitation is expected for the Caribbean region in 2040 in the departments of Bolívar (- 15,09%), Cesar (- 15,32%), La Guajira (- 14,50%), Magdalena (- 18,65%), Sucre (– 11,30%), San Andrés and Providencia (- 30,20%). This will aggravate these departmets' current vulnerability situation.

5.2. Andean Region:

Sectors affected by drought events

According to the UNGRD (2016), the most affected sectors in the Andean Region during the El Niño phenomenon 2014 - 2016 were:

- The drinking water sector due to shortages, being Magdalena (26 municipalities), Boyacá (25 municipalities), Cesar (23 municipalities) and Santander (23 municipalities) the departments with the highest percentage of municipalities with a shortage condition. 42% of the total departments that make up the Andean region presented supply problems, with 162 municipalities in rationing and 77 municipalities in conditions of shortages.

- The agricultural sector was affected mainly in the departments of Nariño (108,250 ha) and Antioquia (92,344 ha), but there was also damage in the departments of Norte de Santander, Santander, southern Bolivar, Caldas, Tolima, Huila and Cauca.

- In the livestock sector, the departments most affected by losses of livestock units were Antioquia (465,157 units) and Boyacá (188,818 units) in 2015 alone. Likewise, Nariño, Cauca and Santander were affected, but to a lesser extent.

- The energy sector was one of the most affected during this drought since the country's main reservoirs are located in the Andean Region. The low level of the reservoirs generated a significant decrease in their energy contribution.

- The environment sector was affected by numerous forest fires during El Niño 2014 - 2016. The most affected departments were Cundinamarca (14,505 ha), Huila (13,103 ha), and to a lesser extent in Tolima (7,753 ha) and Antioquia (7,291 ha).

- In the transport sector, the volume of cargo along the Magdalena River was affected by the navigation restriction due to its low levels. Puerto Wilches is a critical point of navigation.

- Regarding the health sector, the hydroclimate conditions generated during the occurrence of the El Niño Phenomenon favored the outbreak of vector-borne diseases (VBDS) such as Dengue, Chikungunya and Zika. Santander was the most affected Department with 40% of cases of severe dengue in the country.

Vulnerable areas

The precipitation deficit in phenomena such as El Niño affects the Andean Region with a reduction in the flow of rivers. The middle Magdalena basin presents reductions that range between 1% and 35% with regards to the average flow. The highest percentages are recorded in the sub-zone of the Samaná Sur River (35%), Río Negro river (27%) and Carare, Samaná Norte and Opón rivers, with around 20%. The middle Magdalena basin presents reductions that range between 10% and 35% with regards to the average flow. The highest percentages are recorded in the sub-zone of the Samaná Sur River (35%), Río Negro river (27%) and Carare, Samaná Norte and Opón rivers, with around 20%. The Cauca river basin is strongly affected, mainly the subzones such as the La Vieja, Alto Cauca, Rio Frío, Risaralda, Chinchiná, Arma and San Juan rivers, where the decrease in flow exceeds 30% with respect to the average flow. In the Catatumbo basin, the flow of the Algodonal, Sardinata and Pamplonita rivers are mainly affected (IDEAM, 2010).

According to the analysis of parameters, the departments with the greatest vulnerability to drought are:

- Cundinamarca: This department has a high vulnerability. It has subzones with high and very high vulnerability indexes, the most critical hydrological subzone is the Bogotá river, this is because the total annual average precipitation in this region is low with values between 500 - 1500 mm (IDEAM, 2014b) therefore the relationship between supply and demand is critical due to the very high use that is given to the resource in this department. Being an area where much of the country's industry is specially concentrated in the capital makes it more vulnerable. Groundwater is mainly exploited for economic activities. The resource exploitation level being extracted from the aquifer system of the Bogotá savanna is high (IDEAM, 2014a). According to ENA 2010, Anolaima, Cachipay, Chaguaní, Choachí, Chocontá, El Colegio, El Peñón, Fómeque, Guachetá, Guaduas, Guayabal de Síquima, La Mesa, Venicia, San Antonio del Tequendama, Silvania, Subachoque - El Rosal, Suesca, Tabio and Yacopí are the municipal capitals with the greatest vulnerability to water shortages.

- Boyacá: This department presents high vulnerability especially in the hydrological subzones of the Chicamocha and Garagoa rivers, where the water volume index is high, because the total average annual precipitation in this region is low with values between 500 - 1500 mm (IDEAM, 2014b), the demand of water resources is high and water regulation is low to moderate. Groundwaters are exploited as alternative sources of supply. The resource is extracted from the aquifer systems of Tunja and Duitama-Sogamoso (IDEAM, 2013). According to ENA 2010 Tunja, Arcabuco, Chiquinquirá, Duitama, Floresta, Villa de Leiva, Motavita, Nobsa, Nuevo Colón, Paipa, Paz de Río, Puerto Boyacá, Ráquira, Sáchica, Samacá, Siachoque, Soatá, Soracá, Tibasosa and Togüí are the municipal capitals with greater vulnerability to water shortages.

- Tolima: This department has a high vulnerability. The total average annual precipitation is low to moderate with values between 1000 - 2500 mm (IDEAM, 2014b) and the most vulnerable areas of the department are located in the north and east, where the lowest rainfall levels are registered and water vulnerability indexes (WVI) are high due to the high demand of water resources. Groundwaters are exploited as alternative sources of supply. The resource is extracted from the aquifer systems of Ibagué and Purificación-Saldaña, with the agricultural sector being the one that requires the most resources (IDEAM, 2013, CORTOLIMA, 2012). According to ENA 2010, Carmen de Apicalá, Dolores, Fresno and Honda are municipal capitals with increased vulnerability to water shortages.

- Valle del Cauca: This department has a high vulnerability. The total average annual precipitation is low with values between 1000 - 2000 mm (IDEAM, 2014b) and the most vulnerable area is the Cauca river valley, where the hydrographic subzones have high and very high water vulnerability indexes (WVI) due to the very high demand for water resources by the agricultural sector. Groundwater is mainly exploited for economic activities of the Valle del Cauca aquifer system, being the region of the country that extracts more volume with 50% of the national demand. This makes this region's drought adaptation capacity through the use of groundwater as an alternative source low, currently due to the high exploitation of the resource (IDEAM, 2014a). According to ENA 2010, Cali, Alcalá, Algeria, Dagua, El Dovio, Jamundi, La Unión, Obando, Palmira, Restrepo, Roldanillo and Versalles are the municipal capitals with increased vulnerability to water shortages.

- Santander: This department has a medium vulnerability. The total average annual precipitation is low to moderate with values between 1000 - 3000 mm (IDEAM, 2014b). The most vulnerable areas are to the north and east of the department in the Lebrija, Suarez and Chicamocha rivers, where water vulnerability indexes (WVI) are moderate and high, due to the high demand of the resource in these areas and that it is where the lowest values of precipitation of the department (1000 -1500 mm) occur. Although water regulation is moderate and high, in times of drought the superficial supply does not fall to critical levels. Santander is one of the departments with the largest number of hectares dedicated to the agricultural industry, besides being one of the departments where the country's industry is concentrated (data taken from the DANE), making this region sensitive to the effects of drought. Groundwaters are exploited as alternative sources of supply, the resource is extracted from the aquifer systems of San Gil - Barichara, Mesa de los Santos, Bucaramanga - Piedecuesta and Tablazo, and its use is mainly domestic and industrial (IDEAM; 2013). According to ENA 2010, Bucaramanga, Barbosa, Barichara, Charalá, and Velez are municipal capitals with increased vulnerability to water shortages.

- Norte de Santander: This department has a medium vulnerability. The annual average total precipitation is low to moderate with values between 1000 - 5000 mm (IDEAM, 2014b), the water regulation index is low to moderate and the demand is high in the subzones of the Pamplonita and Zulia rivers. The low regulation causes the water supply to decrease in dry times and the drinking water and agriculture sectors to be affected. Groundwaters are exploited as alternative sources of supply and are extracted from the Cúcuta-Villa del Rosario aquifer system. According to ENA 2010, Durania, El Carmen, Los Patios, Ocaña, Pamplona, Pamplonita, Ragonvalia, Salazar, San Calixto, Teorama and Villa del Rosario are municipal capitals with increased vulnerability to water shortages.

- Huila: This department has a high vulnerability. The total annual average precipitation is low with values between 1000 - 2000 mm (IDEAM, 2014b). The most vulnerable areas are located in the central and northern part of the department where the water vulnerability indexes (WVI) are high and very high due to the low water regulation that causes the supply of the resource to decrease considerably in dry periods. Groundwaters are exploited as alternative sources of supply, the resource is extracted from the aquifer system of Neiva - Tatacoa, and mainly supplies the agricultural and industrial sectors. According to ENA 2010, Garzón and Palermo are the municipal capitals with the greatest vulnerability to water shortages.

- Antioquia: This department has a medium vulnerability. The total annual average precipitation is moderate with values between 1500 - 3000 mm (IDEAM, 2014b) and water regulation is moderate to high. The demand for the resource is high in the areas of the Porce and Nare rivers and only these areas have a moderate water vulnerability index (WVI). Although the WVI is low to moderate in the department, the fact that Antioquia is the department with the largest agricultural area in the country, and being a region where much of the national trade and industry is concentrated, as well as having several of the most important reservoirs of the national territory, makes it a highly sensitive department to drought. Groundwaters are exploited as alternative sources of supply in some areas and in others it is the only source of supply. This is the case for the municipalities of Caucasia, Cáceres, Nechí, Tarazá and El Bagre (University of Antioquia, 2011). The aquifers that are exploited in this region are the Antioquia Lower Cauca, Valley of San Nicolás and La Unión, Valley of Aburrá Valley, Santa Fe de Antioquia and Urabá Gulf (IDEAM, 2014a). According to ENA 2010, Angelópolis, Santa Fe de Antioquia, Caldas, Caramanta, Carmen de Viboral, Caucasia, Fredonia, Guarne, Peque, Remedios, Tarazá, Tarso, Titiribí and Venicia are the municipal capitals with increased vulnerability to water shortages.

5.3. Pacific Region

Sectors Affected by Drought Events

The Pacific Region was not affected mostly during the El Niño phenomenon 2014 - 2016. According to UNGRD (2016), the sectors affected during this phenomenon were:

- In the drinking water sector, the municipalities of Riosucio and Medio Baudó, in the department of Chocó were affected by shortages; and two municipalities were affected due to rationing, Vigia del Fuerte and Murindó in Antioquia.

- In the environment sector, forest fires affected mainly the department of Chocó, where approximately 6,000 ha were burned.

- The Health Sector was affected by the outbreak of vector-borne diseases (VBD) such as Dengue, Chikungunya and Zika. In Chocó and the Pacific coast, in the departments of Valle del Cauca, Cauca and Nariño, where the most affected were the poor populations.

Vulnerable Areas

The precipitation deficit in phenomena such as El Niño affects the Pacific Region with decreased flow of rivers; mainly in the area of Patía, where 40% reductions are estimated with regards to normal years. There are also 20% reductions in the flow for the San Juan and Atrato rivers compared to the average flow (IDEAM, 2010).

Vulnerability in the Pacific Region is low, this is mainly due to the fact that the total annual average precipitation is very high with values between 3000 - 11000 mm (IDEAM, 2014b). The water regulation index is high, and the water demand is very low. Groundwater in this region has not been studied a lot, but the aquifer systems of Patía, Cauca, and Raposo that are used as alternate sources of supply are located there.

5.4. Orinoco Region

Sectors Affected by Drought Events

- According to the UNGRD (2016), the most affected sectors in the Orinoquía Region during the El Niño phenomenon 2014 - 2016 were:
- In the water sector, the municipalities of Yopal, Nunchia, Tamara, Paz de Ariporo and Hato Corozal in the department of Casanare were affected by water shortages.
- The environmental sector was one of the most affected by forest fires. The most affected departments were Casanare (42,610 ha), Arauca (28,914 ha) and Meta (11,767 ha).
- The agricultural sector was affected mainly in the department of Casanare where there were losses in 67,575 hectares of crops.
- The livestock sector was mainly affected in the department of Arauca.

Vulnerable Areas

The precipitation deficit in phenomena such as El Niño affects the Orinoco Region with a reduction in the flow of the rivers. The flows of the rivers in general decreases on average up to 30%. These reductions are greater in the Meta, Cabuyarito, Batá and Camoa rivers at the head of the Metica River (IDEAM, 2010).

The departments of Arauca and Casanare have a medium vulnerability. The total annual average precipitation is moderate with values between 2000 - 3000 mm (IDEAM, 2014b). The water regulation index is moderate to low and the demand for the resource is moderate to low. Groundwater in this region is used as a source of supply for some municipalities. Water is extracted from the aquifer systems of Arauca-Arauquita, Yopal Tauramena and Villavicencio-Granada-Puerto López (IDEAM, 2014a). According to ENA 2010, Yopal and Aguazul are the municipal capitals with the greatest vulnerability to water shortages.

5.5. Amazon Region

Sectors Affected by Drought Events

The Amazon Region practically did not suffer the impact of the El Niño phenomenon of 2014 - 2016. According to UNGRD (2016), the sector that was affected during this phenomenon was the drinking water sector, where the department of Puerto Asís in Putumayo showed shortages. The municipalities of Montañita, Valparaiso, Solita, Curillo in Caquetá and Puerto Guzmán in Putumayo were affected by rationing.

Vulnerable Areas

The Amazon Region in general is not affected by extreme events such as the El Niño phenomenon. Normally the flows remain the same or have a reduction no greater than 10% (IDEAM, 2010). According to IDEAM in the national water studies for 2010 and 2014, in the Amazon Region the WVI is low and very low, this is due to its high water yield and the low demand of water resources in this region. Regarding the municipal capitals, none are highly vulnerable, and only a few municipalities in Putumayo and Caquetá are in average vulnerability.

According to IDEAM (2015) for the Amazon Region, a precipitation deficit is expected for 2040 in the departments of Amazonas (-14.84%), Caquetá (-18,99%) and Vaupés (20,49%). This may cause problems with the future water resource in this region.

6. INTEGRATION OF MONITORING AND ALERT SERVICES DUE TO DROUGHT: WMO - CIIFEN. ERFEN (IDEAM - DIMAR)

Photograph UNGRD – Alta Guajira

6. INTEGRATION OF MONITORING AND ALERT SERVICES DUE TO DROUGHT: WMO - CIIFEN. ERFEN (IDEAM - DIMAR)

In the integration of international information, in addition to using information from its own observation networks, IDEAM incorporates follow-up and monitoring of meteorological information from international networks, satellite systems such as NOAA, GOES, and the information provided by the entities of the National Environmental System (SINA, for its acronym in Spanish). It also has national and regional weather forecast applications and numerical models that support the issuance of early warnings on the threat of events such as droughts, particularly due to the influence of the El Niño phenomenon. It also has information from specialized world centers (NOAA), from the models of international centers on climate prediction of large scale climate variability phenomena monitoring (El Niño, La Niña), the International Research Center on El Niño (CIIFEN), the World Meteorological Organization (WMO), the National Oceanic and Atmospheric Administration (NOAA), the International Research Institute for Climate and Society (IRI), among others.

In response to the climate effects and socioeconomic impact caused by El Niño for a long time now, it was considered convenient to study this climate variability event in a regional and global framework. So Colombia, Ecuador, Peru and Chile created the Program for the Regional Study of the El Niño Phenomenon in the Southeast Pacific – ERFEN in 1974, in order to achieve a better understanding of the causes and characteristics, with the purpose of improving the forecasting capacity of its effects and consequences on the regional climate. This Program coordinated by the Colombian Ocean Commission (CCO. for its acronym in Spanish) has been nationally institutionalized and consolidated as a comprehensive and multidisciplinary program for the regional study of the event, in which national research institutions participate in the oceanographic fields (physical and chemical), meteorological, biological marine and biological fishing.

In addition to this integration of drought monitoring, the International Research Center on El Niño (CIIFEN)[10] was created in accordance with Resolution 54/220 of the United Nations General Assembly on International Cooperation to reduce the negative impact of the El Niño Phenomenon.

CIIFEN's work began on January 10th, 2003, and in 2015 it was appointed as a Regional Climate Center for the west of South America, which strengthens it and acquires a greater commitment to this regions' meteorological services, and consequently to Colombia's.

This Institute, with the support of the World Meteorological Organization - WMO, and the active participation of the Meteorological Services of western South America, has coordinated 16 regional climate forums with technicians from the 6 countries of Bolivia, Chile, Colombia, Ecuador, Peru and Venezuela. During the Forum, a review is done and a consensus is reached on the methodology for the preparation of the seasonal forecast with participants. Two forums have been held in Colombia. CIIFEN's mission is to promote and develop actions to consolidate the interaction between science and policy and the strengthening of climate and ocean services with the aim of contributing to risk management and adaptation to better face climate change and climate variability.

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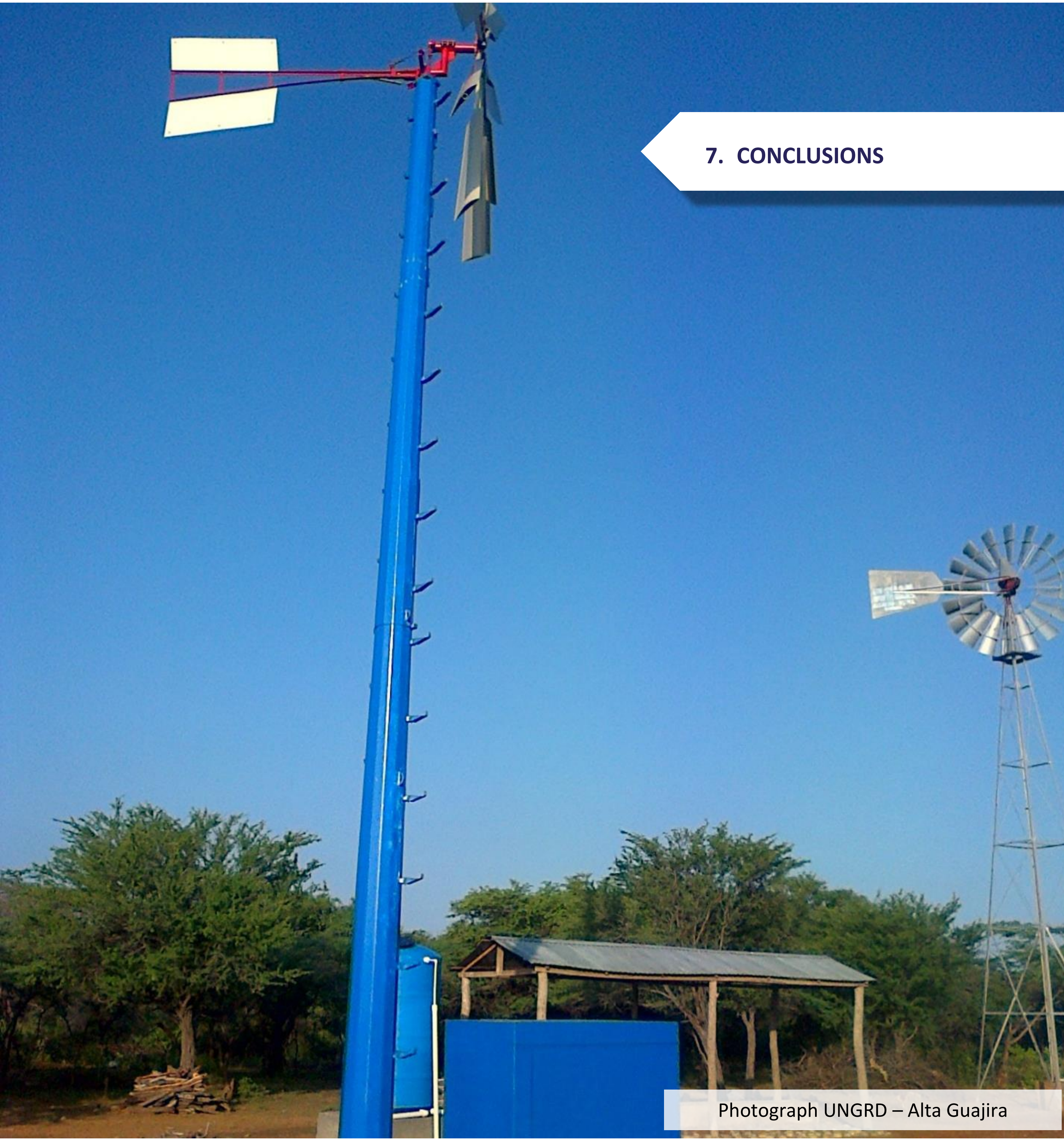
[10] http://www.ciifen.org/index.php?option=com_content&view=article&id=183&Itemid=452&lang=es

It is important to highlight that CIIFEN is responsible for integrating seasonal forecasts for the region since 2005. This information is produced monthly based on information from the Meteorological Services of Western South America and is disseminated among all countries. It is a regional effort to obtain integrated products for regional climate monitoring.

The World Meteorological Organization-WMO, is the specialized entity of the United Nations responsible for operational meteorology and hydrology. It was created in 1950 and is comprised of 185 member states and territories. Colombia has been a member country since January 5th, 1962 and the Institute of Hydrology, Meteorology and Environmental Studies-IDEAM acts as Colombia's representative before this body. Under this framework, international cooperation is exercised for the development of meteorology and operational hydrology and the benefits derived from its application for member countries.

This Organization has the Public Meteorological Services Program (PSMP) and supports the National Meteorological and Hydrological Services, and the Climate Information and Prediction Services (SIPC) project of the WMO promotes the use of new capabilities to predict climate, which have been of great help in some parts of the world especially in the early warning of significant seasonal and climate phenomena associated with El Niño.



7. CONCLUSIONS

Photograph UNGRD – Alta Guajira

7. CONCLUSIONS

Upon Evaluating assessing the early warning systems that exist in Colombia, it can be inferred that many entities have observation systems for the monitoring of hydrometeorological variables which they analyze and process to generate products according to their sector's needs of their sector.

IDEAM monitors the drought, with standardized precipitation rates, and water availability indexes, and issues seasonal and short-term forecast bulletins, but does not specifically issue a drought alert as such.

When under the influence of an El Niño phenomenon, the entire National Disaster Risk Management System is activated by updating its national, departmental and municipal contingency plans at the national, departmental and municipal levels in the face of the water deficit that affects the energy sector (hydroelectric energy production), the agricultural and livestock sectors (reduction of yields in crops yields and increase in production costs), aqueducts (drinking water supply), ecosystems (scarce water supply), health (increase of diseases), etc.

Working together with all sectors sensitive to drought, with integrated surveillance and early warning systems that involves integrating observation networks, drought indices, water source indices, vegetation indices etc., could improve the response to drought, reducing negative impacts.

In Colombia does not need it is not necessary to make create a national drought policy on drought. There is the National Disaster Risk Management Plan-PNGRD, adopted with Decree 308, of 2016, of the Presidency of the Republic, in which identifies projects and related programs are identified with climate variability and whichthat are being executed by state entities with short, medium and long-term goals throughout the chain of Risk Management chain: Knowledge, reduction and disaster management.

Although state entities are carrying out projects aimed at climate variability, there is still a need to strengthen the entities' budget of entities so that they can more agilely undertake the projects identified in the plan, especially those related to studies.

Colombia at the national level has an early warning system for the possibilityle formation of the El Niño Phenomenon. As evidenced in the most recent Phenomenon, the alert was given 7 months in advance, which gave time to prepare nationally. However, at the regionally level it is observed that a greater anticipation of the warning is required for the preparation, which also depends on the sector.

Finally, the participants in the workshop made special recommendations such as having an early warning comprehensive system for drought, under a monitoring platform where the relevant information of all sectors is consolidated for effective and timely monitoring, continue to advance in improving the seasonal predictions, sensitize create awareness in the community with an emphasis on conserving water conservation, greater usetilization of groundwater resources, creating greater institutional capacity, improving coordination and support between the different levels of government with sectors that are affected by drought and private organizations such as irrigation districts and, farmer guilds, to name a few.

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