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Agriculture Drought in Africa Mediterranean and Middle East

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AGRICULTURE DROUGHT IN AFRICA MEDITERRANEAN AND MIDDLE EAST

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Foreword and Preface

"….When one door closes, another opens; but we often look so long and so regretfully upon the closed door that we do not see the one that has opened for us….".

- Alexander Graham Bell

I have to admit that when I have been asked to do the Agriculture **Drought** study for the Global Assessment Report (GAR 2013), I accepted to do the job with a smile but I was afraid, because I have to go again with my team through many challenges:

….. The term drought is widely used but the meaning of the term varies from among different searchers, and defined in various ways. This creates the difficulty of understanding drought characteristics across time and space. **Drought** is an extreme climate event happens on longer time scales and could be persisted over decades. ... We must fulfill the new IPCC definition of **Drought.**

…..We have to create a new **Drought** framework that is scientifically accepted and easy to apply.

..... We have to cover with a limited team (6 people), areas wider than we used to cover as on our studies (The Arab region) and we are targeting Africa & Mediterranean, and

…..We have to finish the work in 9 months

I believe that facing another day in life means facing more **challenges** and gaining more experience.

I said to my team why not? ...Lets accept the challenge like we used to do before; let's gain more experiences and more learning.

…. I remembered when I accepted writing "drought case study in IPCC/SREX report"… I remembered when we wrote the case study about drought in Arab region with 10 years of drought in Syria, and …. I remembered the number of projects I managed successfully during the last 35 years of my scientific life… I remembered my team they never let me down.

Why not? Doing the job, especially if the topic that we have to cover is Drought….. The wards came to my ears be not afraid as you take another step today….you will learn.

***Drought,* is spreading like cancer,**

That was the reason for me to study **Drought** during the last 7 years, when thinking about drought, I think of how cancer starts and spreads slowly before we recognize its diagnosis… especially if this combination of **Drought** and Land Degradation exist …..It's my nightmare.

When **Drought** comes to my mind, I usually ask myself questions like, Is Europe on the way to split into poor Europe and Rich Europe? And if the ongoing increased drought and land degradation since the 1970s has something to do with this weakness and may lead to the shrinking of the western civilization like the old Roman Empire did many dictates ago?.... Before answering this, let's see the problems towards the end of the Roman Empire and ask our self's a question, is there any similarity?

The Roman Empire was getting weak and it was too large to govern effectively, the army was not what it used to be. Civil wars broke out between different political groups, the head of government was not always a capable leader, the increased use of foreigners' worker put many Romans out of work, and the rich became lazy and showed little interest in trying to solve Rome problems. The poor were overtaxed and overworked. They were very unhappy. Prices increased, trade decreased. The population was shrinking due to starvation and disease. This made it difficult to manage farms and government effectively.

The ancient Romans tried to solve some of their problems by splitting the Roman Empire in half, hoping that would make the empire easier to manage. Each side had an emperor, but the emperor in charge was the emperor of the western half, the half that included the city of Rome. The Western Roman Empire did not do well. Instead of getting stronger, they became weaker. By 400 AD, it was pretty much over. The barbarian tribes might have been the group that finally brought Rome down. They were all attacking various pieces of the Western Roman Empire. Europe entered the Dark Ages. The Easter Roman Empire received a new name – the Byzantine Empire. The Byzantine Empire did fine. It lasted for another 1000 years! This, with its center in Constantinople, managed to cling on for almost another thousand years until it was eventually conquered by the Turks under their leader Mohammed II in the year AD 1453.

Africa, Middle East and Mediterranean are facing similar problems but in different severity depending on their capabilities and resilience, problems such as increased hunger and food insecurity, Water scarcity in many places, desertification, decline of bio-diversity, change in life form within forests and rangelands, increased

uncertainty in Agriculture, increased population and increased internal and external migration.

Is the gab created in the Arab region and the changes that took place - that known as Arab Spring- is similar to the same era when the old Roman Empire shrank many dictates ago, living an empty space behind them?

But can people ignore it and try to pretend it’s not hurting them?

In fact the wider it spreads… Both rich and poor people are mistaken if they pretend that it is not their problem, or thinking that the problem is limited to arid-lands and dry zones, and if they thought that it’s a short-term problem and will disappear as started…

In fact we must take action now and should work to mitigate it and reduce its affects before it damages many of our gained civilization permanently.

When thinking about Drought, We mustn’t limit our challenges; challenge our limits. It's true that we don't know what we've got until we lose it, but it's also true that we don't know what we've been missing until it arrives.

I always see the pyramids as a symbol of sustainability; I remember that climate has shaped the cultures of Middle East, The first, Settlements in the world, farming communities, and cities. All began in this region, and all have changed in response to a variable climate. For thousands of years, people of the region have coped with the challenges of climate variability by adapting their survival strategies to changes in rainfall and temperature

Drought is increasing and Land Degradation as well, we don’t have time to lose…… So we must act now…….

1. INTRODUCTION

1.1. Drought part of the History and Environment.

Droughts have been a part of our environment since the beginning of recorded history, and humanity's survival may be testimony only to its capacity to endure this climatic phenomenon. Drought is considered by many to be the most complex but least understood of all natural hazards, affecting more people than any other hazard (Hagman 1984)[1].

Unlike the risks associated with drought remain less well understood. Drought, therefore, is often a less visible risk. Losses and impacts are not systematically captured, global standards for measuring drought hazard are only slowly being introduced, and there are difficulties regarding data collection. As a result, comprehensive assessments of drought risks are only just beginning and, as yet, there is no credible global drought risk model. Case studies indicate that the impacts of drought can only be partly attributed to deficient or erratic rainfall, as drought risk appears to be constructed over time by a range of drivers. These include: poverty and rural vulnerability; increasing water demand due to urbanization, industrialization and the growth of agribusiness; poor soil and water management; weak or ineffective governance; and climate variability and change, (UNISDR 2011)[2].

Droughts have been a part of our environment since the beginning of recorded history, and humanity's survival may be testimony only to its capacity to endure this climatic phenomenon. One of the earliest records of efforts to plan for droughts is the story of "Joseph". The story of Joseph is the world's first recorded national drought extreme event, as the Old Testament tells the story,

> *"……One night, Pharaoh has a dream he doesn't understand and it alarms him. His servant tells him about Joseph and Joseph is brought to the palace and interprets the dream. God reveals to Joseph that Pharaoh's dream is a prophecy of the next seven years. The kingdom will experience seven plentiful harvests followed by seven years of famine. Joseph advises Pharaoh to store grain from the plentiful harvests to be used during the famine. Pharaoh agrees and puts Joseph in a position of power." (Genesis 42:1-36).*

It is also the first Drought management known in the history,

> *"….The storehouses are filled through the seven prosperous years and then when the famine comes, people from all around begin coming into Egypt to try and buy corn. Among those who came in search of grain were Joseph's elder brothers. Joseph is now in a position of power and could gain revenge for the way his brothers had treated him. He does cause them some fear, but in the end is able to spare his brothers and his father from suffering the famine as a result of his position." (Genesis 43-47).*

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[1] Hagman, G.: 1984. Prevention better than cure. Report on Human and Environmental Disasters in the Third World, prepared for the Swedish Red Cross. Stockholm.

[2] UNISDR, 2011. Global Assessment Report on Disaster Risk Reduction. Geneva, Switzerland: United Nations International Strategy for Disaster Reduction.

Drought is a normal event that takes place in almost every climate on Earth, even the rainy ones; it is the most complex of all natural hazards as it affects more people than any other hazard. Aridity is a permanent feature of climate, while drought is a temporary event, Drought is viewed relative to some long-term average of precipitation, stream-flow, temperature, groundwater level, number of rainfall events, etc.,

There is *medium confidence* that droughts will intensify in the 21st century in some seasons and areas, IPCC (2012)[3], due either to an enhanced precipitation deficit or to evapotranspiration excess. Effective disaster risk management and climate change adaptation incorporate a portfolio of strategies, policies, and measures that address exposure and vulnerability within the context of multiple stressors.

As drought has different types and different impacts based on geographic locations, examples of the complex ways in which extreme events, long term trends, and high vulnerability interact to produce extreme impacts in different geographical locations.

There is *medium confidence* that droughts will intensify in the 21st century in some seasons and areas, due either to an enhanced precipitation deficit or to evapotranspiration excess. Effective disaster risk management and climate change adaptation incorporate a portfolio of strategies, policies, and measures that address exposure and vulnerability within the context of multiple stressors.

Pre-disaster financial mechanisms (including remittances, novel forms of insurance such as index-based micro-insurance, and catastrophe bonds) are important components of disaster risk management and climate change adaptation in regions with little formal insurance or post-event government compensation, (UNISDR 2011).

During the last years *Wadid Erian* and his team studied drought in Arab region with especial focus on Syria, we will try to summarize Syria study as an introduction to the on-going study for highlighting the development of the process towered understanding drought.

The region is subject to frequent agriculture (soil moisture) droughts and rainfed crops are strongly affected by precipitation fluctuations; mainly in the areas were annual rainfall range between 120/150 – 400 mm, they are considered moderately to sever vulnerable areas to drought; (Erian et al, 2006)[4].

[3] IPCC, 2012: *Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation*. A Special Report of Working Groups I and II of the Intergovernmental Panel on Climate Change [Field, C.B., V. Barros, T.F. Stocker, D. Qin, D.J. Dokken, K.L. Ebi, M.D. Mastrandrea, K.J. Mach, G.-K. Plattner, S.K. Allen, M. Tignor, and P.M. Midgley (eds.)]. Cambridge University Press, Cambridge, UK, and New York, NY, USA, 582 pp.

[4] Erian, W.F., F.S. Fares, T. Udelhoven and B. Katlan, (2006). "Coupling Long-term NDVI for Monitoring Drought in Syrian Rangelands", The Arab Journal for Arid Environments, volume (1), pp 77-87, Published by ACSAD.

1.2.Drought Consequence in Syria

In a Country like Syria, where the rainfall represents 68.5% of the available water sources, the precipitation concentration index (PCI) for the period (1960-2006) has been studied in three stations in the Northeastern part of Syria, (Kamishli, Tel-Abiad and Hassakah), which present Al Jazerah region, and the study show sever decrease in annual rainfall quantities that has been estimated by (27.7%) in Kamishli, (19.2%) in Tel-Abiad and (26%) in Hassakah and related to the decreasing in spring and winter rainfall quantities; (Skaff and Masbate, 2010)[5].

This negative trend of precipitation during the past century and beginning of 21 century is of a similar magnitude as that predicted by most of the Global Circulation Models for the Mediterranean Region in the coming decades.

Areas affected by drought in Syria have been estimated by 34% of Syrian territory, where area of about 10% is of moderately vulnerable to drought, and area of about 4% is highly vulnerable to drought.

Most of the vulnerable areas are considered important areas for crop production in Syria, (figure 1.1), the spatial distribution of the vulnerability to drought shown that farming regions at south-western and north-eastern parts of the country are mostly affected, especially in Hassakeh governorate; (Erian et al., 2011)[6].

The eastern region of Syria (Hassakah, Deir al-Zor and Raqqa governorates), considered as the most important areas of agricultural production in Syria and most affected by drought. About 7.6 million hectares, that represent 41% of the total area of Syria, with total population number of about 3.5 million person, representing 17% of the population of Syria. Eastern region represent 22.4% of the total rural population in Syria and 30% of the agricultural sector; Kattana, (2011)[7].

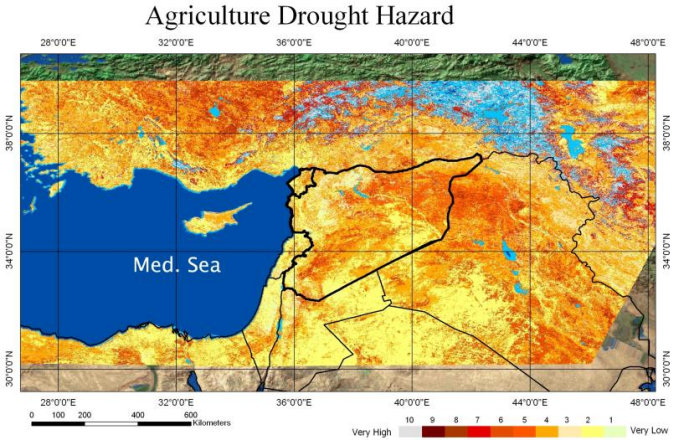


Figure 1.1 Agriculture Droughts in Syria and Surroundings.

[5] Skaff, M. and Masbate, Sh., 2010. Precipitation Change, and Its Potential Effects on Vegetation and Crop Productivity in Syrian Al Jazerah Region. The Arab Journal for Arid Environments 3 (2):71 - 78.

[6] Erian, W., Katlan, B. and Babah, O., 2011. Drought Vulnerability in the Arab Region, Case Study- Drought in Syria Ten Years of Scarce Water (2000 – 2010), ACSAD and UNISDR publication Giorgi, F., 2006: Climate change hot-spots. Geophysical Research Letters, 33(L08707)

[7] Kattana, H. , 2011. Agriculture Production Indicators In North Eastern Part of Syria. WB, MAAR and ACSAD Workshop on: Reducing Vulnerability to climate change in Agricultural Systems in Syria, March 23-24, El-Hassakeh governorate, Syria.

1.2.1. Major impacts of drought

– Agricultural production:

- According to; Kattana, (2011), the eastern part of Syria represent 31.75% of the total rainfed areas of Syria and due to drought has been declined from 1.12 to 0.98 million hectare, during the years from 2000 to 2009.
- The region is contributing by 58% of the total wheat production, 68-78% of the total cotton production, 62-72% of the total maize production and 22% of the total sugar beet production, and have 30% of the goats, 36-41% of the sheep and 31-34% of the cows.
- Rainfed wheat area normally amounts to more than 0.8 million hectares, and is extremely reliant on timely rainfall during the growing season, wheat production has dropped in the eastern part of Syria by 25.9% during the years 2000-2009, and total production from 2.6 to 2.1 million ton during the years 2005-2009 and reaching to 1.2 and 1.9 million ton in 2008 and 2009 respectively. During the agriculture season 2007–2008 and due to severe drought in the Syria, 75% of the country's farmers suffered total crop failure, where, wheat production dropped by 39.8% from 0.43 to 0.25 million ton from the year 2000 to the year in Al-Hassakehh governorate in the eastern part; (Kattana, 2011).
- Barley production which considered an important crop for rainfed areas in the country, and used as fodder for animals has decreased in the last years 2005-2009 up to 40%, beside the absence of natural pastures and at the same time feed prices have doubled, which resulted in the sale of animals, accompanied by a large fall in price of ewes sold or slaughtered as well as young animals in the market; animals weight loss in beside physical deterioration; lower in the amount of newly born young because of Low fertility rate, declining birth rate, low rate hike to zero; and. breeders forced to sell a large proportion of female babies beside the high mortality rate of adult ewes and young animals; (FAO 2011)[8].
- The estimated number of sheep population has dropped from 2.47 million head at the year 2005 to 1.5 million head at the year 2009 and the livestock population was 50 percent below the pre-drought level more than a year after the drought ended; (Kattana, 2011and Erian et al, 2011).

– rural livelihoods:

- The severe shortage of rainfall that has lasted more than four agriculture seasons (2007/2008 – 2010/2011) has crippled agriculture in eastern and Northeastern Syria; farmers who depend on only one crop are in trouble - they have nothing else to help them and they have to move; (Erian et al, 2011; Kattana, 2011; UNISDR, 2011 and FAO, 2011).
- Increased respiratory infections, particularly because of the atmosphere nebular (dusty), particularly in the north-eastern areas lack of water (for drinking and domestic use) or provided by a non-secure health, leading to a variety of digestive diseases tract and diarrhea (especially in children), and kidney disease; (FAO, 2011).

[8] FAO 2011. Food security in Syria under Climate Change; WB, MAAR and ACSAD Workshop on: Reducing Vulnerability to climate change in Agricultural Systems in Syria, March 23-24, El-Hassakeh governorate, Syria

- A rise in the rate of borrowing in rural households in the three provinces between 2006 and 2010 estimated by 350%; (ACSAD, 2010)[9].

– migration:

- During the years 2007 to 2011, Some 1.3 million people of a population of 22 million have been severely affected by the disaster, of which 800,000 have lost almost all of their livelihoods and face extreme hardship.
- Migration out of the affected areas has increased, with estimates indicating that between 40,000 to 60,000 families, with 35,000 from "Hassakeh governorate" alone have driven to urban settlements on so called mass migration toward Syria's cities such as Aleppo, Damascus and Deir ez Zour in search of work and for new sources of income, many ending up with difficult laboring work. in one of the largest internal displacements in the Middle East in recent years; (Nashawatii, 2011[10] and Erian , 2010[11]). Thousands of Syrian farming families have been forced to move to cities in search of alternative work, most of the houses on villages are left empty and less than 10% are occupied by elder people and children, the younger generations left seeking work, many left to Lebanon or Jordon, as workers in the sectors of construction or agriculture. Women left to work in the western part of Syria, for packing vegetables in "Tartou governorate " greenhouses; (Erian et al., 2011).

– ecosystem decline:

- Due to drought that increased in frequency, intensity and duration, the deficit in available water has been estimated of about 651 million M^3 during the years 1995-2005, and still increasing with expectation to rise to 2077 million M^3 by the year in 2030 only because of population growth and the increasing pace of development; (Nashawatii, 2011).
- Decline in availability of irrigation water in the Hassakeh governorate is largely due to the hydrological drought of Khabour River, this has led to the decline in irrigated areas, the water scarcity has led to increasing pressures on ground water resources and brought the water crisis to critical levels; (FAO, 2011 and Mora, 2011[12]).
- Increase of moderate and severe land degradation that estimated during the period from 1999 to 2007 by 34.8% of the total area of Syria; (ACSAD, 2009)[13].

1.2.2. Intervention (preparedness, during, and post)

[9] ACSAD, 2010. Livelihood Development Response to Alleviate Rural Poverty and Drought Conditions in the North East of Syria, project document presentation, ACSAD, MAAR, AECID and ACF.

[10] Nashawatii, H (2010). "Climate Change: impacts and adaptation in Syria", in Arabic. Expert Meeting of the ASPA Countries for developing scientific and technological cooperation on climate change, organized by LAS, ACSAD, MoE in Syria, Damascus, 4-6 May.

[11] Erian, W. F (2010). "Desertification and Drought in Arab Countries". Expert Meeting of the ASPA Countries for developing scientific and technological cooperation on climate change, organized by LAS, ACSAD, MoE in Syria, Damascus, 4-6 May

[12] Mora, S., 2011. Water resources in East Syria; WB, MAAR and ACSAD Workshop on: Reducing Vulnerability to climate change in Agricultural Systems in Syria, March 23-24, El-Hassakeh governorate, Syria.

[13] ACSAD (2009). "Desertification Bulletin", second bulletin, Published in the Arab Center for the Studies of Arid Zones and Dry Lands in cooperation with GTZ and NCRS in Lebanon

Unfortunately, most countries are treating extreme events with so called crisis management rather than drought management, this approach has been ineffective because response is untimely. Poorly coordinated, and poorly targeted to drought stricken groups or areas., two important trends in drought management are to be considered: (1) improved drought monitoring tools and early warning systems EWSs and (2) an increased emphasis on drought preparedness and mitigation; (Wilhite, 2005)[14].

Syria is just beginning to establish a drought monitoring unit at the Ministry of Agriculture and Agrarian reform MAAR, began in 2004**,** aiming at predicting and early warning to the problems of drought, with a focus on rangelands and marginal areas; the unit also is in charge of the development of a national strategy for drought management; (Hamouda, 2011)[15].
The major actions classified upon their relation to sustainable drought management into emergency actions, short to moderate actions. long-term actions:

– <u>Emergency actions:</u>

- MAAR is leading a coordination and cooperation between the governmental, regional and international agencies to mitigate the effects of drought. The coordination included, compensate farmers and mainly for emergency food supply.
- Cooperation between MAAR and FAO started emergency drought projects to maintain the continuity of small farmers and vulnerable herders, provide urgent assistance from the seed of improved wheat and barley, provide fodder for sheep farmers and feed supplements and also provide support to the poorest families by giving them a number of sheep with technical advice; (FAO, 2011). Another cooperation with ACSAD, Spanish Agency for International Cooperation and Development AECID and Action Against Hunger Spain ACF started for providing support in 17 affected areas, each containing 2-3 villages to target poor and middle families, the activities includes: units for ripping agricultural and industrial waste, technical support in the fields of breeding sheep and goats, units for the pasteurization of milk, introduce portfolio method of agriculture agricultural technologies such as conservation agriculture, water harvesting and mitigating the loss of water and improved efficiency of use; (ACSAD, 2010).

– Drought management:

- Establishing a drought monitoring unit at the Ministry of agriculture and agriculture reform MAAR, began in 2004**,** aiming at predicting and early warning to the problems of drought, the unit also is in charge of the development of a national strategy for drought management; (Hamouda, 2011).
- Formulate a framework for an effective approach to minimize the impacts of drought in the urban sector in Syria, .and strengthening capacity development for disaster risk management, and urban risk reduction, that effort is led by ACSAD, Ministry of Local Administration, UNDP and MAAR.

[14] Wilhite, DA. 2000. Drought as a natural hazard: concepts and definitions. In: Wilhite DA, ed. Droughts: Global Assessment. London: Routledge; 3–18

[15] Hamouda, G, 2011. Drought Early warning system in Syria; WB, MAAR and ACSAD Workshop on: Reducing Vulnerability to climate change in Agricultural Systems in Syria, March 23-24, El-Hassakeh governorate, Syria.

- Providing water to irrigate 210,000 hectares in the province of Hassakeh, through pumping water from the Tigris River at the site of Ain Dewar to Khabour River; (Mora, 2011).

1.3. Outcomes / Consequences

- Mediterranean region is strained by unequal water allocation and ecological fragility as population and economics grow, even though, an area in more severe drought increases much more than the area in less severe drought, and this could have serious consequences as the impact of drought on socioeconomics increases with the severity of drought; Burke and Brown, 2007. Even drought causing further degradation of the region's natural resources base is likely, unlikely the size of risks associated with drought remain less well understood, losses and impacts are not systematically captured; (UNISDR 2011).
- Accordingly, countries of the Mediterranean and Middle East, suffering now from the increased drought frequency, intensity and duration are likely to suffer more clear and significant drought losses and impacts on agricultural production, rural livelihoods, migration, urban, economic sectors and ecosystem decline.
- Water resources are dwindling by population increase regardless of drought in most Mediterranean and Middle East countries; Squires, (2001)[16], Water scarce was estimated to reach severe levels by the year 2025; (El- Quosy, 2009)[17]. The already on-going and growing critical situation caused by hydrological drought and soil moisture (agriculture) drought, will reflect extremely severe in water scarce, and contribute to the likelihood of conflicts by causing displacement and migration, increasing competition for scarce resources and exacerbating ethnic tensions; (Barnett and Adger, 2007[18]; Reuveny, 2007[19]; and UNISDR, 2011).
- The continuous increasing gap between countries demands for water for serving its sustainable development and available water resources in many Mediterranean and Middle East countries, The increasingly serious drought conditions throughout the entire Mediterranean and Middle East regions. Syria, Jordon, Palestinian Territories, Lebanon and Iraq have all reported water shortages that are sure to affect both their ecosystem stability and national security; (El- Quosy, 2009).
- Poor rural households with livelihoods that depend on rainfed agriculture are more vulnerable to drought and less able to absorb and buffer the losses. Consequences include increased poverty, reduced human development and negative impacts on health, nutrition and productivity; (de la Fuente and Dercon, 2008 [20];and UNISDR, 2009[21]).

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[16] Squires VR (2001) "Dust and Sandstorms: an early warning of impending disaster. In Yang Youlin, Squires V, Lu Qi (ed.) Global alarm: dust and sandstorms from the World's Drylands, Asia RCU of the UNCCD, Bangkok.

[17] El-Quosy, D.E. (2009). "Fresh Water." In Impact of Climate Change on Arab Countries (Eds .Mostafa K. Tolba and Najib W. Saab). Arab Forum for Environment and Development, Beirut.

[18] Barnett, J. and Adger, W.N. 2007. Climate change, human security and violent conflict. *Political Geography* 26 (6): 639–655.

[19] Reuveny, R. 2007. Climate change-induced migration and violent conflict. *Political Geography* 26 (6): 656–673.

[20] de la Fuente, A. and Dercon, S. 2008. *Disasters, growth and poverty in Africa: Revisiting the microeconomic evidence*. Background paper prepared for the 2009 Global Assessment Report on Disaster Risk Reduction. Geneva, Switzerland: UNISDR

- Drought impacts in some areas is irreversibly, people abandoned their lands, houses and looking for new life in other areas that could offer them other opportunity and alternative chances. Their migration becomes permanent because farmers and badwins failed in obtaining economical yield or feeding their animals, to gain sufficient income to sustain their family's needs. The rain is not enough anymore in amount and variability to sustain crop production and all scenarios showing a more moderate to severe drought in the near future, accompanied by increasing temperatures, disruption of the hydrological cycle, resulting in less and more erratic rainfall that will aggravate even further the already critical state of water scarcity ; (Abou-Hadid, 2006)[22].
- Impacts on animal productivity due to increased variability in weather patterns will likely be far greater than effects associated with the average change in climatic conditions. Lack of prior conditioning to weather events most often results in catastrophic losses in confined cattle feedlots;. With economic losses from reduced cattle performance exceeding those associated with cattle death losses; (Mader, 2003)[23].
- In dry regions, there are risks that severe vegetation degeneration leads to positive feedbacks between soil degradation and reduced vegetation and rainfall, with corresponding losses of pastoral areas and farmlands; (Zheng et al, 2002)[24].
- The impacts of drought can only be partly attributed to deficient or erratic rainfall, as drought risk appears to be constructed over time by a range of drivers. These include: poverty and rural vulnerability; increasing water demand due to urbanization, industrialization and the growth of agribusiness; poor soil and water management; weak or ineffective governance; and climate variability and change; (UNISDR 2011).
- Increased respiratory infections, particularly because of the atmosphere nebular (dusty), particularly in the north-eastern areas lack of water (for drinking and domestic use) or provided by a non-secure health, leading to a variety of digestive diseases tract and diarrhea (especially in children), and kidney disease; (FAO 2011).

1.4. Lessons Identified

Countries of the Mediterranean and Middle East, suffering now from the increased drought frequency, intensity and duration are likely to suffer more drought losses and impacts on agricultural production, rural livelihoods, migration, urban, economic sectors and ecosystem decline. They are in need for:

a) Strengthen commitment for comprehensive disaster risk reduction through CCA and DRR in national policies, legal frameworks, development plans and actions; decentralize resources, community participation; develop capacities to identify, assess and monitor drought risks through national/local multi-hazard risk assessment; build

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[21] UNISDR, 2009. Global Assessment Report on Disaster Risk Reduction. Geneva, Switzerland: United Nations International Strategy for Disaster Reduction.

[22] Abou-Hadid, A.F., 2006. Assessment of impacts, adaptation and vulnerability to climate change in North Africa: food production and water resources.Assessments of Impacts and Adaptations to Climate Change, Washington, DC

[23] Mader, T.L., 2003. 'Environmental stress in confined beef cattle'. Journal of Animal Science,81(electronic supplement. 2):110-119.

[24] Zheng, Y.Q., G. Yu, Y.F. Qian, M. Miao, X. Zeng and H. Liu, 2002. 'Simulations of regional climatic effects of vegetation change in China'. Quarterly Journal of the Royal Meteorological Society, 128:2089-2114,Part B.

capacities/systems to monitor, archive, and disseminate data; regional early warning system and networks.

b) Build resilience through knowledge, advocacy, research and trainings by making information on drought risk accessible to all stakeholders; through educational material, curricula, approaches up to date; public awareness.

c) Integrate disaster risk reduction into emergency response, preparedness and recovery by making preparedness plans, contingency plans; recovery and reconstruction activities inclusive of all society groups and at all administrative levels; allocate budget locally for emergency; and coordination between national and local entities for timely information exchange during hazardous events and disasters.

d) Integrate activities in the national_strategy for CCA and DRR, such as: programs for drought risk loss insurance; Improved water use efficiency; adopting and adapting existing water harvesting techniques; conjunctive use of surface and groundwater; upgrading irrigation practices on both the farm level and on the delivery side; developing crops tolerant to salinity and heat stress; change of cropping patterns; altering the timing or location of cropping activities; diversifying production systems into higher value and more efficient water use options; and capacity building of relevant stakeholders for better understanding of climate change scenarios and risk analysis.

2. DEFINITION AND PROVINCE STUDIES OF DROUGHT.

2.1. Definition of Drought

The term drought is widely used but the meaning of the term varies from among different searchers, and defined in various ways. That creates the difficulty of understanding drought characteristics across time and space. Drought is An extreme climate event happens on longer time scales and could be persisted over decades.

The Glossary, (IPCC 2012)[25], defines drought as follows: *"A period of abnormally dry weather long enough to cause a serious hydrological imbalance. Drought is a relative term, therefore any discussion in terms of precipitation deficit must refer to the particular precipitation-related activity that is under discussion. For example, shortage of precipitation during the growing season impinges on crop production or ecosystem function in general (due to soil moisture drought, also termed agricultural drought), and during the runoff and percolation season primarily affects water supplies (hydrological drought). Storage changes in soil moisture and groundwater are also affected by increases in actual evapotranspiration in addition to reductions in precipitation. A period with an abnormal precipitation deficit is defined as a meteorological drought. A megadrought is a very lengthy and pervasive drought, lasting much longer than normal, usually a decade or more.",* figure (2.1), after (Erian 2012)[26]

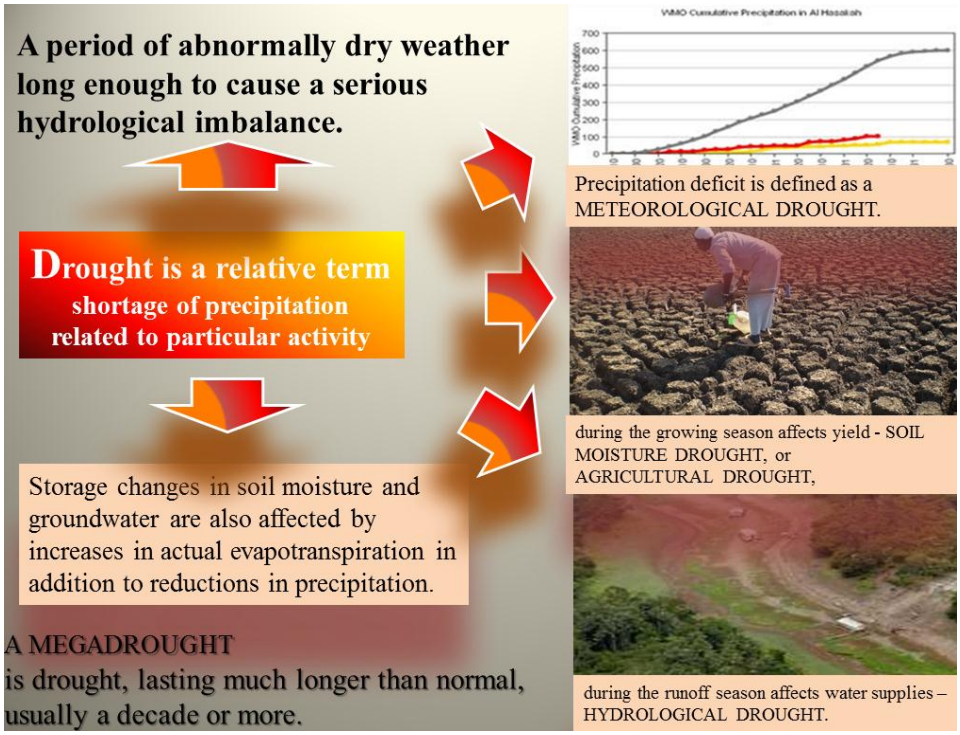


Figure 2.1. IPCC Drought Definition 2012, illustrated after Erian 2012.

[25] IPCC, 2012: *Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation*. A Special Report of Working Groups I and II of the Intergovernmental Panel on Climate Change [Field, C.B., V. Barros, T.F. Stocker, D. Qin, D.J. Dokken, K.L. Ebi, M.D. Mastrandrea, K.J. Mach, G.-K. Plattner, S.K. Allen, M. Tignor, and P.M. Midgley (eds.)]. Cambridge University Press, Cambridge, UK, and New York, NY, USA, 582 pp.

[26] Erian W. 2012. Agriculture Drought in Nile River Basin, ACSAD Workshop in Cairo, 20 23 May 2012

Weather and climate phenomena reflect the interaction of dynamic and thermodynamic processes over a very wide range of space and temporal scales. This complexity results in highly variable atmospheric conditions, including temperatures, motions, and precipitation, a component of which is referred to as 'extreme events.' Extreme events include the passage of an intense tornado lasting minutes and the persistence of drought conditions over decades, (IPCC 2001)[27]. The absence of precipitation as well as excess evapo-transpiration from the soil can be climate extremes, and lead to drought, (McKee et al., 1993)[28].

Soil moisture drought often called agricultural drought, which refers to a deficit of (mostly root zone) soil moisture. IPCC uses the term 'soil moisture drought' instead of 'agricultural drought,' despite the widespread use of the latter term (e.g., Heim Jr., 2002[29]; Wang, 2005[30]), because soil moisture deficits have several additional effects beside those on agro-ecosystems, most importantly on other natural or managed ecosystems (including both forests and pastures).

Drought should not be confused with aridity, which describes the general characteristic of an arid climate (e.g., desert). Indeed, drought is considered a recurring feature of climate occurring in any region and is defined with respect to the average climate of the given region (e.g., Heim Jr., 2002; Dai, 2011)[31]. Nonetheless, the effects of droughts are not affecting different regions equally (e.g., **a short-term lack of precipitation in a very humid region may not be critical for agriculture because of the ample soil moisture supply**). In fact for soil moisture or hydrological droughts, the main drivers as in the definition are reduced precipitation and/or increased evapo- transpiration as shown in figure (2.2), concerning vegetation cover point (nature or cultivated) , the changes in simulated soil moisture drought are mostly driven by changes in precipitation, with increased evapo-transpiration from higher vapor pressure deficit which often linked to increased temperature and available radiation modulating some of the changes (e.g., Burke and Brown, 2008[32]; Sheffield and Wood, 2008[33]; Orlowsky and Seneviratne, 2011[34]).

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[27] IPCC 2001 Climate change 2001: scientific basis, p. 944. Cambridge, UK: Cambridge University Press.

[28] McKee, T.B., N.J. Doesken, and J. Kleist, 1993: The duration of drought frequency and duration to time scales. In: *Eighth Conference on Applied Climatology*, 17-22 January 1993, Anaheim, California, cc.atmos.colostate.edu/relationship of drought frequency. pdf.

[29] Heim Jr., R.R., 2002: A review of twentieth-century drought indices used in the United States. *Bulletin of the American Meteorological Society*, 83(8), 1149-1165.

[30] Wang, G.L., 2005: Agricultural drought in a future climate: results from 15 global climate models participating in the IPCC 4th assessment. *Climate Dynamics*, 25(7-8), 739-753.

[31] Dai, A., 2011: Drought under global warming: a review. *Wiley InterdisciplinaryReviews: Climate Change*, 2(1), 45-65.

[32] Burke, E.J., and S.J. Brown, 2008: Evaluating uncertainties in the projection of future drought. *Journal of Hydrometeorology*, 9(2), 292-299.

[33] Sheffield, J., and E.F. Wood, 2008: Global trends and variability in soil moisture and drought characteristics, 1950-2000, from observation-driven simulations of the terrestrial hydrologic cycle. *Journal of Climate*, 21(3), 432-458.

[34] Orlowsky, B. and S.I. Seneviratne, 2011: Global changes in extremes events: Regional and seasonal dimension. *Climatic Change*, doi:10.1007/s10584-011-0122-9.

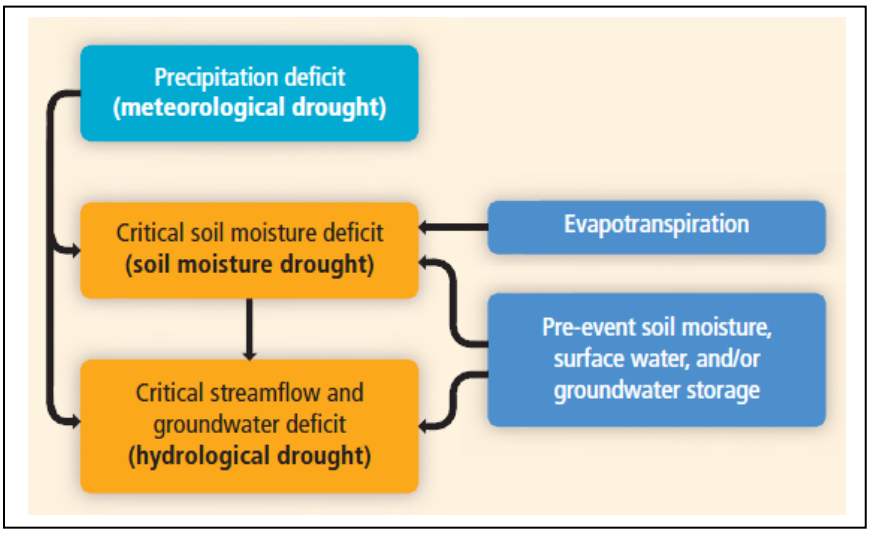


Figure 2.2. Simplified sketch, of processes and drivers relevant for meteorological,

2.2. Drought Indices

Because of the complex definition of droughts, and the lack of soil moisture observations, several indices have been developed to characterize (meteorological, soil moisture, and hydrological) drought (see, e.g., Heim Jr., 2002[35]; Dai, 2011[36]). Some indices are based solely on precipitation data, these include:

- The Standard Precipitation Index (SPI) is a widely used index (McKee et al., 1993[37]; Lloyd-Hughes and Saunders, 2002[38]), which consists of fitting and transforming a long-term precipitation record into a normal distribution that has zero mean and unit standard deviation. SPI values of -0.5 to -1 correspond to mild droughts, -1 to -1.5 to moderate droughts, -1.5 to -2 to severe droughts, and below -2 to extreme droughts. Similarly, values from 0 to 2 correspond to mildly wet to severely wet conditions, and values above 2 to extremely wet conditions (Lloyd-Hughes and Saunders, 2002). SPI can be computed over several time scales (e.g., 3, 6, 12, or more months) and thus indirectly considers effects of accumulating precipitation deficits, which are critical for soil moisture and hydrological droughts.
- The Consecutive Dry Days (CDD) index is Another index commonly used in the analysis of climate model simulations, which considers the maximum consecutive number of days without rain (i.e., below a given threshold, typically 1 mm day-1) within a considered period (i.e., year

[35] Heim Jr., R.R., 2002: A review of twentieth-century drought indices used in the United States. *Bulletin of the American Meteorological Society*, 83(8), 1149-1165.

[36] Dai, A., 2011: Drought under global warming: a review. *Wiley InterdisciplinaryReviews: Climate Change*, 2(1), 45-65.

[37] McKee, T.B., N.J. Doesken, and J. Kleist, 1993: The relationship of drought frequency and duration to time scales. In: *Proceedings of the 8th Conference on AppliedClimatology*, Anaheim, California, 17-22 Jan 1993, pp. 179-184.

[38] Lloyd-Hughes, B., and M.D. Saunders, 2002: A drought climatology for Europe. *International Journal of Climatology*, 22(13), 1571-1592.

in general; Frich et al., 2002[39]; Alexander et al., 2006[40]; Tebaldi et al., 2006[41]). For seasonal time frames, the CDD periods can either be considered to be bound to the respective seasons or considered in their entirety (across seasons) but assigned to a specific season.

Other indices reflect both precipitation and estimates of actual or potential evapo- transpiration, in some cases also accounting for some temporal accumulation of the persistence of the drought anomalies, these include:

- The Palmer Drought Severity Index (PDSI) (Palmer, 1965[42]), which measures the departure of moisture balance from normal conditions using a simple water balance model (e.g., Dai, 2011[43]).
- The Precipitation Potential Evaporation Anomaly (**PPEA**), based on the cumulative difference between precipitation and potential evapo-transpiration used in Burke and Brown (2008)[44].
- The Standardized Precipitation-Evapo-transpiration Index (**SPEI)**, which considers cumulated anomalies of precipitation and potential evapotranspiration and described in (Vicente-Serrano et al. 2010)[45].

There are still large uncertainties regarding observed global-scale trends in droughts. The AR4 reported based on analyses using PDSI that very dry areas had more than doubled in extent since 1970 at the global scale (Trenberth et al., 2007)[46]. This assessment was, however, largely based on the study by Dai et al. (2004)[47] only. These trends in the PDSI proxy were found to be largely affected by changes in temperature, not precipitation (Dai et al., 2004).

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[39] Frich, P., L.V. Alexander, P.M. Della-Marta, B. Gleason, M. Haylock, A.M.G. Klein Tank, and T. Peterson, 2002: Observed coherent changes in climatic extremes during the second half of the twentieth century. *Climate Research*, 19(3), 193-212.

[40] Alexander, L.V., X. Zhang, T.C. Peterson, J. Caesar, B. Gleason, A.M.G. Klein Tank, M. Haylock, D. Collins, B. Trewin, F. Rahimzadeh, A. Tagipour, K.R. Kumar, J. Revadekar, G. Griffiths, L. Vincent, D.B. Stephenson, J. Burn, E. Aguilar, M. Brunet,
M. Taylor, M. New, P. Zhai, M. Rusticucci, and J.L. Vazquez-Aguirre, 2006: Global observed changes in daily climate extremes of temperature and precipitation. *Journal of Geophysical Research – Atmospheres*, 111, D05109.

[41] Tebaldi, C., K. Hayhoe, J.M. Arblaster, and G.A. Meehl, 2006: Going to the extremes. An inter comparison of model-simulated historical and future changes in extreme events. *Climatic Change*, 79(3-4), 185-211.

[42] Palmer, W.C., 1965: *Meteorological Drought.* Report 45, US Weather Bureau, Washington, DC.

[43] Dai, A., 2011: Drought under global warming: a review. Wiley Inter disciplinaryReviews: Climate Change, 2(1), 45-65.

[44] Burke, E.J., and S.J. Brown, 2008: Evaluating uncertainties in the projection of future drought. Journal of Hydrometeorology, 9(2), 292-299.

[45]Vicente-Serrano, S.M., S. Begueria, and J.I. Lopez-Moreno, 2010: A multi-scalar drought index sensitive to global warming: The standardized precipitation evapotranspiration index. Journal of Climate, 23(7), 1696-1718.

[46] Trenberth, K.E., P.D. Jones, P. Ambenje, R. Bojariu, D. Easterling, A. Klein Tank, D.Parker, F. Rahimzadeh, J.A. Renwick, M. Rusticucci, B. Solden, and P. Zhai, 2007: Observations: Surface and atmospheric climate change. In: *Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*
[Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor and H.L. Miller (eds.)]. Cambridge University Press, Cambridge, UK, and New York, NY, pp. 235-336.

[47] Dai, A.G., K.E. Trenberth, and T.T. Qian, 2004: A global dataset of Palmer Drought Severity Index for 1870-2002: Relationship with soil moisture and effects of surface warming. *Journal of Hydrometeorology*, 5(6), 1117-1130.

On the other hand, based on soil moisture simulations with an observation-driven land surface model for the time period 1950-2000, Sheffield and Wood (2008)[48] have inferred trends in drought duration, intensity, and severity predominantly decreasing, but with strong **regional variation** and including increases in some regions. They concluded that there was an overall moistening trend over the considered time period, but also a switch since the 1970s to a drying trend, globally and in many regions, especially in high Northern latitudes. Some regional studies are consistent with the results from Sheffield and Wood (2008a), regarding, for example, less widespread increase (or statistically insignificant changes or decreases) in some regions compared to the study of Dai et al. (2004). More recently, Dai (2011) by extending the record did, however, find widespread increases in drought both based on various versions of PDSI (for 1950-2008) and soil moisture output from a land surface model (for 1948-2004). Hence there are still large uncertainties with respect to global assessments of past changes in droughts . Nonetheless, there is some agreement between studies over the different time frames (i.e., since 1950 versus 1970) and using different drought indicators regarding increasing drought occurrence in some regions, although other regions also indicate opposite trends. See figure (2.3) and Table (), for definitions of regions used in Tables source: after, IPCC2012. describe regional observed changes in temperature and precipitation extremes, including dryness, since 1950 unless indicated otherwise, and using late 20th-century values as reference, generally 1961-1990.

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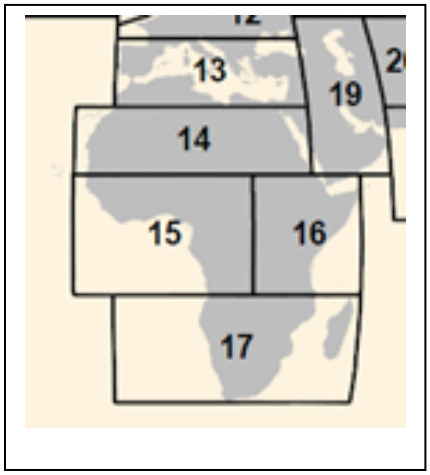


Figure 2.3. Definitions of regions used in Tables source: after, IPCC (2012).

Coherent shifts in drought regimes are expected with changing global circulation patternsprovides regional and continental-scale assessments of observed trends in dryness based on different indices. More details concerned with continent could be reviewed in brief after IPCC (2012), as follows:

– Much more severe and longer droughts occurred in the past centuries with widespread ecological, political, and socioeconomic consequences. Overall, these studies confirm that in

[48] Sheffield, J., and E.F. Wood, 2008a: Global trends and variability in soil moisture and drought characteristics, 1950-2000, from observation-driven simulations of the terrestrial hydrologic cycle. *Journal of Climate*, 21(3), 432-458.

the last millennium several extreme droughts have occurred (Breda and Badeau, 2008[49]; Kallis, 2008[50]; Büntgen et al., 2010[51]).

– In Europe, there is *medium confidence* regarding increases in dryness based on some indices in the Southern part of the continent, Dai et al. (2004)[52] found an increase in dryness for most of the European continent based on PDSI, Lloyd-Hughes and Saunders (2002)[53] and van der Schrier et al. (2006)[54] concluded, that statistically significant changes were observed in extreme and moderate drought conditions in Mediterranean region. Sheffield and Wood (2008a) also found contrasting dryness trends in Europe, with increases in the Southern and eastern part of the continent. Beniston (2009)[55] reported a strong increase in warm-dry conditions over all central-Southern Europe.

– Trends of decreasing precipitation and discharge are consistent with increasing salinity in the Mediterranean Sea, indicating a trend toward freshwater deficits (Mariotti et al., 2008)[56], but this could also be partly caused by increased human water use. In France, an analysis based on a variation of the PDSI model also reported a significant increasing trend in drought conditions, in particular from the 1990s onward (Corti et al., 2009)[57].

– The exceptional 2003 summer heat wave on the European continent was also associated with a major soil moisture drought, as could be inferred from satellite measurements (Andersen etal., 2005)[58], model simulations (Fischer et al., 2007a[59],b[60]), and impacts on ecosystems (Ciais et al., 2005[61]; Reichstein etal., 2007). [62]

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[49] Breda, N., and V. Badeau, 2008: Forest tree responses to extreme drought and some biotic events: Towards a selection according to hazard tolerance? *ComptesRendus Geoscience*, 340(9-10), 651-662.

[50] Kallis, G., 2008: Droughts. *Annual Review of Environment and Resources*, 33, 85-118.

[51] Büntgen, U., V. Trouet, D. Frank, H.H. Leuschner, D. Friedrichs, J. Luterbacher, and J. Esper, 2010: Tree-ring indicators of German summer drought over the last millennium. *Quaternary Science Reviews*, 29(7-8), 1005-1016

[52] Dai, A.G., K.E. Trenberth, and T.T. Qian, 2004: A global dataset of Palmer Drought Severity Index for 1870-2002: Relationship with soil moisture and effects of surface warming. *Journal of Hydrometeorology*, 5(6), 1117-1130.

[53] Lloyd-Hughes, B., and M.D. Saunders, 2002: A drought climatology for Europe.*International Journal of Climatology*, 22(13), 1571-1592.

[54] van der Schrier, G., K.R. Briffa, P.D. Jones, and T.J. Osborn, 2006: Summer moisture variability across Europe. *Journal of Climate*, 19(12), 2818-2834.

[55] Beniston, M., 2009b: Trends in joint quantiles of temperature and precipitation in Europe since 1901 and projected for 2100. *Geophysical Research Letters*, 36, L07707.

[56] Mariotti, A., N. Zeng, J.H. Yoon, V. Artale, A. Navarra, P. Alpert, and L.Z.X. Li, 2008:Mediterranean water cycle changes: transition to drier 21st century conditions in observations and CMIP3 simulations. *Environmental Research Letters*, 3(4), 044001.

[57] Corti, T., V. Muccione, P. Köllner-Heck, D. Bresch, and S.I. Seneviratne, 2009:Simulating past droughts and associated building damages in France.*Hydrology and Earth System Sciences*, 13(9), 1739-1747.

[58] Andersen, O.B., S.I. Seneviratne, J. Hinderer, and P. Viterbo, 2005: GRACE-derived terrestrial water storage depletion associated with the 2003 European heat wave. *Geophysical Research Letters*, 32, L18405.

[59] Fischer, E.M., S.I. Seneviratne, D. Lüthi, and C. Schär, 2007a: The contribution of landatmosphere coupling to recent European summer heatwaves. *GeophysicalResearch Letters*, 34, L06707.

[60] Fischer, E.M., S.I. Seneviratne, P.L. Vidale, D. Lüthi, and C. Schär, 2007b: Soil moisture atmosphere interactions during the 2003 European summer heatwave. *Journalof Climate*, 20(20), 5081-5099.

[61] Ciais, P., M. Reichstein, N. Viovy, A. Granier, J. Ogee, V. Allard, M. Aubinet, N. Buchmann, C. Bernhofer, A. Carrara, F Chevallier, N. De Noblet, A. Friend, P. Friedlingstein, T. Grunwald, B. Heinesch, P. Keronen, A. Knohl, G. Krinner, D. Loustau, G. Manca, G. Matteucci, F. Miglietta, J. Ourcival, D. Papale, K. Pilegaard, S. Rambal, G. Seufert, J. Soussana, M. Sanz, E. Schulze, T. Vesala, and R. Valentini,2005: Europe-wide reduction in primary productivity caused by the heat and drought in 2003. *Nature*, 437(7058), 529-533.

In the different sub-regions of Africa there is overall *low* to *medium confidence* regarding regional dryness trends.

- Changes in drought patterns have been reported for the monsoon regions of Asia and Africa with variations at the decadal time scale (e.g., Janicot, 2009)[63].
- In the Sahel, recent years have been characterized by greater inter-annual variability than the previous 40 years (Ali and Lebel, 2009[64]; Greene et al.,2009[65]), and by a contrast between the western Sahel remaining dry and the eastern Sahel returning to wetter conditions (Ali and Lebel, 2009).
- Giannini et al. (2008)[66] report a drying of the African monsoon regions, related to warming of the tropical oceans, and variability related to ENSO

The regional observed changes in temperature and precipitation extremes within the study area including dryness, are shown Table (2.1), after (IPCC 2012).

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[62] Reichstein, M., P. Ciais, D. Papale, R. Valentini, S. Running, N. Viovy, W. Cramer, A. Granier, J. Ogée, V. Allard, M. Aubinet, C. Bernhofer, N. Buchmann, A. Carrara, T. Grünwald, M. Heimann, B. Heinesch, A. Knohl, W. Kutsch, D. Loustau, G. Manca, G. Matteucci, F. Miglietta, J.M. Ourcival, K. Pilegaard, J. Pumpanen, S. Rambal, S. Schaphoff, S. Seufert, J.F. Soussana, M.J. Sanz, T. Vesala, and M. Zhao, 2007: Reduction of ecosystem productivity and respiration during the European summer 2003 climate anomaly: a joint flux tower, remote sensing and modeling analysis *Global Change Biology*, 13(3), 634-651.

[63] Janicot, S., 2009: A comparison of Indian and African monsoon variability at different time scales. *Comptes Rendus Geoscience*, 341(8-9), 575-590.

[64] Ali, A. and T. Lebel, 2009: The Sahelian standardized rainfall index revisited.*International Journal of Climatology*,29(12),1705-1714.

[65] Greene, A.M., A. Giannini, and S.E. Zebiak, 2009: Drought return times in the Sahel:A question of attribution. *Geophysical Research Letters*, 36, L12701.

[66] Giannini, A., M. Biasutti, and M.M. Verstraete, 2008: A climate model-based review of drought in the Sahel: Desertification, the re-greening and climate change. *Global and Planetary Change*, 64(3-4), 119-128.

Table 2.1. Regional observed changes in temperature and precipitation extremes, including dryness, after, IPCC 2012

EUROPE AND MEDITERRANEAN	
Temp. max	**High confidence:** Likely increase in WD and likely decrease in CD in most of the region. Some regional and temporal variations in significance of trends. Likely strongest and most significant trends in the Iberian Peninsula and Southern France (**Medium confidence:** Smaller or less significant trends in S.E. Europe and Italy due to change point in trends at the end of the 1970s / beginning of 1980s; sometimes linked with changes in sign of trends; strongest WD increase since
Temp.min	**High confidence:** Likely increase in WN and likely decrease in CN in most of the region. Some regional variations in significance of trends. Very likely overall increase in WN and very likely overall decrease in CN in S.W. Europe and W. Mediterranean; likely strongest signals in Spain and Southern France. Likely overall tendency for increase in WN and likely overall tendency for decrease in CN in S.E. Europe and E. Mediterranean
Heat Waves/Warm Spells	**High confidence:** Likely overall increase in HW in summer (JJA). Significant increase in max HW duration since 1880 in Iberian Peninsula and west Central Europe in JJA. Significant increase in max HW duration in Tuscany (Italy). Significant increase in HW indices in Turkey and to a smaller extent in S.E. Europe and Turkey in JJA. Less significant signal in HW indices in S.E. Europe due to presence of change point in trends.
Heavy Precipitation	**Low confidence:** Inconsistent trends within domain and across studies. **Medium confidence:** Overall increase in dryness (SMA, PDSI, CDD), but partial dependence on index and time period.
Dryness	**Medium confidence:** Overall increase in dryness (SMA, PDSI, CDD), but partial dependence on index and time period.

Table 2.1. Cont'd

AFRICA REGIONS	
ALL AFRICA	
Temp. max	**Low confidence to medium confidence:** **Low confidence** due to insufficient evidence (lack of literature) in many regions. **Medium confidence** in increase in frequency of WD and decrease in frequency of CD in Southern part of continent.
Temp.min	**Low confidence to medium confidence** depending on region: Low confidence due to insufficient evidence (lack of literature) in many regions. **Medium confidence** in increase in frequency of WN in Northern and Southern part of continent Medium confidence in decrease in frequency of CN in Southern part of continent.
Heat Waves/Warm Spells	**Low confidence:** Insufficient evidence (lack of literature). Some analyses for localized regions
Heavy Precipitation	**Low confidence:** Partial lack of data and literature and inconsistent patterns in existing studies.
Dryness	**Medium confidence:** Overall increase in dryness (SMA, PDSI); regional variability, 1970s prolonged Sahel drought dominates (Sheffield and Wood, 2008a; Dai, 2011). No apparent continent-wide trends in change in rainfall over the 20th century, although there was a continent-wide drought in 1983 and 1984. Wet season arrives 9–21 days later, large inter-annual variability of wet season start, local scale geographical variability.
W. AFRICA (WAF, 15)	

Table 2.1.Cont'd

Temp. max	**Medium confidence:** Significant increase in temperature of warmest day and coldest day, significant increase in frequency of WD, and significant decrease in frequency of CD in western central Africa, Guinea Conakry, Nigeria, and Gambia. **Low confidence:** Lack of literature in other parts of the region
Temp.min	**Medium confidence:** Decreases in frequency of CN in western central Africa, Nigeria, and Gambia; insignificant decreases in frequency of CN in Guinea Conakry. L**ow confidence:** Lack of literature on changes in CN in other parts of the region. **Medium confidence:** Increases in frequency of WN.
Heat Waves/Warm Spells	**Low confidence:** Insufficient evidence (lack of literature) for most of the region; increases in WSDI in Nigeria and Gambia.
Heavy Precipitation	**Medium confidence:** Precipitation from heavy events has decreased (western central Africa, Guinea Conakry) but low spatial coherence (), rainfall intensity increased.
Dryness	Sahel drought dominates, conditions are still drier (SMA, PDSI, precipitation anomalies) than during the humid 1950s. Dry spell duration (CDD) overall increased from 1961 to 2000. Recent years characterized by a greater Inter-annual variability than previous 40 years, western Sahel remaining dry and the eastern Sahel returning to wetter conditions.
E. AFRICA (EAF, 16)	
Temp. max	**Low confidence:** Lack of evidence due to lack of literature and spatially non-uniform trends. Over time period 1939–1992 spatially non-uniform trends in daytime temperature, some areas with cooling. In Southern tip of domain increases in WD, decreases in CD

Table 2.1.Cont'd

Temp. min	**Medium confidence:** Over time period 1939–1992, spatially non-uniform trends, rise of nighttime temperature at several locations, but with many coastal areas and stations near large water bodies showing a significant decrease . In Southern tip of domain, decreases in CN, increases in WN.
Heat Waves/Warm Spells	**Low confidence:** Insufficient evidence (lack of literature) for most of region; increase in WSDI in Southern tip of domain.
Heavy Precipitation	**Low confidence:** Insufficient evidence (lack of literature) to assess trends.
Dryness	**Low confidence:** Spatially varying trends in dryness (SMA, PDSI).
S. AFRICA (SAF, 17)	
Temp. max	**Medium confidence:** Increases in WD, decreases in CD.
Temp.min	**Medium confidence:** Decreases in CN, increases in WN.
Heat Waves/Warm Spells	**Medium confidence:** Increase in WSDI.
Heavy Precipitation	**Low confidence:** No spatially coherent patterns of trends in precipitation extremes.
Dryness	**Medium confidence:** Slight dry spell duration increase. General increase in dryness (SMA, PDSI)
SAHARA (SAH, 14)	
T. max	**Low confidence:** Lack of literature.

Table 2.1.Cont'd

T. min	**Medium confidence:** Increases in WN (Alexander et al., 2006). **Low confidence:** Lack of literature on trends in CN.
Heat Waves/Warm Spells	**Low confidence:** Insufficient evidence (lack of literature).
Heavy Precipitation	**Low confidence:** Insufficient evidence.
Dryness	**Low confidence:** Limited data, spatial variation in the trends (Dai, 2011).
W. ASIA (WAS, 19)	
Tmax	**High confidence:** More likely than not decrease in CD and very likely increase in WD (Rahimzadeh et al., 2009; Rehman, 2010).
Tmin	**High confidence:** Likely decrease in CN and likely increase in WN (Rehman, 2010).
Heat Waves/Warm Spells	**Medium confidence:** WSDI increase (Alexander et al., 2006).
Heavy Precipitation	**Medium confidence:** Decrease in heavy precipitation events (Kwarteng et al., 2009; Rahimzadeh et al., 2009).
Dryness	**Low confidence:** Lack of studies for part of the region; mixed results (Sheffield and Wood, 2008a; Rahimzadeh et al., 2009).

2.3. Major Key Massage Indicated in IPCC 2012,

We could quote as follows:

- *There is medium confidence that since the 1950s some regions of the world have experienced trends toward more intense and longer droughts, in particular in Southern Europe and West Africa, but in some regions droughts have become less frequent, less intense, or shorter, for example, central North America and northwestern Australia.*

- *There is medium confidence that anthropogenic influence has contributed to some changes in the drought patterns observed in the second half of the 20th century, based on its attributed impact on precipitation and temperature changes (though temperature can only be indirectly related to drought trends).*

- *However there is low confidence in the attribution of changes in droughts at the level of single regions due to inconsistent or insufficient evidence.*

- *Post-AR4 studies indicate that there is medium confidence in a projected increase in duration and intensity of droughts in some regions of the world, including Southern Europe and the Mediterranean region, central Europe, central North America, Central America and Mexico, northeast Brazil, and Southern Africa. Elsewhere there is overall low confidence because of insufficient agreement of projections of drought changes(dependent both on model and dryness index).*

Definitional issues and lack of data preclude higher confidence than medium in observations of drought changes, while these issues plus the inability of models to include all the factors likely to influence droughts preclude stronger confidence than medium in the projections.

2.4. Drought in Study Area

Recent and potential future increases in global temperatures are likely to be associated with impacts on the hydrologic cycle, including changes to precipitation and increases in extreme events such as droughts, (Sheffield and Wood 2008)[67]. Droughts are the world's costliest natural disasters, causing an average $6–$8 billion in global damages annually and collectively affecting more people than any other form of natural disaster, (Wilhite 2000)[68]. Given the consequences and pervasiveness of drought, it is important to assess drought severity, but the precise quantification of drought is a difficult geophysical endeavor. Numerous specialized indices have been proposed to do this; for an extensive listing of available indices, the reader is referred to WMO (1975)[69] and Heim (2000)[70].

The study carried out by Sheffield and Wood 2008, to analyze changes in drought occurrence using soil moisture data, under the future projections, showed decreases in soil moisture globally for all scenarios with a corresponding doubling of the spatial extent of severe soil moisture deficits and frequency of droughts from the mid-twentieth century to the end of the twenty-first. Long-term droughts become three times more common. Regionally, the Mediterranean, west African, central Asian and central American regions show large increases most notably for long-term frequencies as do mid-latitude North American regions but with larger variation between scenarios.

The study conducted by Burke and Brown, (2007)[71] using different indices related to moisture (Palmer drought severity index PDSI, and soil moisture anomaly SMA), shows increases in the proportion of the overall increase in areas affected by drought. The study also showed that all indices that include some measure of the atmospheric demand for moisture (PPEA, PDSI, and SMA) show increases in the proportion of the global land surface in drought ranging from an additional 5%–45%. SPI, based solely on precipitation, shows much smaller global changes ranging from 5% less to 10% more of the land surface. In addition to the overall increase in area affected by drought, the area in more severe drought increases much more than the area in less severe drought. This could have serious consequences as the impact of drought on socioeconomics increases with the severity of drought. They added that regionally, there is a very large range in the sign and magnitude of drought changes. The only regions where there is a consistent increase in drought across all indices and ensembles are those where the annual average precipitation decreases as found for the Mediterranean, Amazonia, and Southern Africa.

In other regions the sign and magnitude of the change in drought is dependent on index definition and ensemble member. The impact of change in drought will be felt at the regional scale. Therefore, in order to perform optimum impact assessments of changes in drought,

[67] Sheffield J and Wood E F 2008 Projected changes in drought occurrence under future global warming from multi-model,multi scenario, IPCC AR4 simulations Clim. Dyn. 31 79–105

[68] Wilhite, D. A., 2000: Drought as a natural hazard: Concepts and definitions. *Drought: A Global Assessment*, D. A. Wilhite, Ed., Routledge, 3–18.

[69] WMO, 1975: Drought and Agriculture. WMO Tech. Note 138, 127 pp.

[70] Heim, R. R., Jr., 2000: Drought indices: A review. *Drought: A Global Assessment,* D. A. Wilhite, Ed., Routledge, 159–167.

[71] Burke, E.J., and S.J. Brown, 2008: Evaluating uncertainties in the projection of future drought. Journal of Hydrometeorology, 9(2),292-299

regional studies are required using locally appropriate drought indices. For example, a soil-moisture-based drought index on a daily basis over the growing season will be most relevant for studying the impacts in agriculture.

Regional climate simulations highlight the Mediterranean region as being affected by more severe droughts, consistent with available global projections; Giorgi, (2006)[72], calculated the Regional Climate Change Index RCCI using wet season (WS) and dry season (DS) as defined by Giorgi and Bi, (2005)[73], temperature and precipitation over 26 land regions of the world, as shown in figure (2.4), and out of 20 global model simulations the RCCI for the different regions showed that the most prominent Hot-Spots emerging from the RCCI analysis are the Mediterranean and North Eastern Europe (NEE) regions, Mediterranean was identified as the most prominent Hot-Spots emerging from the Regional Climate Change Index RCCI analysis, a large decrease in mean precipitation and an increase in precipitation variability during the dry (warm) season, which makes the Mediterranean one of the most responsive regions to global change,; (Giorgi 2006). the analysis presented here identifies the Mediterranean and Northeastern Europe regions as the most prominent climate response Hot-Spots, followed by high latitude Northern hemisphere regions and Central America. The latter appears to be the primary Hot-Spot in the tropics, immediately followed by Southern Equatorial Africa and Southeast Asia. Other prominent mid-latitude Hot-Spot regions are Eastern North America and Central Asia.

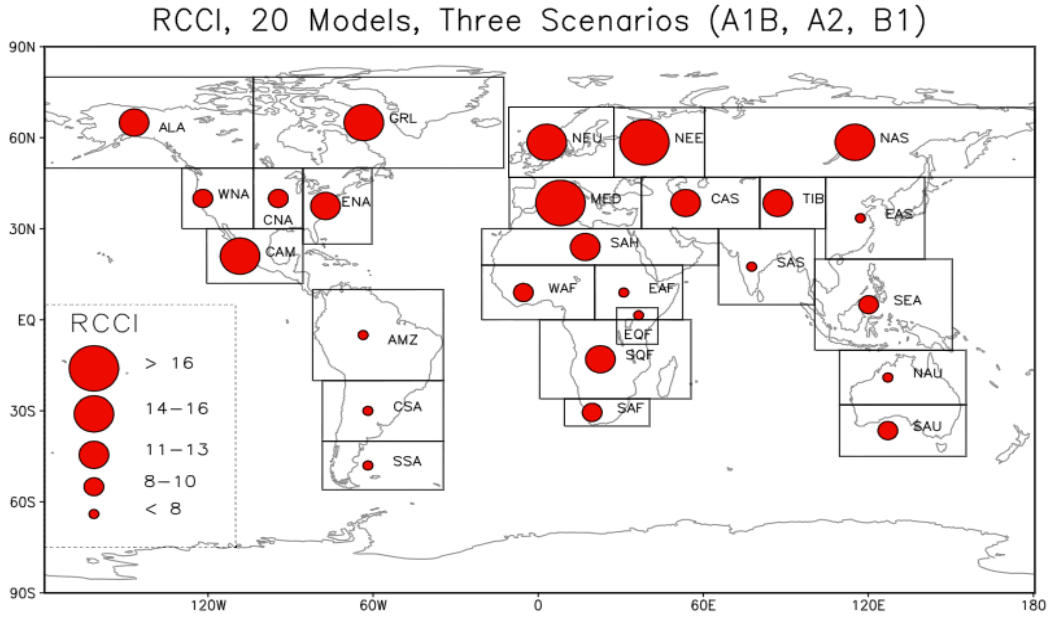


Figure 2.4. Regional Climate Change Index RCCI

Simulated precipitation regimes depict a globally drier Mediterranean in 2030–2060, with a 10–20% drop in annual rainfall, a drier Mediterranean in 2031– 2060 translates into about 1 week of additional dry days along the coast and in the already dry southeast basin; Over land areas in the

[72] Giorgi, F., (2006): Climate change hot-spots. Geophysical Research Letters, 33(L08707).

[73] Giorgi, F., and X. Bi (2005), Updated regional precipitation and temperature changes for the 21st century from ensembles of recent AOGCM simulations, Geophys. Res. Lett., 32, L21715, doi:10.1029/2005GL024288.

Northern part, up to and over 3 weeks of additional dry days; thus, if the effects of ozone are to be included in an assessment of crop yields in the Mediterranean under a future climate scenario, the results are likely to be greater yield reductions; (figure 2.5), (Giannakopoulos et al, 2009 and Dai, 2010).

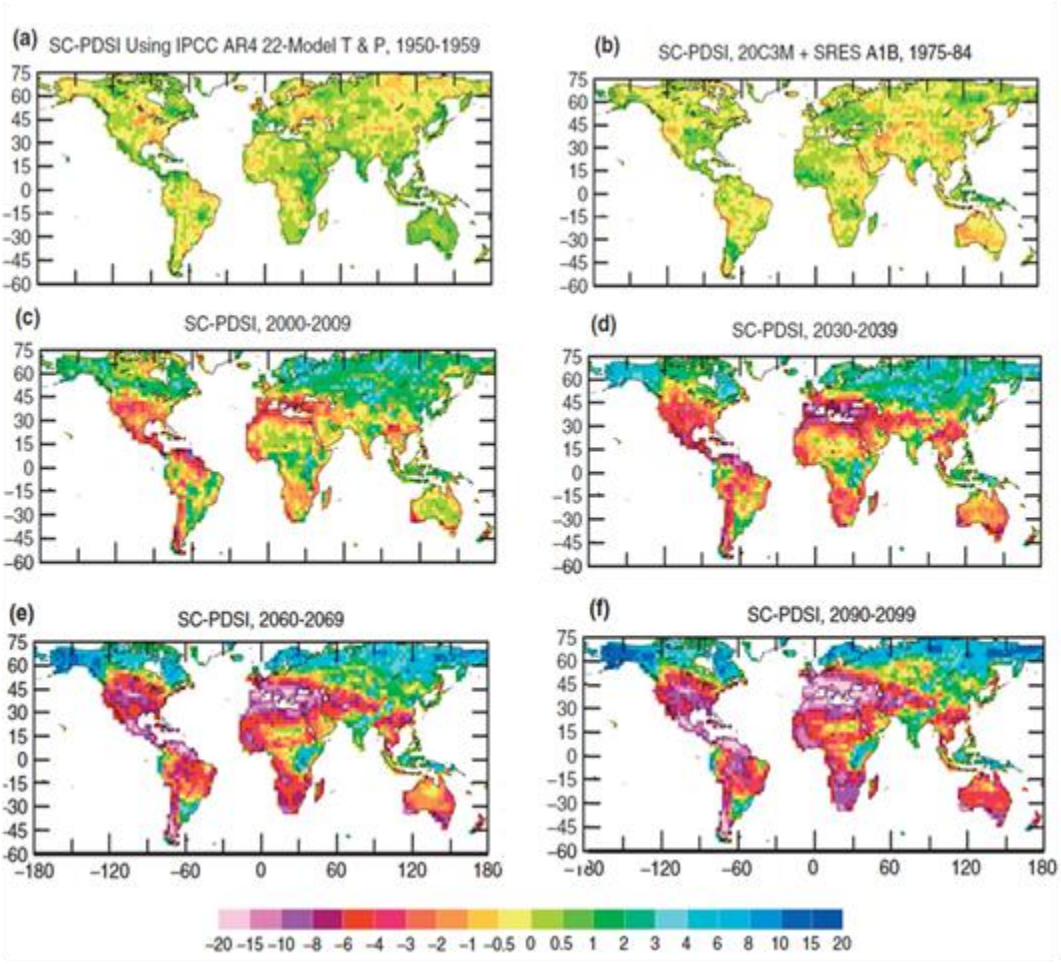


Figure 2.5. Mean annual sc-PDSI pm for years (a) 1950–1959, (b) 1975–1984, (c) 2000–2009, (d) 2030–2039, (e) 2060–2069, and (f) 2090–2099 calculated using the 22-model ensemble-mean surface air temperature, precipitation, humidity, net radiation, and wind speed used in the IPCC AR4 from the 20th century and SRES A1B 21st century simulations.128 Red to pink areas are extremely dry (severe drought) conditions while blue colors indicate wet areas relative to the 1950–1979 mean.

2.4.1. Drought in Mediterranean:

Mariotti et al., (2008 described the Southern Europe-Mediterranean region as a well-known region for its pleasant climate that has favored the rise of past great civilizations. People have learned to deal with an almost total lack of rainfall during the summer months, but water is still one of the most vulnerable aspects of life in the region, now supporting an increased local population. Under a suite of global climate change scenarios, the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC-AR4 hereafter; (IPCC 2007)[74]) projects major changes in the Mediterranean region, in particular as a 'Hot Spot' in hydrological change with significant impacts on both mean precipitation and variability (Gibelin and Deque 2003[75], Giorgi 2006[76], Ulbrich et al 2006[77], Giorgi and Lionello 2008[78], Sheffield and Wood 2008[79]). In fact Mediterranean countries are experiencing an increased drought frequency, intensity and duration that have resulted in increased drought losses and impacts on agricultural production, rural livelihoods, migration, urban, economic sectors and ecosystem decline.

Mariotti et al., (2008)[80] , the CMIP3 model simulations show a progressive decrease in rainfall in the Mediterranean region that has been on-going during the 20th century (−0.007 mm/d per decade; see table 2S (available at stacks.iop.org/ERL/3/044001) for a summary of all trends) and accelerates around the turn of the 21st century, followed by rapid drying from 2020 and onwards (figure 1; −0.02 mm/d per decade). The projected changes will cause Mediterranean land regions to become gradually more arid, with roughly 15% less precipitation in 2070–2099 compared to 1950–2000, and an 8% decrease already by 2020–2049. The amplitude of the mean change foreseen by 2020–2049 (about 0.1 mm/d) is comparable to that of the driest spells experienced by the region during the 20th century, (figures 2.6 a, b). CMIP3 simulations for the 20th century suggest that the Mediterranean region has a tendency toward drier and warmer conditions. All datasets, winter season precipitation shows a major downward deviation over the period 1960–2004 (−0.09±0.02 mm/d per decade), with inter-decadal variations, a decrease during the period mid-1960s to early-1990s and an increase after that while dry season showed negative trends over the period 1950–2000 have also been observed in relation to a blocking-like pattern deflecting storms away from much of western and Southern Europe (Pal et al 2004). These tendencies are supported by observational evidence of century-long negative trends in regionally

[74] IPCC 2007 Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (Cambridge: Cambridge University Press) p 996

[75] Gibelin A L and Deque M 2003 Anthropogenic climate change over the Mediterranean region simulated by a global variable resolution model Clim. Dyn. 20 237–339

[76] Giorgi F 2006 Climate change hot-spots Geophys. Res. Lett. 33 L08707

[77] Ulbrich U et al 2006 The Mediterranean climate change under global warming Mediterranean Climate Variability and Predictability ed P Lionello et al (Amsterdam: Elsevier) pp 398–415

[78] Giorgi F and Lionello P 2008 Climate change projections for the Mediterranean region Glob. Planet. Change 63 90–104

[79] Sheffield J and Wood E F 2008 Projected changes in drought occurrence under future global warming from multi-model,multi scenario, IPCC AR4 simulations Clim. Dyn. 31 79–105

[80] Mariotti, A., N. Zeng, J.H. Yoon, V. Artale, A. Navarra, P. Alpert, and L.Z.X. Li, 2008: Mediterranean water cycle changes: transition to drier 21st century conditions in observations and CMIP3 simulations. Environmental Research Letters, 3(4), Art. 044001 (8 pp.)

averaged precipitation, PDSI and discharge from numerous rivers; and are consistent with reported increases in Mediterranean sea water salinity, (figure 2.7).

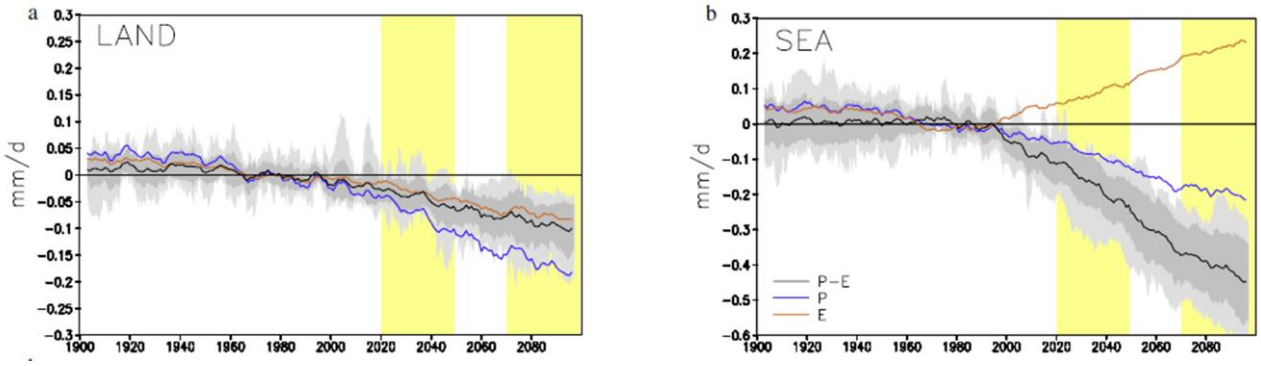


Figure. 2.6 Mediterranean water cycle anomalies over the period 1900–2100 relative to 1950–2000. Area-averaged evaporation (brown), precipitation (blue) and precipitation minus evaporation (black; P − E) are based on an average of CMIP3 model, after . Mariotti et al., 2008

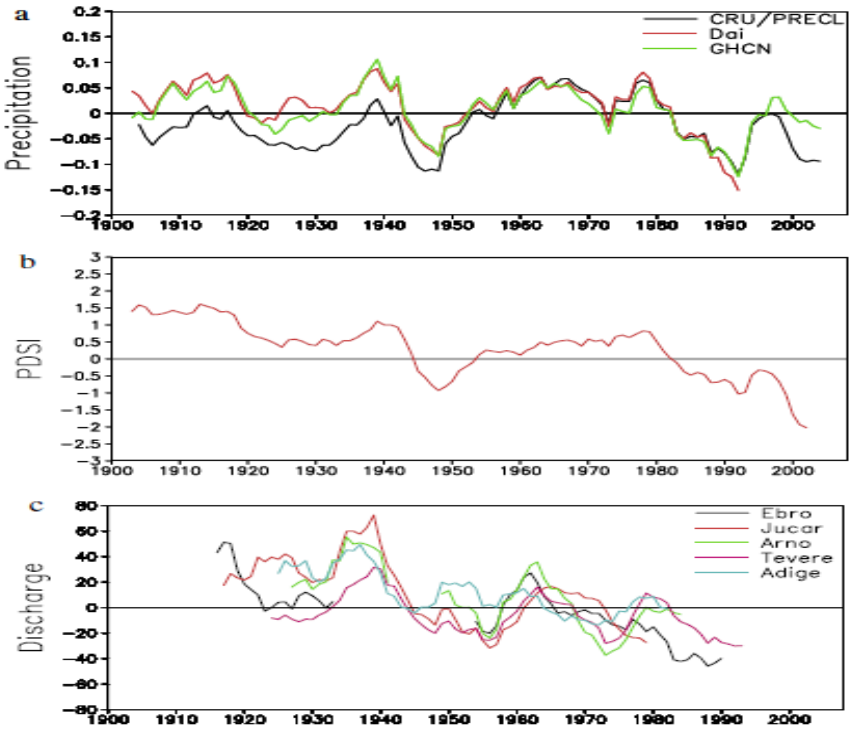


Figure 2.7 Mediterranean water cycle changes observed during the 20th century relative to the period 1950–2000. Area-averaged annual mean precipitation anomalies (six years running means) from various datasets (panel a; mm/d) and PDSI (panel b; au); discharge anomalies (units are % of climatology) for various Mediterranean rivers (panel c). Due to data availability, discharge anomalies are relative to the 1960–1980 period.

The study reflected that By 2070–2099, that precipitation is projected to decrease throughout the year and particularly during the dry season about −10% and 23% for the wet and dry seasons, respectively. In contrast, most of the land evaporation decrease occurs during the summer dry

season (−12%) when land surface aridity will be greatest. The combination of these changes results in a decrease in effective land precipitation that is similar during the wet and dry seasons (about 20%). Over the sea, freshwater deficit will increase throughout the year and particularly during the wet season (29%) when evaporation increase will be at a maximum (about 7%). The pattern of maximum precipitation changes has a general South to North migration going from winter into summer, following the climatological seasonal cycle of precipitation (figure 2.8)

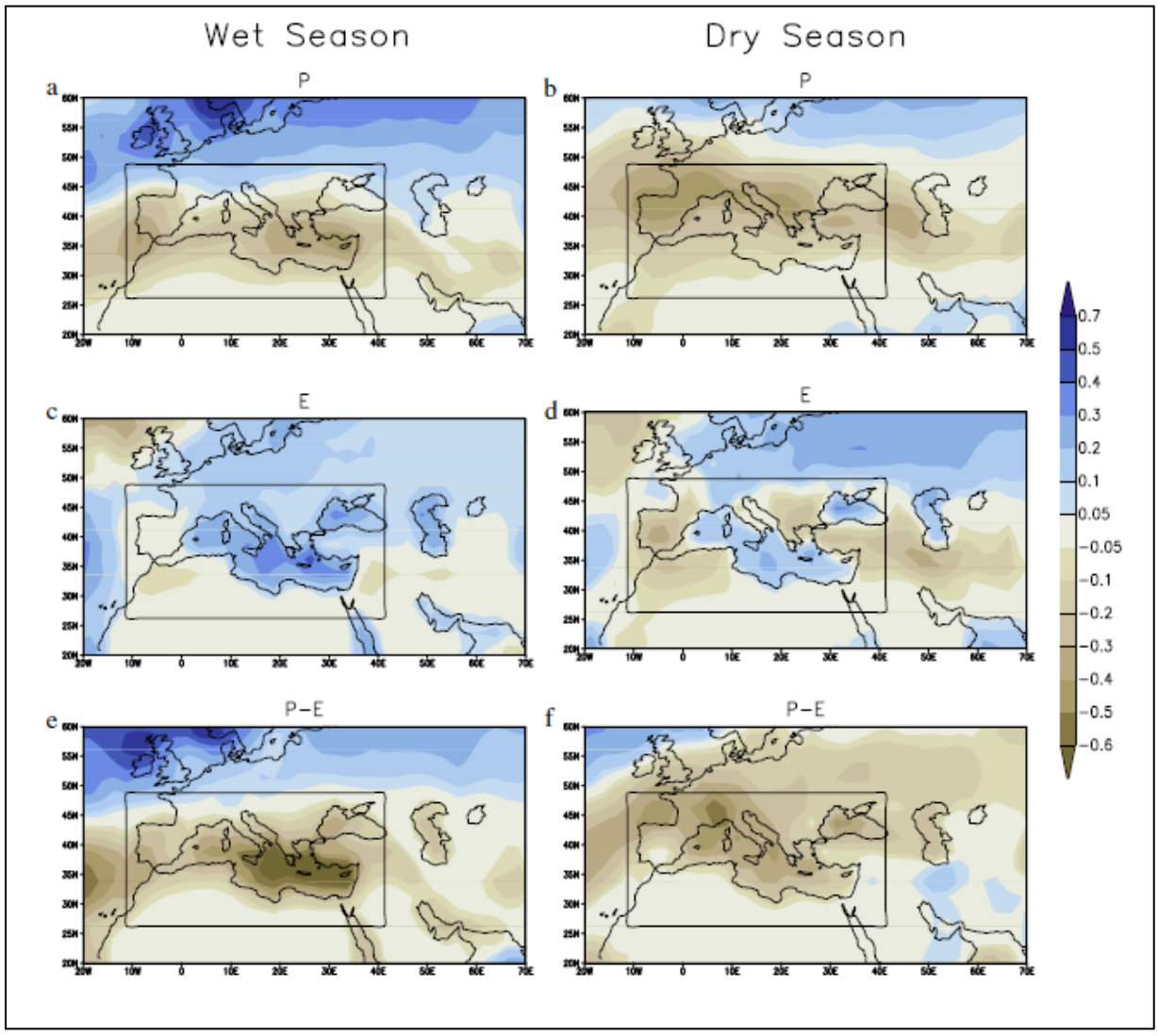


Figure 2.8. Mediterranean water cycle changes by 2070–2099 compared to 1950–2000 for the 'wet' and 'dry' seasons. Precipitation (a) and (b), evaporation (c) and (d), and precipitation minus evaporation (e) and (f). Anomalies are based on an average of CMIP3 model runs. For all, units are mm/d. The box broadly depicts the Mediterranean region.

2.4.2. .Drought in Arab Region

The precipitation regime over the Arab region is characterized for most countries by a strong seasonal behavior, with a rainy season mostly concentrated between November and March. While the average precipitation in transition months (e.g. April, May, October) has a small impact on annual totals, summer (June to September) precipitation can be considered irrelevant. Therefore, all major droughts in this region are characterized by the lack of rainfall during several months of the winter half of the year (e.g. Soltani et al., 2007)[81]. The occurrence of droughts in this semi-arid region is a usual feature driven by its precipitation regime, characterized by a strong inter-annual and decadal variability (e.g. Morid et al., 2006[82]; Freiwan and Kadioglu, 2008[83]).

Drought is extremely serious problem in the Arab region, and will increase causing serious threat for all Arab countries that already are suffering from fragility ecosystems, and facing severe risks of depletion of soil, vegetation, and water resources on daily basis. The strong seasonal and inter-annual variability of vegetation in most semi-arid regions is a subject of particular interest due to the ecological and economic impacts. **In particular, the high sensitivity of vegetation to climate forcing may result in rapid land use changes and high vulnerability to land degradation, as result of human action (Evans and Geerken, 2004)[84]. Over longer periods, small changes may have a considerable impact on the viability of agricultural and pastoral systems (deMenocal, 2001[85]; Hole, 1994[86]; Weiss and Bradley, 2001[87]).** In this environment, natural vegetation and non-irrigated crops are crucially dependent on soil moisture provided by seasonal rains or springtime snowmelt.

This dependence leads to quite different vegetation activity levels on seasonal and inter-annual time scales (Dall'Olmo and Karnieli, 2002[88]; Weiss et al., 2004). Consequently, opportunistic annual species may appear rapidly in response to humid condition of the soil and their greenness is mainly related to recent precipitation (Zaitchik et al., 2007[89]). On the other hand, winter crops and persistent vegetation are dependent on deeper reserves of soil moisture and their vegetative cycle is the result of the combined effect of precipitation (over weeks and months), evaporation

[81] Soltani, S., Modarres, R., Eslamian, S.S., 2007. The use of time series modeling for the determination of rainfall climates of Iran. Int. J. Climatol. 27, 819–829.

[82] Morid, S., Smakhtin, V., Moghaddasi, M., 2006. Comparison of seven meteorological indices for drought monitoring in Iran. Int. J. Climatol. 26, 971–985.

[83] Freiwan, M., Kadioglu, M., 2008. Climate variability in Jordan. Int. J. Climatol. 28,69–89.

[84] Evans, J.P., Geerken, R., 2004. Discrimination between climate and human-induced dryland degradation. J. Arid Environ. 57, 535–554.

[85] deMenocal, P.B., 2001. Cultural responses to climate change during the Late Holocene. Science 292, 667–673.

[86] Hole, F., 1994. Environmental instabilities and urban origins. In: Chiefdoms and Early States in the Near East: the Organizational Dynamics of Complexity. Prehistory Press, pp. 121–151.

[87] Weiss, H., Bradley, R.S., 2001. What drives societal collapse? Science 291, 609–610.

[88] Dall'Olmo, G., Karnieli, A., 2002. Monitoring phenological cycles of desert ecosystems using NDVI and LST data derived fromNOAA-AVHRRimagery. Int. J.RemoteSens.23, 4055–4071.

[89] Zaitchik, B.F., Evans, J.P., Geerken, R.A., Smith, R.B., 2007. Climate and vegetation in the Middle East: inter-annual variability and drought feedbacks. J. Climate 20,3924–3941.

and in some regions, of temperature. The strong dependence of vegetation dynamics on water availability has been for long recognized in the Mediterranean and other semi-arid regions (Eagleson, 2002[90]; Rodríguez-Iturbe and Porporato, 2004[91]; Vicente-Serrano and Heredia-Laclaustra, 2004[92]; Vicente-Serrano, 2007[93]). A combined effect of lack of precipitation over a certain period with other climatic anomalies, such as high temperature, high wind and low relative humidity over a particular area may result in reduced green vegetation cover. When drought conditions end, recovery of vegetation may follow (Nicholson et al.1998) but such recovery process may last for longer periods of time (Diouf and Lambin, 2001[94]).
This is coupled with a population increase within this region rushing at scary rates further increase stresses on natural resources.

According to Erian et al, (2011)[95], 28 percent of the Arab countries‘ population already lives in areas vulnerable to drought as shown in table ( )

Table Agriculture drought Hazard in Arab Region and affected population.

Country	Area in Km ²	HIGH	MOD	LOW	NO
Algeria	2,381,741	4.53%	7.11%	9.62%	78.74%
Libya	1,759,540	0.55%	1.66%	6.07%	91.72%
Mauritania	1,030,700	1.42%	5.41%	13.27%	79.90%
Morocco	712,550	7.79%	17.51%	29.75%	44.95%
Tunisia	163,610	9.82%	27.52%	14.55%	48.10%
Arab Maghreb	6,048,141	3.37%	7.01%	11.71%	77.90%
Djibouti	23,200	11.73%	14.58%	23.97%	49.72%
Egypt	1,001,450	0.43%	1.61%	7.71%	90.24%
Somalia	637,657	7.37%	47.28%	25.14%	20.21%
Sudan	2,505,813	10.02%	11.70%	17.72%	60.56%
Central Region	4,168,120	7.32%	14.73%	16.49%	61.46%
Iraq	438317	21.00%	31.47%	20.86%	26.68%
Jordan	89,342	2.69%	8.56%	14.15%	74.60%
Lebanon	10,400	17.13%	25.67%	16.45%	40.75%
Syria	185,180	26.69%	36.96%	14.58%	21.76%
Palestine Authority	6,220	8.72%	36.85%	14.69%	39.74%
Arab Mashreq	729459	20.04%	30.02%	18.33%	31.61%
Bahrain	741	-	-	-	-
Kuwait	17,818	11.46%	43.03%	27.79%	17.72%
Oman	309,500	0.68%	2.67%	11.92%	84.73%
Qatar	11,586	0.00%	40.48%	27.00%	32.52%
Saudi Arabia	2,149,690	2.91%	7.85%	17.13%	72.11%
U A E	83,600	0.99%	2.75%	11.75%	84.51%
Yemen	527,968	5.24%	9.73%	13.52%	71.51%
Arabian Peninsula	3,100,903	3.07%	7.84%	15.95%	73.14%
TOTAL	14,046,623	5.34%	10.68%	14.41%	69.57%

[90] Eagleson, P., 2002. Ecohydrology. In: Darwinian Expression of Vegetation Form and Function. Cambridge University Press, Cambridge.

[91] Rodríguez-Iturbe, I., Porporato, A., 2004. Ecohydrology of water-controlled ecosystems.Cambridge.

[92] Vicente-Serrano, S.M., Heredia-Laclaustra, A., 2004. NAO influence on NDVI trends in the Iberian Peninsula (1982–2000). Int. J. Remote Sens. 25, 2871–2879.

[93] Vicente-Serrano, S.M., 2007. Evaluating the impact of drought using remote sensing in a Mediterranean, semi-arid region. Nat. Hazards 40, 173–208, doi:10.1007/s11069-006-0009-7.

[94] Diouf, A., Lambin, E.F., 2001. Monitoring land-cover changes in semi-arid regions: remote sensing data and field observations in the Ferlo, Senegal. J. Arid Environ. 48, 129–148.

[95] Erian, W., Katlan, B. and Babah, O. 2010. Drought vulnerability in the Arab region: Special case study: Syria. Background paper prepared for the 2011Global Assessment Report on Disaster Risk Reduction. Geneva, Switzerland: UNISDR.

The study of the standardized precipitation index SPI, for the east MED shows that, over the last century the SPI has dropped by around 0.5 to 1 points with the exception of a part of Iraq, the entire region has negative trends of annual SPI and annual precipitation, and countries most affected by the decrease are Jordan, Syria, Lebanon and Palestine; figure (11) (Göbel and De Pauw, 2010)[96].

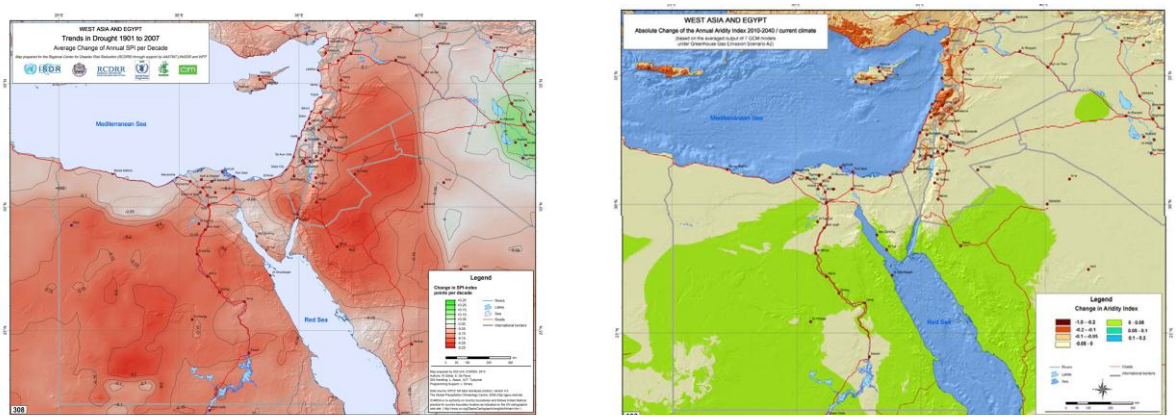
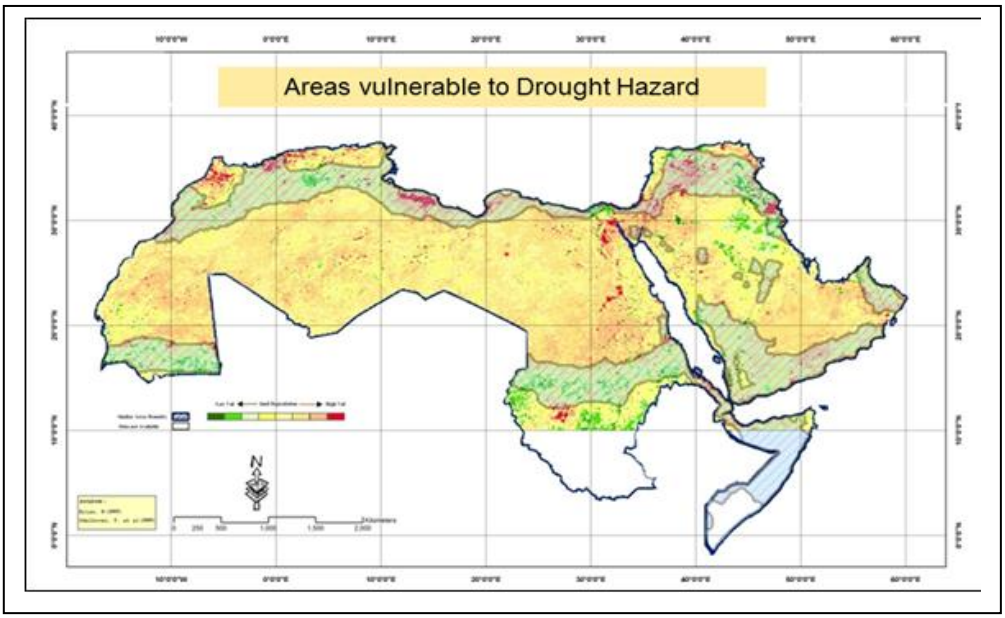


Figure 11. Change in SPI index points by decade (left), Absolute change in the annual Aridity Index (right)

The region is subject to frequent agriculture (soil moisture) droughts and rainfed crops are strongly affected by precipitation fluctuations; mainly in the areas were annual rainfall range between 120/150 – 400 mm, they are considered moderately to sever vulnerable areas to drought; figure (13) (Erian et al, 2006) .

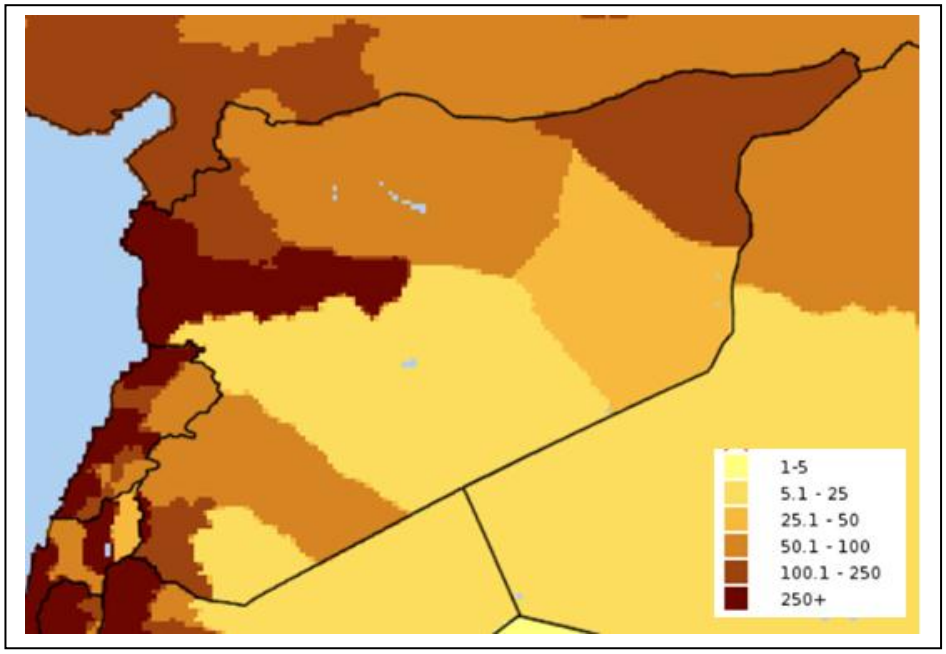


[96] Göbel, W and De Pauw, E, 2010. Climate and Drought Atlas for parts of the Near East A baseline dataset for lanning adaptation strategies to climate change". .International Center for Agricultural Research in the Dry Areas, ICARDA

Figure 13. Areas That Are Vulnerable to drought Hazard.

a. Drought in Syria

Syria occupies the Eastern coast of the Mediterranean sea. The surface area of the country is about 185.518 Km² of which 32.2% is arable land (six million ha.), and 45% steppe and pasture lands. .The country is divided into 14 governorates with a total population in 2007 of about 20.7 million The annual growth rate has decreased from 3.35% in the 1970s to about less than 3% during the last five years, (Figure.). The population density has increased from 34 inhabitant in km2 in 1970 to about 102 in 2007.The percentage of urban population has increased very fast from about 43.5 in the seventies to about 53.5 in 2007 (SINC report,2009)[97].



The density population map of Syria 2010 (person/Km2),source: SEDAC Map Client

In Syria, where the rainfall represents 68.5% of the available water sources, the precipitation concentration index (PCI) for the period (1960-2006) has been studied in Al Jazerah region (area tht include 3 governorates in the North Eastern part) , and the study show sever decrease in annual rainfall quantities that has been estimated by (27.7%) in Kamishli, (19.2%) in Tel-Abiad and (26%) in Hassakah and related to the decreasing in spring and winter rainfall quantities; (Skaff and Masbate, 2010[98]).The model-derived climate sensitivity of the Euphrates, Upper Tigris and Greater Zab river discharges (Smith et al. 2000[99]) shows that for Euphrates River, an increase or decrease in precipitation by 25% raises or lowers the discharge profile while keeping

[97] Syrian initial national communication report to UNFCCC2009

[98] Skaff, M. and Masbate, Sh., 2010. Precipitation Change, and Its Potential Effects on Vegetation and Crop Productivity in Syrian Al Jazerah Region. The Arab Journal for Arid Environments 3 (2):71 - 78.

[99] Smith, R.B., J. Foster, N. Kouchoukos, P.A. Gluhosky, R. Young and E. De Pauw.(2000) : Spatial analysis of climate, landscape, and hydrology in the Middle East: modeling and remote sensing. Center for Earth Observation Report No.2., Yale University, New haven, USA

its shape unchanged. The annual discharge rises to 40655 M cm or drops to 15751 M cm /y compared to the reference value of 27048 M cm. This is a 50% rise and a 42% drop, nearly twice the imposed percentage change in precipitation. Knowing that regional modeling studies expected a reduction of rainfall in mid 21st century Evans, (2008)[100] , figure ( ) around 40-50 mm in the upper Euphrates and Tigris basin which is 14 about 7% of average rainfall, it is expected to have about 11% drop in Euphrates river discharge.

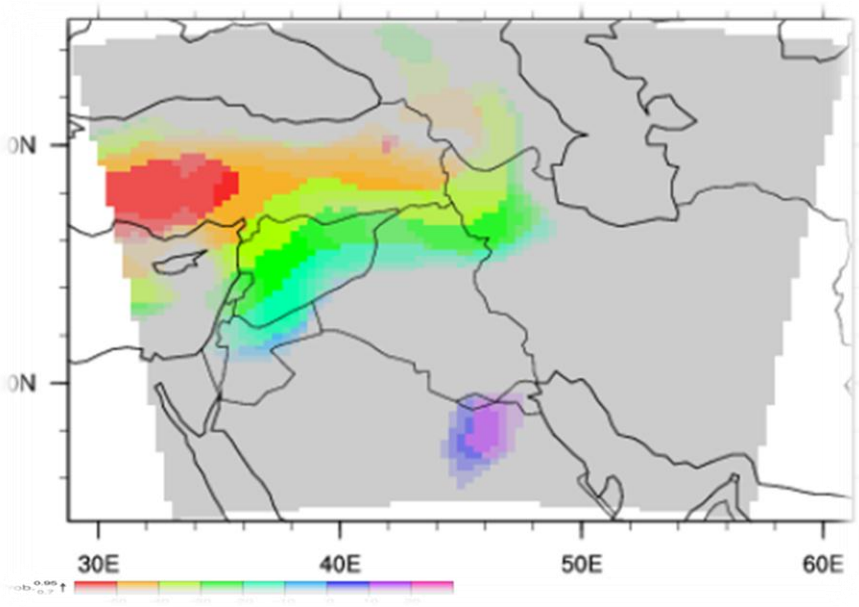


Figure . Demonstrates an the change in precipitation by amount and significance.
(the probability (significance) of the change is calculated as a t-test between the precipitation now and the precipitation simulated in mid 21st. century),after (Evans, 2008).

Other studies (Lehner et al, 2001[101] and EEA, 2004[102]) also expected around 10 to 25% reduction in river runoff in the upper Euphrates and Tigris basin in 2070 versus 2000 which prove the previous argument. .Kitoh et al. (2008)[103], presented even more pessimistic results in their projections of rainfall and stream-flow in the 'Fertile Crescent' of the Middle East. They found that the annual discharge of the Euphrates River will decrease significantly (29%–73%), as will the stream-flow in the Jordan River. Thus countermeasures for water shortages will become much more difficult. This negative trend of precipitation during the past century and beginning of 21 century is of a similar magnitude as that predicted by most of the GCM for the Mediterranean Region in the coming decades.

[100] (Evans, 2008); http://web.maths.unsw.edu.au/~jasone/eplots/pics/evans_4_1_lg.png

[101] Lehner, B.; Henrichs, T.; Döll, P.; Alcamo, J., 2001. EuroWasser Model- based assessment of European water resources and hydrology in the face of global change. World Water Series 5, Center for Environmental Systems Research, University of Kassel.

[102] EEA, 2004. Impact of climate change, EEA Report No 2/2004. Available at http://reports.eea.eu.int/climate_report_2_2004/en.

[103] Kitoh A., Yatagai, A., and Alpert, P. 2008. First super-high-resolution model projection that the ancient 'Fertile Crescent' will disappear in this century.Hydrological Research Letters, 2, 1–4. The Japan Society of Hydrology and Water Resources.

Syria is part of the historical region of Fertile Crescent area that was recently hit by an intense and prolonged drought episode as a consequence of the very low values of precipitation registered during the two hydrological years comprised between 2007 and 2009. This drought event had major socio-economic impacts in several countries located within the affected area, namely; Iraq, Jordan, and Iran beside to Syria. The economic impact was mostly due to the steep decline in agricultural productivity in the highly populated areas of the Euphrates and Tigris river basins (Shean, 2008a[104],b[105],c[106]). The occurrence of the two strongest prolonged droughts in the last decade (1997-2000 and 2005-2009) raises some concerns that this could become the norm, rather than the exception, in the future.

According to Trigoa (2010)[107], the most affected part of the Fertile Ceresin region by the drought are eastern Syria and Northern Iraq and Iran, which correspond to the major grain-growing areas of these countries. With the exception of the irrigated areas within the Euphrates and Tigris basin, the vast majority of crops in these regions are non-irrigated and thus dependent on winter precipitation.

When the whole two-year events are considered, the agricultural impacts of the 2007–2009 drought emerges especially severe in Iraq compared to the 1999–2000 drought, and more acute in barley production, whereas Syria and Iran production levels remained similar or even higher than those for the 1998–2000 drought.

Areas affected by drought hazard in Syria have been estimated by 34% of Syrian territory, where area of about 10% is of moderately hazard to drought, and area of about 4% is highly hazard. Most of the hazard areas are considered important areas for rainfed crop production in Syria, the spatial distribution of the hazard to drought shown that farming regions at south-western and north-eastern parts of the country are mostly affected, especially in Hassakeh governorate; Erian et al., (2011) [108],(the light blue color over the Turkey Mountains is correspond with the snow water presented by Onol, B. & Semazzi, F. 2006[109], as shown in figure).

[104] Shean, M., 2008a. Iran: 2008/09 wheat production declines due to drought. United States Department of Agriculture, Foreign Agricultural Service. May 9. Accessed 30.05.08.

[105] Shean, M., 2008b. Iraq: drought reduces 2008/09 winter grain production. United States Department of Agriculture, Foreign Agricultural Service. May 9. Accessed 30.05.08.

[106] Shean, M., 2008c. Syria: wheat production in 2008–09 declines owing to season-long drought. United States Department of Agriculture, Foreign Agricultural Service.May 9. Accessed 30.05.08.

[107] Trigoa R M.,b,, Célia M. Gouveiaa,c, David Barriopedroa 2010, The intense 2007–2009 drought in the Fertile Crescent: Impacts and associated atmospheric circulation Agricultural and Forest Meteorology 150 1245–1257

[108] Erian, W., Katlan, B. and Babah, O. 2010. Drought vulnerability in the Arab region: Special case study: Syria. Background paper prepared for the 2011Global Assessment Report on Disaster Risk Reduction. Geneva, Switzerland: UNISDR.

[109] Onol, B. & Semazzi, F. 2006: regional impacts on climate change on water resources over Eastern Mediterranean: Euphrates -Tigris basin. 18th conference on climate variability and change,86th AMS meeting. USA.

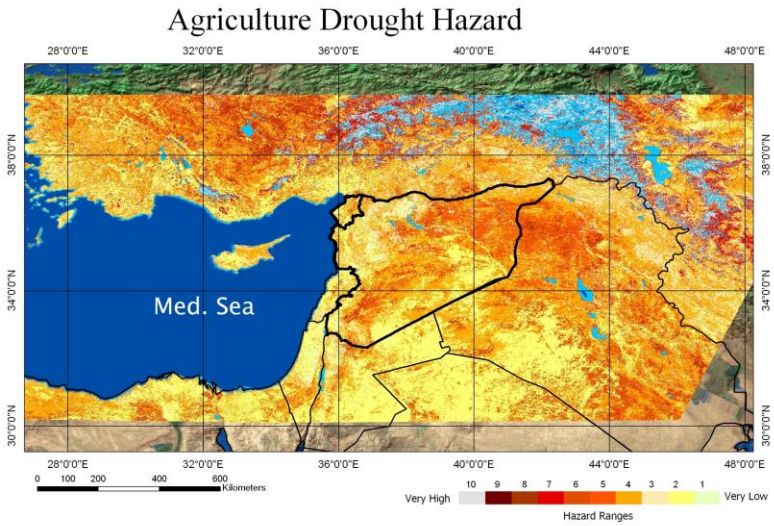


Figure Agriculture drought hazard in Syria and surroundings

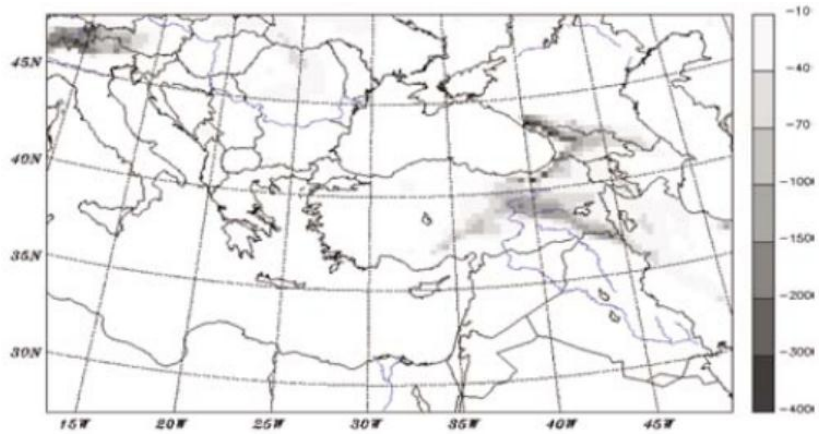


Figure. Climate change prediction for Turkey: Changes in snow water equivalent (in mm) affecting Euphrates and Tigris basins (Onol, B. & Semazzi F. 2006).

Major impacts of drought in Syria could be described as follows:

- Agricultural production:

  The eastern part of Syria represent 31.75% of the total rainfed areas of Syria and due to drought has been declined from 1.12 to 0.98 million hectare, during the years from 2000 to 2009; The region is contributing by 58% of the total wheat production, 68-78% of the total cotton production, 62-72% of the total maize production and 22% of the total sugar beet production, and have 30% of the goats, 36-41% of the sheep and 31-34% of the cows. Kattana, 2011. Rainfed wheat area normally amounts to more than 0.8 million hectares, and is extremely reliant on timely rainfall during the growing season, wheat production has dropped in the eastern part of Syria by 25.9% during the years 2000-2009, and total

production from 2.6 to 2.1 million ton during the years 2005-2009 and reaching to 1.2 and 1.9 million ton in 2008 and 2009 respectively

- Rural Livelihoods:

  The severe shortage of rainfall that has lasted more than four agriculture seasons (2007/2008 – 2010/2011) has crippled agriculture in eastern and Northeastern Syria; farmers who depend on only one crop are in trouble - they have nothing else to help them and they have to move; Erian et al, 2011; Kattana, 2011; UNISDR, 2011 and FAO, 2011. Increased respiratory infections, particularly because of the atmosphere nebular (dusty), particularly in the north-eastern areas lack of water (for drinking and domestic use) or provided by a non-secure health, leading to a variety of digestive diseases tract and diarrhea (especially in children), and kidney disease; FAO, 2011. A rise in the rate of borrowing in rural households in the three provinces between 2006 and 2010 estimated by 350%; ACSAD, 2010.

- Migration:

  During the years 2007 to 2011, Some 1.3 million people (206000 households) of a population of 22 million have been severely affected by the disaster, of which 800,000 have lost almost all of their livelihoods and face extreme hardship. Migration out of the affected areas has increased, with estimates indicating that between 40,000 to 60,000 families, with 35,000 from "Hassakeh governorate" alone have driven to urban settlements on so called mass migration toward Syria's cities such as Aleppo, Damascus and Deir ez Zour in search of work and for new sources of income, many ending up with difficult laboring work. in one of the largest internal displacements in the Middle East in recent years; Nashawatii, 2011 and Erian et al , 2010. , most of the houses on villages are left empty and less than 10% are occupied by elder people and children, The younger generations left seeking work, many left to Lebanon or Jordon, as workers in the sectors of construction or agriculture. Women left to work in the western part of Syria, for packing vegetables in "Tartous" green houses; Erian et al., 2011.

- Ecosystem decline:

  Due to drought that increased in frequency, intensity and duration, the deficit in available water has been estimated of about 651 million M3 during the years 1995-2005, and still increasing with expectation to rise to 2077 million M3 by the year in 2030 only because of population growth and the increasing pace of development; Nashawatii, 2011. Decline in availability of irrigation water in the Hassakeh governorate is largely due to the hydrological drought of Khabour River, this has led to the decline in irrigated areas, the water scarcity has led to increasing pressures on ground water resources and brought the water crisis to critical levels; FAO, 2011 and Mora, 2011. Increase of moderate and severe land degradation that estimated during the period from 1999 to 2007 by 34.8% of the total area of Syria; ACSAD, 2009.

2.4.3. .Drought in Europe

Droughts were long considered a hazard affecting mainly developing countries, but public awareness has increased in the past years in the industrial countries especially with respect to the climate change issue predicting more extreme hydrological conditions (Demuth and Stahl, 2001[110]). The European countries' agricultural GDP share is well below 5%, (FAO 2012) and in most of the countries it is less than 3%. Therefore, in Europe drought impacts on the industry and service sector are more harmful to the economy than agricultural losses.

Since the demand for European water resources has increased in the past decades, future conflicts between human requirements (commercial, social and political) and ecological needs are likely to increase, too. These conflicts are most critical and intensive during severe and extensive droughts. In the early 1990s Europe experienced severe droughts resulting in significant economic and environmental costs. The damage in Spain (1992-95), where the drought affected about 500 000 hectares of irrigated land alone in the Guadalquivir river basin, was estimated at several billion Euro (Garrido and Gómez-Ramos, 2000[111]). The 2003 drought in Europe accounted for almost 1/3 of the economic natural hazard losses (US$ 12.4 billion) Agriculture and industry in Southern Spain and Portugal were hit by severe drought in 2004. France and the UK suffered similar problems in 2006, (Munich Re 2004[112]).

The assessment carried out in the past thirty years reveals that drought events have regularly occurred. The duration of each event, the area and population affected have been variable throughout this period, (EU 2007[113]). Information provided by EU member States made it possible to identify severe events that on annual basis affected more than 800 000 km² of the EU territory (37%), figure ( ) and 100 million inhabitants (20%) in 1989, 1990, 1991 and more recently in 2003, (figure). Information also revealed that at least Austria, Belgium, Cyprus, France, Hungary, Italy, Lithuania, Malta, Netherlands, Norway, Portugal, Spain and United Kingdom have been affected by droughts in the last thirty years, but with different degrees of intensity. Italy, Portugal, Cyprus, Spain and France have registered the highest frequency of droughts from 1976 to nowadays, with 8 to 21 events per country. However, several Northern and Eastern countries (Belgium, UK, Finland, Germany, Hungary, Lithuania, Netherlands, Norway, Slovakia,) have also experienced severe droughts, particularly in recent years.

The same report illustrated that drought duration is largely variable from one country to another. In Cyprus, Italy, Portugal, Spain, droughts may last one or several years. In other countries, droughts have been predominant during one month (Hungary, Germany, Lithuania) or from two

[110] Demuth, S., Stahl, K. (eds.) (2001): Assessment of the Regional Impact of Droughts in Europe. Final Report to the European Union, ENV-CT97-0553, Institute of Hydrology, University of Freiburg, Germany.

[111] Garrido, A., Gómez-Ramos, A. (2000): Socio-economic aspects of droughts. In Vogt, J.V., Somma, F. (eds.): Drought and Drought Mitigation in Europe. Advances in Natural and Technological Hazards Research, Vol. 14, pp. 197-207. Kluwer Academic Publishers

[112] Munich Reinsurance Company 2004. Topics Geo Annual review: Natural catastrophes 2004, http://www.munichre.com/publications/302–04321_en.pdf> ,

[113] EU 2007. Water Scarcity & Droughts In-Depth Assessment Second Interim Report

to six months (Austria, Belgium, France). Finland was affected by a 270 day drought from August 2002 to April 2003.

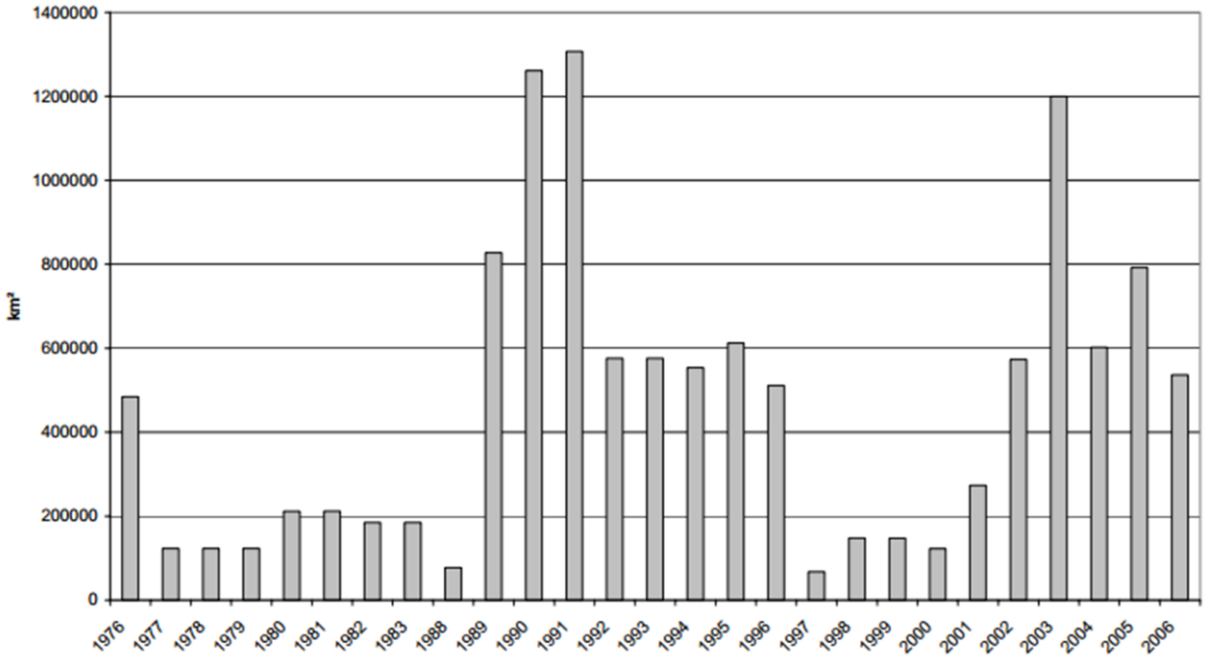


Figure EU area affected by droughts in the last 30 years. Source: EU Member State data, Commission, November 2006

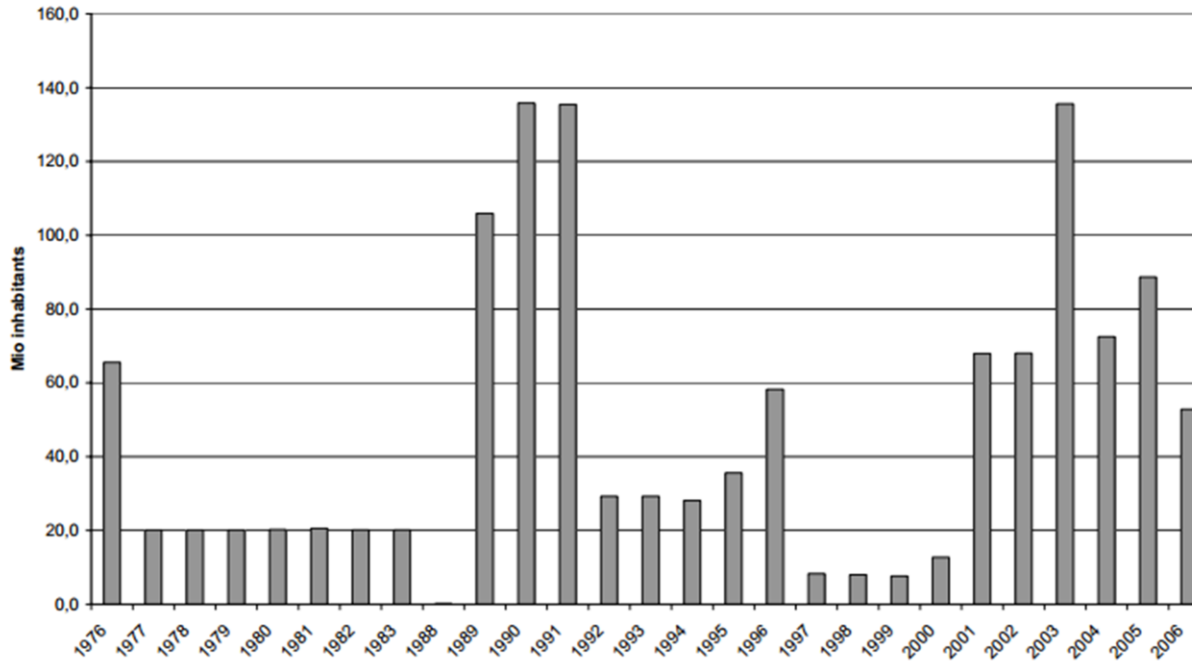


Figure EU population affected by droughts in the last 30 years. Source: EU Member State data, Commission, November 2006

The report figures stress a significant increase in annual average EU territory (from 6% to 13%) and population (from 6% to 13%) affected by droughts between the 1976-1990 period and 1991-2006 period Information from Member States provides a first estimation of the main drought impacts. Some countries provided economic costs incurred due to specific drought.

The compilation of this data and the translation in unit costs made it possible to estimate the overall economic impacts of drought events in the past thirty years to a total of 100 billion € at EU level. Results show that the annual average impact has doubled between the 1976-1990 period and the next 1991-2006 period. It reached an average of 6.2 billion €/year in the most recent years, with an exceptional cost of 8.7 billion € in 2003. These estimations only cover economic costs. They do not include social and environmental costs due to an absence of data. Therefore, attention will have to be paid in a near future to the enhancement of data collection at EU and national levels, in order to improve the economic, social and environmental impact assessment.

Winter droughts are caused by precipitation being stored in the catchment in the form of snow and ice, preventing any recharge of rivers or aquifers until air temperatures rise again and snow melting starts, or to the timing (i.e. principal season of occurrence, delays in the start of the rainy season, occurrence of rains in relation to principal growth stages) and the effectiveness of the precipitation (i.e. rainfall intensity, number of rainfall events). (MED Joint Process FD/EUWI 2006)[114].

Drought is also related to the timing (i.e. principal season of occurrence, delays in the start of the rainy season, occurrence of rains in relation to principal growth stages) and the effectiveness of the precipitation (i.e. rainfall intensity, number of rainfall events). Droughts usually have long-term impacts, on natural water resources, as the water reservoirs, both surface and subsurface, need several rainy periods to be restored. As they are climate risks (rainfall deficiencies in relation to the annual or seasonal average) with hydrological consequences, that is to say consequences on renewable water resources, droughts are quite naturally the principal cause of random water shortage due to lack of water resources in all places where water demands are close in quantity to average annual water "blue water" resources; this is moreover because "green water" deficits (soil humidity) increase irrigation water demand: the drought both reduces available water resources, while increasing the demands for natural water (MED WS&D WG 2007[115]).

Climate change is expected to reduce water availability and increase irrigation withdrawals in Mediterranean river basins. Under mid-range assumptions on temperature and precipitation changes, water availability is expected to decline in Southern and south-eastern Europe (by 10 % or more in some river basins by 2030). The overall area affected by water scarcity can be estimated to 418 600 km² and the overall population to 76 375 000 inhabitants. In other words, at

[114] MED Joint Process WFD/EUWI – Water scarcity drafting group 2006.: water scarcity management Water Scarcity and Drought Management in the Mediterranean and the Water Framework,

[115] Med WS&D WG. Mediterranean - Water Scarcity & Drought Working Group 2007. Water Scarcity and Drought Management in the Mediterranean and the Water Framework,

least 11% of the EU territory and 17% of the EU population have been affected so far by water scarcity situations, figure ( ). Most affected river basins are located in Southern Europe, representing 62% of the total estimated EU area being affected. Apart from Southern countries, it is obvious that some river basins in Northern and Eastern countries are being affected by water scarcity. Drought is one of the most damaging natural hazards affecting the Iberian Peninsula, causing detrimental impacts on agriculture, water resources and ecosystems (Vicente-Serrano 2006c , López-Moreno et al. 2009 , Lorenzo-Lacruz et al. 2010). There has been an increase in drought severity on the Iberian Peninsula in recent decades (Vicente-Serrano et al. 2004 , Vicente- Serrano 2006a), mainly associated with a decrease in precipitation that has affected most of the region (González-Hidalgo et al. 2009). The evolution of drought on the NW Iberian Peninsula from 1930 to 2006, studied after Vicente-Serrano et al (2011) , identified differences between the effects of precipitation variability and warming processes on drought severity and surface water resources. The vulnerability of semi-arid basins such as the Segura River basin (southeast Spain), to rainfall variability, implies uncertainties in agricultural activities, (ANDRA 2011),

Agriculture in Spain is considered one of the most affected countries by Drought, figure ( ) (Niemeyer S 2010) . Agriculture is now experiencing limited developments: extraction costs are increasing, agricultural margins are reducing and a greater uncertainty is being put on production, leading to loss of competition, (EU 2007). Employment in the farming sector seems to decrease in water scarcity areas (Spain, Cyprus). But this information needs to be further addressed, notably by comparing this evolution with evolutions in other areas and with future mid-term or long-term evolutions in areas where production is profitable but water is being used unsustainably.

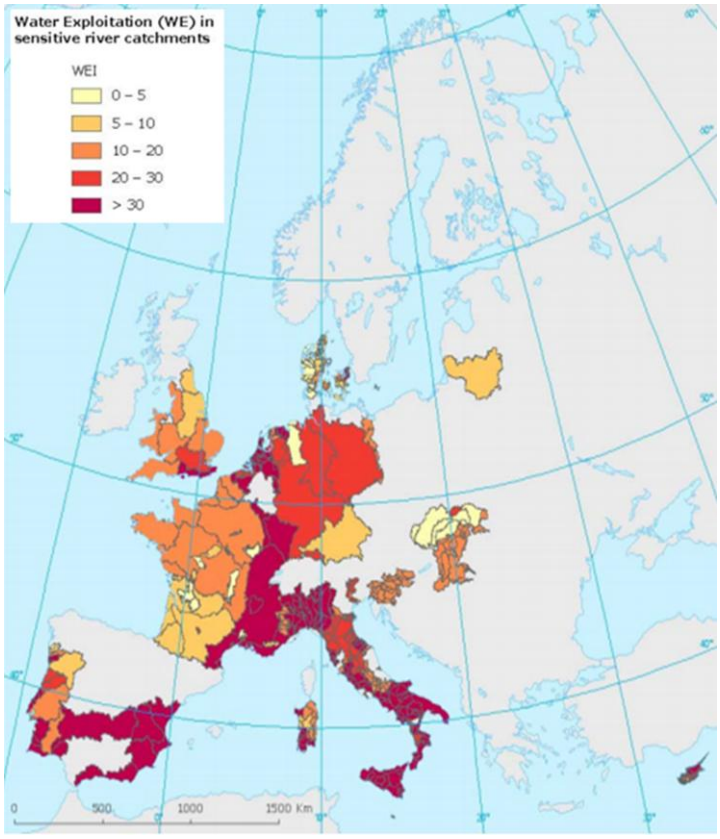


Figure Areas with River Basins Affected by Water Scarcity

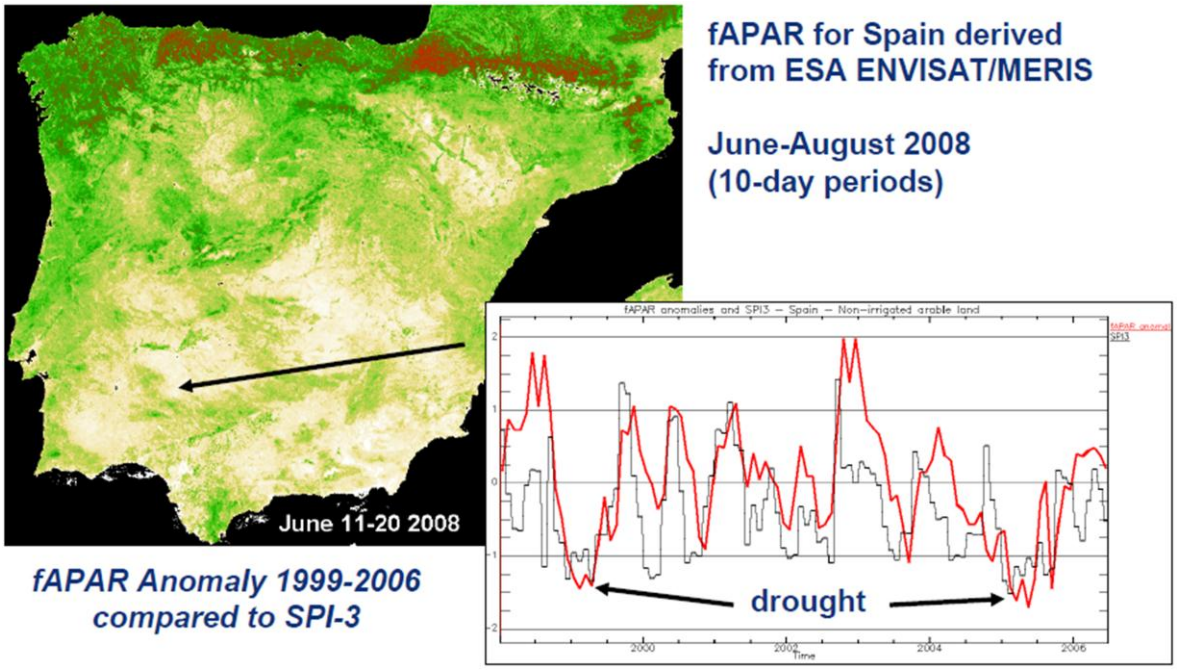


Figure Drought index SPI for the period1999-2006 in rainfed agriculture area in Spain

In fact droughts and long dry periods in Europe have led to serious power failures in Europe and as a result, to great economic losses in the industrial and tourism sectors. Differently from other areas, and while most drought assessments concentrate on the effect on vegetation and estimated economic losses to agricultural production, drought risk might also consider the effects on the producing industry and service sector, e..g. nuclear power plants might have to run on lower production rates because their cooling systems depend on rivers or lakes.

Additionally, power plants might have to shut down because the cooling water taken from lakes, rivers or the sea might be too warm to be used. combination of drought and a heat wave is dreadful. The power support is not only getting shorter due to the drought effects mentioned above, it is also stressed by the need for cooling systems that also demand a lot of energy. Most of the hydro power plants in areas affected by droughts suffer from reduced energy production due to lower water levels. Norway and other countries in Northern Europe that have a high consumption of hydropower also experience the economic effects of rising electricity prices during droughts (Cherry et al. 2000 and Acher 2002).

Drought hazard map presented by Alvarez & Estrela (2001[116]) depended on large historically drought events. Accordingly the data accuracy is variable. Therefore, the map is applicable as a general overview map on past large drought events in Europe. The resulting potential drought hazard is calculated from the amount of recorded droughts during the last century. The map shows that the Mediterranean area has a wide variety of drought potentials. While Portugal and

[116] Alvarez, J. & Estrela, T., 2001. Large scale droughts in Europe. In: Demuth, Siegfried & Stahl, K. (ed.) Assessment of the Regional Impact of Droughts in Europe, ARIDE final report 2001.

western Spain have the largest drought potential in Europe, eastern Spain appears to generally have a lower potential. Some areas in Southern Europe that are usually associated with droughts appear less dramatic in this map. The reason for this lies in stronger local effects of agricultural droughts, as these might be partly related to the adequacy of agricultural systems and related water scarcity. A problem in this map is the severe jumps of two classes in some areas, like Northern Europe. Also, Southern Italy appears to have a low drought potential, even though areas with a higher drought potential surround it. The reason for this might be that the drought problem in Southern Italy is not directly related to precipitation deficits but to other reasons not displayed here. As mentioned above, the data and map shown here represent one indication for drought potential, (Schmidt-Thomé, P. & Kallio, H. 2006[117]).

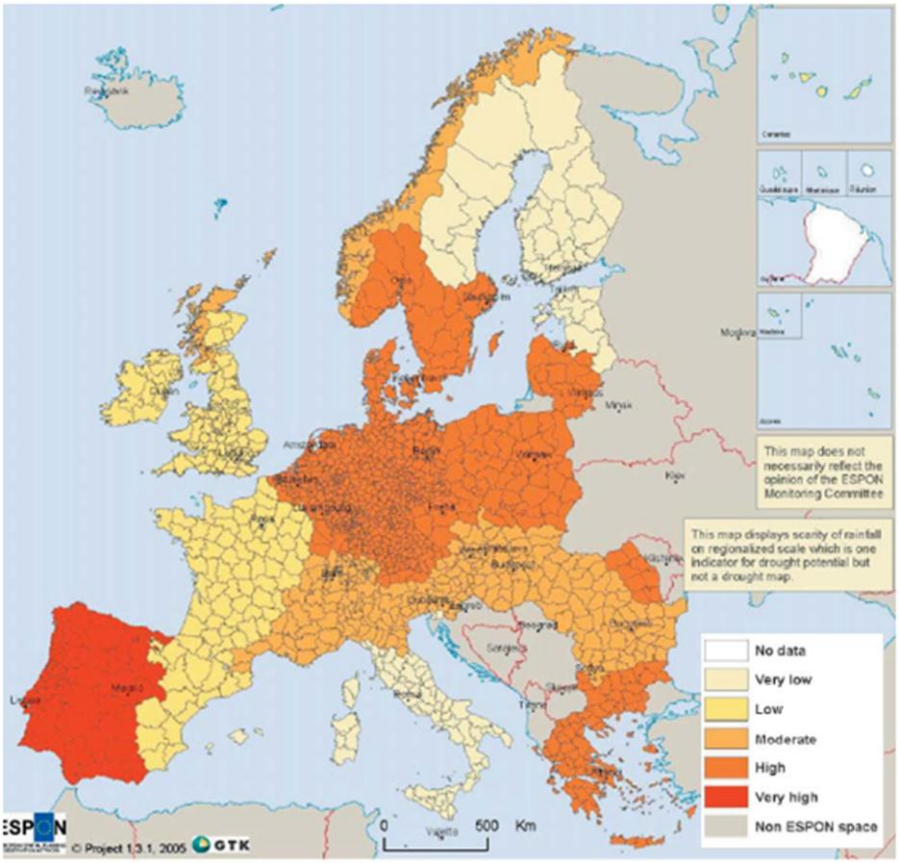


Figure Drought hazard map of Europe, after Alvarez & Estrela (2001)

[117] Schmidt-Thomé, P., J. Klein & Schmidt-Thomé, K. 2006 Natural and technological hazards and risks affecting the spatial development of European regions. Geological Survey of Finland, Special Paper 42, 17–63

The following table summarizes the information provided by member States on the impacts of several drought events, after, (MED WS&D WG 2007[118]). .

Table Drought losses incurred by Member States due to past droughts (Million €), after (MED WS&D WG 2007).

Period	EU State	Economic impacts					Social impacts	Environmental impacts	Others
		Public water supply	Industry	Energy	Agriculture	Navigation			
1975-1976	Portugal			147	53				
1976	Belgium**		350	5	21				
1961-1990	Hungary	50	300	200	4000	50	0.04	7	310
1981-1983	Portugal	14		238	62				1
1989-2002	France				1540			145/year	330/year
1990-1995	Spain	22		210	1800				1541
1992-1993	Portugal			426	241				12
1995	UK***	352	265	24	324	141	0.5		
2002-2003	Finland	10	1	50	17	.1	25	2.5	13
2003	Belgium**		1		1	.05			
2003	France			300	590				
2003	Germany				1000				
2004-2005	Portugal	9	32	261	519			9	14+23*
2005	France			270	250				
2005	Spain			713	2500			114	
2006	Netherlands			10	600	72			
2006	Lithuania				201				

* During the 2004-2006 drought, Portugal had to spend 23 Mio € in urban water supply. In 66 municipalities (100 500 inhabitants), urban water supply was supplemented by 22 850 water tank operations.

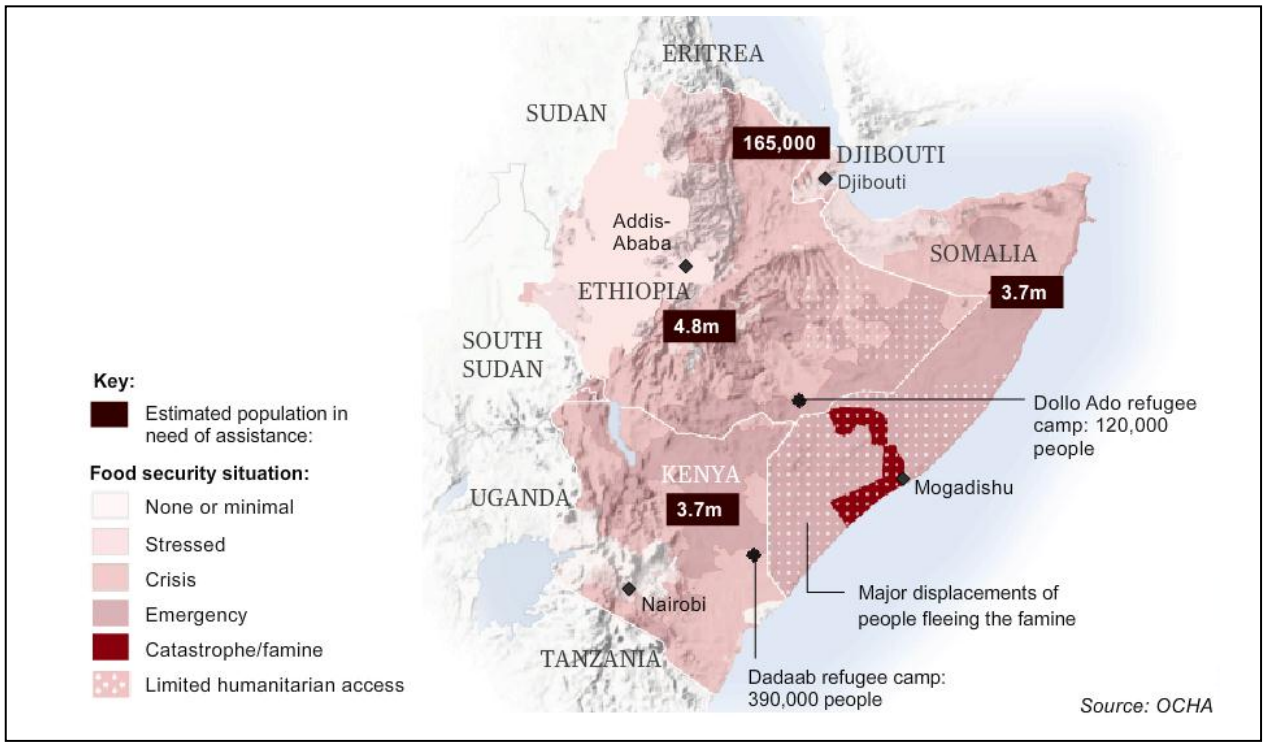
** These figures are the results of simulations. For 1976, damages have been estimated taking into account actual water uses (2002).

*** Costs are related to the 1995 hot dry summer and drought together. The impact of the 1995 drought itself was around € 140 Mio.

[118] Med WS&D WG. Mediterranean - Water Scarcity & Drought Working Group 2007. Water Scarcity and Drought Management in the Mediterranean and the Water Framework,

2.4.4. Drought in the Horn of Africa and Sahel.

Since mid-July 2011, a severe drought has been affecting the entire East Africa region, According to OCHA (2011)[119], weather conditions over the Pacific, including an unusually strong La Niña, have interrupted seasonal rains for two consecutive seasons. The rains failed in 2011 in Kenya and Ethiopia, and for the previous two years in Somalia. FEWS NET declared that the crisis was "the most severe food security emergency in the world today, and the current humanitarian response is inadequate to prevent further deterioration. A cycle of severe droughts has led to a humanitarian crisis in the Horn of Africa (which includes Somalia, Kenya, Djibouti, Ethiopia and Uganda). It is estimated that over 13 million people have been affected, many fleeing their homes and are now left with limited access to food, clean water and shelter[120]. Many refugees from Southern Somalia have fled to neighboring Kenya and Ethiopia, where crowded, unsanitary conditions together with severe malnutrition have led to a large number of deaths. Other countries in East Africa, including Sudan, South Sudan and parts of Uganda, are also affected by a food crisis.



Areas Affected by the Horn of Africa drought, source: OCHA, 2011

[119] OCHA (UN Office for the Coordination of Humanitarian Affairs) (10 June 2011). "Eastern Africa Drought Humanitarian Report No. 3". reliefweb.int. Archived from the original on 3 July 2011.. Retrieved 12 July 2011.

[120] http://www.redcross.ca/article.asp?id=40022

Long-rains precipitation has declined in much of Kenya and Ethiopia in the past 30 years. These rainfall declines have been particularly strong in central and eastern Ethiopia and Kenya, with rainfall totals declining by **35–45 percent** of the 1950–79 mean rainfall throughout much of the area south and east of the Ethiopian Highlands as shown in figure 1. The long rains of 2009 were the driest in at least 60 years throughout much of this region (Funk and Verdin, 2009)[121].

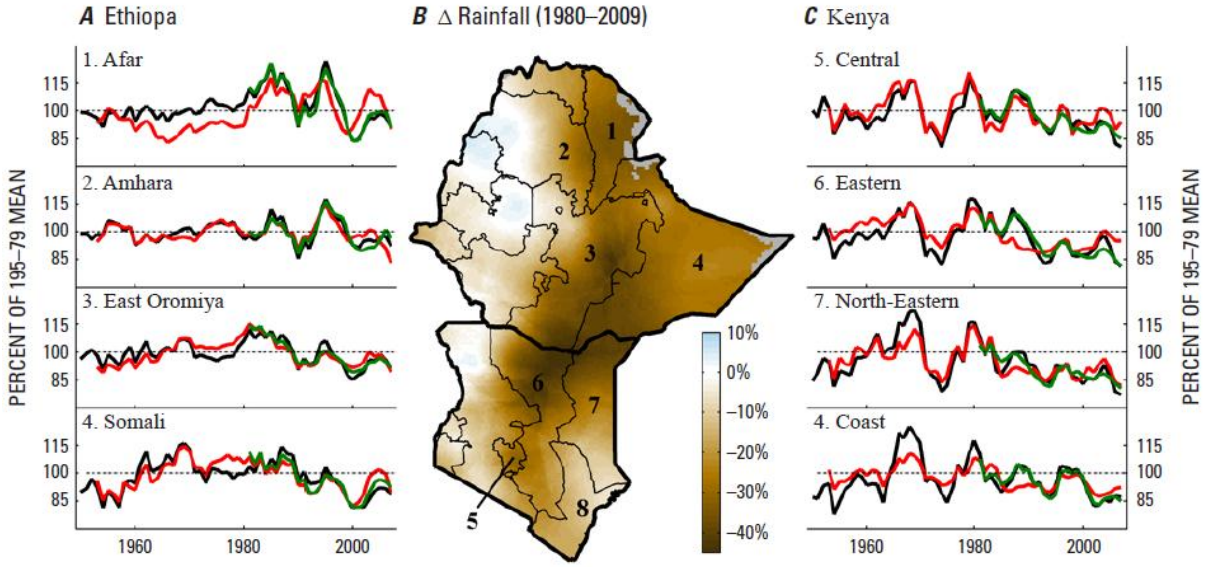


Figure Plots (*A* and *C*) show March–June rainfall within various divisions of Ethiopia and Kenya relative to the 1950–79 mean. Analysis only represents areas where mean March–June precipitation was greater than 100 millimeters.

This trend toward March-June dryness contrasts starkly with projections of increased rainfall in eastern Africa by the Intergovernmental Panel on Climate Change, or IPCC (Christiansen and others, 2007)[122]. The climate models that make projections of increased precipitation in this region probably do so because the model results generally forecast more 'El Niño-like' conditions globally in coming decades. El Niño conditions historically have been associated with increased rainfall in eastern Africa. The link between El Niño indices and long-rains precipitation, however, is weak, (Williams, and Funk, 2010)[123]. According to Williams, and Funk, (2010) and Funk et al, (2008)[124], the specific process that causes rainfall declines may be a

[121] Funk, C., and Verdin, J.P., 2009, Real-time decision support systems—The famine early warning system network *in* Gebremichael, M., and Hossain, F., eds., 2010, Satellite Rainfall Applications for Surface Hydrology: Springer, Netherlands, p. 295–320, *ftp://chg.geog.ucsb.edu/pub/pubs/SatelliteRainfallApplications_2010.pdf*.

[122] Christensen, J.H., Hewitson, B., Busuioc, A., Chen, X.G., Held, I., Jones, R., Kolli, R.K., Kwon, W-T., Laprise, R., Rueda, V.M., Mearns, L., Menéndez, C.G., Räisänen, J., Rinke, A., Sarr, A., and Whetton, P., 2007, Regional climate projections, chap. 11, *in* Solomon, S., Qin, D., Manning, M., Chen, Z., Marquis, M., Averyt, K.B., Tignor, M., and Miller, H.L., eds., Climate Change 2007—The Physical Science Basis, Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change: Cambridge University Press, Cambridge, U.K., p. 849–940, *http://www.ipcc.ch/publications_and_data/ar4/wg1/en/ch11.html*.

[123] Williams, A.P., and Funk, Chris, 2010, A westward extension of the tropical Pacific warm pool leads to March through June drying in Kenya and Ethiopia: U.S. Geological Survey Open-File Report 2010–1199, 7 p.

[124] Funk, C.C., Dettinger, M.D., Michaelsen, J.C., Verdin, J.P., Brown, M.E., Barlow, M., and Hoell, A., 2008, Warming of the Indian Ocean threatens eastern and southern African food security but could be mitigated by

westward extension of the tropical Pacific warm pool that has occurred because of rapid warming in the Indian Ocean and much slower warming in the central tropical Pacific. The equatorial Indian Ocean has warmed approximately twice as fast as the central tropical Pacific since 1900, as shown in (figure). A similar process has been implicated previously as a possible cause of drought in the African Sahel (Giannini and others, 2003)[125]. These findings are significant for adaptation planning for the region. Drier, rather than wetter conditions in the century ahead appear likely. The anthropogenic Indian Ocean warming response appears to be one of the most consistent (Hoerling et al. 2004[126]; Barnett et al. 2005[127]) and well understood (Du and Xie 2008[128]) responses to greenhouse gas emissions. This anthropogenic warming appears to have already significantly altered the earth's largest circulation feature and impacted its most food insecure inhabitants.

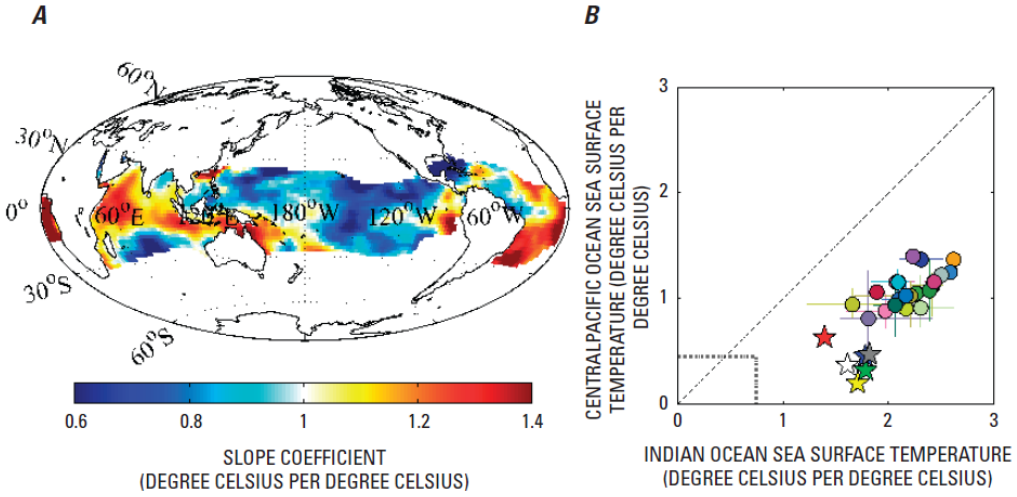


Figure . (*A*) Slope coefficients from the regression of 5-year running mean (March–June) NOAA extended sea surface temperatures (SSTs) against 5-year running mean March–June Goddard Institute for Space Studies (GISS) global temperature from 1900–2009, where mean 1951–81 (March–June) SSTs were above 24 degrees Celsius, for the Indian Ocean and central Pacific Ocean. (*B*) The same slope coefficients as in (*A*), but contrasting the (y-axis) central Pacific Ocean versus the (x-axis) Indian Ocean. Coefficients in (*B*) were calculated using observed (stars) and Intergovernmental Panel on Climate Change (IPCC) modeled (circles) climate datasets, source: Funk et al, (2008).

agricultural development: Proceedings of the National Academy of Science, U.S., 105: p. 11,081–11,086, *ftp://chg.geog.ucsb.edu/pub/pubs/PNAS_2008.pdf*.

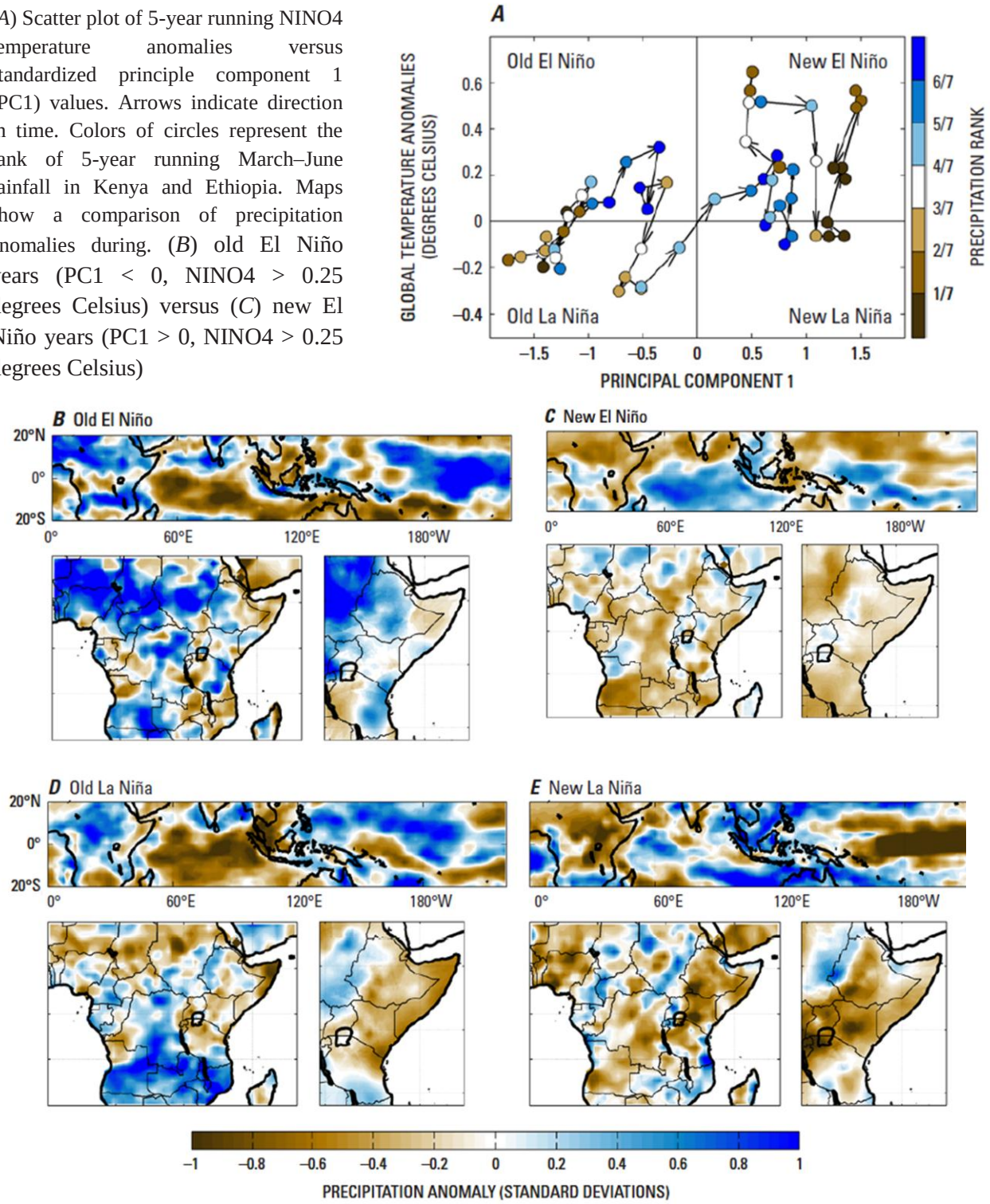
[125] Giannini, A., Saravanan, R., and Chang, P., 2003, Oceanic forcing of Sahel rainfall on interannual to interdecadal time scales: Science, v. 302, p. 1,027–1,030.

[126] Hoerling MP, Hurrell JW, Xu T, Bates GT, Phillips AS (2004) Twentieth century North Atlantic climate change. Part II:understanding the effect of Indian Ocean warming. Clim Dyn 23:391–405

[127] Barnett TP, Pierce DW, AchutaRao KM, Gleckler PJ, Santer BD, Gregory JM, Washington WM (2005) Penetration of humaninduced warming into the world's oceans. Science 309:284–287

[128] Du Y, Xie SP (2008) Role of atmospheric adjustments in the tropical Indian Ocean warming during the 20th century in climatemodels. Geophys Res Lett 35:391–405

(*A*) Scatter plot of 5-year running NINO4 temperature anomalies versus standardized principle component 1 (PC1) values. Arrows indicate direction in time. Colors of circles represent the rank of 5-year running March–June rainfall in Kenya and Ethiopia. Maps show a comparison of precipitation anomalies during. (*B*) old El Niño years (PC1 < 0, NINO4 > 0.25 degrees Celsius) versus (*C*) new El Niño years (PC1 > 0, NINO4 > 0.25 degrees Celsius)

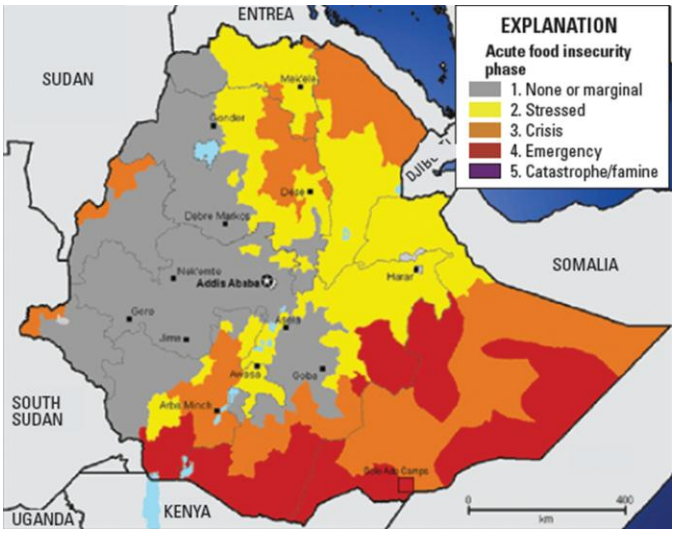


(*D*) old La Niña years (PC1 < 0, NINO4 < –0.25 degrees Celsius) versus (*E*) new La Niña years (PC1 > 0, NINO4 < –0.25 degrees Celsius). Each set of three maps in *B*–*E*, were calculated using three different precipitation datasets to demonstrate consistency among datasets. Top maps: National Center for Environmental Prediction/National Center for Atmospheric Research (NCEP/NCAR), Bottom-left map: GPCC, Bottom-right map: CHG-CLIM.

a. Ethiopia,

Ethiopia is a large complex country, with complex patterns of rainfall and livelihoods (Livelihoods Integration Unit, 2010). In Ethiopia, higher elevations receive more rainfall than low arid areas and support agricultural livelihoods and higher population densities (fig. 1). Lowlands receive minimal rainfall, and people generally support themselves by raising livestock. In between, agro-pastoralists rely on a mixture of the two livelihood strategies. The population density of Ethiopia varies dramatically (Livelihoods Integration Unit, 2010), from more than 300 people per square kilometer (km2) in some parts of the Southern Nations, Nationalities, and Peoples Region (SNNPR, see Objectives and Methods section for a map with region names), to less than 10 people per km2 in areas dominated by pastoral livelihoods. Most rural people live in the highlands and middle-highlands, which comprise only one-third of the country, and this population tends to be concentrated primarily in Oromia or Northern SNNPR. The seasonality of rainfall varies in different areas of Ethiopia. In the eastern Somali region, rains come twice a year–during the March–June Belg season, and during the October–December Deyr season. In the south-central part of the country, most areas receive both Belg and summer (June–September) Kiremt rains. Many farmers plant slowly maturing but high yielding 'long cycle' crops that grow during both the Belg and Kiremt seasons.

In 2011, Ethiopia, with a population of 90.9 million (CIA, 2011)[129] and a population growth rate of 3.2 percent (a doubling time of 22 years), faces increased levels of food insecurity. Pre-planned assistance provided by the Productive Safety Net Program supported some 7.4 million people, whereas an additional 4.5 million people required emergency humanitarian assistance because of decreased precipitation and extremely high food prices (FEWS NET, 2011)[130].These 4.5 million people tended to be located in the south-central, southeastern, or eastern part of the country. Approximately 65 percent of these at-risk households relied primarily on agricultural livelihoods; the remainder were pastoralists or agro-pastoralists.



The December 2011 food security outlook for January–March 2012 from *www.fews.net*.

Spatial patterns and quantities of projected future rainfall reductions and temperature increases, by extending the rate of observed 1960–2009 changes for each season, through 2010–2039 , based on an assumed persistence of the observed trends. For the Belg rains, rainfall declines range from -150 to -50 mm across the south-central and eastern parts of the country, and will be

[129] CIA (Central Intelligence Agency), 2011, The World Factbook, accessed December 15, 2011, *https://www.cia.gov/library/publications/the-world-factbook/geos/et.html*.

[130] FEWS NET, 2011, Ethiopia Food Security Outlook Update, August 25, 2011, accessed December 15, 2011, at *http://www.fews.net/docs/Publications/ Ethiopia_Dekadal_08_20_final_ext.pdf*.

associated with lower Belg harvests and poorer pastoral rangelands during the summer and early fall. This may be particularly disruptive for pastoralists and agro-pastoralists living in Southern Oromia and western Somali regions who currently (2012) rely upon meager Belg rains for their livelihoods. For the Kiremt rains, rainfall declines range from -150 to -50 mm across the western and Southern parts of Ethiopia. The combined Belg and Kiremt rainfall reductions total a loss of more than 150 mm of rainfall per year in the most densely populated long cycle crop growing area of the country. If recent warming trends continue, most of Ethiopia will experience more than a 1.0° Celsius (°C) increase in air temperature, with the warming tendency projected to be greatest in the south-central part of the country. This warming will intensify the impacts of droughts, and could particularly reduce the amount of productive crop land for coffee, since coffee plants typically prefer temperatures cooler than 22°C.,
A decline in rainfall of approximately 0.5 standard deviation, and an increase in the frequency of droughts of approximately 40 percent, is sufficient to markedly increase the number of poor harvests that can be expected. The impacts of increasingly frequent droughts could be offset by improved water and agricultural management practices. Raising yields in the more agriculturally viable areas may be a better option than extending agriculture into ever more marginal areas; however, rapid population growth may make it difficult to slow the process of agricultural extensification into those more marginal areas, (Funk etal 2012)[131].

Whereas the agricultural viability of the areas highlighted above appears threatened, it is also important to note that large parts of the country are likely to continue receiving adequate amounts of rainfall. Agricultural development in the western highland areas is much less threatened and, with better agricultural practices and water management, could dramatically enhance food security at the national level. The spatial pattern of the drying and warming trends, however, tends to indicate disproportionate stresses on south-central Ethiopia, where trends have likely already been affecting yields during the Belg, Kiremt, and long cycle growing seasons. These increasingly frequent droughts will impact the large number of farmers and agro-pastoralists living in this area, while also decreasing food availability on a national scale. During the Belg season, more frequent droughts across the southeast have impacted marginal pastoral and agro-pastoral areas, further eroding resilience and increasing poverty at the sub-national scale, after Funk, (2012) could be summarized as follows:

- Spring and summer rains in parts of Ethiopia have declined by 15–20 percent since the mid-1970s.
- Substantial warming across the entire country has exacerbated the dryness.
- An important pattern of observed existing rainfall declines coincides with heavily populated areas of the Rift Valley in south-central Ethiopia, and is likely already adversely affecting crop yields and pasture conditions.
- Rapid population growth and the expansion of farming and pastoralism under a drier, warmer climate regime could dramatically increase the number of at-risk people in Ethiopia during the next 20 years.
- Many areas of Ethiopia will maintain moist climate conditions, and agricultural development in these areas could help offset rainfall declines and reduced production in other areas.

[131] Funk C, Jim Rowland, Gary Eilerts, Emebet Kebebe, Nigist Biru, Libby White and Gideon Galu 2012. A Climate Trend Analysis of Ethiopia USAID-funded FEWS NET, agreement with USGS.

In Ethiopia, Meher season crop production is well correlated with April-May rainfall in the Ethiopian 'long cycle' crop growing region, (figure). This relationship is used to estimate 2003 Meher small-holder gross production at 87 ± 10 million quintals (8.7 million MT ± 1 million MT) of cereals, pulses and other crops, using data from the Central Statistical Authority (CSA). Assuming recent levels of commercial and food aid imports, Belg production and population growth, this estimate will produce food deficits of about 23 million quintals (2.2 million MT) for 2003-04, smaller than those experienced during 2002-03 (34 million Qt, or 3.4 million MT), but similar to the deficits experienced in 1997-98.

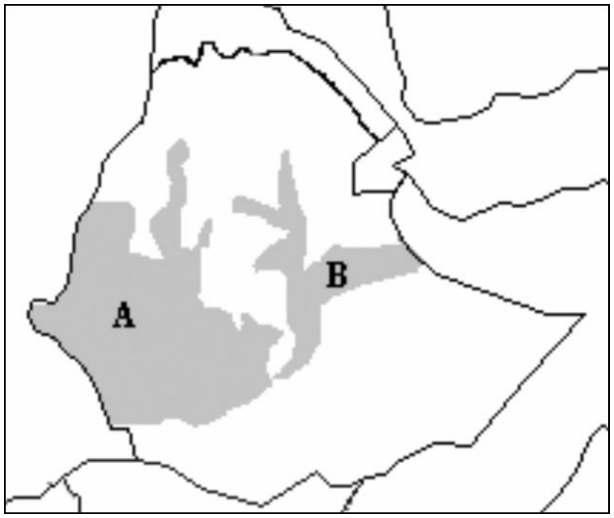


Figure Long cycle crop growing region

Large long-term negative trends in March-September precipitation totals (~23 mm/year) may be aggravating the situation. Data show an increasing aridity, adding a major additional threat to fragile rain fed farming. Increasing food requirements and decreasing precipitation point toward chronic food shortages in the near future, (figure).

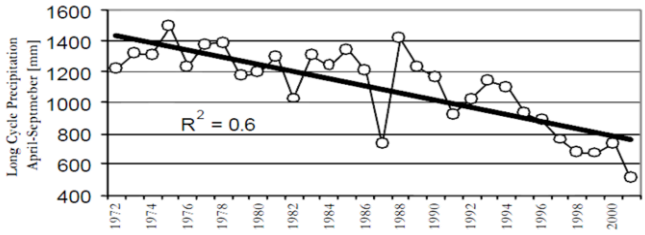


Figure April-September precipitation in the long cycle crop growing region.

The implication of these rainfall and crop production trends is that projected food shortages in Ethiopia may soon pass beyond chronic into tragic, exceeding the ability of food aid to make up the difference. To halt and reverse these ominous trends, Ethiopia will require urgent changes in its rural landscape and national development – security of land holdings, improvements in crop yields and production technologies, restoration of the environment, more efficient markets, protection of livelihoods and entitlements, and reductions in population growth.

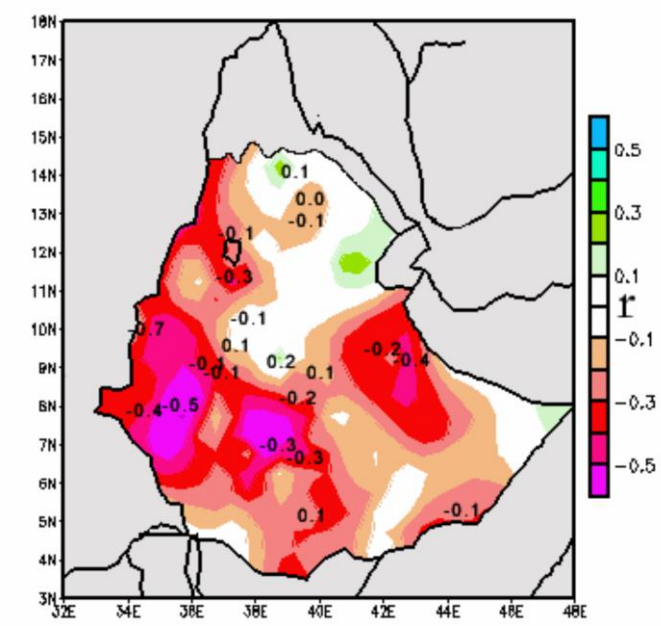
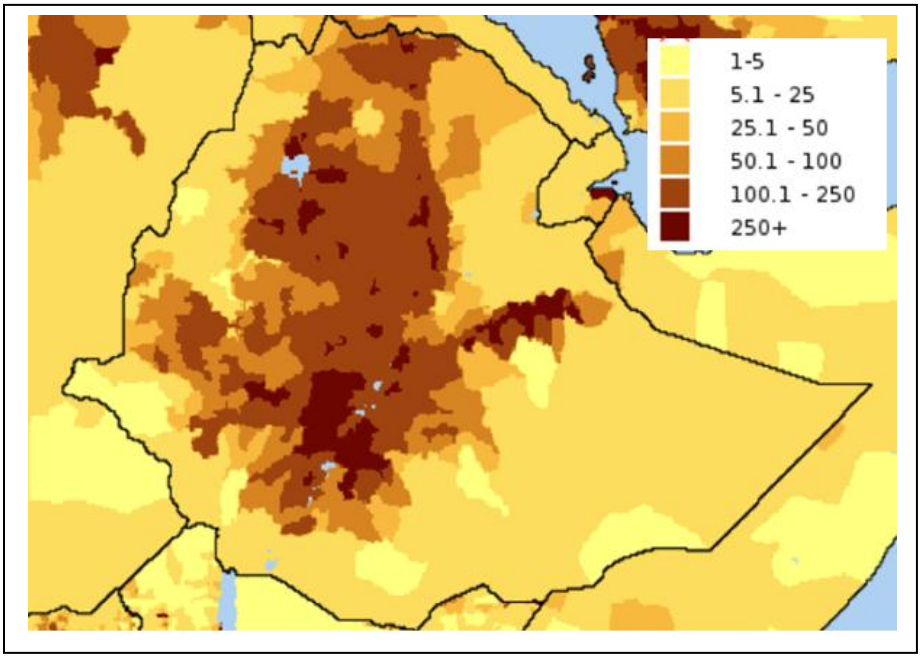


Figure Shading shows the correlation between each grid cell's June-September rainfall and a linear trend over the 1961-1996 time period. Super-imposed numbers denote correlations with a trend calculated at quality - controlled stations over the same range of years

A more diversified and trade-oriented economy can help reduce reliance on low-input, low-yield rainfed agriculture on small plots and solve the pervasive problem of rural poverty and hunger.

The main highlights of Meher season crop production as mentioned by Funk et al (2003)[132] , could be summarized as follows:

- National Meher yield and production correlate well with April-May rainfall in the 'long cycle' crop growing region of Ethiopia.
- Rainfall in April-May 2003 suggests Meher production will be about average when compared with the last seven years.
- Population growth (1.8 million per year) adds 3.3 M Qt per year to the national consumption requirement, nearly half of annual food aid received.
- A coarse food balance shows that about 13 million people would meet none of their food needs at all in 2003-04, assuming equitable distribution.
- The 'long cycle' crop growing region has experienced a strongly negative rainfall trend since 1972, with adverse consequences for production.
- Ethiopia requires rapid changes in its rural landscape and national development.



The density population map of Ethiopia 2010 (person/Km^2),source: SEDAC Map Client

[132] Funk Chris, Alemu Asfaw, Phil Steffen, Gabriel Senay, Jim Rowland and Jim Verdin 2003. Estimating Meher Crop Production Using Rainfall in the 'Long Cycle' Region of Ethiopia, USGS.

b. Kenya

The analyses carried out by (Funk and others, 2005[133]; Verdin and others, 2005[134]; Brown and Funk, 2008[135]; Funk and Verdin, 2009)[136], in Kenya indicates that Central Kenya is highlighted as an area that has already experienced, and will likely continue to experience, substantial and important changes in climate as a result of recent and projected trends in rainfall and temperature.

Study results indicate the likelihood of strong impacts on agriculture by the observed and projected rainfall deficits on the semi-arid eastern and Northern flanks of the central highlands. These areas, around cities like Eldoret, Nakuru, Nyeri, and Meru, have traditionally been important crop production areas, and declining rainfall in them should have impacts on national crop production and food prices.

An important question to answer is 'how much'?. In 2008, some 26 million people lived in central Kenya, and this number will likely increase to 34 million by 2025. Average 2001–2006 yields and per capita harvested area are both low (1,100 kilogram per hectare [kg/ha], and 0.03 hectare per person), and the annual per capita crop production also is low at 34 kg per person. By examining trends in area and yield, an imprecise, but potentially useful projection of the country's future food availability can be provided. The per capita harvested area trend is negative, as population is growing faster than cultivated land area.

Maize yields, although quite low compared to what they might be with improved practices, are actually increasing, despite increasing dryness and temperatures. If both these trends continue through 2025, the analysis indicates that per capita harvested area will drop slightly (approximately 7 percent), but yields may increase by 50 percent (to 1,850 kg/ha) in 2025. The result indicates future maize production may actually ***increase*** by approximately 40 percent from current levels.

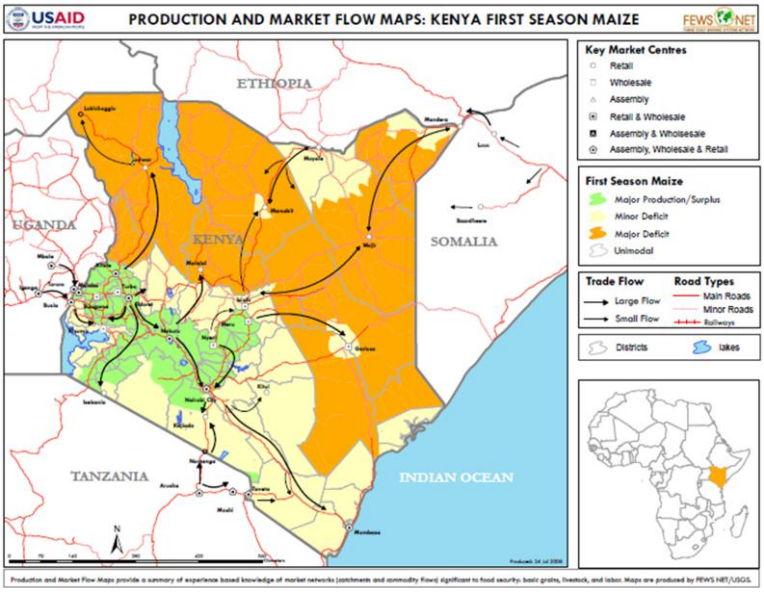


Figure Production And Market Flow Maps: Kenya First Season Maize

[133] Funk, C., Senay, G., Asfaw, A., Verdin, J., Rowland, J., Michaelsen, J., Korecha, D., Choularton, R., 2005, Recent drought tendencies in Ethiopia and equatorial-subtropical eastern Africa: U.S. Agency for International Development, Washington, D.C., *ftp://chg.geog.ucsb.edu/pub/pubs/ FEWSNET_2005.pdf*.

[134] Funk, C., and Verdin, J.P., 2009, Real-Time Decision Support Systems: The Famine Early Warning System Network *in* Gebremichael, M., Hossain, F., eds., 2010, Satellite Rainfall Applications for Surface Hydrology: Springer, Netherlands, p. 295–320, *ftp://chg.geog.ucsb.edu/pub/pubs/SatelliteRainfal lApplications_2010.pdf*.

[135] Brown, M., and Funk, C., 2008, Food security under climate change, Science, (319): p. 580–581, *ftp://chg.geog.ucsb.edu/ pub/pubs/Science_2008.pdf*.

[136]

Kenya's marginal growing areas currently (2010) are, and in the future likely will be, facing less rainfall and more crop water loss because of greater evaporation, a focus on an intensification of agriculture in the higher, cooler, humid areas may be one of the underpinnings of a sustainable and productive agricultural strategy for Kenya.

The analyses also Indicated cohesive patterns of observed climate change during the 1960–2009 era in rainfall (fig. 1) and temperature data (fig. 2). Extending the observed 1960–2009 changes out until 2025, we find that large parts of Kenya will have experienced more than a 100 millimeter (mm) decline in long-season rainfall by that date. Evaluations of independent rainfall data sets produce similar results (Williams and Funk, 2010). For Kenya, the relative magnitude of the identified long-season rainfall declines is generally more than three times the associated standard errors (table 1, supplemental *map 1*).
These decreases in rainfall were accompanied by significant increases in average air temperatures, with the MAMJ temperature increases generally being more than twice the interpolation standard errors (table 1, supplemental *map 2*). This 1° Celsius warming value can be compared to the typical inter-annual standard deviation of MAMJ station temperatures, about 0.6° Celsius.

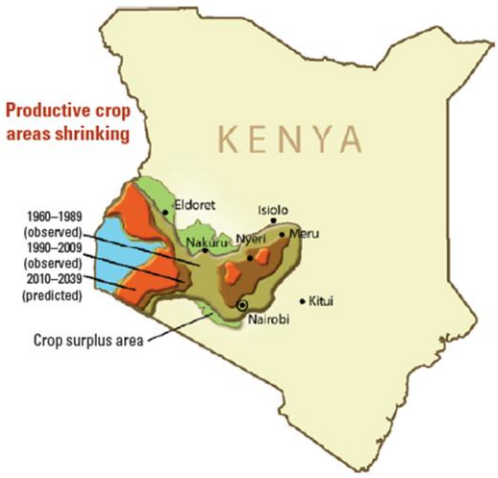


Figure. Climate change in Kenya: Average location of the 500 millimeter rainfall isohyets for the years 1975 (light brown), 1995 (dark brown), and 2025 (predicted, orange). The green polygon in the background shows the main crop surplus region of Kenya.

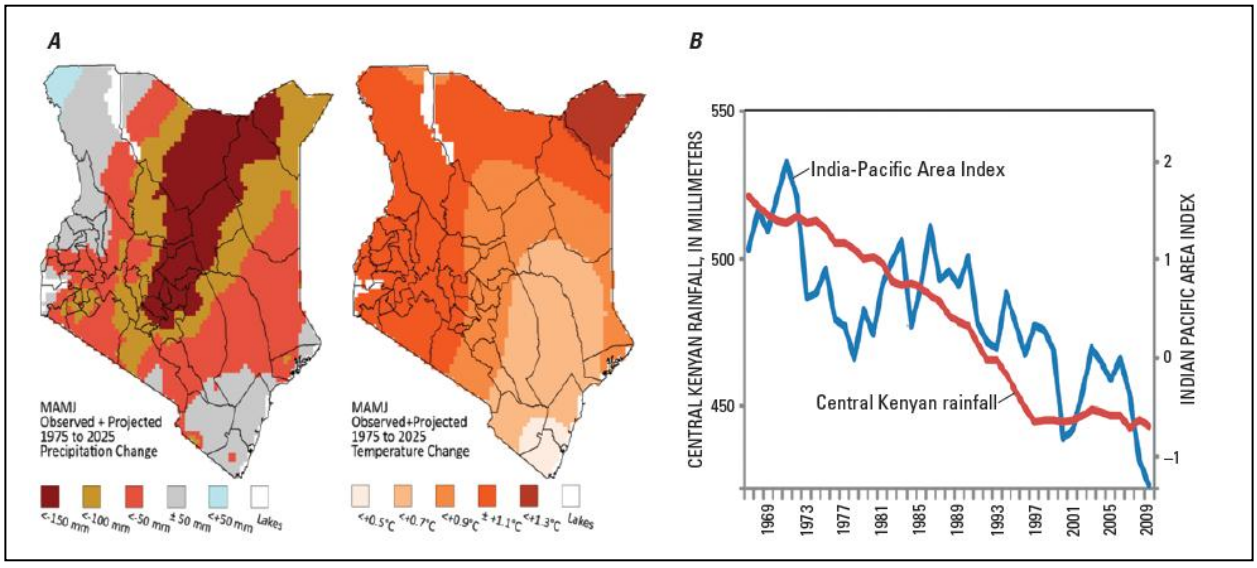


Figure 2. ***A***, Observed and projected change in rainfall and temperature, together with smoothed central Kenyan rainfall and ***B***, a smoothed version of the Indian-Pacific-Area climate index.

The U.S. Geological Survey_Fact Sheet 2010–3074, highlighted the following:

- Long rains in central Kenya have declined more than 100 millimeters since the mid-1970s. This decline is probably linked to warming in the Indian Ocean, and seems likely to continue.
- A warming of more than 1° Celsius may exacerbate drying impacts, especially in lowland areas.
- The drying trends could particularly impact densely populated areas to the east, north, and north-west of Nairobi.
- Critical surplus crop growing areas in Central Kenya are threatened, and the amount of prime arable land could diminish substantially.

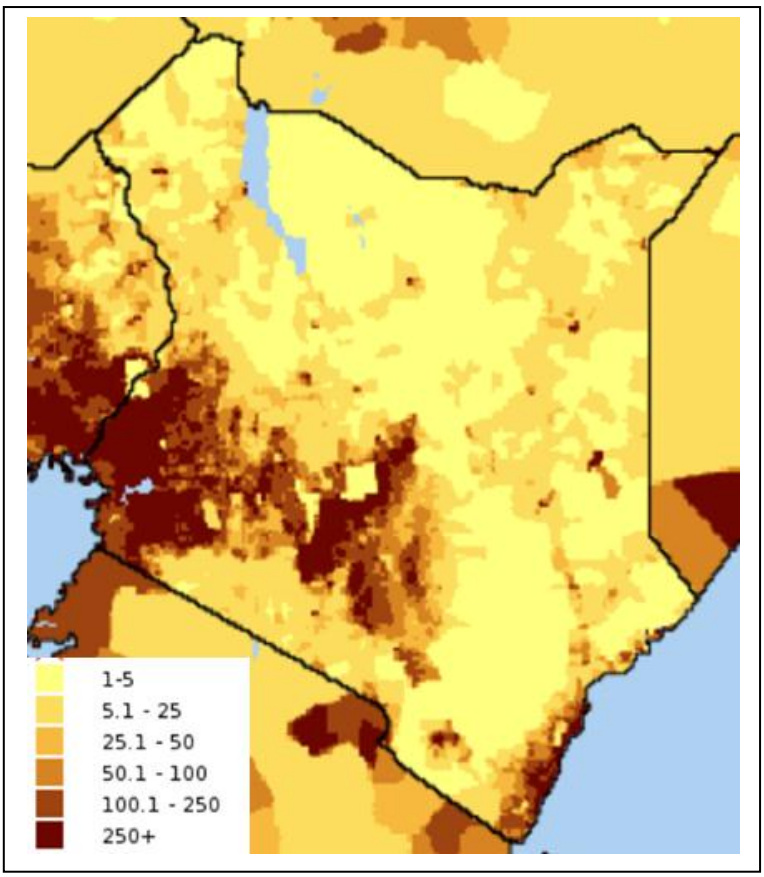


Figure. The density population map of Ethiopia 2010 (person/Km^2),source: SEDAC Map Client

c. Sudan and South Sudan

The U.S. Geological Survey Fact Sheet 2011–3072, illustrated that in 2010, approximately 8 million people faced moderate to high levels of food insecurity in Northern and Southern Sudan (Famine Early Warning Systems Network, 2010)[137]. These food insecure populations, primarily agro-pastoralists, tend to be located in western parts of Northern Sudan (Darfur and Kordofan) or in drier portions of Southern Sudan (Jonglei, East Equatoria, Warrap, and North Bahr el Ghazal). Between the mid-1970s and late 2000s, summer rainfall decreased by 10–20 percent across parts of western and Southern Sudan, placing already food insecure populations at greater risk.

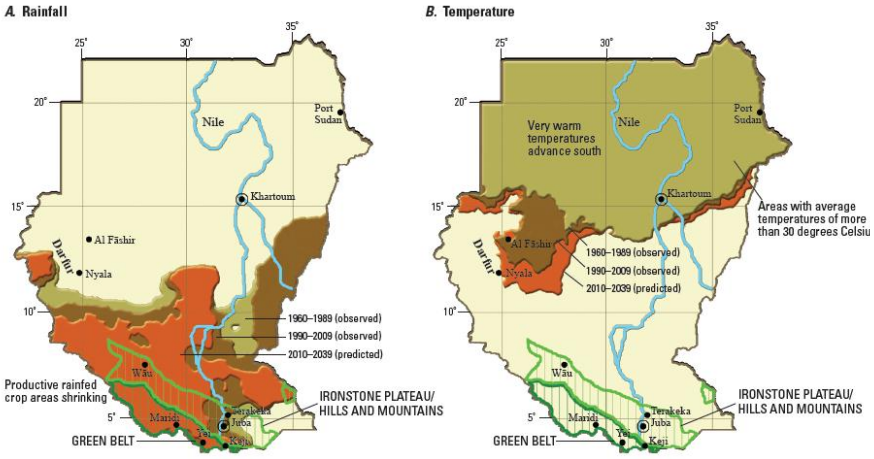
Sudan receives most of its rain between June and September, and rainfall totals of more than 500 millimeters (mm) during this season typically provide enough water for farming and livestock. Between 1960 and 1989, the region receiving (on average) this much rain or more was vast, over 858,000 square kilometers (km2). Figure 1 and should be understood to lie beneath the dark brown and orange areas. Over the past 20 years, this region has contracted (dark brown polygon), exposing populations in Darfur, Kordofan, Upper Nile, Jonglei, and East Equatoria to increased rainfall deficits. In the west, this contour shifted from approximately 11 degrees north to 10 degrees north. In the Upper Nile, the shift was even more drastic from approximately 11 degrees north to 9 degrees north. A third westward retraction is occurring in Jonglei and East Equatoria, with the 500 mm contour shifting from approximately 33 degrees east to 32 degrees east.

If present rainfall trends continue, by 2025 the drying impacts likely will reach into West and North Bahr Al Ghazal, Warrap, Unity, Central Equatoria, and Al Buhairat (fig. 1, orange polygon); an area with a total population of 4.1 million. The area receiving more than 500 mm of rainfall could shrink by 249,000 km2 (30 percent of the 1960–89 area), leaving a large number of people exposed to increased food insecurity and impacting crop production in the southeastern part of the country. Rainfall reductions can be visualized by combining the observed 1960–2009 changes with predicted 2010–39 changes, based on persistence of the observed trends (fig. 2, top panels). Rainfall declines range from -150 to -50 mm across the western and Southern portions of the country, large numbers for a drought-prone country. Observed changes alone account for 63 percent of the change magnitudes. South Darfur exhibits the largest declines, followed by Blue Nile and West Equatoria. These reductions in rainfall appear most likely to affect the insecure areas around the cities of Al Fāshir, Nyala, and Wāu.

Smoothed time series (fig. 2, middle and lower panels, 5-year running means) of 1900–2009 rainfall, extracted for the extended Darfur region (10 to 16 degrees north, 22 to 29 degrees east) and Southern Sudan (3 to 7 degrees north, 27 to 35 degrees east), show that 1990–2009 rainfall has been, on average, about 20 percent lower (-1 standard deviation) than rainfall between 1900 and 1989.

[137] Famine Early Warning Systems Network, 2010, Food security framework, available at *http://www.fews.net/ml/en/info/ Pages/fmwkfactors.aspx?gb=sd&l=en&loc=2*.

Figure 1. Climate change in Sudan. *A*, Average location of the 500-millimeter rainfall isohyets for the years 1960–1989 (light brown), 1990– 2009 (dark brown), and 2010–2039 (predicted, orange). The green polygons in the foreground show the main crop surplus region (the Green Belt livelihood zone) and the agro-pastoral Ironstone Plateau and Hills and Mountains livelihood zones. *B*, Similar changes for the 30 degrees Celsius isotherm. Areas north of this line are very hot; this intense heat makes plant growth and pastoral livelihoods difficult.



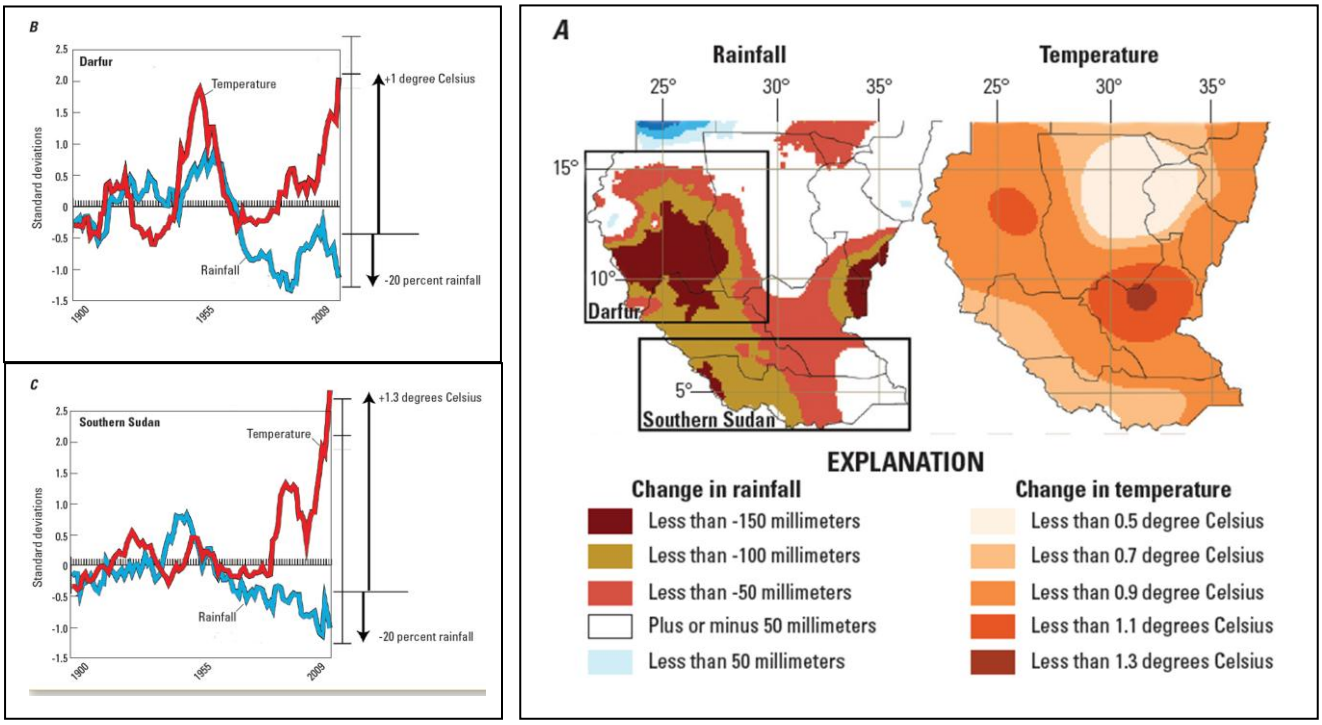


Figure 2. Observed and projected change in rainfall and temperature. *A*, Together with smoothed rainfall and air temperature time series, *B*, for the extended Darfur region (10–16 degrees north, 22–29 degrees east), and *C*, for Southern Sudan (3–7 degrees north, 27–35 degrees east).

Summer rains in western and Southern Sudan have declined by 10–20 percent since the mid-1970s. Observed warming of more than 1 degree Celsius is equivalent to another 10–20 percent reduction in rainfall for crops. The warming and drying have impacted Southern Darfur and areas around Juba. Rainfall declines west of Juba threaten Southern Sudan's future food production prospects.

Rapid population growth and the expansion of farming and pastoralism under a more variable climate regime could dramatically increase the number of at-risk people in Sudan over the next 20 years.

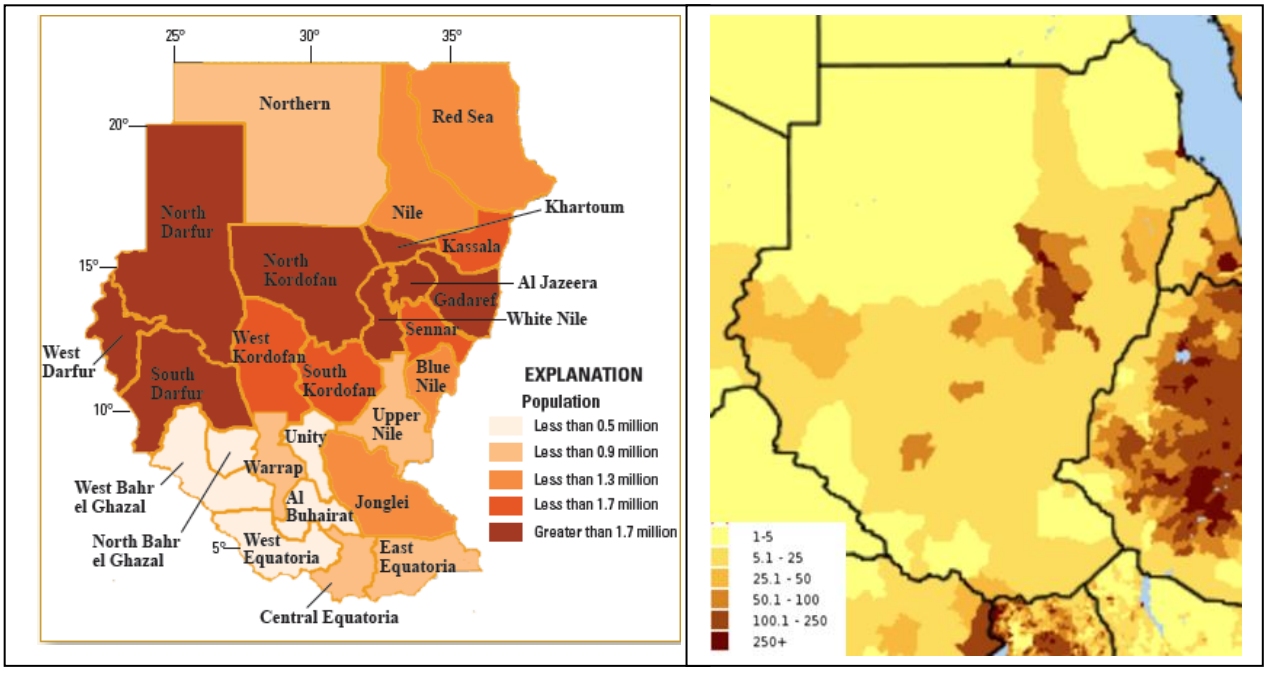


Figure 4.
Left: 2008 census data for Southern Sudan and Landscan 2007 population for Northern Sudanese states (*http://www.populationexplorer.com*).
Right: Figure. The density population map of Ethiopia 2010 (person/Km^2),source: SEDAC Map Client

d. **Uganda**

Although the general level of food insecurity in Uganda is relatively low compared to its neighbors in the region, internally Displaced Persons (IDPs), and pastoralists and agro-pastoralists, in the Northern and northeastern parts of the country face chronic and intermittently higher levels of food stress (FEWS NET, 2010)[138]. Smoothed time series of 1900–2009 rainfall, extracted for crop growing regions in Uganda, indicate that 2000–2009 rainfall has been, on average, about 8% lower (-0.65 standard deviation) than rainfall between 1920 and 1969. Although the June–September rainfall appears to have been declining for a longer period, the March–June decline has only occurred recently. These declines have been visualized in figure 1 as a contraction of the regions receiving adequate rainfall for viable agricultural livelihoods.

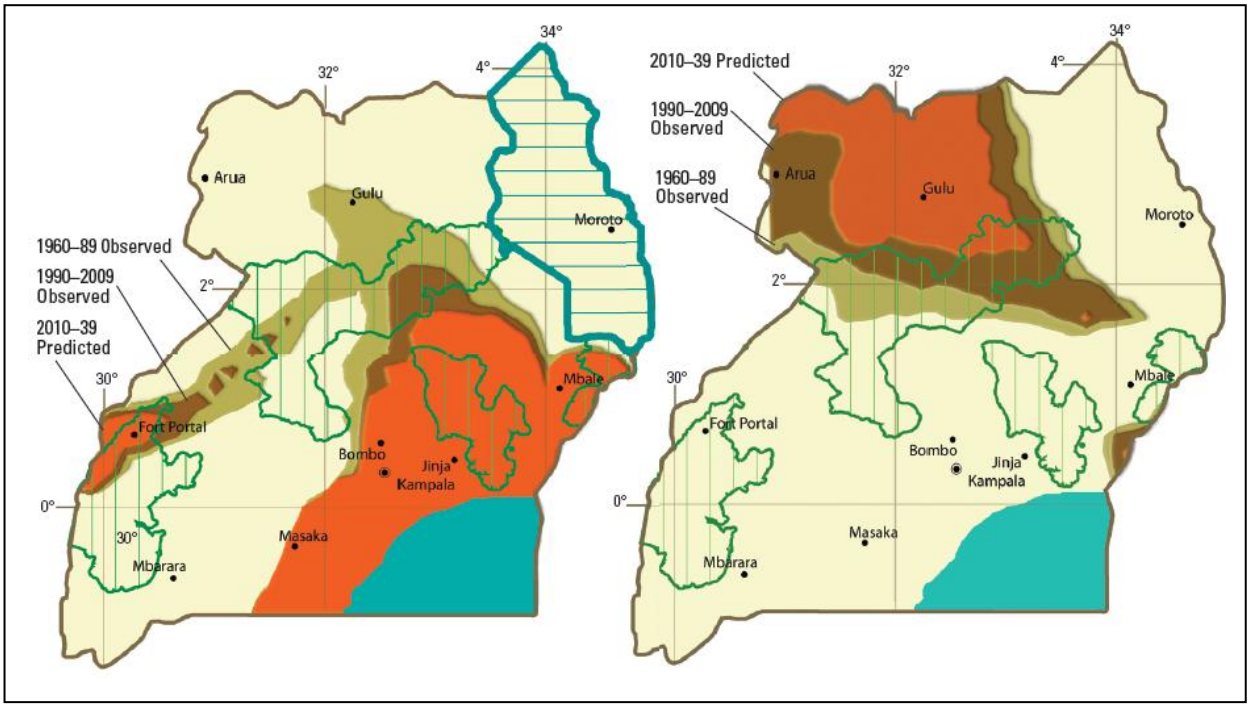


Figure 1. Climate change in Uganda: The left map shows the average location of the March–June 500 mm rainfall isohyets for 1960–1989 (light brown), 1990–2009 (dark brown), and 2010–2039 (predicted, orange). The green polygons in the foreground show the main maize surplus regions; these areas produce most of Uganda's maize. The blue polygon in the upper-right shows the Karamoja region.The right map shows analogous changes for the June–September 500 mm rainfall isohyets.

Uganda receives most of its rain between March and June, and rainfall totals of more than 500 millimeters (mm) during this season typically provide enough water for crops and livestock. Between 1960 and 1989, the region receiving this much rain (on average) during March–June is shown in light brown in the left panel of figure 1 and should be understood to lie beneath the dark brown and orange areas. During the past 25 years, this region has contracted (dark brown polygon), exposing populations in the central and western parts of the country to increased rainfall deficits. Cropping areas northeast of Fort Portal, south of Gulu, and northwest of Bombo

[138] FEWS NET, 2010, Food Security Framework: Accessed December 15, 2011, available at *http://www.fews.net/ml/en/info/Pages/fmwkfactors.aspx?gb=ug&l=en&fmwk=factor*.

no longer receive, on average, the bountiful rains that were the norm between 1960 and 1989. If present rainfall trends continue, by 2025 the drying impacts will likely lead to a further contraction (orange polygon). A similar set of polygons is also shown for the June–September season (right panel). Uni-modal rainfall areas across the north of the country are likely to be affected by earlier cessation of summer rains.

Observed rainfall reductions of the 1960–2009 period are projected to the 2010–2039 period, assuming a persistence of the observed trends (figure. 2). The projected rainfall declines range from -150 to -50 mm across the Northern part of the country, and appear likely to impact the already chronically insecure IDPs and the inhabitants of Kamajora.

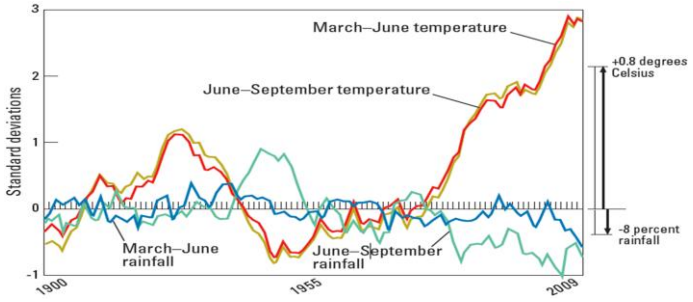


Figure 2. Smoothed 1900–2009 March–June and June–September rainfall and air temperature time series for crop-growing regions.

Actual and projected (extending recent patterns forward) changes are mapped across the country in, (figure 3). This transition to an even warmer climate is likely to amplify the impact of decreasing rainfall and periodic droughts, and will likely reduce crop harvests and pasture availability.

Uganda is becoming drier and hotter, during the March–June and June–September rainy seasons. Such warming in regions with high average air temperatures can amplify the impact of water shortages on agriculture. Warming temperatures may adversely affect coffee production, which is an important cash commodity in Uganda. Temperature sensitivities vary by coffee varieties, but most coffee plants fare poorly in areas with average air temperatures greater than 24°C. During March–June and June–September, these areas have been expanding (figure. 4), and this expansion of warm areas will likely continue during the next century as the earth continues to warm.

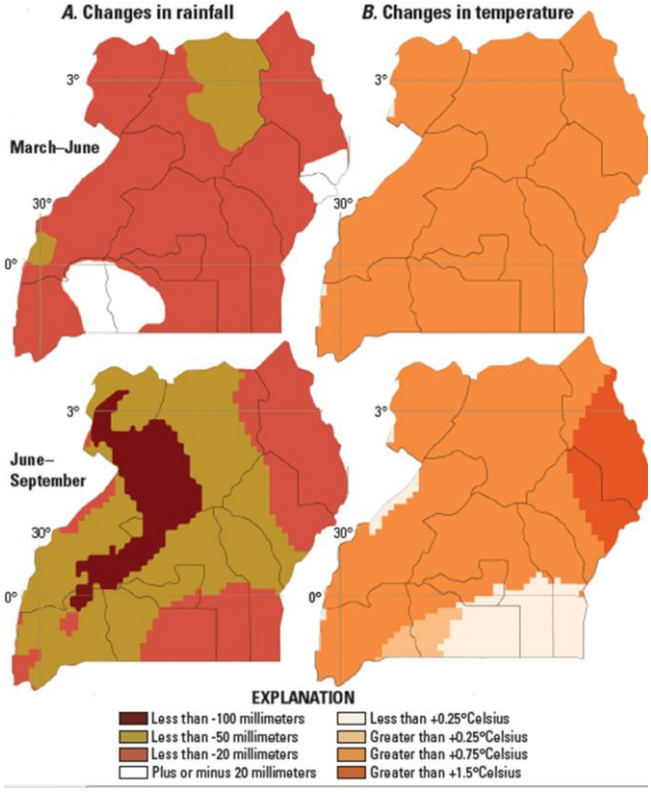


Figure 3. Observed (1960–2009) and projected (2010–2039) changes in March–June and June–September rainfall and temperature.

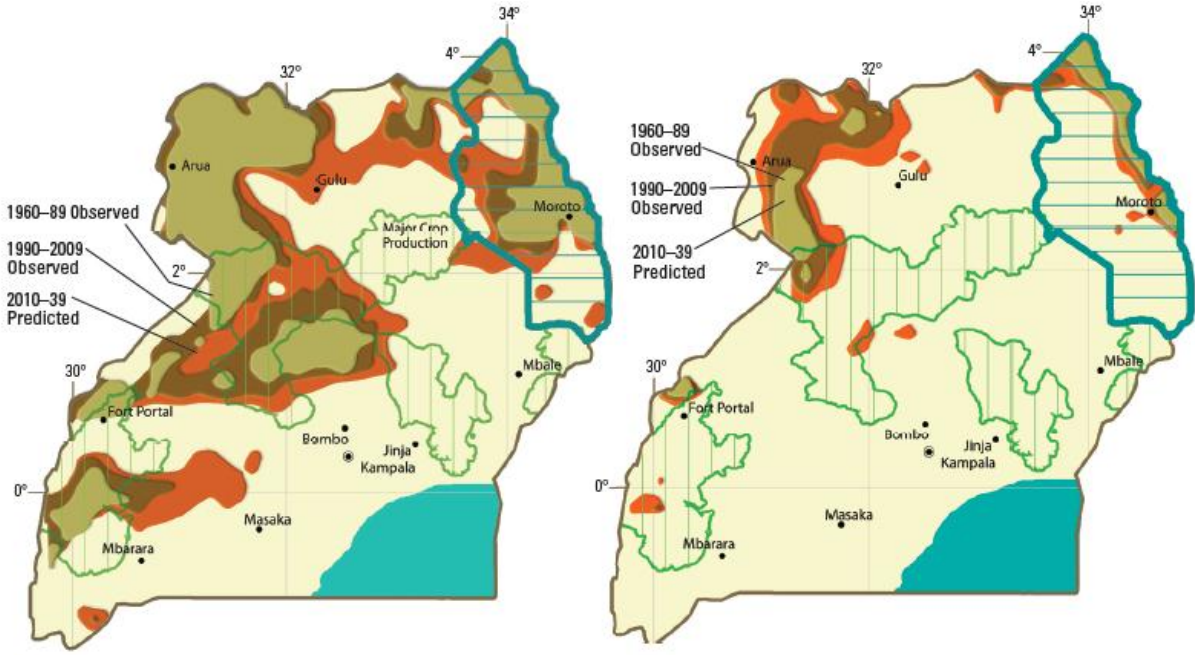


Figure 4. Warm regions expand in Uganda: The left map shows the average location of the March–June 24 degrees Celsius (°C) isotherms for 1960–1989 (light brown), 1990–2009 (dark brown), and 2010–2039 (predicted, orange). The green polygons in the foreground show the main maize surplus regions. The blue polygon in the upper-right shows the Karamoja region. The right map shows analogous changes for the June–September 24°C isotherms.

The U.S. Geological Survey Fact Sheet 2012–3062, highlighted the following:

- Both spring and summer rains have decreased in Uganda during the past 25 years.
- The magnitude of observed warming, especially since the early 1980s, is large and unprecedented within the past 110 years, representing a large (2+ standard deviations) change from the climatic norm.
- Cropping regions in the west and northwest appear most affected by the observed changes in climate.
- Rainfall declines in the west and northwest threaten Uganda's future food production prospects.
- Warming temperatures may be adversely affecting coffee production.
- Rapid population growth and the expansion of farming and pastoralism under a drier and warmer climate regime could dramatically increase the number of at risk people in Uganda during the next 20 years.
- In many cases, areas with changing climate are coincident with zones of substantial conflict, indicating some degree of association; however, the contribution of climate change to these conflicts is not currently understood.

In 2011, Uganda's population was 30.6 million, with a rapid population growth rate of 3.6 percent (CIA, 2011)[139], That means doubling population every 20 years. Because Uganda is a

[139] CIA, 2011, The World Factbook: Accessed December 15th 2011,available at *https://www.cia.gov/library/publications/the-worldfactbook/geos/ug.html*.

landlocked country that depends on agricultural, agro-pastoral, and pastoral livelihoods, this population expansion will place increasing stress on limited natural resources. Crop statistics from the FAO indicate that per capita cereal production in Uganda is low (150 kilograms per person per year). While yields have been improving, the amount of farmland per person has been declining twice as fast. If these trends persist, then per capita cereal production could decline by 35 percent by 2025. This level of food production could leave hundreds of thousands more Ugandans exposed to hunger and under nourishment.

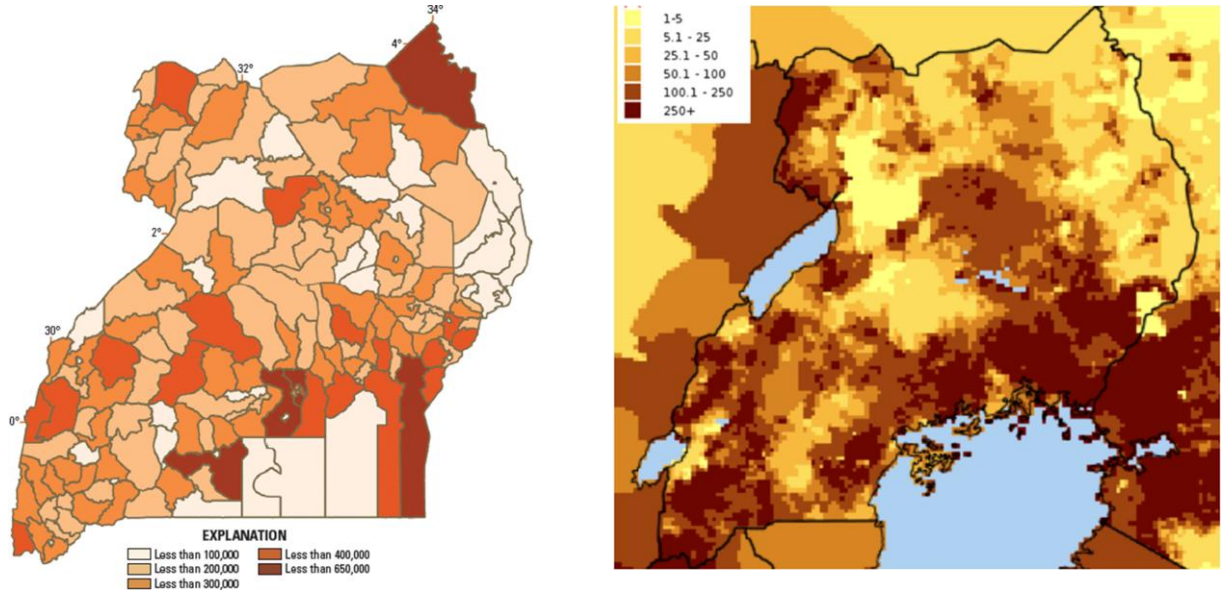


Figure 5.
Left: Landscan 2008 population for Uganda (*http://www.populationexplorer.com*).
Right: Figure. The density population map of Uganda 2010 (person/Km^2),source: SEDAC Map Client

e. **Mozambique**

Climate change may be affecting Mozambique's primary food crop in potentially significant way, The changes in air temperature in Mozambique between 1979 and 2008, and its relation on the duration of specific maize plant growth phases to differing temperatures. Mozambique-specific planting dates were estimated, (Harrison and others,2011)[140]. In most locations, as shown in figure (1), the dominant changes in temperature patterns related to maize plant growth phases were temperature increases during the early part of the growing season, from planting until flowering. If identified warming patterns continue, Mozambique maize production could be threatened by the stress of hotter early season temperatures and by faster maturation. The central region appears most at risk. This changes in climate in Mozambique that are probable to occur, and likely to continue, at least for the near future, and may have significant effects on food production if adaptation does not occur.

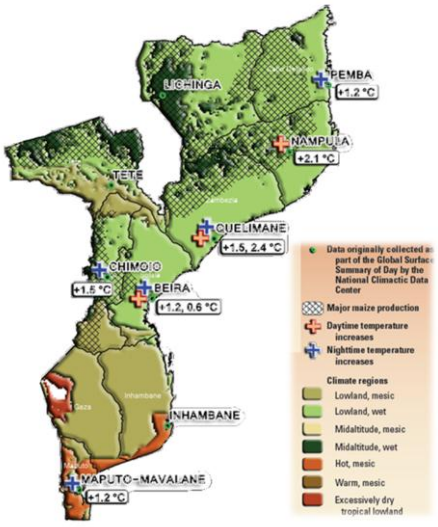


Figure 1. Magnitude of significant ($p < 0.05$) changes in growing season mean minimum and maximum temperature (1979–80 to 2008–09). (Harrison and others, 2011).

<u>The U.S. Geological Survey Fact Sheet 2011–3110, highlighted the following:</u>
30 years of substantial warming have increased temperatures during the primary growing season in central Mozambique by ~1.5 degrees Celsius, The warming is affecting the maize crop's phenology by causing an onset of flowering 4 days earlier and a 5 to 7 percent decline in total time to plant maturation. Warmer temperatures earlier in the season threaten maize yields by exposing the plant at sensitive crop phases to increased heat and drought, and shortening the crop's growth cycle, thus reducing the size of the plant and the weight of its grains. Continued warming could increase the risk of these hazards and affect crop production, regardless of any changes in rainfall.

[140] Harrison, L., Michaelsen, J., Funk, C., and Husak, G., 2011, Effects of temperature changes on maize production in Mozambique: Climate Research, v. 46, p. 211–222. *http://www.int-res.com/abstracts/cr/v46/ n3/.*

f. Niger

Niger is a landlocked country (area: 1,267,000 square kilometers) with a population estimated at 16.5 million people; it has an annual growth rate of 3.6 percent and a total fertility rate of 7.6 births per woman, the highest fertility rate in the world (CIA, 2011)[141].

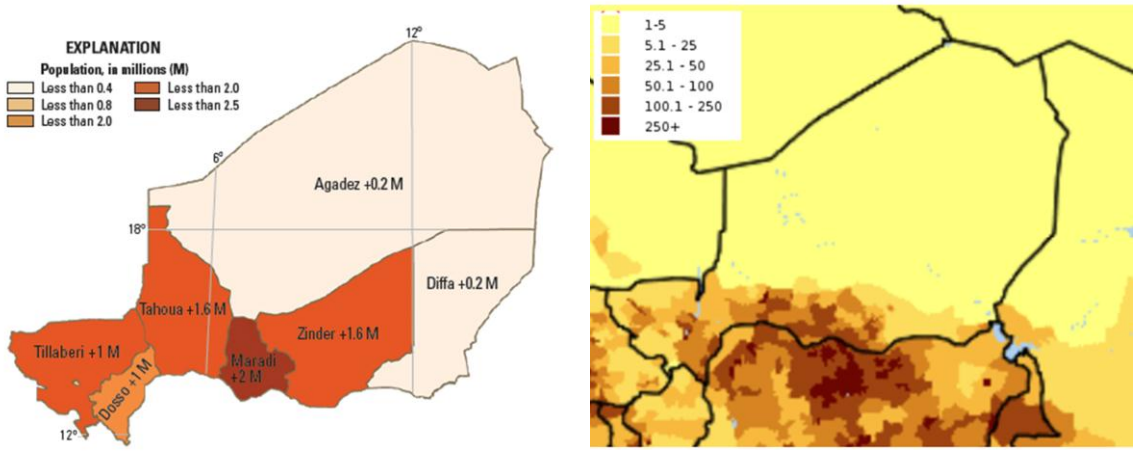


Figure. Left: Landscan 2008 population for Niger , Right : The density population map of Niger 2010 (person/Km^2), source: SEDAC Map Client

Rainfall in Niger declined rapidly between 1950 and the mid-1980s and partially recovered during the 1990s and 2000s. Between 2000 and 2009, the average rainfall in Niger's crop growing districts was about 8 percent lower than the 1920–69 mean. Niger receives most of its rain between June and September, and rainfall totals of more than 500 millimeters (mm) during this season typically provide enough water for crops and livestock. Between 1960 and 1989, the region receiving (on average) this much rain during June–September is shown in light brown in the left panel of figure (1) and should be understood to lie above the dark brown and orange areas. During the past 20 years, this region has expanded (dark brown polygon), increasing the regions of viable agriculture in Dosso, Maradi, and Zinder. Cropping areas near 13°N have seen a northward extension of the 500 mm contour.

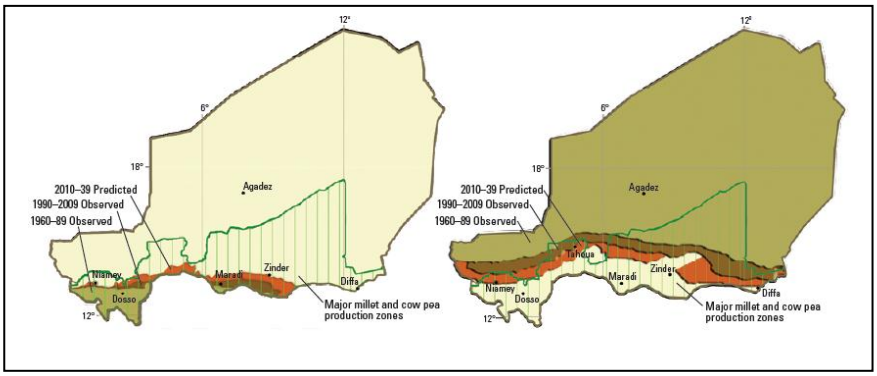


Figure 1. Climate change in Niger: The left map shows the average location of the June–September 500 millimeter rainfall isohyets for 1960–89 (light brown), 1990–2009 (dark brown), and 2010–39 (predicted, orange). The green polygons in the foreground show the main crop production districts. The right map shows analogous changes for the June–September, 30 degrees Celsius air temperature isotherms.

[141] CIA (Central Intelligence Agency), 2011, The World Factbook: *https://www.cia.gov/library/ publications/the-world-factbook/geos/ng.html*.

Rainfall and temperature increases as could be seen in the observed trends (fig. 2, top panels). Rainfall increases range from 0 to 50 mm across most of the country. Observed changes (between 1960 and 2009) account for 63 percent of the change magnitudes.

A smoothed time series (fig. 2, lower panel, 10-year running means) of rainfall from 1900–2009, extracted for crop growing regions in Niger, indicates that 2000–2009 rainfall has been, on average, about 8 percent lower (-0.6 standard deviations) than the rainfall between 1920 and 1969. For eastern and western Niger, rainfall has steadily recovered since the mid-1970s but remains moderately (less than 0.5 standard deviations) below its long-term mean. These time series were based on crop growing regions in western Niger (Tahoua, Tillaberi, and Dosso regions) and eastern Niger (Diffa, Zinder, and Maradi regions),(Funk et al 2012)[142].

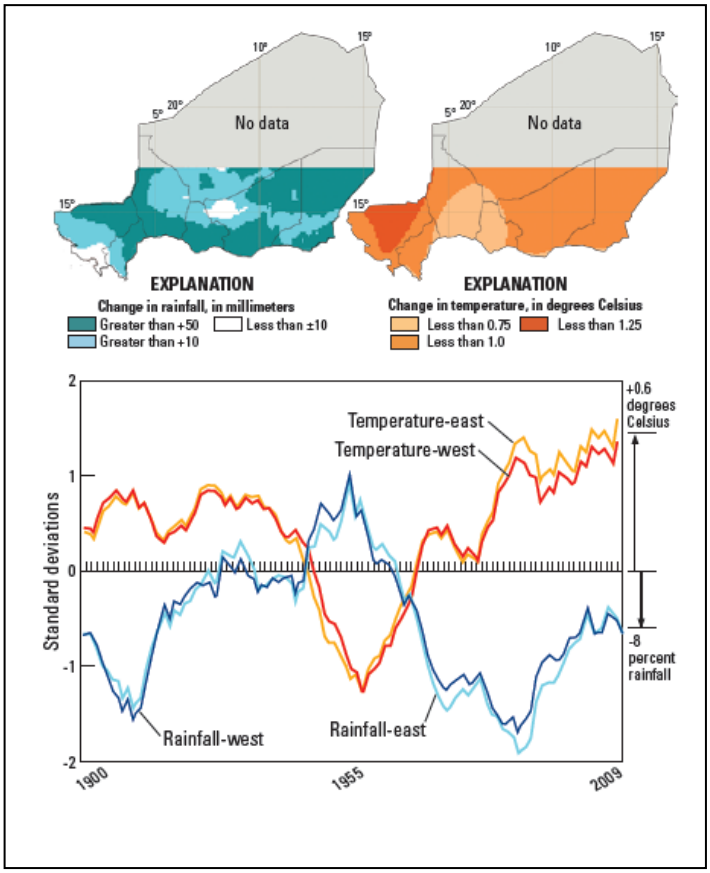


Figure 2. Observed and projected change in June–September rainfall and temperature for 1960–2039 (top), together with smoothed rainfall and air temperature time series for June–September for eastern and western Niger. Mean rainfall and temperature are based on the 1920–69 time period.

Only a small fraction (3.3%t) of the country receives more than 500 mm of precipitation, and although recent increases in rainfall have seen this area expand by 25 percent, Niger's expanding food needs may soon outstrip its agricultural expansion.

In recent years (2005–2009), per capita cereal production has been reasonably high for Sahelian countries (270 kilograms per person per year; FAO, 2011), but crop statistics from the FAO indicate that a massive expansion of cultivated area brought about this level of cereal production. Between the 1980s and 1990s, the amount of farmland expanded faster (+51 percent) than the population (+37 percent), resulting in a net increase in per capita cereal production. Between the 1990s and 2000s, however, the amount of farmland increased by 20 percent, whereas the population increased by 42 percent, resulting in a net decrease in food availability. By 2025, if Niger's rapid expansion of farmland slows while its yield growth remains stagnant, Niger's projected population of 26 million people could face substantial food availability shortfalls.

[142] Funk C., Jim Rowland Alkhalil Adoum, Gary Eilerts, and Libby White 2012. A Climate Trend Analysis of Niger,USGS **Fact Sheet 2012–3080**

g. Burkina Faso

Burkina Faso is a landlocked country (area: 274,200 square kilometers) with a population estimated at 16.8 million people; it has an annual growth rate of 3.1 percent (CIA, 2011). At this rate the population will double every 23 years. The agriculture sector engages more than 80 % of the active population. Like other Sahelian countries, Burkina Faso's agriculture is mainly rainfed, making it highly dependent upon rainfall amounts and distribution. In good seasons, the country's coarse grain production covers domestic consumption needs, and cereal imports are limited to rice and wheat. The Northern part of the country, namely the regions of Nord, Centre-Nord, and Sahel is characterized by a shorter growing season, higher rainfall variability, and less diversified agriculture. This area, therefore, is the most vulnerable to food insecurity.

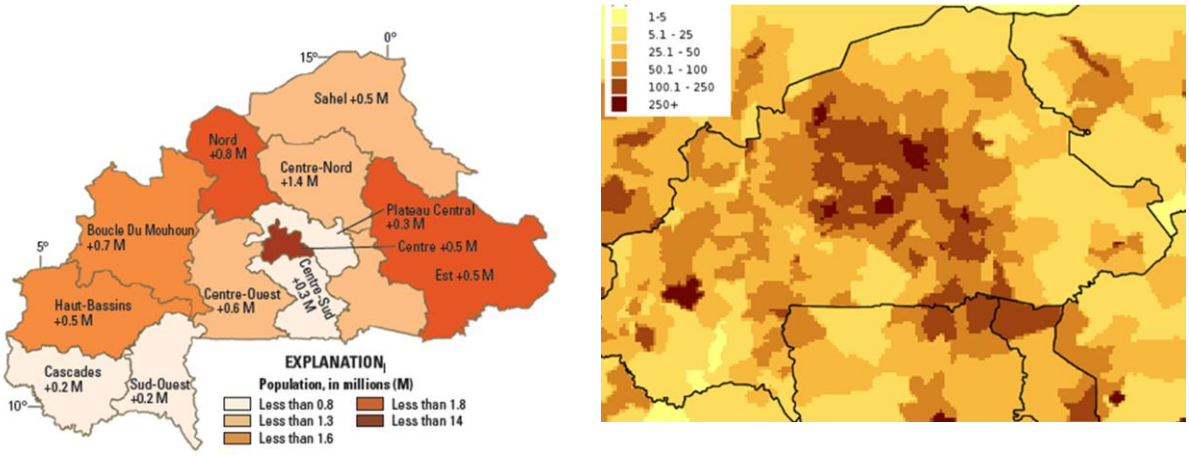


Figure. Left: Landscan 2008 population for Burkina Faso , Right : The density population map of Niger 2010 (person/Km^2), source: SEDAC Map Client

Rainfall in Burkina Faso declined rapidly between 1950 and the mid-1980s, and recovered in the 1990s. Between 2000 and 2009, however, the recovery stalled, and the 2000–2009 average remained about 15 percent lower than the 1920–69 mean average. Burkina Faso receives most of its rain between June and September, and rainfall totals of more than 500 millimeters during this season typically provide enough water for crops and livestock. Between 1960 and 1989, the region receiving (on average) this much rain during June–September is shown in light brown in the left panel of figure (1) and should be understood to lie beneath the dark brown and orange areas. During the past 20 years, this region has remained fairly constant.

A smoothed time series (figure 2, lower panel, 10-year running means) of rainfall from 1900–2009, extracted for crop growing regions in Burkina Faso, indicate that 2000–09 rainfall has been, on average, about 15 percent lower than rainfall between 1920 and 1969. Rainfall recovered since the mid- 1980s, but the increase has leveled off during the past decade, and 2000–2009 rainfall remains substantially below its 1920–69 mean. These time series were based on crop growing regions in western Burkina Faso (Nord, Boucle Du Mouhoun, Centre- Ouest, Haut-Bassins, and Sud-Ouest regions) and eastern Burkina Faso (Centre-Nord, Est, Plateau Central, Centre, Centre-Est, and Centre-Sud regions).

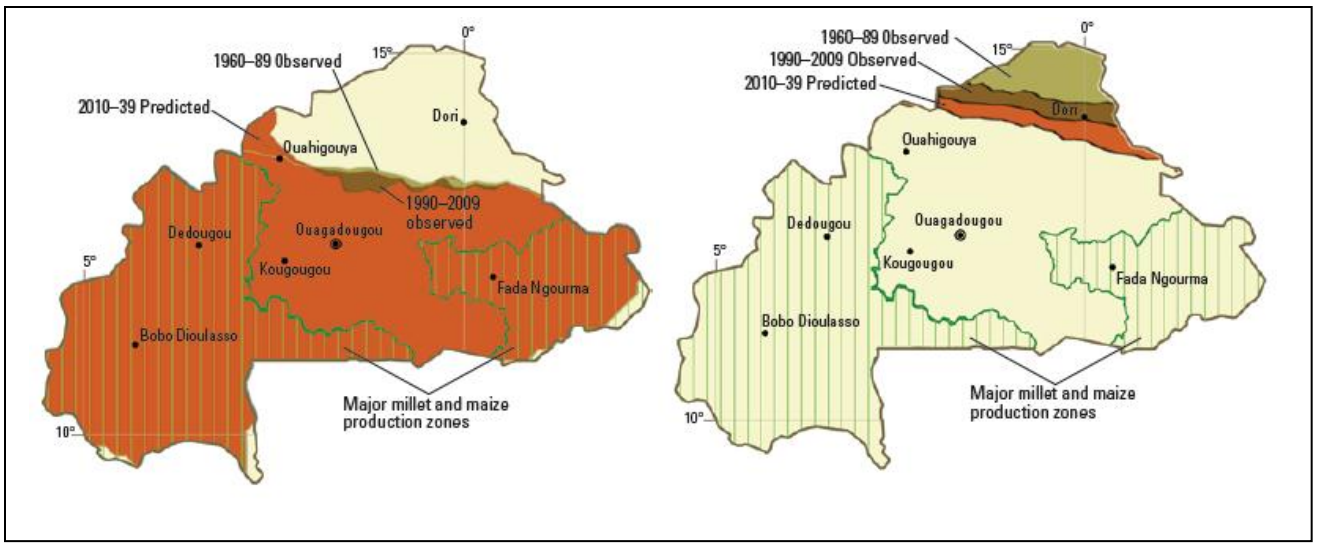


Figure 1. Climate change in Burkina Faso: The left map shows the average location of the June–September 500 millimeter rainfall isohyets for 1960-89 (light brown), 1990–2009 (dark brown), and 2010–39 (predicted, orange). The green polygons in the foreground show the main crop production regions for millet and maize. The right map shows analogous changes for the June- September 30 degrees Celsius air temperature isotherms.

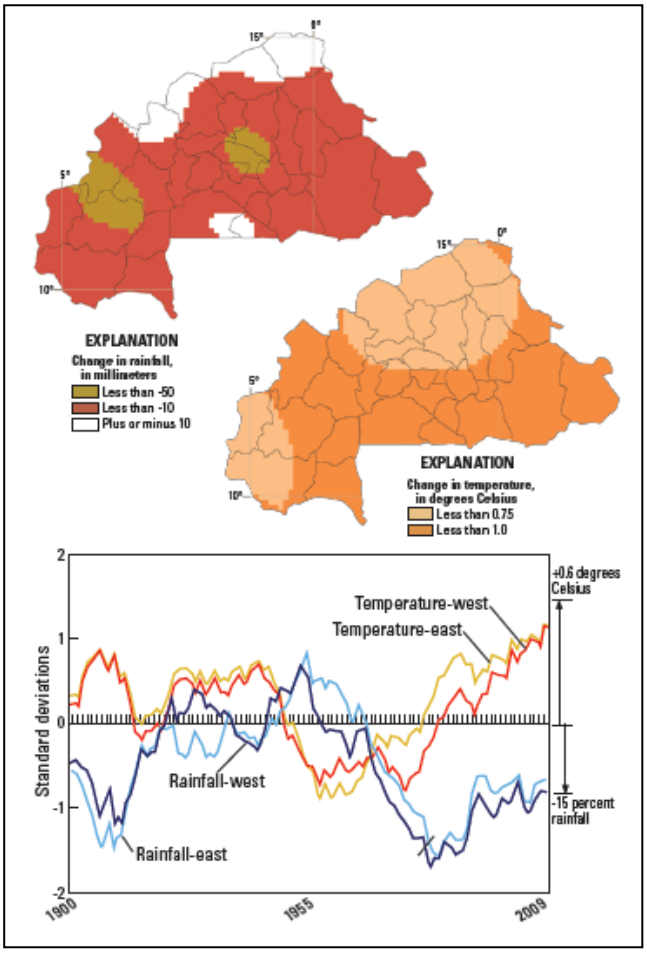


Figure 2. Observed and projected change in June–September rainfall and temperature (top), together with smoothed rainfall and air temperature time series for east and west Burkina Faso. Mean rainfall and temperature are based on the 1920–69 time period.

Analysis of crop statistics, FAO (2011)[143], shows that increases in crop yields have kept pace with population growth. Between the 1960s and 2000s, Burkina Faso's crop yields doubled an increase unmatched in any other Sahelian country. Over the same period, the amount of farmland per person declined by 36 percent; however, the overall trajectory appears favorable, and 2025 projections based on these trends suggest that Burkina Faso will continue to produce about the same amount of cereal crops per person (236 kilograms per person per year).

In conclusion

- Summer rains have remained steady over the past 20 years, but remain 15 percent below the 1920–69 average.
- Temperatures have increased by 0.6° Celsius since 1975, amplifying the effect of droughts.
- The amount of farmland per person is low, and declining.
- Burkina Faso has offset rapid population growth with improved yields.
- Continued yield growth would maintain current levels of per capita food production.

[143] FAO (Food and Agriculture Organization of the United Nations), 2011, FAOSTAT: Accessed December 15, 2011, at *faostat.fao.org.*

2.4.5. Southern Africa

Since 1980, the number of undernourished people in eastern and Southern Africa has more than doubled. Rural development stalled and rural poverty expanded during the 1990s. Population growth remains very high, and declining per-capita agricultural capacity retards progress. main growing-season rainfall receipts have diminished by 15% in food-insecure countries clustered along the western rim of the Indian Ocean. Occurring during the main growing seasons in poor countries dependent on rain-fed agriculture, these declines are societally dangerous.

in eastern and Southern Africa, the combination of declining per-capita agricultural capacity[144] (7) and increasing aridity is exacerbating vulnerability (8)[145] and rural poverty (9)[146]. Declining investments in rural development, rapidly increasing rural populations, the depletion of soil nutrients through erosion, and the cultivation of most cultivatable areas limit agricultural productivity growth (10)[147], at the meantime population growth remains high (2.3% per year). In eastern and Southern Africa (Fig. 1, 2 and 3)., population growth has exceeded increases in agricultural infrastructure and cultivated area. Second, there has been a tendency for main growing-season rainfall to decline. Empirical

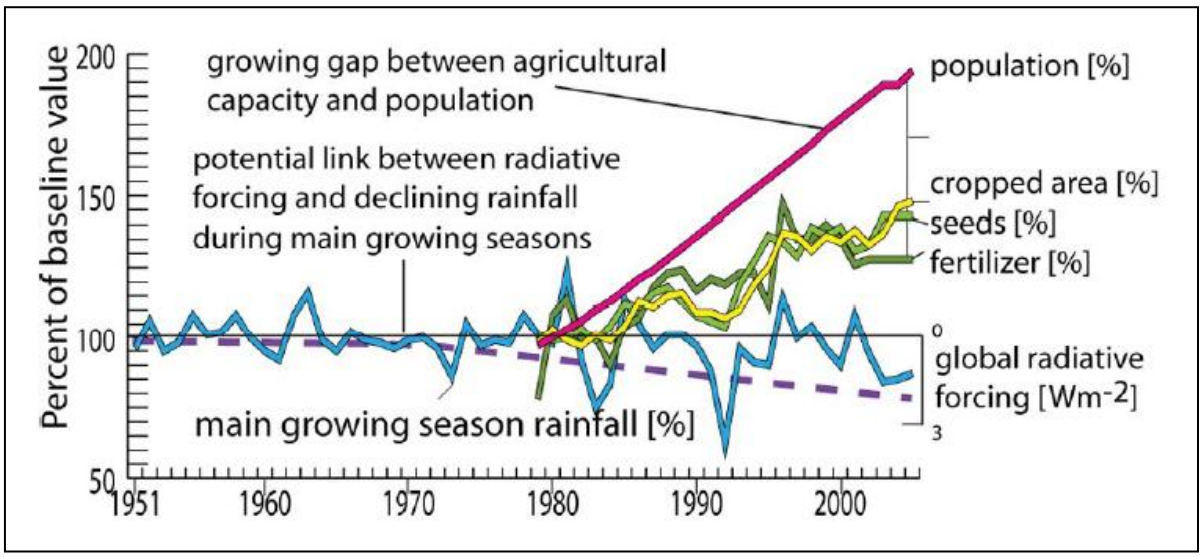


Figure Rainfall, population, cropped area, seed use, and fertilizer use for eastern and Southern Africa. Rainfall is expressed as a percentage of the 1951–1980 average. The other variables are expressed as percentages of 1979–1981 averages. Global radiative forcing is shown with a stippled line on an inverted axis.

[144] WorldBank (2008) World Development Report 2008: Agriculture for Development (International Bank for Reconstruction and Development/World Bank, Washington, DC).
[145] Turner BL, II, et al. (2003) A framework for vulnerability analysis in sustainability science. Proc Natl Acad Sci USA 100:8074–8079.
[146] Oxfam (2006) Causing hunger. Oxfam Briefing Paper (OXFAM, Washington, DC).
[147] Kates RW, Parris TM (2003) Long-term trends and a sustainability transition. Proc Natl Acad Sci USA 100:8062–8067.

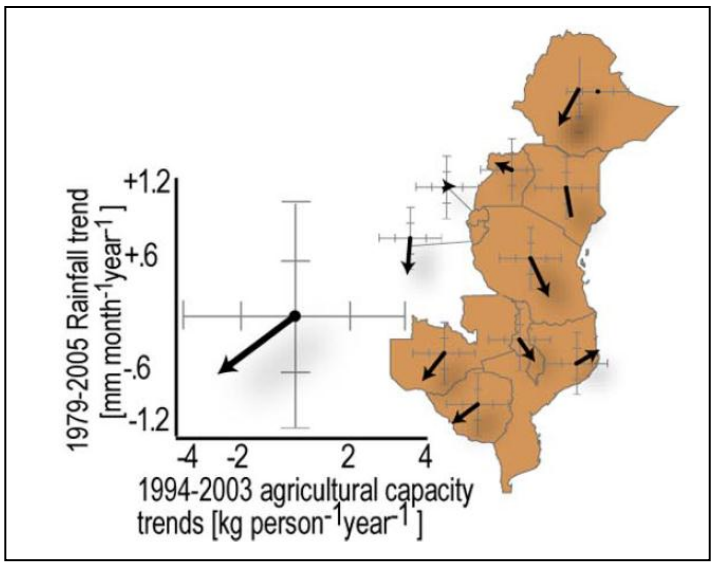


Figure The black vectors denote recent observed rainfall and agricultural capacity tendencies. Agricultural data were obtained from the Food and Agriculture Organization.

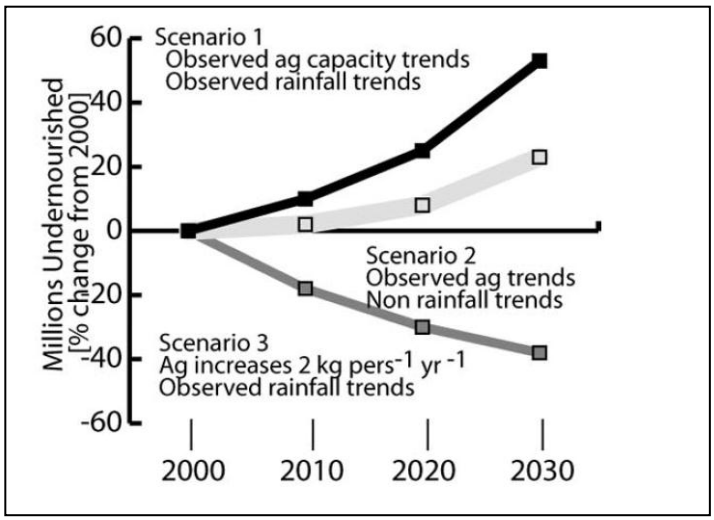


Figure Empirical food-balance model results expressed as percentages of the millions undernourished in 2000.

Several studies have investigated the likely changes in mean and extreme precipitation in many parts of the globe, including Africa (Kharin and Zwiers 2000[148]; Groisman et al. 2005[149]; Meehl et al. 2005[150]; Kharin et al. 2007[151]). Most of these studies have focused on likely patterns of

[148] Kharin, V. V., and F. W. Zwiers, 2000: Changes in the extremes in an ensemble of transient climate simulations with a coupled atmosphere–ocean GCM. J. Climate, 13, 3760–3788.

[149] Groisman, P. Ya., R. W. Knight, D. R. Easterling, T. R. Karl, G. C. Hegerl, and V. N. Razuvaev, 2005: Trends in intense precipitation in the climate record. J. Climate, 18, 1326–1350.

[150] Meehl, G. A., J. M. Arblaster, and C. Tebaldi, 2005: Understanding future patterns of increased precipitation intensity in climate model simulations. Geophys. Res. Lett., 32, L18719, doi:10.1029/2005GL023680.

[151] Kharin, V. V., X. Zhang, and C. Hegerl, 2007: Changes in temperature and precipitation extremes in the IPCC ensemble of global coupled model simulations. J. Climate, 20, 1419–1444.

change over large regions of Africa despite the high degree of spatial variability exhibited by precipitation. Regionally specific studies have been carried out in other parts of the globe (e.g., van Ulden and van Oldenborgh 2006[152] van den Hurk et al. 2006[153];), but few for Africa and even fewer for Southern Africa, (Shongwe et al 2009)[154].

Using seven global climate models (GCMs), Hulme et al. (2001)[155] reported significant decreases in mean December–February (DJF) precipitation were found in the interior Southern Africa south of about 10^{o}S (most of South Africa, Botswana, and Namibia). These projected decreases are substantial after 2050. , (Shongwe et al 2009) have pointed out from their study a possible contraction in the rainfall season in locations south of about 158S, also mentioned that to the north, the rainy season is projected to shift to later months. Mean summer precipitation rates are projected to decrease near the hype-rarid and semiarid areas of Southern Africa. Over these areas, the severity of future droughts is projected to increase. North of about 158S, mean summer precipitation is projected to increase and more severe droughts are expected to the southwest. Wet events are projected to become more intense to the north and southeast. To the north, this is consistent with more prolonged wet spells from persistent convective activity related to the tropical–temperate trough TTT. The increase in the intensity of wettest events to the southeast is in qualitative agreement with (Hewitson and Crane 2006[156]). These increases in wet extremes may exacerbate the rise in reported flood disasters in the region. Future projections of wettest events are less trustworthy owing to the inability to accurately simulate small-scale disturbances such as west Indian Ocean tropical cyclone activity in most models. In general, the pattern of summer precipitation change, in particular coupled with increasing temperatures, may result in an eastward extension of desert areas in Southern Africa, water scarcity, reduced agricultural productivity, and increased risks of food insecurity and famine. Not only is desertification a potential impact of global warming in Southern Africa, but shorter growing seasons are possible consequences in a large area.

[152] van Ulden, A. P., and G. J. van Oldenborgh, 2006: Large-scale atmospheric circulation biases and changes in global climate model simulations and their importance for climate change in Central Europe. Atmos. Chem. Phys., 6, 863–881.

[153] van den Hurk, B. J. J. M., and Coauthors, 2006: KNMI climate change scenarios 2006 for the Netherlands. Tech. Rep. WR-2006-01, KNMI, 82 pp.

[154] Shongwe M. E.,* G. J. Van Oldenborgh, B. J. J. M. Van Den Hurk B. De Boer , C. A. S. Coelho, M. K. Van Aalst 2009 Projected Changes in Mean and Extreme Precipitation in Africa under Global Warming. Part I: Southern Africa

[155] Hulme, M., R. Doherty, T. Ngara, M. New, and D. Lister, 2001:African climate change: 1900–2100. Climate Res., 17, 145–168.

[156] Hewitson, B. C., and R. G. Crane, 2006: Consensus between GCM climate change projections with empirical downscaling: Precipitation downscaling over South Africa. Int. J. Climatol., 26,1315–1337.

3. BUILDING BLOCKS OF DROUGHT RISK ANALYSIS - METHODOLOGY.:

The basics of building blocks in drought risk analysis is shown in figure (3.1), after IPCC (2012) and could be described describes as follows

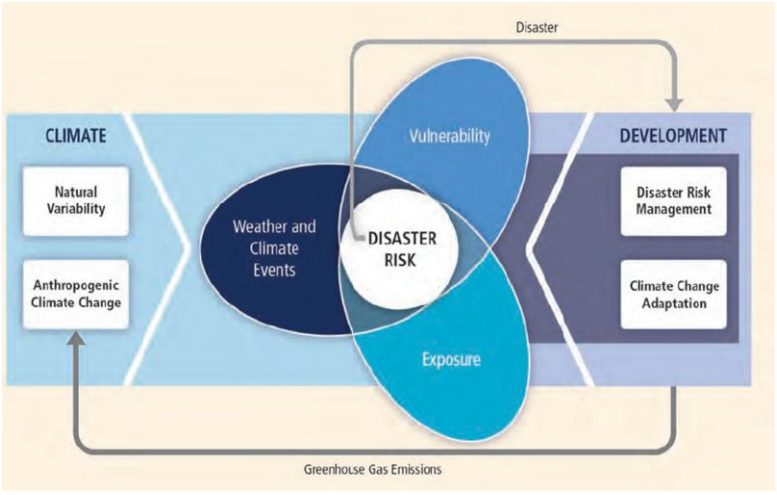


Figure 3.1. Exposure and vulnerability to weather and climate events (drought in our study) determine impacts and the likelihood of disasters (disaster risk).

The overall implemented methodology for ACSAD is shown in figure (3.2), based on the framework described above, our notes from the conference call last week and the data availability/gaps described during the call, we propose the following approach:

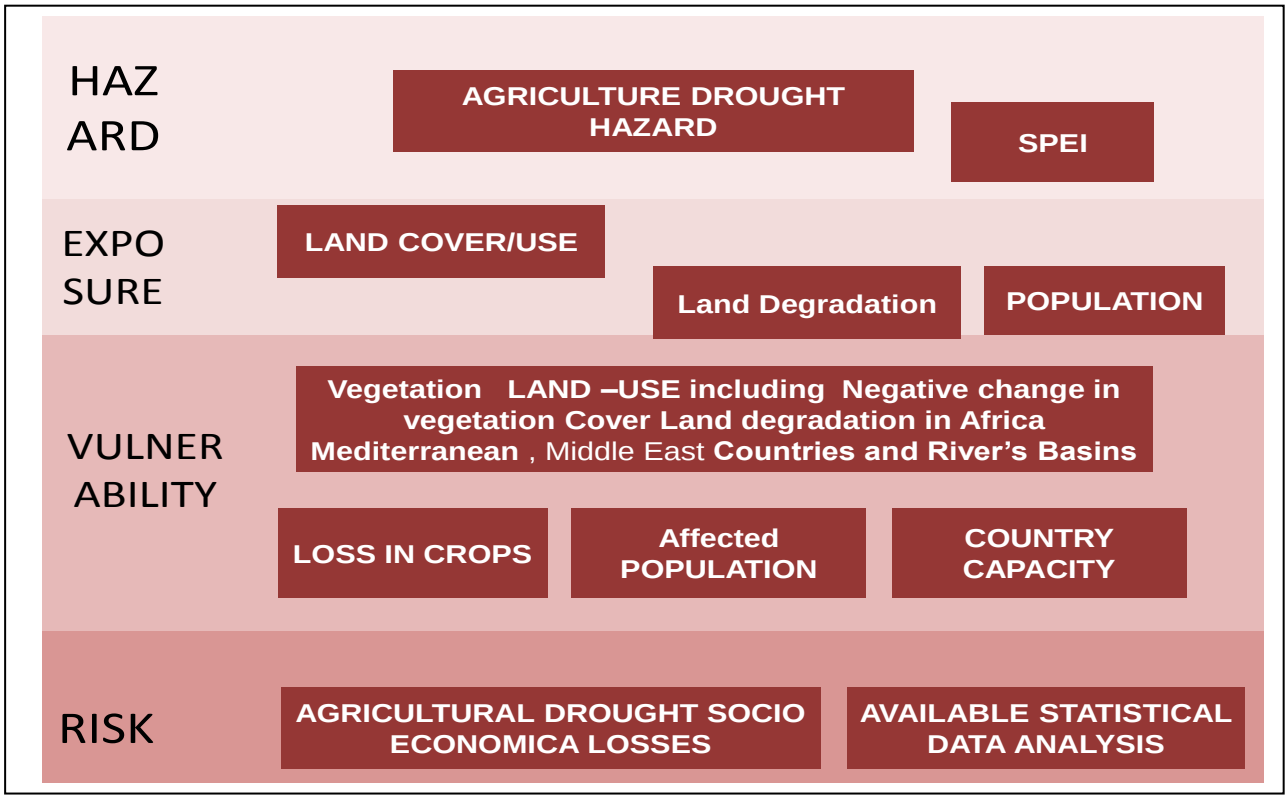


Figure 3.2. ACSAD Methodology For Studying ADH , Exposure and Vulnerability

A. Hazard analysis:

Traditional methods of drought hazard assessment and monitoring rely on rainfall data and also on Evapo-transpiration, which are limited, often inaccurate and, most importantly, difficult to obtain in near-real time. In contrast, the satellite-sensor data are consistently available and can be used to detect the onset of drought, its duration and magnitude (Thiruvengadachari and Gopalkrishna 1993[157]). Even crop yields can be predicted 5 to 13 weeks prior to harvests using remote-sensing techniques (Ungani and Kogan 1998[158]).

Vegetative conditions over the world are reported occasionally by NOAA National Environmental Satellite Data and Information System NESDIS data (Kogan 2000[159]). Drought indicators can be derived for any world region using these data, but the characteristic spatial resolution of 1km, 500m or 250m (at which well-calibrated long-term historical data are freely available), is likely to be moderate for effective drought monitoring at small scales. The Moderate-Resolution Imaging Spectrometer (MODIS), an advanced narrowband-width sensor, from which composited reflectance data are made available at no cost every 8 days by NASA and USGS, through the Earth Resources Observation Systems (EROS) data center (Justice and Townshend 2002[160]). Raw images are available on a daily basis, but their use involves considerable extra processing. Time series of MODIS imagery provide near real-time, continuous and relatively high-resolution data, on which the assessment of drought development and severity in a country or a region with scarce and inaccurate on-the-ground meteorological observations (like most Arab countries) could be based.

For selecting the Drought index (s) in this study it was understood that although the role of deficits in precipitation is generally considered more prominently in the literature, several drought indicators also explicitly or indirectly consider effects of evapo-transpiration. In the context of climate projections, analyses suggest that It should nonetheless be noted that under strong drought conditions, soil moisture becomes limiting for evapo-transpiration, thus limits further soil moisture depletion. Other important aspects for soil moisture and hydrological droughts are persistence and pre-conditioning. Because soil moisture, groundwater, and surface waters are associated with water storage, they have a characteristic memory (e.g., Vinnikov et al., 1996[161]; Eltahir and Yeh, 1999[162]; Koster and Suarez, 2001[163]; Seneviratne et al., 2006[164])

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[157] .Thiruvengadachari S., Gopalkrishna H.R., 1993. An integrated PC environment for assessment of drought. International Journal of Remote Sensing 14:3201–3208

[158] Ungani, L.S.; Kogan, F.N. 1998. Drought Monitoring and com Yield Estimation in Southern Africa from AVHRR Remote Sensing of Environment 63: 219=232.

[159] Kogan, F.N. 2000. Contribution of remote sensing to drought early warning . In early warning systems for drought preperdiness and drought management , ed D,A. Wilhite and D.A. Wood, 75-87. Geneva: WMO.

[160] Justice, C.; Townshend, J. 2002. Spacial issue on the Moderate Resolution Imaging Spectro-radiometer (MODIS): A new generation of land surface monitoring. Remote Sensing of Environment 83:1-2.

[161] Vinnikov, K.Y., A. Robock, N.A. Speranskaya, and A. Schlosser, 1996: Scales of temporal and spatial variability of midlatitude soil moisture. *Journal of Geophysical Research – Atmospheres*, 101(D3), 7163-7174.

[162] Eltahir, E.A.B. and P.A.J.F. Yeh, 1999: On the asymmetric response of aquifer water level to floods and droughts in Illinois. *Water Resources Research*, 35(4), 1199-1217.

[163] Koster, R.D. and M.J. Suarez, 2001: Soil moisture memory in climate models. *Journal of Hydrometeorology*, 2(6), 558-570.

[164] Seneviratne, S.I., R.D. Koster, Z.C. Guo, P.A. Dirmeyer, E. Kowalczyk, D. Lawrence, P. Liu, C.H. Lu, D. Mocko, K.W. Oleson, and D. Verseghy, 2006b: Soil moisture memory in AGCM simulations: Analysis of global land-atmosphere coupling experiment (GLACE) data. *Journal of Hydrometeorology*, 7(5), 1090-1112.

and thus specific response times to drought forcing (e.g., Begueria et al., 2010[165]; Fleig et al., 2011[166]). The memory is also a function of the atmospheric forcing and system's feedbacks (Koster and Suarez, 2001[167]; Wang et al., 2009[168]), and the relevant storage is dependent on soil characteristics and rooting depth of the considered ecosystems. This means that drought has a different persistence depending on the affected system, and that it is also sensitive to pre-conditioning. Effects of pre-conditioning also explain the possible occurrence of multi-year droughts, whereby soil moisture anomalies can be carried over from one year to the next (e.g., Wang, 2005[169]). However, other features can induce drought persistence, such as persistent circulation anomalies, possibly strengthened by land-atmosphere feedbacks (Schubert et al., 2004[170]; Rowell and Jones, 2006[171]). The choice of variable (e.g., precipitation, soil moisture, or stream flow) and time scale can strongly affect the ranking of drought events (Vidal et al., 2010[172]).

In this study and due to the relatively limited available time coverage of MODIS (available only from 1999), The Vegetation Healthy Index (VHI) has been calculated and agriculture drought intensity, frequency and consecutive were extracted from it, while agriculture drought variability were extracted from the Phase of the time series analysis using Timestat Software produced by Trier University /ACSAD and GIZ. Agriculture Drought Hazard (ADH), were produced from combining agriculture drought intensity, Variability, frequency and consecutive , SPEI were calculated for few points for calibrating the obtained ADH map.

Hazard analysis consists of using a hydro-meteorological index to describe the intensity, spatial and temporal characteristics of drought. The hydro-meteorological proxy index can be rainfall and Evapo-transpiration-deviation from normal (percentile, tercile), standardized precipitation Evapo-transpiration index (SPEI), palmer drought severity index (PDSI), water requirement satisfaction index (WRSI), moisture availability index (MAI), and such. In this study SPEI was selected and calculated for long term 1901 – 2006 and 2000 – 2011.and with satellite images (MODIS (1 km*1km) and MODIS (250m*250m) for Arab Mashriq, The following induces were calculated:

- Calculate monthly, and seasonally Vegetation Condition Index VCI, Temperature Condition Index TCI and Vegetation healthy Index VHI, for (12 month), from covering

[165] Begueria, S., S.M. Vicente-Serrano, and M. Angulo-Martinez, 2010: A multiscalar global drought dataset: The SPEIbase: A new gridded product for the analysis of drought variability and impacts. *Bulletin of the American Meteorological Society*, 91(10), 1351-1354.

[166] Fleig, A.K., L.M. Tallaksen, H. Hisdal, and D.M. Hannah, 2011: Regional hydrological drought in north-western Europe: linking a new Regional Drought Area Index with weather types. *Hydrological Processes*, 25(7), 1163-1179.

[167] Koster, R.D. and M.J. Suarez, 2001: Soil moisture memory in climate models. Journal of Hydrometeorology, 2(6), 558-570.

[168] Wang, X., P. Zhai, and C. Wang, 2009: Variations in extratropical cyclone activity in northern East Asia. *Advances in Atmospheric Sciences*, 26(3), 471-479.

[169] Wang, G.L., 2005: Agricultural drought in a future climate: results from 15 global climate models participating in the IPCC 4th assessment. *Climate Dynamics*, 25(7-8), 739-753.

[170] Schubert, S.D., M.J. Suarez, P.J. Pegion, R.D. Koster, and J.T. Bacmeister, 2004: On the cause of the 1930s Dust Bowl. *Science*, 303(5665), 1855-1859.

[171] Rowell, D.P. and R.G. Jones, 2006: Causes and uncertainty of future summer drying over Europe. *Climate Dynamics*, 27(2-3), 281-299.

[172] Vilibic, I. and J. Sepic, 2010: Long-term variability and trends of sea level storminess and extremes in European Seas. *Global and Planetary Change*, 71(1-2), 1-12.

all Arab region and countries sharing main trans-boundary river basins, figure (33) , for the period 2000 – 2010.

- Calculate Agriculture Drought (AD), Intensity ADI, Variability ADV, Frequency ADF and Consecutive ADC.
- Calculate Agriculture Drought Hazard (ADH) from ADI, ADV, ADF and ADC

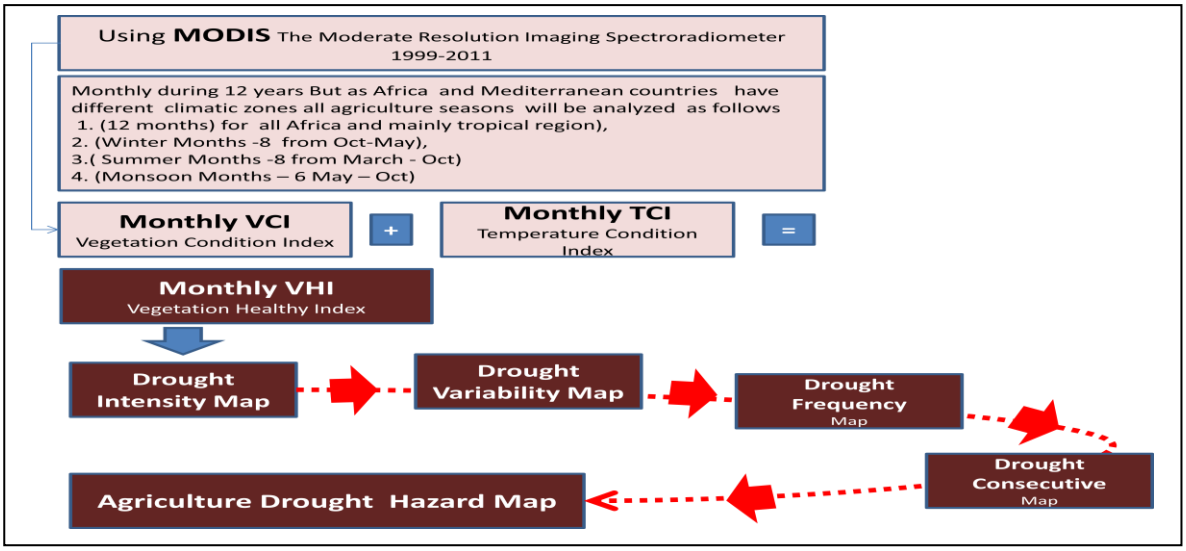


Figure 3.3. Main analysis for Producing ADH map

The need for proper quantification of drought impacts and monitoring and reporting of drought development is of critical importance. But the major constrain that reduce the ability of many countries to deal with droughts is the absence of reliable data, weak information networks as well as the lack of technical and institutional capacities. In countries they are either just beginning to establish relevant drought monitoring and management procedures and institutions or didn't start yet. But in general and in most countries existing drought monitoring and declaration procedures lag behind the development of drought events.

1.1. Steps Toward Monitoring Agriculture Drought Hazard.

For better understanding the drought, its severity, distribution and impacts, the Arab Center for the Studies of Arid Zones and Dry Lands (ACSAD) took the initiatives in cooperation with GIZ and the National Center of Remote Sensing in Lebanon (NCRS) for establishing their Regional/National drought monitoring system based on the most recent applications of remote sensing. The images source from MODIS NDVI 1 km , 250m; and MODIS LST (8 days).

1.1.1. Step 1: Computing Vegetation Healthy Index

In areas with limited in situ data, NDVI and satellite rainfall estimates are routinely used to identify areas prone to drought related crop failure and poor pasture conditions (FEWS, 2000[173];

[173] FEWS (2000). Framework for food crisis contingency planning and response. Arlington, VA: FEWS-ARD.

Field, 1991[174]; Hutchinson, 1998[175]). MODIS - NDVI and MODIS - LST, images were down loaded from NASA site, https://wist.echo.nasa.gov/wist-bin/api , (figure 3.4).

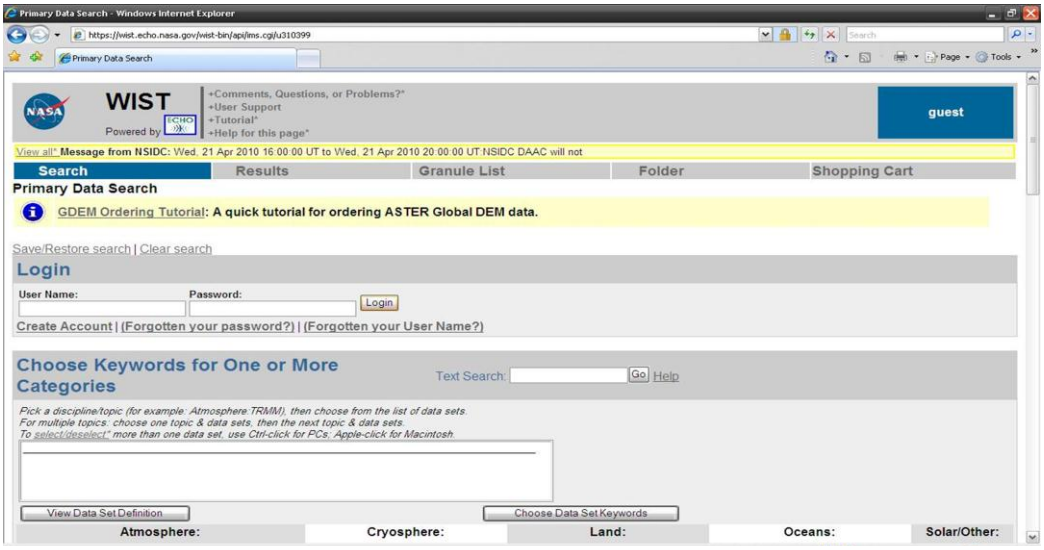


Figure 3.4. NASA Site for down loading MODIS.

Several drought indicators have been used, after, Thenkabail et al (2004) and European Commission (2006), for calculating the following monthly indices for all agriculture season's months during the years from 2000 till 2011:

- The Normalized Difference Vegetation Index NDVI = (λNIR – λred) / (λNIR + λred)
- Vegetation Condition Index VCI = (NDVI – NDVI min)/(NDVI max- NDVI min)*100
- Temperature Condition Index TCI= (BT max – BT min)/(BT max- BT min)*100
  Where, BT is the brightness temperature (MODIS LST)
- Vegetation Healthy Index VHI= VCI * 0.5 + TCI * 0.5

a. The Normalized Difference Vegetation Index

NDVI were also used for identifying the main agriculture seasons in the region and for calculating VCI. Number of months with value for NDVI were calculated and the seasons were then prepared, the crop calendar for the different studied countries is also presented in table (3.1), after (WFP 2011)[176].

[174] Field, J. O. (1991). Beyond relief: Toward improved management of famine. In H. G. Bohle, T. Cannon, G. I. Hugo, & F. N. Ibrahim (Eds.), Famine and food security in Africa and Asia: Indigenous response and external intervention to avoid hunger (pp. 151−166). Bayreuth, Germany: Verlag.

[175] Hutchinson, C. F. (1998). Social science and remote sensing in famine early warning. In D. Liverman, E. F. Moran, R. R. Rindfuss, & P. C. Stern (Eds.), People and pixels: Linking remote sensing and social science (pp. 189−196). Washington, DC: National Academy Press.

[176] WFP 2011. Seasonal and Hazards Calendar Emergency Preparedness and Response Branch

Table 3.1. examples of Crop Calendar For The Studied Countries, after WFP 2011

Seasonal crop Calendar												
Countries	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec.
Algeria,						wheat, barley (winter crops) harvest				wheat, barley		
Egypt,				maize, millet, rice sowing							wheat	barley
				barley harvest	wheat harvest				millet	maize, rice harvest		
Iran				rice					wheat, potato,barley			
			barley			wheat		rice	potato			
Iraq,		potato	millet, sorghum, maize		rice		maize			wheat, barley		
				barley	wheat	maize,potato	sorghum, millet		rice		maize	
Syria			potato, rice							wheat, barley		
					barley, wheat, potato				rice			
Yemen			main rainy season				summer monsoon					
					early sowing	planting starts						winter planting
			winter harvest							harvest		
Benin,												
		yams	maize	rice	cassava, millet, sorghum, irrigated rice			2nd maize				
	cassava, 2nd						yams	main maize, rice		millet, sorghum, irrig rice		cassava, 2nd
	maize											maize
Burkina Faso,												
					sowing							rice sowing
			rice, sorghum harvest					main harvest				
Cameroon,				rainy season/coast		rainy season/north				rainy season/coast		
					rainy season/western highlands							
				short rainy season/centre					rainy season/central plateau			
	land prep	yams	maize		cassava, sorghum , millet, rice			land prep	2nd maize			
							main maize, yams harvest		sorghum, millet, rice, 2nd maize, cassava			

Table 3.1. Cont'd

Seasonal crop Calendar												
Countries	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec.
Cape Verde,												
						dry planting	sowing					
										harvest		
Central African Republic												
		yams	maize		cassava, millet, rice, sorghum			2nd maize				
							main maize, yams harvest			illet, s main maize, yams harvest orghum, rice, cassava harve		
Chad,												
					sowing						2nd sowing	land prep
									harvest			
Cote d'Ivoire,					rainy season/northern savana							
				rains in coastal parts and centre						ains in coastal parts and centre		
			maize, yams and cassava		millet, sorghum and rice			2nd maize				
	2nd maize	cassava					yams	maize main harvest		millet, sorghum, rice		2nd maize
GAMBIA												
					maize	ice, sorghum, millet, groundnut						
									maize	ice, sorghum, millet, groundnut		
Ghana,				major rainy season					rainy season			
				rainy season/north								
		yams	cassava		millet, sorghum							
				rice/south		rice/north						
			main maize/north			main maize/north		2nd maize				
	cassava							maize, yams	sorghum, millet, rice			2nd maize
Guinea,												
	cassava harvest		palm nuts				rice, maize	yams harvest		maize, rice, sorghum, millet		
Guinea-Bissau,												
					maize, millet, sorghum		rice sowing					
									maize, millet, sorghum		rice harvest	
Liberia,												
		sowing										
	cassava						yams		rice harvest			

Table 3.1. Cont'd

Seasonal crop Calendar												
Countries	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec.
Mali,				land prep	millet, rainfed rice, sorghum, maize					irigated rice		
	rainfed rice		irrigated rice harvest						cereal harvest			rainfed rice
Mauritania,	Maraichage /rice					irrigated rice, maize, millet, sorghum				low lying	Walo crops	off--season
	low lying areas harvest		off--season rice, walo crops							main harvest brainfed		
										and winter irrigated areas		
Niger,	second sowing season			land preparation		sowing season					second sowing season	
	second harvest								maize, millet, sorghum harvest			
Sao Tome and Principe												
		second sowing season								sowing season		
	maize harvest					second maize harvest				cacao harvest (80 to 90%)		
Senegal,												
						rice, maize, millet, sorghum						
									maize, millet, sorghum		rice harvest	
Sierra Leone,												
		yams	cassava	rice, sorghum, maize, millet								
	cassava						yams harvest		rice, millet, maize, sorghum harvest			
Togo				rainy season/south					rainy season/south			
					rainy season/north							
		yams	main maize		cassava, millet, sorghum, rice			2nd maize				
	2nd maize						yams	main maize harvest		millet, sorghum, rice		cassava
Burundi,												
		main sowing				small season			second sowing			
	second season (A)					main season (B)			small season			
D R of Congo,												
SOUTH	rainy season									rainy season		
	maize 2nd sowing season								maize main sowing season		extra season	
	Maize main harvest		Maize extra harvest		Maize 2nd harvest							
	rice, cassava											
			rice, cassava									
NORTH												
		maize 2nd sowing season				maize main sowing season						
						maize 2nd harvest				maize main harvest		
				rice, cassava sowing								
	rice, cassava Harvest								rice, cassava Harvest			
CENTER	maize						maize main Sowing				maize 2nd sowing	
	maize		maize 2nd harvest								maize main harvest	
All REGIONS				millet, sorghum Sowing								
									millet, sorghum Harvest			

Table 3.1. Cont'd

Seasonal crop Calendar												
Countries	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec.
Sudan	dry spell (northeasterlies)											
						millet, sorghum					wheat	
			wheat								millet and sorghum	
South Sudan	dry spell (northeasterlies)											
				maize, millet, sorghum,cassava, sweet potato, rice								
			1st cropping season maize, millet, sorghum,			main cropping season				2nd cropping		
	2nd harvest						1st harvest		harvest in Jun--Sept areas		harvest in Jun--Nov areas	
Djibouti,	Heys/Dada coastal rains		Diraa/ Sougoum rains				Karan/Karma inland rains			Heys/Dada coastal rains		
			kidding					kidding				
							fruit harvest					
Eritrea,	Bahri rains		Azmera rainy season			Kremti rainy season				Bahri rains		
				sorghum, wheat, maize,millet, pulses, barley, roots and tubers								
				short season		main season					minor Season	
	minor Harvest	secondary harvest								main harvest/short season		
Ethiopia,		Gu rains	Belg rainy season			Meher rainy season				Deyr rains		
		maize, sorghum, wheat,millet, barley, oats, teff										
		Belg sowing	Meher sowing									
			long cycle crops planting									
						Belg sowing				Meher harvest		
Kenya,												
			ONG RAINS season-- maize,wheat, barley, millet,sorghum, bea									
			sowing		wheat							
						millet	barley	sorghum	wheat, maize, beans harvest			
										barley, millet, sorghum,beans		
Lesotho,												
					wheat, peas winter/ Lowlands			wheat/Highlands		main growing season / Lowlands		
	summer wheat/low lands		wheat, peas harvest / highlands		maize, sorghum, beans main							summer wheat/low lands
Madagascar,												
		rice, cassava, maize,wheat, sorghum, (sweet and not) potatoes										
			sweet potato		wheat	rice HOSY	off--season		potato		rice, maize, sorghum	
		potato harvest		rice, maize, sorghum harvest			sweet potato harvest				wheat	rice HOSY
Malawi,												
		maize, cassava, rice,sorghum, wheat, potato,pulses										
		wheat	winter planting							main sowing season		
		Green harvest		maize, rice, sorghum harvest			wheat harvest			winter harvest		

Table 3.1. Cont'd

Seasonal crop Calendar												
Countries	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec.
Mozambique,				maize, cassava, sorghum, rice, millet, beans, wheat								
					nd sowing wheat / south & cent						main	
			Main H		maize	sorghum		2nd harvest		wheat		
Namibia,				millet, maize, wheat, sorghum, roots and tubers								
					wheat							
										wheat		
Rwanda,	short dry season						long dry season			short rainy season		short d.s.
	cassava, sorghum, potato, beans, maize, rice											
		second sowing				3rd season			sowing			
						second harvest						
Somalia,	Jilaal dry season						Haga dry season					
	maize, sorghum, cassava, beans, rice, cowpea											
				Gu season						Deyr season		
			Deyr harvest					Gu harvest		Karan harvest		
Swaziland,												
					wheat					maize, rice, sorghum		
		rice harvest			maize, sorghum harvest						wheat	
Tanzania,												
Unimodal Areas (southern,	dry spell	msimu rains									msimu rains	
south--west, central and											maize, sorghum, wheat msimu	
western parts)					msimu harvest							
Bimodal Areas			masika rains						vuli rains			
(north --northern coast)			maize, sorghum, wheat masika						maize, sorghum, wheat vuli			
	vuli harvest					masika harvest						
Uganda,												
Bimodal areas							dry spell					
	land prep		beans, maize, millet main					land prep	2nd sowing			
	2nd							main				2nd
Unimodal areas (Karamoja)												
				ssava, sweet potato, maize, mil			weeding					
							maize	main H				
Zambia,												
					maize, wheat, millet, sorghum, cassava							
					wheat	winter crops sowing			land prep			
	winter crops		Green harvest		main harvest					wheat	winter crops	
Zimbabwe												
					aize, wheat, sorghum, cassava, millet, soybear							
					wheat and winter planting					land prep	maize, sorghum	
			Green harvest		main harvest				wheat and winter maize			

b. Vegetation Condition Index

A GIS model were created for studying VCI as shown in figure (3.7), its main steps includes:

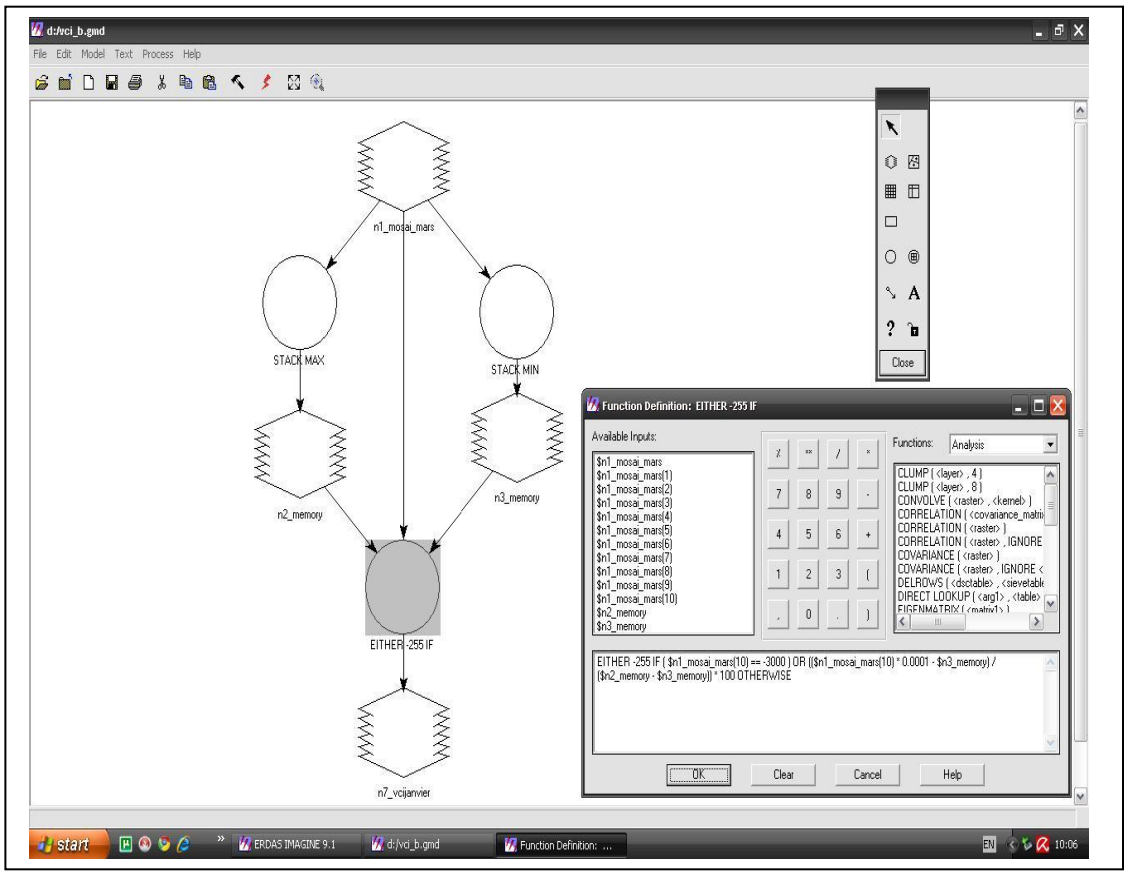


Figure 3.7. GIS model for Studying VCI.

- Preparation of monthly mosaic
- Preparation for monthly minimum NDVI and monthly maximum NDVI stocks. The NDVI Stack layer were prepared for each month covering the period from 2000 – 2011, as shown in (figure 3.8 a and b).
- Storing results in memory
- Calculating monthly Vegetation Condition Index using the following equation Monthly VCI = (NDVI – NDVI min)/(NDVI max- NDVI min)*100,
- The VCI values were classified to the following classes:

Class Description	**%**
Extremely Sever Drought	Less than 10
Severe Drought	10 – 20
Moderate Drought	20 – 30
Slight Drought	30 – 40
No Drought	More than 40

- Finally, a VCI classified map for each month has been produced.

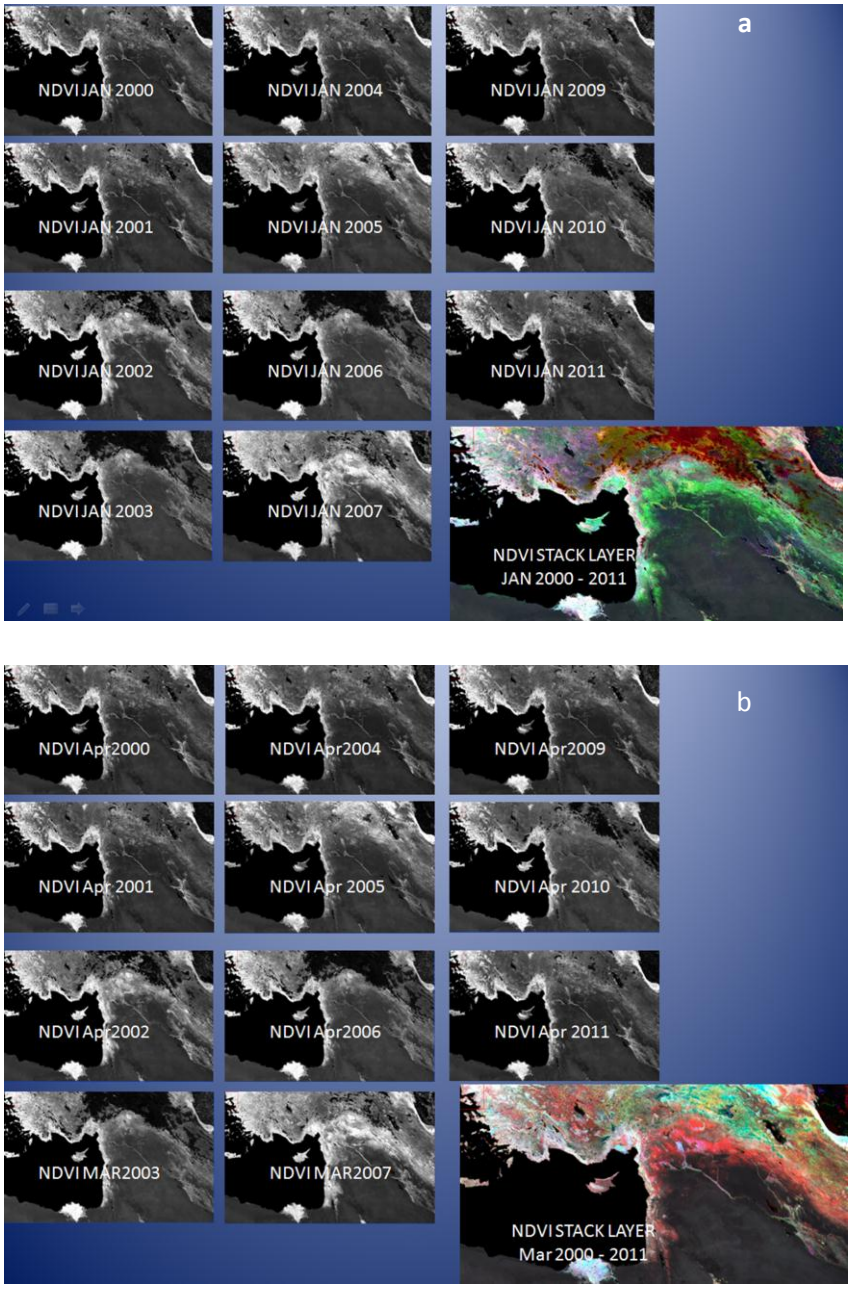


Figure 3.8. Preparing Monthly NDVI Stack Layer

c. Temperature Condition Index

A GIS model were created for studying TCI as shown in figure (3.9), its main steps includes:

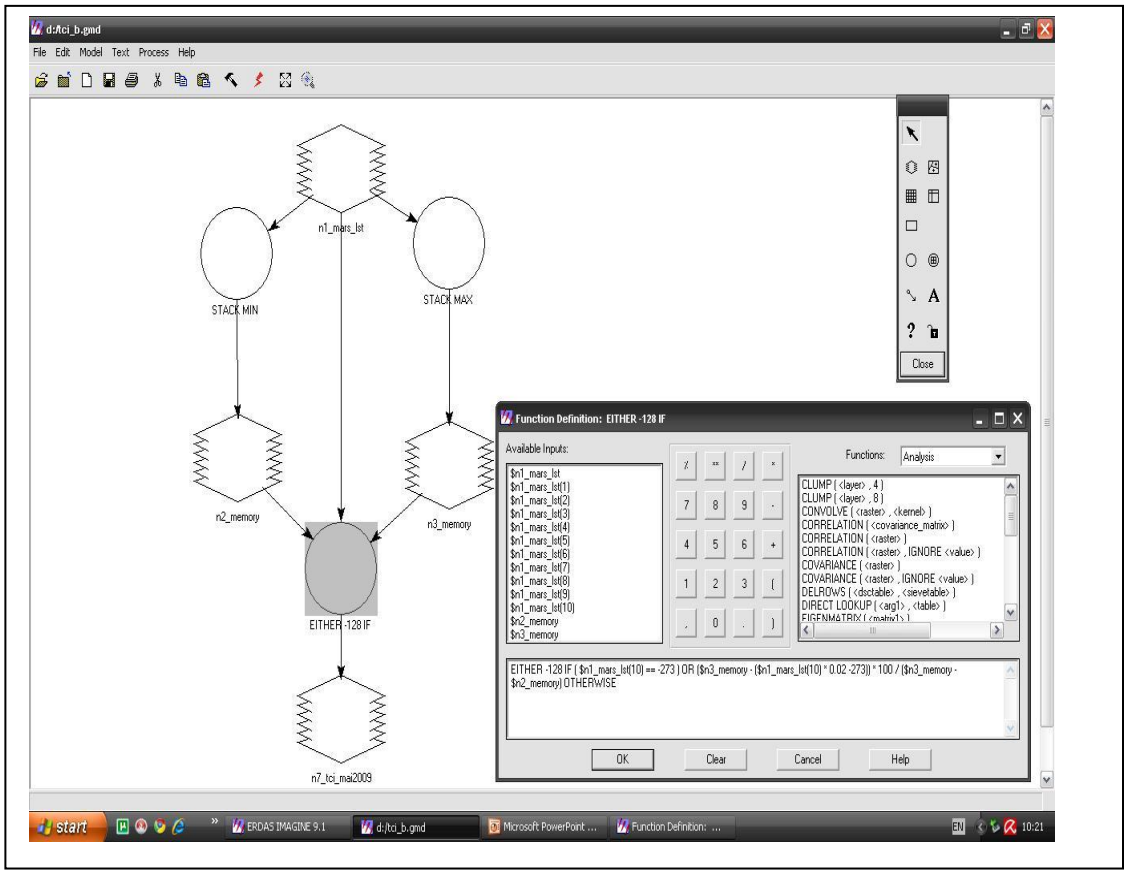


Figure 3.9. GIS model for studying TCI.

- Preparation of monthly mosaic
- Preparation for monthly minimum and monthly maximum **brightness temperature BT (MODIS LST)** stocks. The NDVI Stack layer were prepared for each month covering the period from 2000 – 2011, as shown in (figure 3.10 a, b and c).
- Storing results in memory
- Calculating monthly Tempreature Condition Index using the following equation Monthly TCI= (BT max – BT min)/(BT max- BT min)*100
- The TCI values were classified to the following classes:

Class Description	**%**
Extremely Sever Drought	Less than 10
Severe Drought	10 – 20
Moderate Drought	20 – 30
Slight Drought	30 – 40
No Drought	More than 40

- Finally, a TCI classified map for each month has been produced.

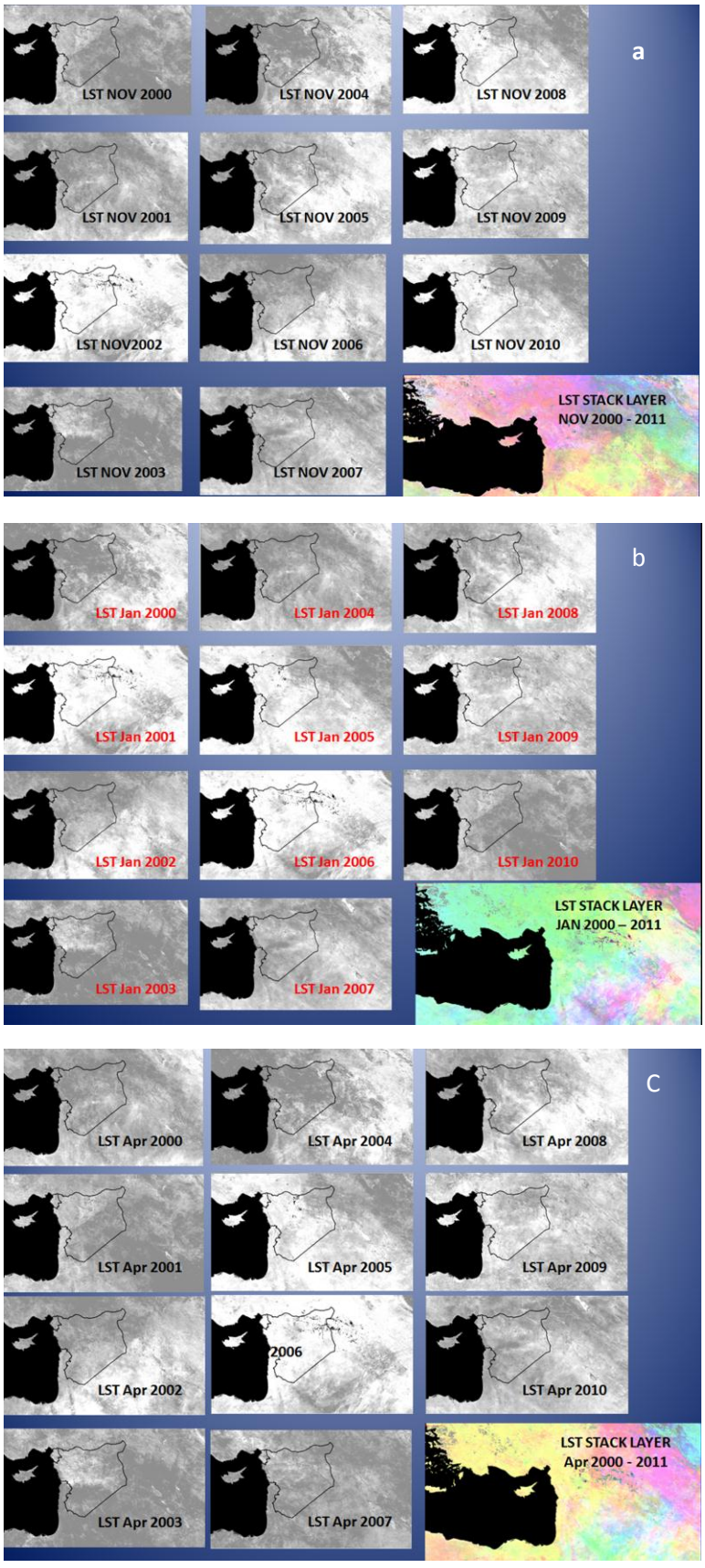


Figure 3.10 Preparing Monthly NDVI Stack Layer

d. Vegetation Healthy Index

A GIS model were created for studying VHI as shown in figure (3.11), its main steps includes:

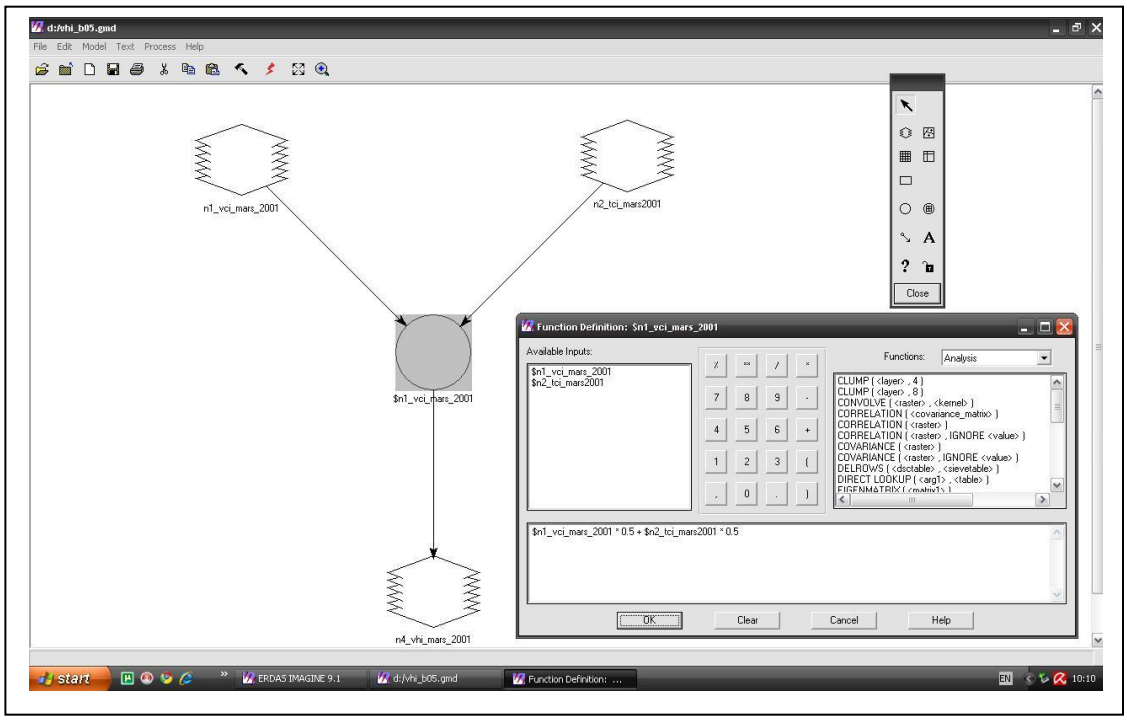


Figure 3.11. GIS model for studying VHI

- Calculating monthly Vegetation Healthy Index using the following equation Monthly VHI= (TCI *0.5)+(VCI*0.5)
- The VHI values were classified to the following classes:

Class Description	**%**
Extremely Sever Drought	Less than 10
Severe Drought	10 – 20
Moderate Drought	20 – 30
Slight Drought	30 – 40
No Drought	More than 40

- Finally, a VCI classified map for each month has been produced.

1.1.2. Step 2: Developing Agriculture Drought Hazard Map

a. The monthly obtained VHI were classified to 2 classes, the first class correspond to areas with no drought (class 1 was given a value 1) and the second class correspond to areas with any level of drought (class 2 was given value 0), as shown in (figure 3.12).

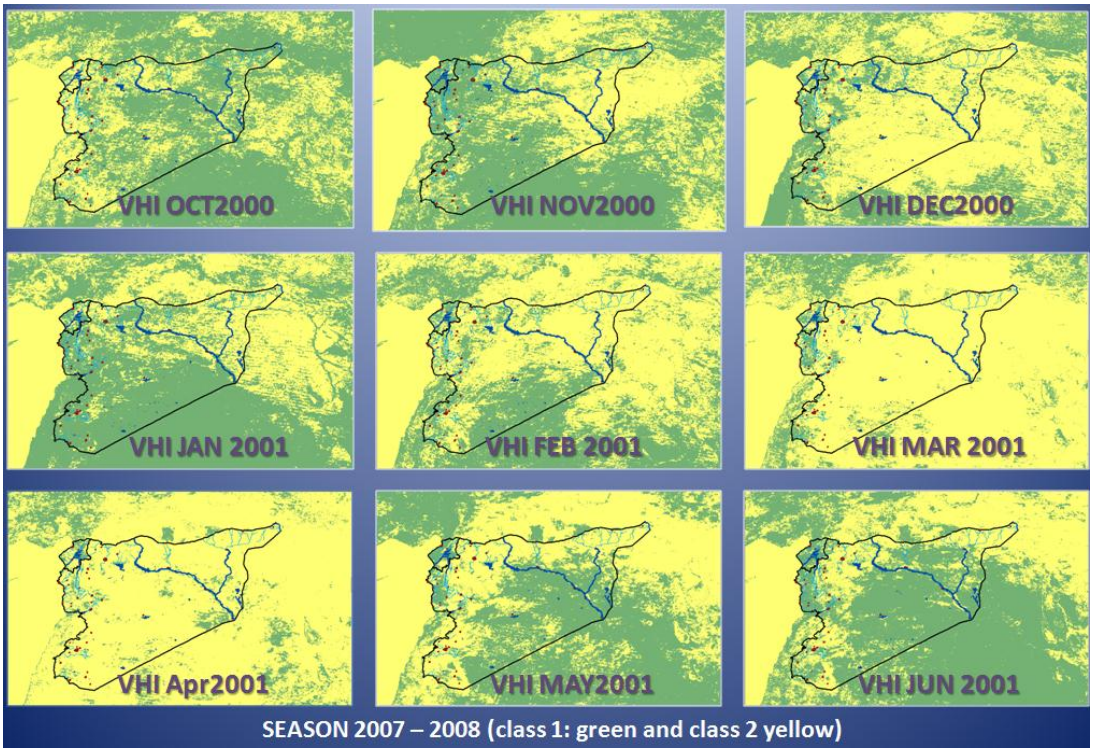


Figure 3.12. monthly VHI presented in 2 classes (1,0) for the agriculture season 2007/2008), Area shown in the map is east Mediterranean Sea and Syrian boundary is shown in black.

b. The monthly VHI for each agriculture season were then but horizontally in order starting from the month in the beginning of the season till the end of the season, (figure 3.13).

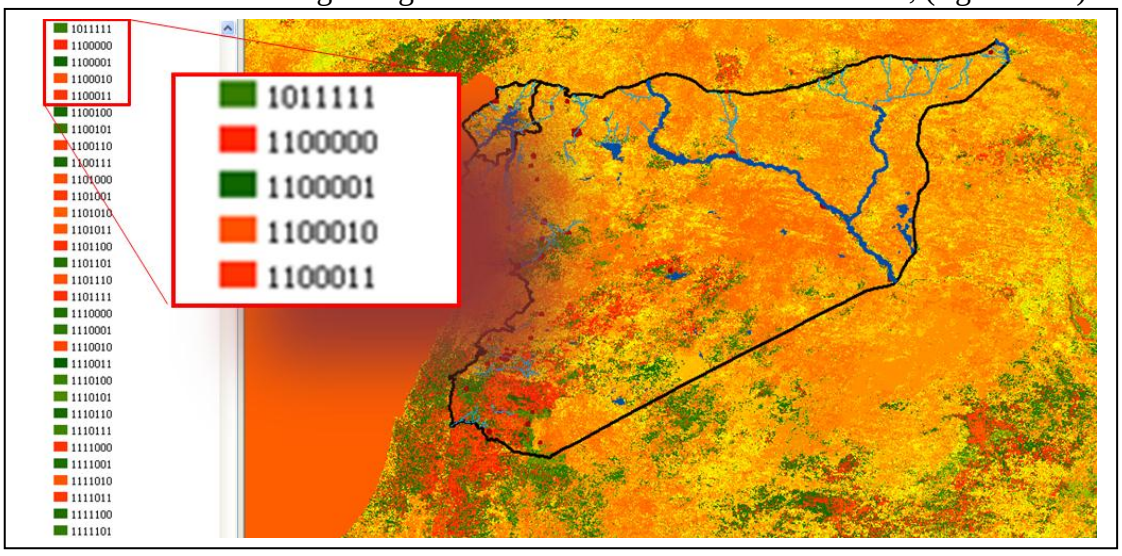


Figure 3.13. VHI classification map for the agriculture season 2007/2008), Area shown in the map is for east Mediterranean Sea and Syrian boundary is shown in black.

c. Classification for each winter's months and monsoon season's months for the years from 2000 till 2011, took place to illustrate the seasonal drought spatial variability to four classes. The drought grouping classification system is as follow:
   - Group (1), very slight impacts of drought, where the VHI is more than 40% through 6 to 7 months during the winter season, and 5 to 6 months during summer season in monsoon areas.
   - Group (2), slight impacts of drought, where the VHI is more than 40% through 5 months including October and November in the beginning of the season and March and April months during the winter season in Northern Africa, April and May in the beginning of season and October and November months during the summer season in Southern Africa, the VHI must not be less than 40% for one month during summer season in monsoon areas north of equator , and VHI is more than 40% through 3 from July to September , and must not must not be less than 40% for one month during winter season in monsoon areas south of equator , and VHI is more than 40% through 3 from January to March
   - Group (3), Moderate impacts of drought, where the VHI is more than 40% through 5 months including October and November in the beginning of the season and March and April months during the Winter season, , April and May in the beginning of season and October and November months during the summer season in Southern Africa,. The VHI must not be less than 40% for another one or two months during the winter season in North Africa and in south Africa, and where the VHI is less than 40% through most months during summer season in monsoon areas including August or September North of equator and including February and March south of equator.
   - Group (4), Sever impacts of drought, didn't fulfill any of the above mentioned conditions and the VHI is less than 40% for most of the months.

An example of the obtained result for illustration could be presented as in (Figure 3.14)

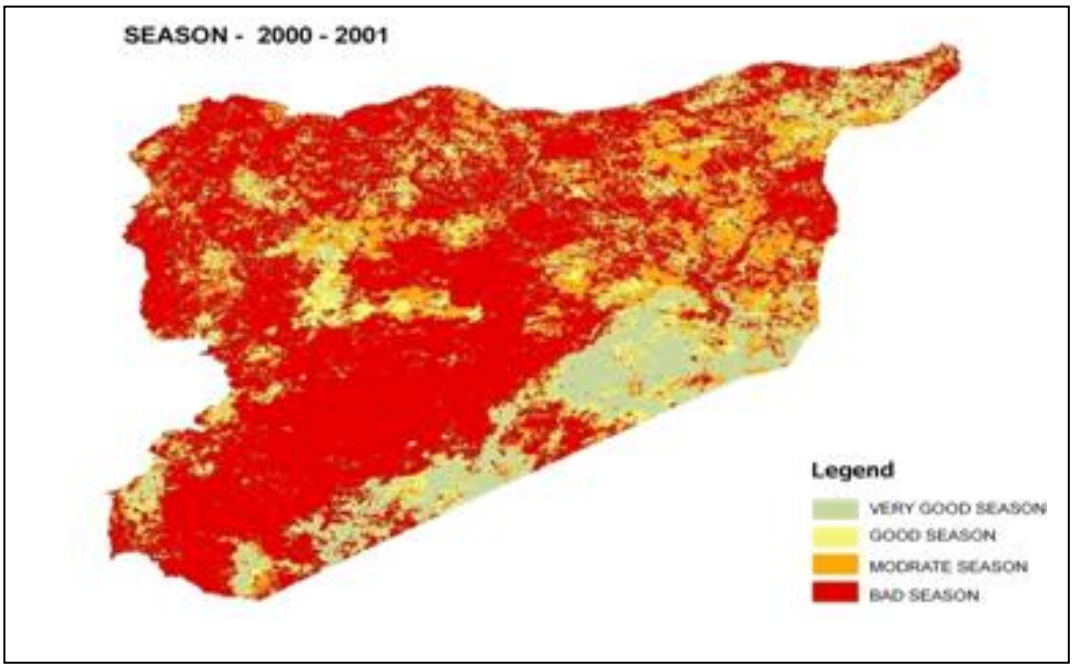


Figure 3.14. VHI map for the season 2000/2001, Area shown in the map is for Syria

The Seasonally VHI maps for the studied seasons were classified to 2 classes, the first class correspond to areas with no drought (the first class was given a value 1) and the second class correspond to areas with any level of drought (the second class was given value 0), as shown in (figure 3.15 and 3.16).

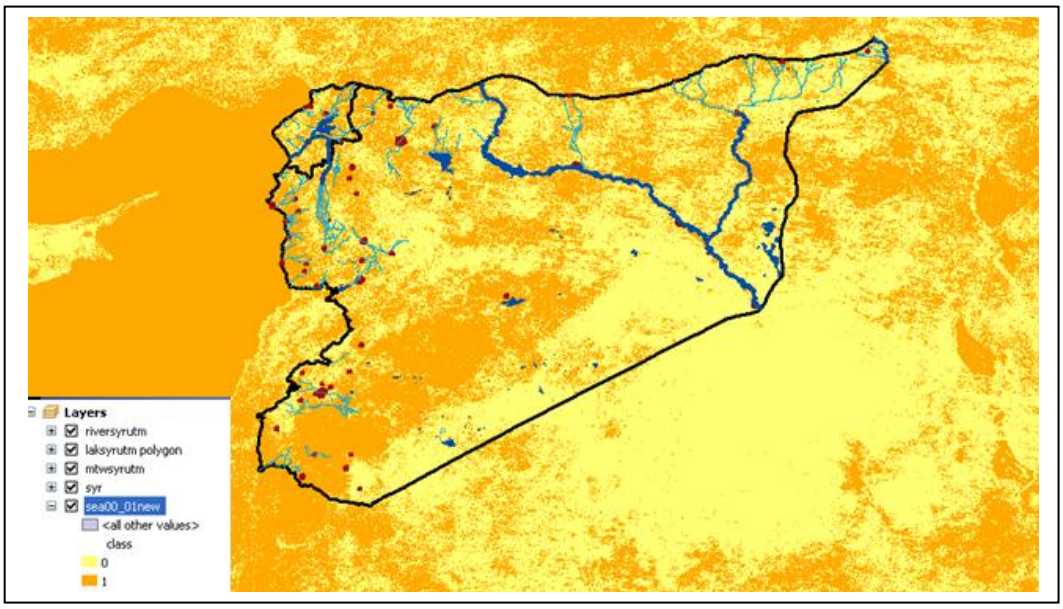


Figure 3.15. VHI map for the season 2000/2001 after classification to 2 classes (0,1), Area shown in the map is for east Mediterranean Sea and Syrian boundary is shown in black.

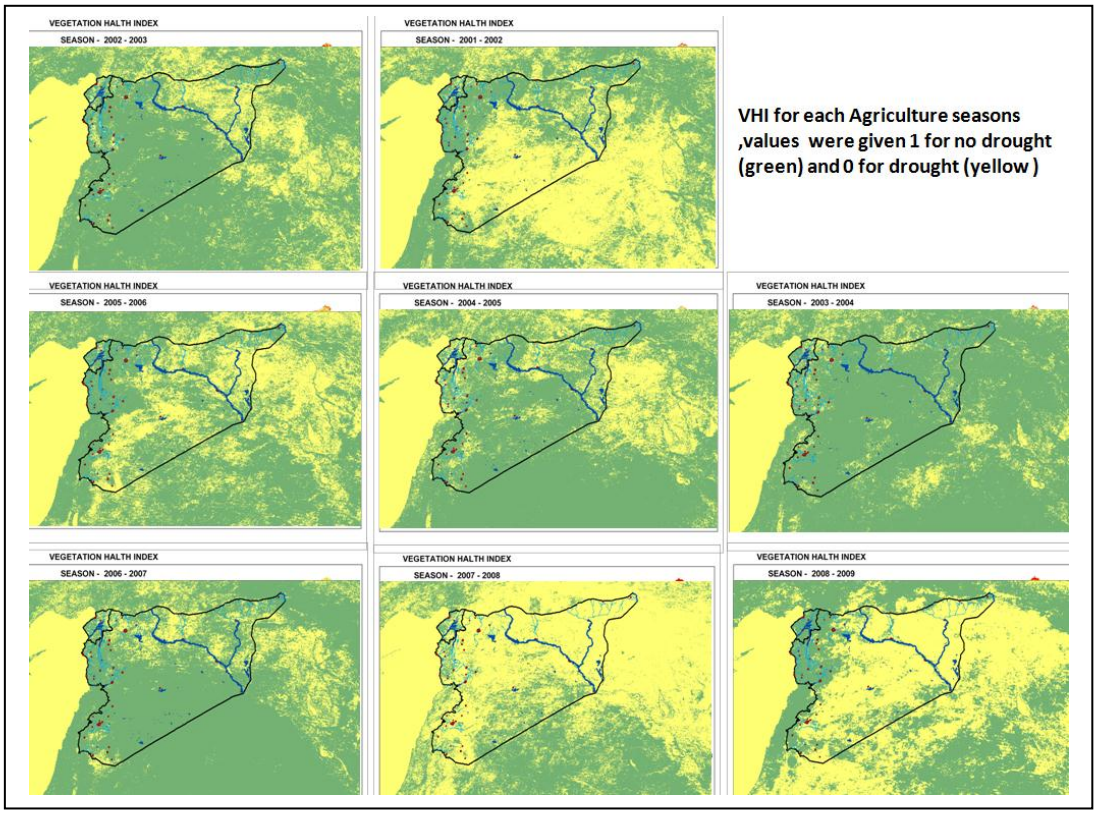
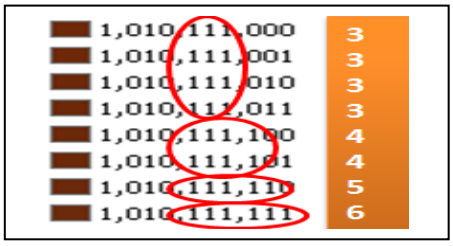


Figure 3.16. HI map for agriculture seasons 2000/2001- 2008/2009 after classification to 2 classes (0,1), Area shown in the map is for east Mediterranean Sea and Syrian boundary is shown in black.

d. Agriculture drought frequency could be obtained from the vertical calculation from **(0,1)** classified **VHI maps for the different agriculture seasons. The total studied seasons were 11 seasons**

e. Agriculture drought consecutive could be obtained from the horizontal calculation from **(0,1)** classified **VHI maps for the different agriculture seasons. The total studied seasons were 11 seasons**



f. Agriculture drought intensity could be calculated for each pixel as an average of all studied monthly VHI for all seasons, 88 maps that represents (11 seasons*8 months in each season), as shown in (figure 3.17). The obtained results were then classified into 4 classes as follows

Severe Drought	less than 15
Moderate Drought	15– 30
Slight Drought	30 – 45
No Drought	More than 45

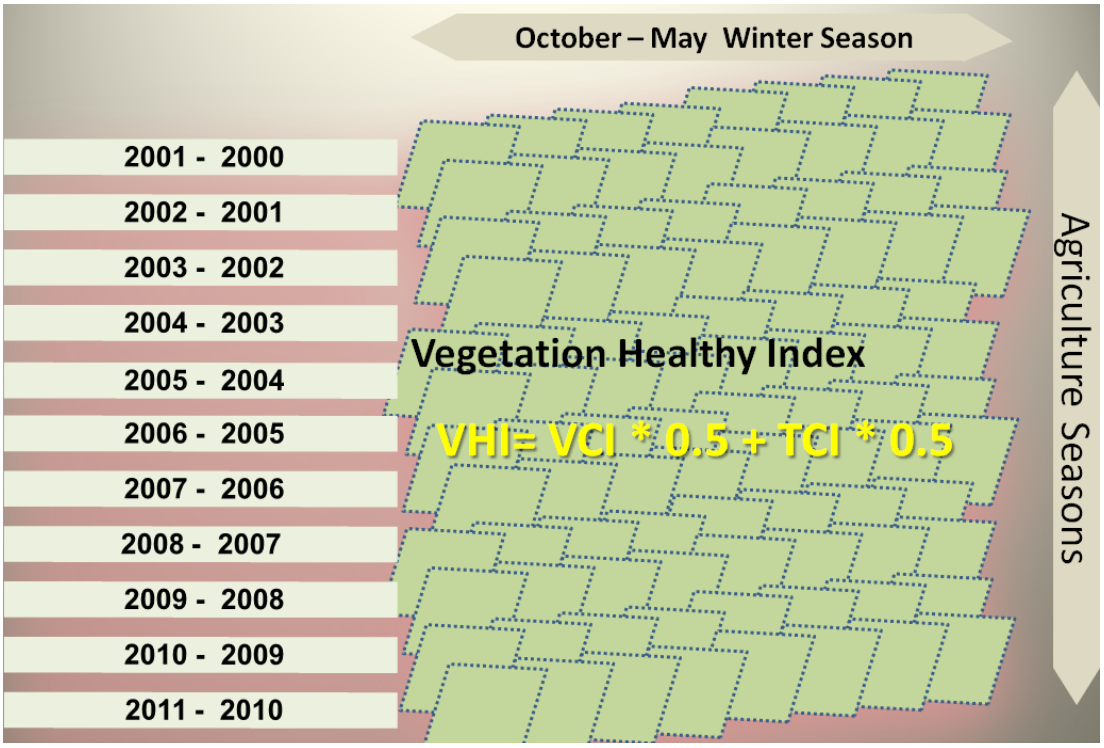


Figure 3.17. Calculating Agriculture Drought Intensity as an Average of all Studied Months of the Seasons.

g. Agriculture drought variability was studied as of the countries of interest of this study located as previously mentioned in the region that considered with the lowest precipitation and highest variability of the world, (World Bank 2007)[177], (figure 48). Accordingly, Agriculture drought variability could be considered as important factor that affect Agriculture Drought Hazard. It could be calculated from the Phase (the month of the year that each pixel has its maximum NDVI value).

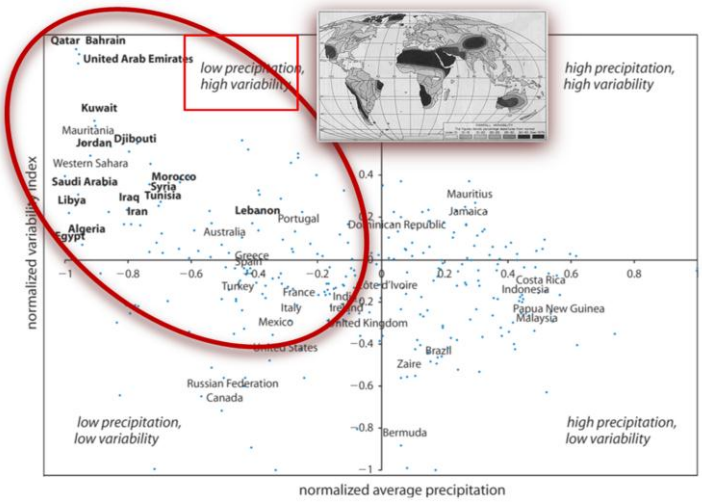
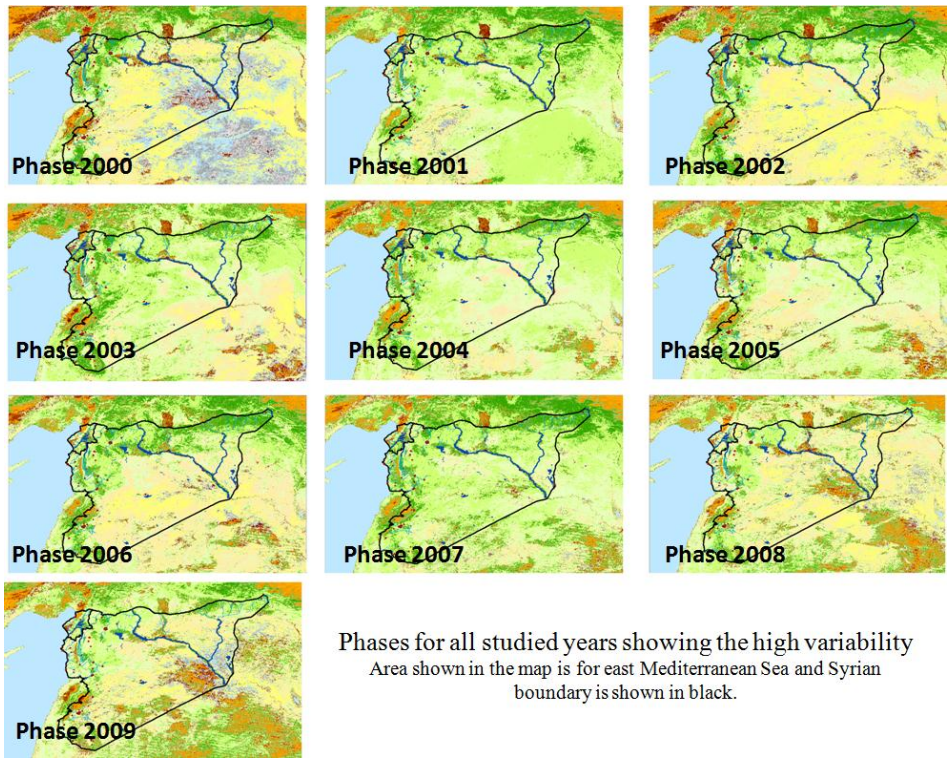


Figure 3.18. shows the high normalized variability index of all the studied area, after (World Bank 2007)

For calculating variability classes, we first subtract the annual NDVI shown in figure (3.19) from the maximum average NDVI of all studied years as shown in Figures (3.20).

[177] World Bank (2007). "Making the Most of Scarcity - Accountability for Better Water Management Results in the Middle East and North Africa." International Bank for Reconstruction and Development, Washington, D.C..

The result as shown in figure (3.21) shows the number of months that deviated from average for each pixel.



Phases for all studied years showing the high variability
Area shown in the map is for east Mediterranean Sea and Syrian boundary is shown in black.

Figure 3.19 annual Phase (s) of Studied Years.

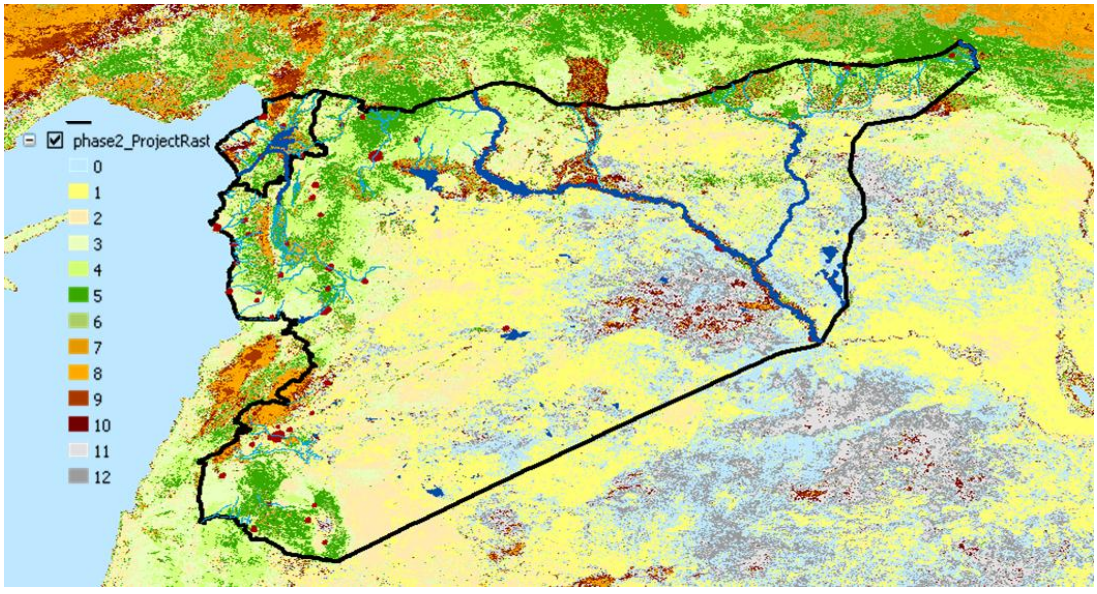


Figure 3.20 Average Phase of all Studied Years.

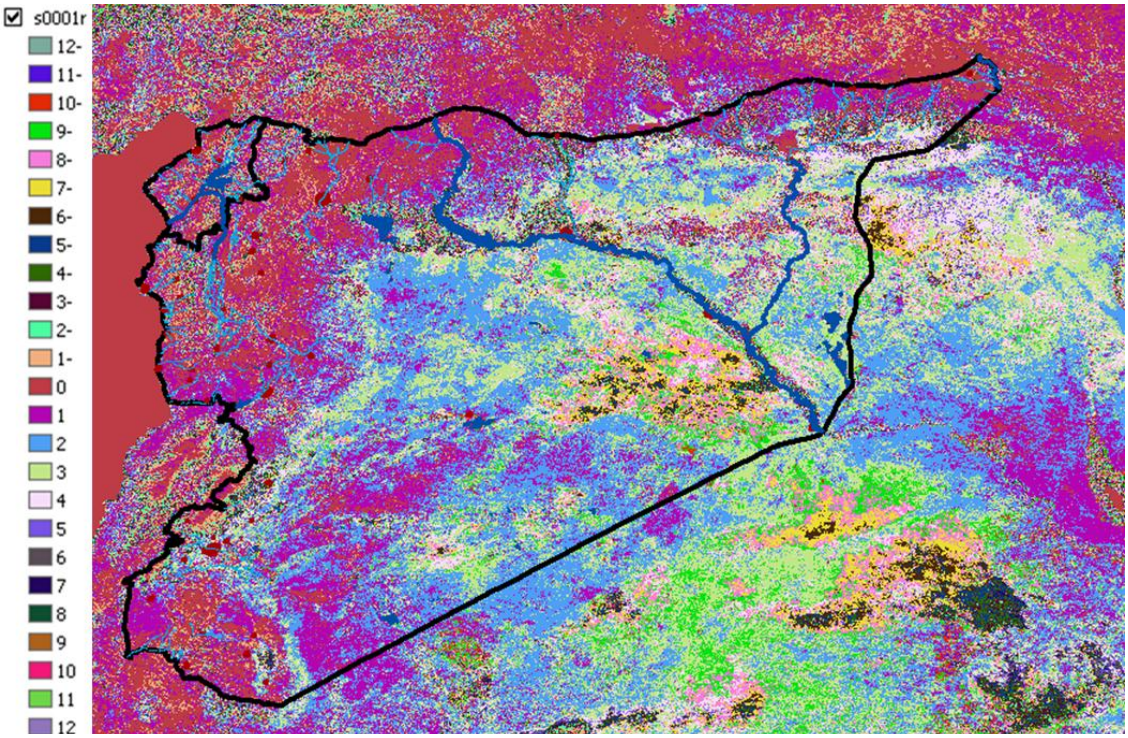


Figure 3.21. Annual Deviation from the Average Phase in the Studied Years.

The obtaining significant variability classes only the shift of 5 to 6 months from average could be considered, as crop calendar for vegetation and natural vegetation in rangelands showing that in many years the crop cycle is not completed and NDVI reached its maximum in January instead of the normal months in April, May and sometimes early June.

The deviation from average were calculated for all years and grouped to 4 classes as follows:

No variability : If the positive and negative values were calculated from (0 - 1 month).
Low variability : If the positive and negative values of (2 month).
Moderate variability: if the positive and negative values of (3 - 4 months).
High variability : If positive and negative values of (5 -6).

h. Finally, the Agriculture drought Hazard ADH map for the studied area was created by crossing between the agriculture drought "Intensity", "Variability", "frequency" and "Consecutive" maps in order.

The historical drought data of the studied area is presented in (table), after (WFP 2011)[178]..

[178] WFP 2011. Seasonal and Hazards Calendar Emergency Preparedness and Response Branch

Table 3.2. Historical Drought Hazard in Studied Area.

Countries	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec.
Algeria,	2000	2008										
Egypt,												
Iran				1999	2008	2000	2001					
Iraq,												
Occupied PalestinianTerritories												
Syria												
Yemen												
DROUGHT In West AFRICA												
Regional Office, Dakar												
Benin,	1983 - 84											
Burkina Faso,				2001				2005			1980	1990, 1995
Cameroon,	1971				2005	2001						
Cape Verde,			1998			2002			2004, 2005			
Central African Republic,												
Chad,				2001			2010	2010	2010			2009, 1993
Cote d'Ivoire,		2007	2007	2007								
GAMBIA												
Ghana,												
Guinea,							2001--02					
Guinea-Bissau,					2002, 2006							
Liberia,												
Mali,	1980		1991				2005, 2010	2009, 2006				
Mauritania,				1997	1980	2001	2005	2002				
Niger,				2001		1980	2002	2005	2009			
Sao Tome and Principe,												
Senegal,						2008		2002	2002			
Sierra Leone,												
Togo	1989, 1971											
Burundi,	2005, 2001			2008						1999	2000	2008
Sudan	dry spell								2009	1991		1996

Table 3.2. Cont'D

Countries	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec.
South Sudan	2001		2000	1983	1998				2009	1991		1996
Djibouti,	2010			2005	2007	2007	2008	1999				
Eritrea,			2000		2001					2004, 1999	2002	
Ethiopia,	2000	2006	2001	1999, 1997	2009	2002	2003	2008	2009			
Kenya,	2000	2006	1997	2001		2009	2009	2002	2002			
Lesotho,	2004		2007	2002		2007	2007					
Madagascar,			2007 south	1988	1988	2008, 2000	2009 south				2002/2003	2006
Malawi,	2005	2002, 1990	2004	1992						2007		
Mozambique,	2009, 03,01	2004	2002, 1991	2002, 1991				2007				2005
Namibia,					2007	2007	2002					
Republic of Congo,												
Rwanda,			2006, 2003								1999	2001, 1996
Somalia,	2000	2006	2004	2009	2008				2009			2001
Swaziland,		2004									1990	
Tanzania,			2006	2009				2003		2004	2006	
Tanzania,												
Tanzania,												
Uganda,	2000				2001		2009	2009	2009			
Zambia,		2001	2002	2005				1995				
Zimbabwe	2007	2001	2002	2005, 1991	2008					1982	1998	2004

1.1.3. Calibrating the ADH map using SPEI and NDVI-Precipitation Relationship.

For the purpose of calibrating the obtained ADH map, special studies were done.
The first study focused on the NDVI relationship to rainfall for different locations under rain-fed agriculture, rangelands and forestry areas. Such study would lead to better understanding environmental constraints on vegetation growth. The relationship can also help to establish the climatological limits in which NDVI is a useful indicator of vegetation growth (Nicholson et al 1990) [179], accordingly the NDVI and rainfall relationship were studied. The literature shows that NDVI values are highly correlated with multi-month rainfall as rainfall effects on Vegetation in cumulative. The results found from literatures are unchanging because of the different spatial and temporal aggregation, e.g. Nicholson et al (1990) ' found the best correlation of NDVI with rainfall for the concurrent plus two antecedent months at most representative stations, while Propastin (2007)[180] obtained the highest correlation between NDVI and precipitation average by whole study area by imposing time lag of approximately 2-3 10- day. Not only temporally, but also there is a good spatial agreement between NDVI and rainfall (Nicholson, et al. 1990), as the spatial distribution of the vegetation cover is strongly related to climatic conditions (Richard et al.,1998)[181]. The correlation coefficients of NDVI-rainfall exhibit a clear structure in terms of spatial distribution in semi-arid area of Great Plain, USA (Wang et al., 2003[182]) and China (Liu et al., 2010[183]). Further, it was reported that change in NDVI values can be affected by the amount and timing of rainfall, (Schultz,et al., 1995)[184]. Nicholson et al (1990) demonstrates that a linear relationship between NDVI and rainfall as long as the rainfall does not exceed approximately 500 mm/year or 50-100 mm/month, above these limits a "saturation" response occurs and NDVI increases the amount of rainfall only very slowly.

The second study selected a metrological indicator for monitoring long term drought for the purpose of calibrating the obtained ADH map. In Global and Regional levels Standardized precipitation index (SPI) and Palmer drought severity index (PDSI) played and still playing a major role in drought monitoring. The main strength of Palmer Drought Severity Index (PDSI) that it considers both water supply (precipitation) and demand (potential Evapo-transpiration) but its weakness that it does not work well over mountainous and snow covered areas; may require re-normalization. At the meantime the main strength of Standardized Precipitation Index (SPI) that it can be computed for different time scales; symmetric for both dry and wet spells; relates to

[179] Nicholson S.E, Davenport, L.L & Malo, A.R 1990, A comparison of the vegetation response to rainfall in the Sahel and East Africa, using normalized difference vegetation index from NOAA, AVHRR Climatic Change, 17(2), 209-241

[180] Propastin, P, A, Kappas, M, Ersami, S.&Murastova, N.R (2007); remote sensing based study on intra-annual dynamics of vegetation and climate in dry lands of Kazakhstan. Basic and Applied Dry land Research 1(2), 138-154

[181] Richard Y, & Poccard,I (1998) A statistical study of NDVI sensitivity to seasonal and International rainfall variations in Southern Africa . International journal of Vegetation Science, 5(5), 703-714

[182] Wang, J.,rich,P.M., and Price, K.P. 2003 Temporal responses of NDVI to precipitation and temperate in the central Great Plains, USA. International journal of Remote Sensing 24(11), 2345-2364.

[183] Liu C.S, Shi, R H, Gao, W.,&Gao,Z,Q.2010. Application of MODIS time series data for drought assessment in the East China In W.Gao, T.J.Jackson & j.Wang (Eds.) remote sensing and modeling of Ecosystem for Sustainability Vii (Vol.7809);

[184] Schultz,P.A.,&Halpert, M.S (1995) Global analysis of the relationship among a vegetation index precipitation and land surface temperature. International Journal of Remote Sensing 16(15),2755-2777

probability but its weakness that it does requires long-term precipitation data; no consideration of evaporation.
Recently a new global drought dataset based on the Standardised Precipitation-Evapo-transpiration Index (SPEI) has been developed, which covers time scales from 1-48 months at a spatial resolution of 0.5°, and provides temporal coverage for the period 1901-2006. This dataset represents an improvement in spatial resolution and operative capability of previous gridded drought datasets based on the PDSI, and enables identification of various drought types. The Standardized Precipitation-Evapotranspiration Index (SPEI) is increasingly used, SPEI, fulfils the requirements of a drought index since its multi-scalar character enables it to be used by different scientific disciplines to detect, monitor and analyze droughts. Like the sc-PDSI and the SPI, the SPEI can measure drought severity according to its intensity and duration, and can identify the onset and end of drought episodes. The SPEI allows comparison of drought severity through time and space, since it can be calculated over a wide range of climates, as can the SPI. Moreover, Keyantash and Dracup (2002) indicated that drought indices must be statistically robust and easily calculated, and have a clear and comprehensible calculation procedure. All these requirements are met by the SPEI. However, a crucial advantage of the SPEI over other widely used drought indices that consider the effect of PET on drought severity is that its multi-scalar characteristics enable identification of different drought types and impacts in the context of global warming. The SPEI index is a standardised monthly climatic balance computed as the difference between the cummulative precipitation and the potential evapo-ranspiration.

The standardized precipitation evapo-transpiration index (SPEI) (Vicente-Serrano et al. 2010) , which takes into account both precipitation and ET demand of the atmosphere. For this index a simple water balance is calculated as the difference between monthly precipitation and the potential evapo-transpiration (PET). The difference series are then transformed to z-scores, as for the SPEI. This method is recommended when the required parameters to apply the Penman-Monteith equation are not available (Droogers & Allen 2002) . In addition, some experimental studies have showed similar PET estimations by means of the Penman-Monteith and Hargreaves methods in Spain (Martínez-Cob 2002 , López-Urrea et al. 2006 , Gavilán et al. 2008 , Vanderlinden et al. 2008 , López-Moreno et al. 2009). The SPEI can be calculated at the monthly scale with timeInterval = 1, or accumulated at more than one month with timeInterval > 1. Typical values are 1, 3, 6, 12 and 24 months. If the accumulated index is calculated, the starting date of the resulting SPEI series will be lagged a number of months equal to time Interval – 1.

The SPEI were calculated for 382 location covering areas of different ADH classes and for more than 30 years for the purpose of calibrating the ADH map and making sure that the map match the reality within the studied duration.

1.1.4. Step 3: Identifying Exposure to Agriculture Drought Hazard:

Elements of exposure to agriculture drought hazards might include long term records of vegetation and time series trend analysis (degradation, no change and improvement) , Land cover/land use, crop area, crop production, and population affected.

a. Vegetation Changes

There is a wealth of recent investigations on effects of global change, suggesting for instance that more than 50 % of natural ecosystems have been altered by superimposed human use, (Kareiva et al., 2007)[185]; biodiversity is declining at unprecedented rates (Pimm and Raven, 2000)[186]; and greenhouse gas levels are dramatically changing as a result of population growth and economic activities (Steffen et al., 2004)[187]. Since the interactions of people and the environment mostly play out at the land surface, land use change has become a major driver and indicator of environmental change (Lambin and Geist, 2006)[188]. Large areas of the Mediterranean are believed to be affected by land degradation processes that lead to desertification mainly emerging from conflicts between past and present land uses, or between economic and ecological priorities (Puigdefábregas and Mendizabal, 1998)[189].

Land degradation may then be conceived as a process in which disturbances have gone beyond the resilience of the land and have caused, at human timescales, an irreversible loss of the land's carrying capacity or biological production potential. It embraces all degradation processes which imply an irreversible loss of, or reduction in, potential productivity of the land in dry climates (Puigdefábregas, 1995)[190]. If the system is endowed with feedback mechanisms to reverse this condition, it can recover and return to the steady state. Otherwise it falls into an overexploitation loop that leads to further decline, thus constituting desertification (Brandt and Thornes, 1996[191]; Millenium Ecosystem Assessment, 2005[192]). A particularly important issue in assessing and monitoring desertification is to gain an overview about affected areas, and to connect the global dimension with regional and local processes. Remote sensing data are of considerable value in the context of monitoring environmental processes. With the history of operational earth observation sensors reaching back over three decades, they allow retrospective analysis of the state and development of ecosystems at different scales and with different spatial coverage. Remote sensing data adhere to the principles of repetitiveness, objectivity and consistency, which are prerequisites in the frame of monitoring and surveillance (Hill et al., 2004)[193].

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[185] Careiva, P., Watts, S., McDonald, R. and Boucher, T., 2007. Domesticated nature: Shaping landscapes and ecosystems for human welfare. Science, 316: 1866-1869.

[186] Pimm, S.L. and Raven, P., 2000. Biodiversity - extinction by numbers. Nature, 430: 843-845.

[187] Steffen, W. et al., 2004. Global Change and the Earth System. Global Change - The IGBP Series. Springer Verlag, Berlin Heidelberg New York, 336 pp.

[188] Lambin, E.F. and Geist, H.J., 2006. Land Use and Land Cover Change. Local Processes and Global Impacts. Global Change - The IGBP Series. Springer Verlag, Berlin, Heidelberg, New York, 222 pp.

[189] Puigdefábregas, J. and Mendizabal, T., 1998. Perspectives on desertification: western Mediterranean. Journal of Arid Environments, 39: 209-224.

[190] Puigdefábregas, J., 1995. Desertification: stress beyond resilience, exploring a unifying process structre. Ambio, 24(311-313).

[191] Brandt, C.J. and Thornes, J.B. (Editors), 1996. Mediterranean desertification and land use. Wiley & Sons, London

[192] Millenium Ecosystem Assessment, 2005. Ecosystems and human well-being: Desertification synthesis. World Resources Institute, Washington, D.C

[193] Hill, J., Hostert, P. and Röder, A., 2004. Long-term Observation of Mediterranean Ecosystems with Satellite Remote Sensing. In: S. Mazzoleni, G. di Pasquale, M. Mulligan, P. di Martino and F. Rego (Editors), Recent Dynamics of the Mediterranean Vegetation and Landscape. John Wiley & Sons Ltd., Chichester, pp. 33-43.

Consequently, 'ecosystem observatories' based on earth observation satellite data and additional information have frequently been suggested, with the goal of serving requirements of policy-making, planning and land management (Group of Earth Observation, 2005).

Time series generated from remotely sensed data are important for regional to global monitoring, estimating long-term trends, and analysis of variations due to droughts or other extreme events, Temporal vegetation patterns including phenological states, photosynthetic activity, or biomass estimations are an essential input for climate modeling. Since 1981 the NOAA–AVHRR instruments acquire data at one respective four kilometer resolution in five spectral bands. In particular, ten-day and monthly NOAA–AVHRR normalized difference vegetation index (NDVI) composites have been extensively used for phenological studies[194], monitoring land-surface variability[195], and land-cover mapping[196]. Since 1997, several high-temporal-resolution, near-polar orbiting systems have been launched, including SeaWiFS, SPOT VEGETATION, EOS-MODIS, or ENVISAT MERIS. The MODIS instruments onboard the Terra and Aqua platforms acquire data since. A unique concept of quality assurance and product validation, as well as high standards of radiometric, geometric, and atmospheric correction, allow for the generation of science quality time series[197].

In this study MODIES 1 km were used for time-series analysis of images from 2000 - 2011.In statistics, a time series is defined as a collection of observations made sequentially through time[198]. The time series calculations were carried out using the TimeStats software package[199], which was specifically developed for analyzing long-term hyper-temporal satellite data archives (Udelhoven, 2006)[200]. The trend model used in the TimeStats software package contain linear and nonliner analysis.

$$NDVI_t = \alpha + \beta_1 \cdot t + \left(\sum_{i=1}^{NoOfLags} \beta_i NDVI_{t-i} \right) + \left(\sum_{j=1}^{NoOfX} \sum_{k=1}^{NoOfLags} \beta_{jk} X_{jk} \right) + \left(\sum_{m=1}^{NoOfHarm} a_m \cos 2\pi \frac{1}{P_m} \cdot t + b_m \sin 2\pi \frac{1}{P_m} \cdot t \right) + \varepsilon$$

Where

Constant	linear trend	stochastic component	external variables	Periodic components (cycles, long-periodical trends	white-noise

[194] de Beur K. M. s and G. M. Henebry, 2004 "Land surface phenology, climatic variation, and institutional change: Analyzing agricultural land cover change in Kazakhstan," *Remote Sens. Environ.*, vol. 89, no. 4, pp. 497–509.

[195] Anyamba A., C. J. Tucker, and R. Mahoney, 2002 . "From El Niño to La Niña: Vegetation response patterns over east and southern Africa during the 1997–2000 period," *J. Clim.*, vol. 15, no. 21, pp. 3096–3103.

[196] Hansen M. and R. S. DeFries, 2004. "Detecting long-term global forest change using continuous fields of tree-cover maps from 8 km Advanced VeryHigh Resolution Radiometer (AVHRR) data for the years 1982–99,"*Ecosystems*, vol. 7, no. 7, pp. 695–716.

[197] Justice C. O., J. R. G. Townshend, E. F. Vermote, E. Masuoka, R. E.Wolfe, N. Z. El Saleous, D. P. Roy, and J. T. Morisette, 2002. "An overview of MODIS land data processing and product status," *Remote Sens. Environ.*, vol. 83, no. 1, pp. 3–15.

[198] Chatfield C., 2003. *The Analysis of Time Series: An Introduction*, 5th ed. London, U.K.: Chapman & Hall,.

[199] TimeStats is a collection of established methods in time-series analysis (TSA) to retrieve different sources of variability in spatial-temporal databases on a pixel-by-pixel basis.

[200] Udelhoven, T., 2006. TimeStats: a software tool for analyzing spatial-temporal raster data archives: In: 1st conference on Remote Sensing and Geoinformation. In: A. Röder and J. Hill (Editors), Proceedings of the 1st International Conference on "Remote Sensing and Geoinformation Processing in the Assessment and Monitoring of Land Degradation and Desertification. In support of the UN Convention to Combat Desertification, Trier, Germany, pp. 247-255

b. Land Cover/ Land Use

The Global Land cover (LC) map, after Arino et al (2008[201]) and ESA (2009)[202], figure (52) were used in this study. This Global Land cover map considered the most detailed maps ever of Earth's land surface have been created with the help of ESA's EnviSat environmental satellite. This global map has a resolution 10 times sharper than any of its predecessors. The global portrait is based on 40 terabytes of imagery – equivalent to the content of 40 million books – acquired by Envisat's Medium Resolution Imaging Spectrometer (MERIS). ESA made a continuous effort to ensure the acquisitions and the production of the MERIS 300 m Full Resolution Full Swath (FRS) products for the period from 1 December 2004 to 30 June 2006. There are 22 different land cover types shown in the map, including croplands, wetlands, forests, artificial surfaces, water bodies and permanent snow and ice. For maximum user benefit, the map's thematic legend is compatible with the UN Land Cover Classification System (LCCS), figure 3.22).

Land cover/Land use of the studied region is likely to be exposed to both ADH and LD. The crossing between both ADH map and LC within each studied trans-boundary river's basin and also between the LD map and LC map, allowed for better understanding for the type (s) of land use that is more vulnerable to ADH and/or LD.

[201] Arino O. , P. Bicheron, F. Achard, J. Latham, R. Witt, and J.-Louis Weber 2008 GLOBCOVER The most detailed portrait of EarthEuropean Space Agency | Bulletin 136 |

[202] http://www.esa.int/images/globcover_poster2010_H.jpg

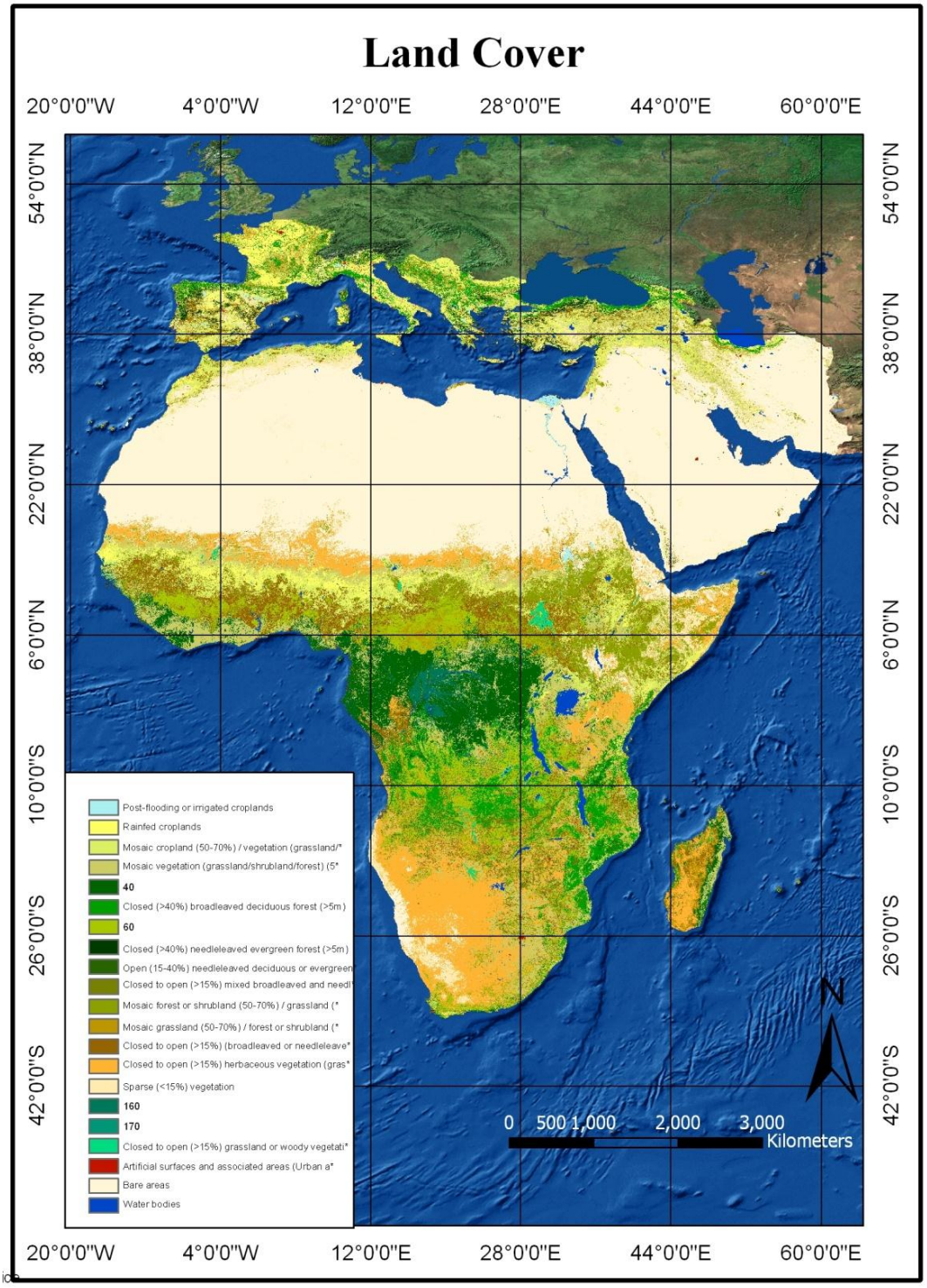


Figure 3.22. Global Land Cover Map of the Studied Area, ESA 2009.

c. Population density and Affected Population

The main source for the density map is http://sedac.ciesin.columbia.edu/gpw/, the map has been rectified and digitized for analysis, (figure

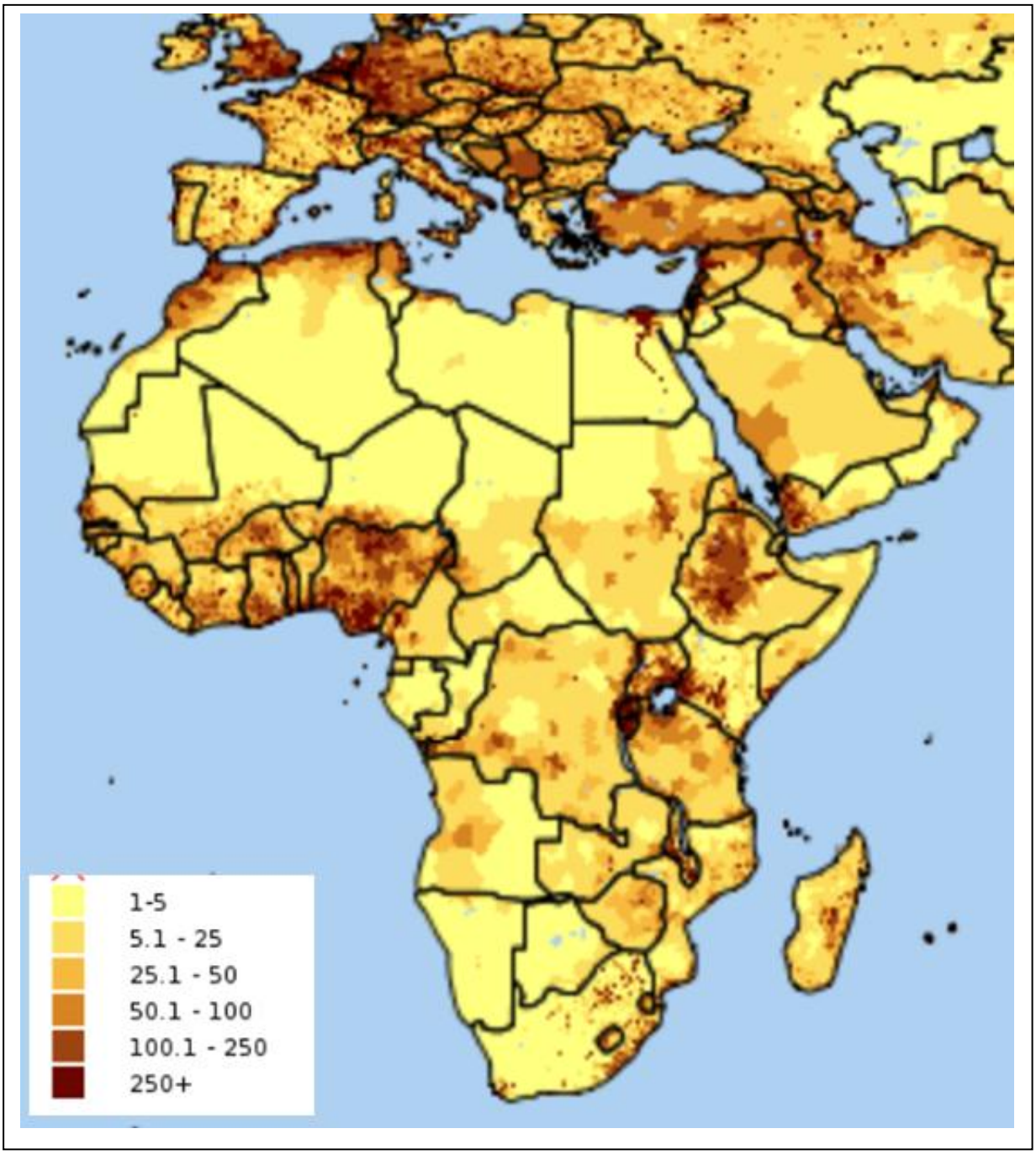


Figure 3.23. Population Density Map

Population Density map of the studied region are likely to be exposed to both ADH and LD. The crossing between both ADH map and PD within each studied trans-boundary river's basin and also between the LD map and PD map, allowed for better understanding for the affected population that are more vulnerable to ADH and/or LD.

1.1.4. Step 4: Vulnerability to Agriculture Drought Hazard:

Vulnerability describes the functional relationship between differing hazard intensities and the corresponding impact on the assets-at-risk. Vulnerable areas could be identified through the identification of the most affected zones of rainfall, areas under, rain-fed agriculture and / or rangelands, beside land degradation and population density.

The produced maps for the affected areas and the crossing between the vulnerable areas of the (rain-fed agriculture, rangelands, land degradation and affected population), maps were then descripeddescription of major factors playing the role will lead to clear identification for vulnerable areas and type of drought vulnerability

1.1.5. Step 5: Risk analysis to Agriculture Drought Hazard:

Risk analysis helps in ascertaining the metrics that quantify losses (in physical and financial terms) and attribute probabilities of their occurrence. Drought analysis in semi-arid countries is especially important, because they tend to induce large economic losses (Morales et al., 2000[203]; Iglesias et al., 2003[204]), mostly associated to the strong dependence of the regional economy and society on agriculture production (Vicente-Serrano, 2006[205]). In this study we will try to study the economic and social impacts after grouping the most affected countries, the study will focus on reduction in crop area, reduction in yield, reduction in total production, affected population and shortfall per unit population.

- **Crop Production**

Droughts affects both rain-fed and irrigated agricultural production, reducing economic output and creating social stress. The economic consequences of droughts begin at the farm level, reaching the macro level along the production chain value.

The FAO statistic crop production data , http://faostat.fao.org/site/339/default.aspx for the main crops of the studied area were studied and analyzed for understanding the impact of ADH on the stability of crop production. The main studied crops are Wheat, Barley, Cassava, Sorghum, Maize, Potatoes, Sweet Potatoes, Millet and Green Maize.

- **Socio-Economy**

For studding the impact of ADH on socio-economy the FAOSTAT/ country profile data were used, the main indicators used to compare the changes during the last decade and the changes during the last five years were:

i. ECONOMICAL INDICATOR coded as Ec
ii. POPULATION coded as Po

[203] Morales, A., Olcina, J., and Rico, A. M.: Diferentes persepciones de la sequ´ıa en Espa˜na: adaptaci´on, catastrofismo e intentos decorrecci´on, Investigaciones Geogr´aficas, 23, 5–46, 2000.
[204] Iglesias E., Garrido A. and Gómez-Ramos A., 2003. Evaluation of drought management in irrigated areas. In: Agricultural Economics, 29, p. 211-229.
[205] Vicente-Serrano SM (2006) Evaluating the impact of drought using remote sensing in a Mediterranean, semi-arid region. Nat Hazards 40: 173–208

iii. LAND USE coded as Lu
iv. WATER AVAILABILITY coded as Wa

- **ECONOMICAL INDICATOR**

EcA. GDP in Million US$.
EcB. GDP Growth rate.
EcC. NGI US$.
EcD. Agriculture Share In GDP %.
EcE. Labor Force% in Agriculture.
EcF. Unemployment Rate:%.
EcG. Below Poverty Line %.
EcH. Agriculture, value added per agricultural worker (USD) 2009-1999.
EcI. Evaluation of the Value of Total Agriculture Production and Food Production Value (millions of 2004-2006 in ($).
EcJ Change in crop production value per ha %

- **POPULATION**

PoA. Mean Population Density person/Km^2
PoB. People in working age (15-64) years %.
PoC. Population growth rate.
PoD. Net migration rate: for each 1000 person.
PoE. Females % of Labour force in Agriculture- 2011.
PoF. Average Agriculture population Change 2011 - 2001%.

- **LAND USE**

LuA. Arable Area % from Total
LuB. Change in Arable Areas 1999 - 2009
LuC. Permanent Crops Area % from Total
LuD. Change in Permanent Crops Areas 1999 - 2009
LuE. Forest Area % from Total
LuF. Change in Forest Areas 1999 - 2009

- **WATER AVAILABILITY**

WaA. Total Renewable Water Resources cu km
WaB. Fresh water Withdrawal Total Cu km/y
WaC. Fresh water Withdrawal agricultural %
WaD. Fresh water Withdrawal per Capita Cu km/y

i. ECONOMICAL INDICATOR

EcA. GDP in Million US$.

Classes	Description
1	GDP more than 1000000 Million US$
2	250000 - 1000000
3	100 000– 250 000 Million US$
4	50000 - 100000 Million US$
5	25000 - 50000 Million US$
6	10000 – 25000 Million US$
7	less than 10000

EcB. GDP Growth rate.

Classes	Description
1	>6
2	5 - 6
3	4 - 5
4	3 - 4
5	2 - 4
6	1 - 2
7	< 1

EcC. NGI US$.

Classes	Description
1	>40000
2	25000 – 40000
3	10000 – 25000
4	5000 – 10000
5	2500 - 5000
6	1000 –2 500
7	< 1000

EcD. Agriculture Share In GDP %.

Classes	**Description**
1	<5 %
2	5 – 10%
3	10 – 20%
4	20 – 30%
5	30– 40 %
6	40 – 50
7	➢ 50

EcE. Labor Force% in Agriculture.

Classes	Description
1	>5 %
2	5 – 10%
3	10 – 15%
4	15 – 25%
5	25– 35 %
6	35 – 50
7	➢ 50

EcF. Unemployment Rate:%.

Classes	Description
1	<5 %
2	5 – 10%
3	10 – 15%
4	15 – 20%
5	20– 25 %
6	25 – 30
7	➢ 30

EcG. Below Poverty Line %.

Classes	Description
1	>5 %
2	5 – 10%
3	10 – 15%
4	15 – 25%
5	25– 35 %
6	35 – 50
7	➢ 50

EcH. Agriculture, value added per agricultural worker (USD) 2009-1999.

Classes	**Description**
1	**>5000**
2	**3000 – 5000**
3	**1500 – 3000**
4	**750 – 1500**
5	**500 - 750**
6	**200 - 500**
7	**< 200**

EcI. Evaluation of the Value of Total Agriculture Production and Food Production Value (millions of 2004-2006 in ($).

Classes	Description
1	>100%
2	50 – 100%
3	25 – 50 %
4	0 – 25%
5	No change
6	0 - (25%)
7	< (25)

EcJ Change in crop production value per ha %

Classes	Description
1	>50%
2	25 – 50%
3	0 – 25 %
4	No change
5	(1) - (25%)
6	(25) - (50)
7	< (50)

ii. POPULATION

PoA. Mean Population Density person/Km2

Classes	Description
1	>50
2	50 - 100
3	100 -500
4	250 - 500
5	500 - 750
6	750 – 1000
7	less than 1000

PoB. People in working age (15-64) years %.

Classes	Description
1	>60
2	60 - 50
3	50 - 40
4	30 - 40
5	20 - 30
6	10 -20
7	less than 10

PoC. Population growth rate.

Classes	Description
1	< 0.5
2	0.5 - 1
3	1 – 1.5
4	1.5 - 2
5	2 – 2.5
6	2.5 - 3
7	➢ 3

PoD. Net migration rate: for each 1000 person.

Classes	Description
1	➢ 0
2	0 – (2)
3	(2) – (4)
4	(4) – (6)
5	(6) – (8)
6	(8) – (10)
7	➢ (10)

PoE. Females % of Labour force in Agriculture- 2011.

Classes	Description
1	Less than 10
2	10- 20
3	20 - 30
4	30 - 40
5	40 – 50
6	50 -60 %
7	More than 60

PoF. Average Agriculture population Change 2011 - 2001%.

Classes	Description
1	More than 10
2	5 - 10
3	0 - 5
4	No change
5	(0) – (5)
6	(5) – (10)
7	Less than 10

iii. LAND USE

LuA. Arable Area % from Total

Classes	Description
1	**>25%**
2	**20 – 25%**
3	**15 – 20 %**
4	**10 - 15**
5	**5 - 10**
6	**2 - 5**
7	➢ **Less than 2**

LuB. Change in Arable Areas 1999 - 2009

Classes	Description
1	**More than 50**
2	**25 – 50**
3	**0 - 25**
4	**No change**
5	**0 - (25)**
6	**(25) – (50)**
7	**Less than (50)**

LuC. Permanent Crops Area % from Total

Classes	Description
1	**>25%**
2	**20 – 25%**
3	**15 – 20 %**
4	**10 - 15**
5	**5 - 10**
6	**2 - 5**
7	**Less than 2**

LuD. Change in Permanent Crops Areas 1999 - 2009

Classes	Description
1	**More than 50**
2	**25 – 50**
3	**0 - 25**
4	**No change**
5	**0 - (25)**
6	**(25) – (50)**
7	**Less than (50)**

LuE. Forest Area % from Total

Classes	Description
1	**>25%**
2	**20 – 25%**
3	**15 – 20 %**
4	**10 - 15**
5	**5 - 10**
6	**2 - 5**
7	➢ **Less than 2**

LuF. Change in Forest Areas 1999 - 2009

Classes	Description
1	**More than 50**
2	**25 – 50**
3	**0 - 25**
4	**No change**
5	**0 - (25)**
6	**(25) – (50)**
7	**Less than (50)**

iv. WATER AVAILABILITY

WaA. Total Renewable Water Resources cu km

1	More than 500
2	200- 500
3	100 - 200
4	75 - 100
5	50 - 75
6	25 - 50
7	Less than 25
1	More than 500

WaB. Fresh water Withdrawal Total Cu km/y

Classes	Description
1	More than 60
2	45 - 60
3	35 - 45
4	25 - 35
5	10 - 25
6	5 - 10
7	Less than 5

WaC. Fresh water Withdrawal agricultural %

Classes	Description
1	Less than 50
2	50 - 65
3	65 - 70
4	70 - 75
5	75 - 80
6	80 - 85
7	More than 85

WaD. Fresh water Withdrawal per Capita Cu km/y

Classes	Description
1	More than 1200
2	800 - 1200
3	600 - 800
4	500 - 600
5	400 - 500
6	200 - 400
7	Less than 200

Risk analysis was carried out using the FAOSTAT data related to Crop production for the years 1999-2011. The change in crop production from the average were used to study economic crop losses.

4.5. Vulnerability to Agriculture Drought Hazard

Vulnerability refers to the propensity of exposed elements to suffer adverse effects when impacted by hazard events (UNDRO, 1980[206]; Cardona, 1986[207], 1990, 1993[208]; Liverman, 1990[209]; Maskrey, 1993[210]; Cannon, 1994[211], 2006[212]; Blaikie et al., 1996[213]; Weichselgartner, 2001; Bogardi and Birkmann, 2004[214]; UNISDR, 2004, 2009[215]; Birkmann, 2006[216]; Janssen et al., 2006[217]; Thywissen, 2006[218]). Vulnerability can be seen as situation-specific, interacting with a hazard event to generate risk (Lavell, 2003[219]; Cannon, 2006; Cutter et al., 2008[220]). In fact, future vulnerability is embedded in the present conditions of the communities that may be exposed in the future (Patt et al., 2005[221], 2009[222]); that is, new hazards in areas not previously

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subject to them will reveal, not necessarily create, underlying vulnerability factors (Alwang et al., 2001[223]; Cardona et al., 2003[224]; Lopez-Calva and Ortiz, 2008[225]; UNISDR, 2009[226]).

Many approaches **for assessing vulnerability rely on an assessment of capacity**. In simple terms, coping ('coping' or 'adaptive') capacity refers to the "*ability of people, organizations, and systems, using available skills and resources, to face and manage adverse conditions, emergencies, or disasters*" (UNISDR, 2009), in another way a system can survive the impacts of an extreme event. On the whole, the literature describes the relationship between vulnerability and capacity in two ways, which are not mutually exclusive (Bohle, 2001[227]; IPCC, 2001; Moss et al., 2001[228]; Yodmani, 2001[229]; Downing and Patwardhan, 2004[230]; Brooks et al., 2005[231]; Smit and Wandel, 2006[232]; Gaillard, 2010[233]):

1) Vulnerability is, among other things, the result of a **lack of capacity**.
2) Vulnerability is the opposite of capacity, so that **increasing capacity means reducing vulnerability, and high vulnerability means low capacity.**

Our assessment for identifying vulnerability to ADH will rely on the level of capacity within a country, in general term, Africa countries considered developing countries and countries in transition, are recognized as facing the greater impacts and having the most vulnerable populations, in the greatest number, who are least able to easily adapt to changes in inter alia temperature, water resources, agricultural production, human health, and biodiversity (IPCC, 2001[234]; McCarthy et al., 2001[235]; Beg et al., 2002[236]), the pathway from capacity to vulnerability could be illustrated as in (figure 4.53).

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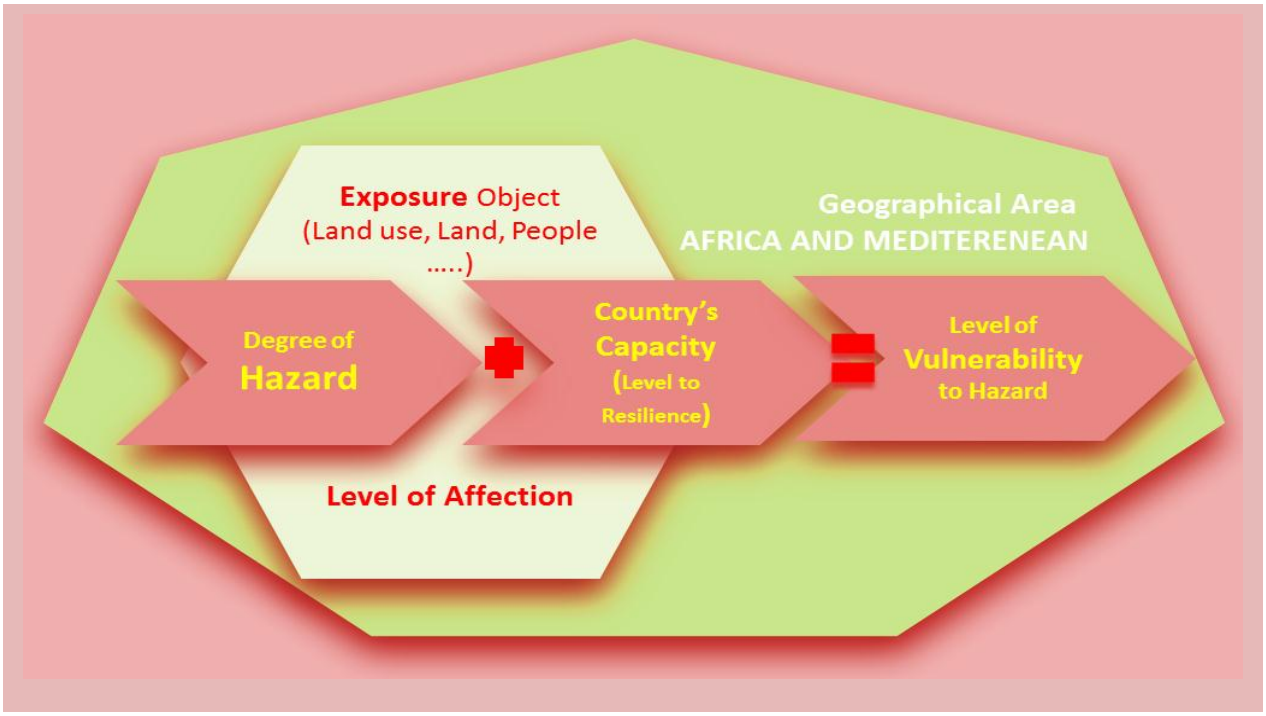


Figure 4.53. Path way from Capacity to Vulnerability

As recognized by the 2009 and 2011 Global Assessment Reports on Disaster Risk Reduction (UNISDR, 2009, 2011[237]), the poorer communities often entirely depend on ecosystem services and functions to meet their livelihood needs, Also same meaning was explained as well as by the Millennium Ecosystem Assessment (MEA, 2005[238]).
In Weak communities -Low Capacity like most Africa rural Communities- people who depend upon growing their own food are most affected by droughts of this kind because they wipe out their crops and they are left with nothing to eat. Instead of depending on aid, which is not provided, people must either migrate to other parts of the country or sustain themselves by eating 'inferior food'.

From another angle for looking to the subject, we could see degradation of ecosystem services and functions strongly contribute to an exacerbation of both the natural hazard context and the vulnerability of people. The low capacity to resilience, could contribute to the decrease of level

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or degree of coping and adaptive capacities in terms of reduced alternatives for livelihoods and income-generating activities due to the degradation of natural resources.

Additionally, in rural communities affected by droughts a worsening of environmental services and functions might also increase the costs of accessing these services, availability of water resources, deterioration in water quality, aggravation of agriculture uncertainty, and acceleration of land degradation process in severity and scale that likely lead to, reduction of land productivity, loss of crops.

Accordingly, The main steps chosen for assessing vulnerability could be ordered as follows:

Step 1: Assessing The Main Economical Capacity Characteristics of the Studied Countries.
Step 2: Assessing The Main Population Capacity Characteristics of the Studied Countries.
Step 3: Assessing The Main Land Use and Water Availability Capacities Characteristics of the Studied Countries.
Step 4: Assessing the Main Water Availability and Water Use Capacities Characteristics of The Studied Countries.
Step 5: Ranking Countries According to Their Overall Resilience Capacities.
Step 6: Identifying the most ADH Vulnerable Countries and describe their Degree of Affection by ADH in Rainfed Agriculture, Rangelands, Forestry, Land Degradation.

Step 1: Assessing The Main Economical Capacity Characteristics of the Studied Countries.

African economies have made relatively low levels of investment in infrastructure and directly productive capital goods-and hence continue to rely heavily on natural capital (natural resources). This natural capital is at risk because poverty and high population growth often induce land degradation and deforestation-which in turn lead to growing food insecurity and loss of biodiversity. This pattern contributes to migration into rural areas that often are less suitable for agricultural expansion and to urban areas with inappropriate physical, social, and economic infrastructure.

Countries main economical capacity characteristics were selected for the study are:

EcA. GDP in Million US$.
EcB. GDP Growth rate.
EcC. NGI US$.
EcD. Agriculture Share In GDP %.
EcE. Labor Force% in Agriculture.
EcF. Unemployment Rate:%.
EcG. Below Poverty Line %.
EcH. Agriculture, value added per agricultural worker (USD) 2009-1999.
EcI. Evaluation of the Value of Total Agriculture Production and Food Production Value (millions of 2004-2006 in ($).
EcJ Change in crop production value per ha %

The value for each character were studied and presented as in table (4.10), the evaluation of the main Economical Capacity Characteristics for Studied Countries are shown in table (4.11), countries have been ranked from the lowest to highest capacity, (figure 4.54)

Table 4.10. Main Economical Capacity Characteristics for Studied Countries

Country	EcA	EcB	EcC	EcD	EcE	EcF	EcG	EcH	EcI	EcJ
Algeria	190700	1.16	7,400	12	14	10	23	2100	495	43
Angola	100900	3.4	6,000	9.6	85	25	40.5	300	515	59.2
Bahrain	31500	1.8	27,900	0.4	1	15			3851	35.6
Benin	14870	3.1	1,500	36	58		37.4			
Botswana	30090	4.6	16,200	2.1	40	7.5	30.3	600		
Burkina Faso	22320	5.6	1,500	34.7	90	77	46.4	190	240	-23.8
Burundi	5250	4.2	600	31	93.6		68		487	-38.2
Cameroon	47860	4.1	2,300	19.5	70	30	48	790	501	34.5
Central Africa	3688	3.1	800	53.1	61.3	8	28	400	241	14.9
Chad	19790	1.6	1,900	52.7	80		80		237	6.8
Comoros	580	4.5	800	45	71	25	45	450	431	-1.4
Congo	15670	4.5	4,600	4.2	39		50			
Cote D Lvoire	36530	-4.7	1,600	30	68	45	42	950	722	-2.5
Djibouti	2,163	4.5	2700	3	28.5	59	42	80	4646	-69.4
DR Of The Congo	25590	6.9	400	37.5	68	71	25	170	443	-3.4

Table 4.10. Cont'd

Country	EcA	EcB	EcC	EcD	EcE	EcF	EcG	EcH	EcI	EcJ
Egypt	525600	1.8	6,600	14.5	32	12.2	20	3000	4687	23.7
Eq Guinea	26480	7.1	19,600	3.6	36.7	22.3				
Eritrea	4089	8.7	700	11	80		50	65	122	-82
Ethiopia	96090	7.5	1,100	41	85		29	220	427	20.6
France	2246000	1.7	35,600	1.8	3.8	9.3	6.2	59000	1170	-3.5
Gabon	24890	5.8	16,400	5.2	60	21	4.8	1900	456	21.7
Gambia	35410	3.3	2,000	26.7	75		34	275	314	-24.8
Gaza Strip	12790	7	2,900	3.7	5.1	40	38			
West Bank					16.1	23.5	18.3			18.3
Ghana	75900	13.6	3,100	28.3	56	11	28.5		832	-19.7
Greece	298100	-6.9	26,600	**3.3**	12.4	17.3	20	11000	1630	15.7
Iran	1003000	2	13,200	10.4	25	15.3	18.7	3000	948	5.9
Iraq	129300		3,900	9.7	21.6	15	25		404	5.7
Jordan	37370	2.5	6,000	4.5	2.7	12.3	14.2	3000	2384	
Israel	242900	4.7	31,400	**2.5**	2	5.6	23.6		1876	46.6
Italy	1871000	0.4	30,900	2	3.9	8.4				6.4
Kenya	72340	5	1,800	19	75	40	50	330	519	
Kuwait	155500	8.2	42,200	0.3		2.2				-12
Lebanon	61310	1.5	15,700	4.6	13		28	40000	3218	-49.1
Lesotho	3853	4.2	2000	7.5	86	45	49	200	112	-9.7
Liberia	1792	6.4	500	76.9	70	85	80		538	2.6
Libya	37970		14,100	3.2	17	30			347	27.9
Madagascar	20660	0.5	900	28.3			50	190	760	
Malawi	14080	5.5	900	30.3	90		53			15.7
Mali	18100	2.7	1,100	38.8	**80**	30	36.1	550	356	15.9
Mauritania	7184	3.6	2,200	17.8	50	30	40	400	176	
Mauritius	11310	4.1	15,100	4.5	9	7.8	8			42.1
Morocco	164700	4.3	5,100	16.6	44.6	8.9	15	3400	672	2
Mozambique	24190	7.1	1,100	31.5	81	21	54	230	344	37.7
Namibia	15940	3.6	7,500	7.2	16.3	51.2	55.8	1700	146	31.6
Niger	11780	2.3	800	39	90		63		95	-3.6
Nigeria	418700	7.2	2,600	35.4	70	21	70		742	-83.7
Oman	82820	5.5	26,900	1.5		15			1630	7.1
Portugal	252200	-1.5	23,700	2.5	11.7	12.7	18	7000	1138	17.2
Qatar	184300	18.8	104,300	0.1		0.4			1737	20.2
Rwanda	13860	8.8	1,400	33	90		60		1095	
Sao Tome And Principe	384	4.9	2,200	15			54			27.3
Saudi Arabia	691500	6.8	24,500	2	6.7	10.9		21000	490	1
Senegal	25470	2.6	1,900	15	77.5	48	54	250	303	-10
Sierra Leane	5158	5.3	900	51.5			70.2		468	
South Africa	562200	3.1	11,100	2.5	9	25	50			
Spain	1432000	0.7	31,000	**3.2**	4.2	21.7	19.8	22000	1260	
Sudan	90190	-3.9	2,800	25	80	18.7	40	998	178	18.1

Somalia	5896	2.6	600	60.2	71					
Swaziland	6313	0.3	5,400	8.2	70	40	69			25.4
Syria	107600	-2	5,100	16.9	17	12.3	12	4800	808	32.9
Tanzania	64710	6.7	1,500	27.8	80		36	280	462	25.5
Togo	6497	4.1	900	46	65		32		306	6.5
Tunisia	102300	-0.8	9,600	10.6	18.3	18	3.8	3700	540	21.1
Turkey	1087000	8.5	14,700	9.3	25.5	9.8	16.9	3500	1099	-111.5
Uae	262100	4.9	48,800	0.8	7	2.4	19.5	30000	1893	-7.6
Uganda	46960	6.7	1,300	22	82		35	200	541	
Yemen	58710	10.5	2,300	7.9	70	35	45			43.9
Zambia	22160	6.6	1600	21.4	85	14	64	220	298	34.9
Zimbabwe	6206	9.3	500	20.4	66	95	68	140	195	-73.8

Table 4.11Evaluating Economic Indicator

Country	EcA	EcB	EcC	EcD	EcE	EcF	EcG	EcH	EcI	EcJ	EC ALL
Cote D Lvoire	5	7	5	5	7	7	6	4	4	5	7
Somalia	7	4	7	7	7						6
Chad	7	5	6	7	7		7		6	3	6
Swaziland	7	7	5	2	7	7	7				6
Zimbabwe	7	1	7	4	7	7	7	7	6	7	6
Liberia	7	1	7	7	7	7	7		4	5	6
Mauritania	7	3	6	3	7	6	6	5	6	3	6
Burundi	7	2	7	5	7		7		5	6	6
Eritrea	7	1	7	3	7		6	7	6	7	6
Mozambique	6	1	6	5	7	5	7	6	5	3	6
Niger	6	4	7	5	7		7		7	2	6
Burkina Faso	6	1	6	5	7	7	6	7	6	5	6
Comoros	7	2	7	6	7	5	6	6	5	5	6
Lesotho	7	2	6	2	7	7	6	7	6	6	6
Sierra Leane	7	1	7	7			7		5	5	6
DR Of The Congo	6	1	7	5	7	7	5	7	5	5	6
Malawi	6	1	7	5	7		7				6
Madagascar	6	7	7	4			6	7	4	2	5
Central Africa	7	3	7	7	7	2	5	6	6	3	5
Mali	6	4	6	5	**7**	6	6	5	5	3	5
Senegal	5	4	6	3	7	7	7	6	5	3	5
Sudan	4	7	5	4	7	5	6	4	6	5	5
Togo	7	2	7	6	7		5		5	2	5
Gambia	5	3	6	4	7		5	6	5	5	5
Congo	6	2	5	1	6	6	7	7			5
Sao Tome And Principe	7	2	6	3			7				5
Namibia	6	3	5	2	3	7	7	3	6	2	5
Djibouti	7	2	5	1	5	7	6	7	1	7	5
Uganda	5	1	6	4	7		5	6	4	5	5
Rwanda	6	1	6	5	7		7		3	3	5
Benin	6	3	6	5	7		6				5
Kenya	4	1	6	3	7	7	6	6	4	3	5
Zambia	6	1	6	4	7	3	7	6	5	2	5
Nigeria	2	1	5	5	7	6	7		4	5	5
Ethiopia	4	1	6	6	7		5	6	3	3	5
Iraq	3		5	2	4	15	4		5	3	5
Cameroon	5	2	6	3	7	6	6	4	4	2	5
Tanzania	4	1	6	3	7		6	6	5	2	4
Yemen	4	1	6	2	7	7	6			2	4
Angola	3	3	5	2	7	5	6	6	4	1	4
Gabon	6	1	3	2	7	5	1	3	5	3	4
Gaza Strip	6	1	5	1	2	7	6				4
Ghana	4	1	5	4	7	3	5		4	3	4
Botswana	5	2	4	1	6	2	5	6			4
Libya	5		4	1	3	6			5	3	4
Eq Guinea	5	1	4	1	7	5					4
West Bank	6	1	5	1	3	6	4				4

Table 4.11 Cont'd

Country	EcA	EcB	EcC	EcD	EcE	EcF	EcG	EcH	EcI	EcJ	EC ALL
Morocco	3	2	5	3	6	2	4	2	4	2	4
Algeria	3	6	5	3	3	2	4	3	5	2	4
Iran	1	4	3	3	4	4	4	2	4	3	4
Greece	5	7	3	**1**	3	4	4	1	2	5	4
Syria	3	7	5	3	3	3	3	2	4	2	4
Tunisia	3	7	5	3	3	4	1	2	4	3	4
South Africa	2	3	4	1	2	6	6				3
Lebanon	4	5	4	1	3		5	1	1	5	3
Egypt	2	5	5	3	5	3	4	2	1	2	3
Portugal	2	7	3	1	3	3	4	1	3	3	3
Spain	1	7	2	**1**	1	6	4	1	3	3	3
Oman	4	1	2	1		3			2	7	3
Jordan	5	4	5	1	1	3	3	2	2	2	3
Turkey	1	1	4	2	4	2	4	2	3	3	3
France	1	5	2	1	1	2	2	1	3	5	3
Bahrain	5	5	2	1	1	3			1	2	3
Italy	1	7	2	1	1	2					2
Uae	2	2	1	1	2	1	4	1	2	7	2
Israel	3	2	2	**1**	1	2	4		2	3	2
Saudi Arabia	2	1	3	1	2	3		1	5	2	2
Mauritius	6	2	4	1	2	2	2				2
Qatar	3	1	1	1		1			2	3	2
Kuwait	3	1	1	1		1					1

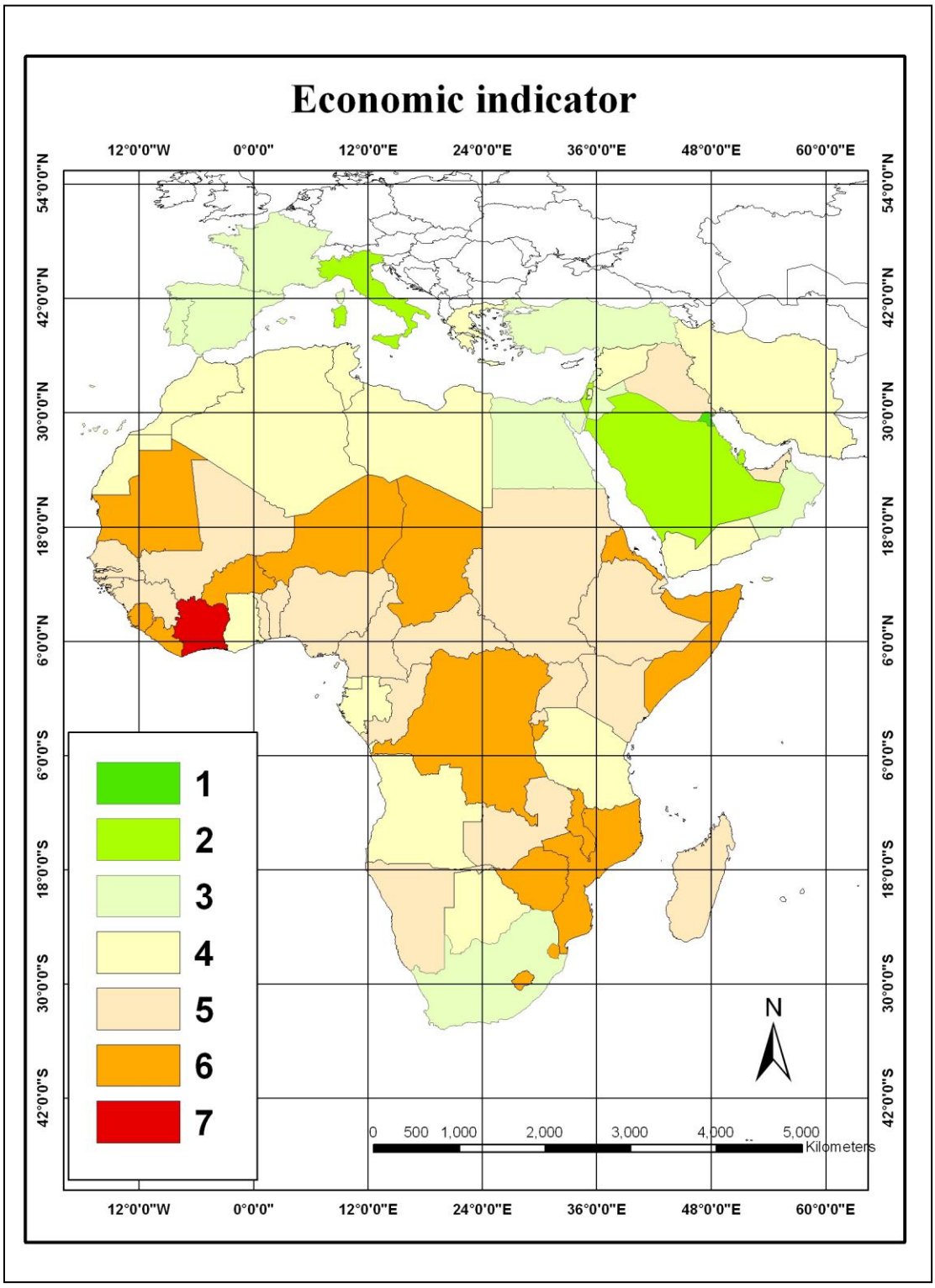


Figure 4.54. Evaluating Economic Indicator

Step 2: Assessing The Main Population Capacity Characteristics of the Studied Countries.

The process of rely heavily on natural capital contributes to population growth by creating an incentive for large families: Adding family labor becomes one way of coping with the increasing time costs of gathering fuel and water and clearing new land. The severity of this population-agriculture-environment nexus is compounded by low investment in human capital (human resource development), which often restricts individuals to continued reliance on unskilled labor and short-term exploitation of natural resources (the land) as the only feasible survival options.
Although Africa's youthful population represents future social capital, a great deal of investment in terms of education, training, and skills development will be required to ensure its full productivity in the next decade and beyond. Particular attention will need to be paid to capacity-building in information technology to better prepare African societies for efficient, sustainable management of the continent's fragile resources. In addition, the region's political structures, which determine decision making in resource allocation and consumption, will have to be stabilized.

PoA. Mean Population Density person/Km^2
PoB. People in working age (15-64) years %.
PoC. Population growth rate.
PoD. Net migration rate: for each 1000 person.
PoE. Females % of Labour force in Agriculture- 2011.
PoF. Average Agriculture population Change 2011 - 2001%.

The value for each character were studied and presented as in table (4.12), the evaluation of the main Population Capacity Characteristics for Studied Countries are shown in table (4.13), countries have been ranked from the lowest to highest capacity, (figure 4.55)

Table 4.12 Main Population Capacity Characteristics for Studied Countries

Country	PoA	PoB	PoC	PoD	PoE	PoF
Algeria	14.87	70.60	1.17	-0.27	52.7	-1.66
Angola	14.48	54.1	2.78	0.55	55	-1.87
Bahrian	1642.56	77	2.65	14.74	0	-0.28
Benin	85.23	52.6	2.87	0		
Botswana	3.61	62.2	1.48	4.75	0	
Burkina Faso	63.00	2.5	3.07	0	48.1	-0.99
Burundi	379.35	51.6	3.1	-0.18	56	-0.31
Cameroon	42.34	56.2	2.08	0	47.2	-1.71
central Africa	8.12	55.3	2.142	0	49.7	-0.23
Chad	8.55	51	1.98	-3.74	57.2	-0.58
Comoros					51.8	-0.09
Congo	12.77	51.7	2.849	-0.35	56.1	-0.92
Cote d lvoire	68.08	57.2	2.04	0	36	-1.29
Djibouti	33.38	61.7	2.26	4.5	46.4	-0.16
DR of the Congo	31.39	53	2.58	-0.47	48.7	-0.81
Egypt	83.57	62.8	1.92	-0.2	40.5	-0.12
Eq Guinea	24.46	54.4	2.6		1.04	19.57
Eritrea	51.76	54.3	2.42		43.5	-0.49
Ethiopia	84.96	51	3.18	-0.01	45.5	-0.2
France	101.94	64.7	0.5	1.1	33.3	-3.66
Gabon	6.01	54	2	-2.16	46.2	-2.89

Table 4.12Cont'd

Country	PoA	PoB	PoC	PoD	PoE	PoF
Gambia	162.94	56.9	2.34	-2.46	53.7	-1.78
Gaza Strip	4750.71	53.5	3.1	0		
Ghana	105.82	60	1.79	-0.56	44.1	-1.35
Greece	81.60	66.2	0.06	2.32	52.8	-0.46
Iran	47.85	70.9	1.24	-0.11	47.3	-1.83
Iraq	71.02	58.9	2.34		51.4	0.48
Israel	365.47	62.2	1.54	1.94	73.4	-0.78
Italy	203.30	65.9	0.38	4.67	8.93	-54.26
Jordan	72.85	**59.9**	-0.96	-33.42	62.5	-0.19
Kenya	74.11	55.1	2.44	-0.23	48.6	-0.33
Kuwait	148.52	72.2	1.88		0	-1.06
Lebanon	398.10	68	-0.38	-12.08	33.3	-0.89
Lesotho	63.60	61.1	0.33	-8.15	65.5	-0.88
Liberia	34.91	52.7	2.6	0	43.9	-0.64
Libya	3.83	**62.7**	2.007	0	73.1	-0.68
Madagascar	38.47	**53.8**	2.952	0	53.4	-0.44
Malawi	137.77	52.2	2.75	0	4.66	27.70
Mali	11.72	49.7	2.613	-5.08	37	-1.07
Mauritania	3.26	56.2	2.32	-0.89	54.8	-0.28
Mauritius	643.67	70.7	0.7	0	-1.10	-50.00
Morocco	72.35	66.1	1.05	-3.67	48.4	-1.12
Mozambique	29.42	51.1	2.44	-2.13	65.2	-1.13
Namibia	2.63	61.7	0.81	0.15	43.5	-0.85
Niger	13.5	**48**	3.63	0	36.5	-0.12
Nigeria	184.16	55.9	2.55	-0.22	39.8	-1.28
Oman	9.98	65.7	2.04	-0.47	6.9	-0.63
Portugal	117.08	65.8	0.18	2.9	64.9	-1.39
Qatar	168.44	76.7	4.93	40.62	0	-1.64
Rawanda	443.83	54.7	2.75	1	56.4	-0.52
SAO TOME AND PRINCIPE	190.02	52.2	2	-9.14	4.23	10.00
Saudia	12.34	67.6	1.52	-0.64	5.5	-1.12
Senegal	65.93	53.9	2.53	-1.82	47.6	-0.37
Sierra leane	76.47	54.5	2.27	-3.86	61.9	-0.47
Somalia	15.82	52.9	1.59	-11.62	45.9	-0.65
South Africa	40.04	65.8	-0.412	-6.22	-4.44	-27.73
Spain	93.09	67.7	0.654	5.02	37.9	-0.52
Sudan	18.38	55.2	1.88	-4.52	39.8	-1.04
Swaziland	79.87	58.6	1.19	0	-8.50	-8.82
Syria	121.67	61	-0.79	-27.82	61.6	-0.8
Tanzania	46.03	55.1	1.96	-0.29	55	-0.54
Togo	122.59	56	2.75	0	41.5	-1.11
Tunisia	65.60	69.3	0.96	-1.78	32.9	-1.07
Turkey	101.78	**67.1**	1.19	0.5	53.1	-1.39
UAE	63.57	78.7	3.05	16.82	0	-1.91
Uganda	148.83	48.1	3.58	-0.02	49.6	-0.15
West Bank	447.53	60.5				
Yemen	46.92	54.4	2.57	0	40.5	-0.77
Zambia	19.01	**50.8**	3.03	-0.76	46.2	-0.34
Zimbabwe	32.30	54.3	4.35	23.77	52.3	-0.7

Table 4.13. Evaluating Population Indicator

Country	PoA	PoB	PoC	PoD	PoE	PoF	Po All
Zimbabwe	1	2	7	7	6	5	4
Burkina Faso	2	7	7	2	5	5	4
Djibouti	1	1	5	6	5	5	3
Burundi	4	2	7	1	6	5	3
Rwanda	4	2	6	2	6	5	3
Qatar	3	1	7	7	1	5	3
Uganda	3	3	7	1	5	5	3
UAE	2	1	7	7	1	5	3
Libya	1	**2**	5	2	7	5	3
Madagascar	1	**2**	6	2	6	5	3
Niger	1	**3**	7	2	4	5	3
Bahrain	7	1	6	7	1	5	3
ISRAEL	4	1	4	3	7	5	3
Togo	3	2	6	2	5	5	3
Ethiopia	2	2	7	1	5	5	3
Angola	1	2	5	2	6	5	3
Congo	1	2	6	1	6	5	3
Liberia	1	2	6	2	5	5	3
Mozambique	1	2	5	1	7	5	3
Yemen	1	2	6	2	5	5	3
Zambia	1	**2**	7	1	5	5	3
Gambia	3	2	5	1	6	5	3
Senegal	2	2	6	1	5	5	3
Spain	2	1	2	7	4	5	3
Cameroon	1	2	5	2	5	5	3
central Africa	1	2	5	2	5	5	3
DR of the Congo	1	2	6	1	5	5	3
Mali	1	3	6	1	4	5	3
Mauritania	1	2	5	1	6	5	3
Nigeria	3	2	6	1	4	5	3
Portugal	3	1	1	4	7	5	3
Cote d Ivoire	2	2	5	2	4	5	3
Greece	2	1	2	4	6	5	3
Kenya	2	2	5	1	5	5	3
Sierra leane	2	2	5	1	5	5	3
Chad	1	2	4	1	6	5	3
Tanzania	1	2	4	1	6	5	3
Turkey	3	**1**	3	2	6	5	2
Eritrea	2	2	5		5	5	2
Iraq	2	1	5		6	5	2
Gabon	1	2	4	1	5	5	2
Ghana	3	1	4	1	5	5	2
Italy	3	1	1	6	1	7	2
Egypt	2	1	4	1	5	5	2
Algeria	1	1	3	1	6	5	2
Somalia	1	2	4	1	4	5	2
Sudan	1	2	4	1	4	5	2

Table 4.13 Cont'd

Country	PoA	PoB	PoC	PoD	PoE	PoF	Po All
France	3	1	2	3	4	5	2
Syria	3	1	1	1	7	5	2
Jordan	2	**1**	1	1	7	5	2
Morocco	2	1	3	1	5	5	2
Iran	1	1	3	1	5	5	2
Namibia	1	1	2	2	5	5	2
Swaziland	2	2	3	2	1	6	2
Mauritius	5	1	2	2	1	7	2
Lebanon	4	2	1	1	4	5	2
Tunisia	2	1	2	1	4	5	2
Benin	2	2	6	2	1	2	2
Oman	1	1	5	1	1	5	2
Kuwait	3	2	4		1	5	2
Malawi	3	2	6	2	1	1	2
Saudi Arabia	1	1	4	1	1	5	2
Gaza Strip	7	2	7	2			2
Botswana	1	1	3	6	1		2
South Africa	1	1	1	1	1	7	2
Comoros					6	5	2
Sao Tome And Principe	3	2	4	1	1	2	1
Lesotho	2	2	1	1	1	5	1
Eq. Guinea	1	2	6		1	1	1

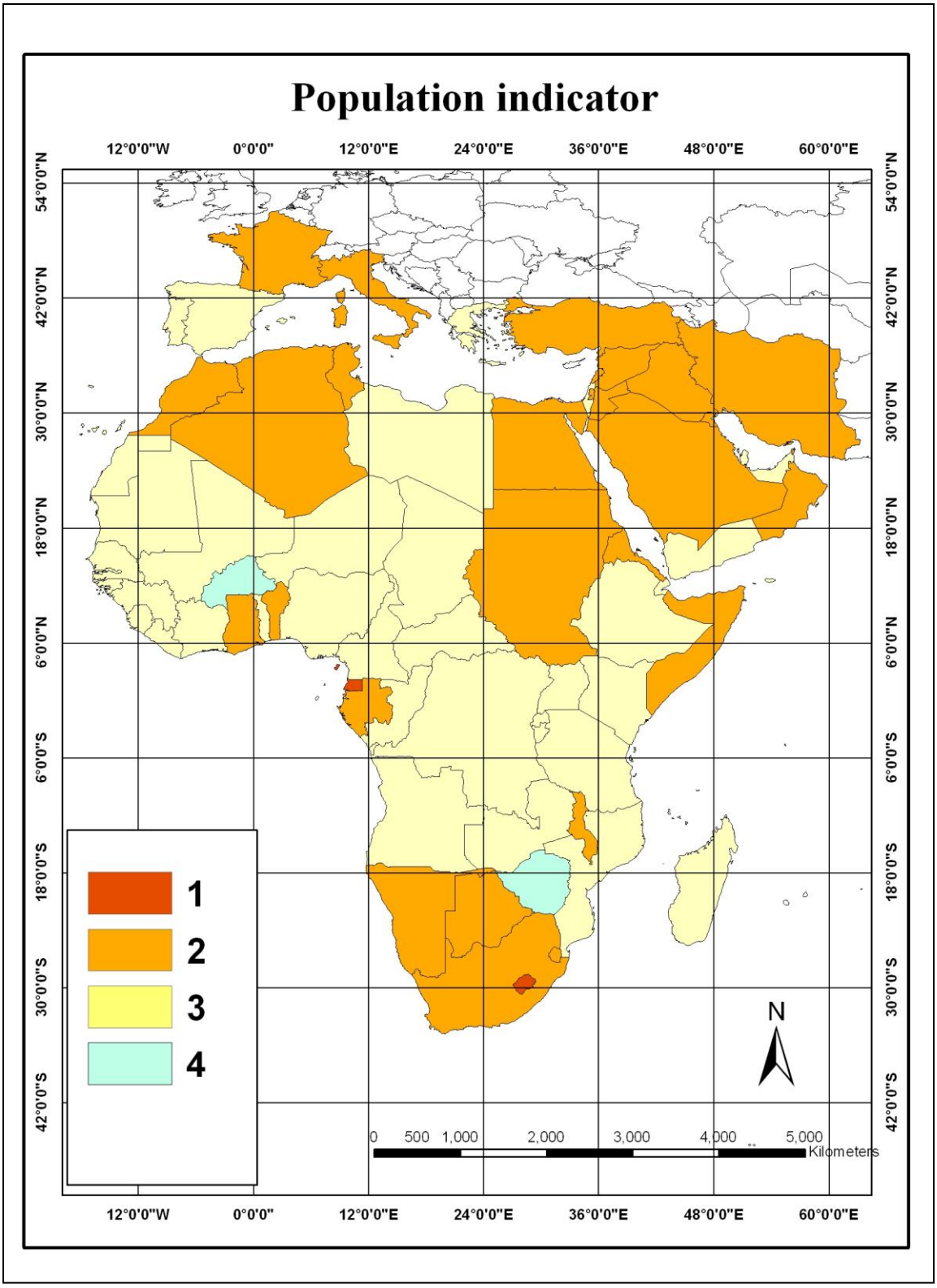


Figure 4.55. Evaluating Economic Indicator

Step 3: Assessing The Main Land Use Capacity Characteristics of the Studied Countries.

LuA. Arable Area % from Total
LuB. Change in Arable Areas 1999 - 2009
LuC. Permanent Crops Area % from Total
LuD. Change in Permanent Crops Areas 1999 - 2009
LuE. Forest Area % from Total
LuF. Change in Forest Areas 1999 - 2009

The value for each character were studied and presented as in table (4.14), the evaluation of the main Population Capacity Characteristics for Studied Countries are shown in table (4.15), countries have been ranked from the lowest to highest capacity, (figure 4.56)

Table 4.14 Main Land use Capacity Characteristics for Studied Countries

Country	LuA	LuB	LuC	LhD	LuE	LuF
Algeria	3.1	-2.22	0.39	80.77	0.63	-5.66
Angola	3.2	33.33	0.23	-27.5	47	-2.09
Bahrain			0	0	0	0
Benin						
Botswana	0.4	4.17	0	0	20.45	-8.38
Burkina Faso	21.6	49.75	0.26	16.67	20.87	-9.51
Burundi	35	-6.25	13.62	-2.78	6.61	-19.05
Cameroon	12.6	0	2.96	16.67	42.61	-9.85
central Africa	3.1	1.04	0.14	0	36.34	-1.26
Chad	3.4	22.16	0.02	0	9.21	-6.45
Comoros	42.1	0	31.58	20	0	-100
Congo	1.5	0	0.18	20	65.65	-0.66
Cote d lvoire	8.8	0	13.52	13.16	32.7	0.78
Djibouti			0	0	0.43	0
DR of the Congo	3	0	0.33	-6.25	68.13	-1.97
Egypt	2.9	-3.68	0.81	65.31	0.07	16.67
EQ GUINEA	4.6	0.0	2.5	-42.9	58.4	-10.4
Eritrea	6.8	38	0	0	15.25	-2.53
Ethiopia	14	39.6	1.04	52.94	12.44	-10.18
France	33.5	-0.05	1.92	-8.7	29.05	4.19
Gabon	1.3	0	0.58	-11.76	85.37	0
Gambia	40	66.67	1	0	48	4.35
Ghana	19.3	14.29	12.31	40	22.24	-18.78
Greece	19.8	-7.61	8.92	3.6	30.02	8.4
Iran	10.6	5.26	1.1	32.59	6.8	0
Iraq	10.4	-18.18	0.58	-26.47	0.58	-69.51
Israel	13.9	-16.7	3.7	-12.5	6.9	6.7
Italy	23.4	-21.1	8.9	-2.7	30.8	12.9
Jordan	2.3	5.26	0.9	-11.11	1.13	0
Kenya	9.5	5.88	1.14	35.42	6.11	-3.06
Kuwait	0.6	0	0	0	0	0
Lebanon	13.7	7.69	13.73	0	13.73	7.69
Lesotho	11.2	3.03	0	0	1.32	0
Liberia	4.2	5.26	2.18	10.53	45.28	-6.44

Table 4.14. Cont'd

Country	LuA	LuB	LuC	LhD	LuE	LuF
Libya	1	-3.31	0.17	-11.76	0.13	0
Madagascar	5.1	1.72	1.03	0	21.69	-4.32
Malawi	38.2	41.7	1.3	8.3	34.7	-15.0
Mali	5.2	39.17	0.08	11.11	10.3	-5.91
Mauritania	0.4	-20.41	0.01	0	0.24	-24.24
Mauritius	45.0	111.1	0.0	0.0	15.0	0.0
Morocco	18	-8.73	2.24	13.64	11.47	1.99
Mozambique	6.4	27.85	0.32	4.17	49.89	-5.26
Namibia	1	-2.44	0.01	0	8.94	-9.25
Niger	11.8	6.87	0.05	200	0.96	-12.23
Nigeria	37.3	13.33	3.29	15.38	10.38	-30.26
Oman	0.3	233.33	0.13	0	0	0
Portugal	12.3	-34.3	8.52	9.86	37.7	1.17
Qatar	87.1	0	0	0	0	0
Rwanda	52.6	49.43	11.34	12	17	23.53
Sao Tome and Principe	45.0	111.1	0.0	0.0	15.0	0.0
Saudi Arabia	1.5	-10.86	0.11	21.05	0.46	0
Senegal	20	27.91	0.31	0	44.21	-4.81
Sierra leane	15.8	135.42	1.82	8.33	38.41	-6.46
Somalia	1.6	-3.85	0.05	50	10.87	-10.14
South Africa	11.8	-1.7	0.8	5.3	7.6	0.0
Spain	25.1	-7.13	9.46	-3.08	36.09	7.98
Sudan	8.5	23.08	0.1	91.67	29.46	-1.52
Swaziland	9.9	0.0	0.6	0.0	32.6	4.0
Syria	25.4	-0.64	5.39	23.75	2.61	11.63
Tanzania	11.3	12.99	1.69	30.43	38.19	-10.67
Togo	40.4	-12.35	3.31	50	5.7	-39.22
Tunisia	17.4	-6.87	3.92	-33.33	45.1	0
Turkey	27.7	-12.07	14.35	5.69	6.05	14.63
UAE	0.7	50	3.82	16.67	14.58	11.09
Uganda	33	29.41	2.39	17.65	3.83	6.67
West Bank			11.26	9.76	15.42	-22.22
Yemen	2.2	-24.52	0.53	133.33	1.04	0
Zambia	4.5	15.52	0.05	33.33	66.76	-3.26
Zimbabwe	10.8	18.41	0.31	0	41.23	-17.01

Table 4.15. Evaluation of the Land Use Capacity Indicators

Country	LuA	LuB	LuC	LhD	LuE	LuF	LuAll
Libya	7	5	7	5	7	4	6
Mauritania	7	5	7	4	7	5	6
Botswana	6	6	7	4	6	5	6
Kuwait	7	4	7	4	7	4	6
Saudi Arabia	7	5	7	3	7	4	6
Bahrain	7	4	7	4	7	4	6
Iraq	4	5	7	2	7	7	5
Jordan	6	3	7	5	7	4	5
Algeria	6	5	7	1	7	5	5
Yemen	6	6	7	1	7	4	5
Chad	6	3	7	4	5	5	5
Madagascar	5	3	7	4	6	5	5
Oman	7	1	7	4	7	4	5
Egypt	6	5	7	1	7	3	5
Lesotho	4	3	7	4	7	4	5
Somalia	7	5	7	1	4	5	5
Eq Guinea	6	4	6	7	1	5	5
DR of the Congo	6	4	7	5	1	5	5
Gabon	7	4	7	5	1	4	5
Israil	4	5	6	5	5	3	5
Angola	6	2	7	6	1	5	5
Congo	7	4	7	3	1	5	5
Namibia	1	5	7	4	5	5	5
Niger	4	3	7	1	7	5	5
Qatar	1	4	7	4	7	4	5
South Africa	4	5	7	3	4	4	5
central Africa	6	3	7	4	1	5	4
Eritrea	5	2	7	4	3	5	4
Kenya	4	3	7	2	5	5	4
Mali	5	2	7	3	4	5	4
Zambia	6	5	7	2	1	5	4
Zimbabwe	4	5	7	4	1	5	4
MAURITIUS	1	5	7	4	3	6	4
Burkina Faso	2	2	7	3	6	5	4
Iran	4	3	7	2	5	4	4
ISRAEL	3	4	2	4	7	4	4
Liberia	6	3	6	3	1	5	4
Morocco	3	5	6	3	4	3	4
Syria	1	5	6	3	6	3	4
Togo	1	5	6	1	5	6	4
UAE	7	1	6	3	4	3	4
Swaziland	5	4	7	4	1	3	4
Comoros	1	4	1	3	7	7	4
Ethiopia	4	2	7	1	4	5	4
Mozambique	5	2	7	3	1	5	4
Nigeria	1	3	6	3	4	6	4
Tunisia	3	3	6	6	1	4	4
Burundi	1	5	4	3	5	5	4

Table 4.15. Cont'd

Country	LuA	LuB	LuC	LhD	LuE	LuF	LuAll
SAO TOME AND PRINCIPE	4	1	7	4	3	4	4
Djibouti			7	4	7	4	4
France	1	5	7	5	1	3	4
Greece	3	5	5	3	1	5	4
Lebanon	4	3	4	4	4	3	4
Portugal	4	6	5	3	1	3	4
Sudan	5	3	7	1	1	5	4
Tanzania	4	3	7	2	1	5	4
Ghana	3	3	4	2	6	3	4
Senegal	2	2	7	4	1	5	4
Uganda	1	2	6	3	6	3	4
Italy	2	5	5	5	1	3	4
Cote d lvoire	5	4	4	3	1	3	3
Sierra leane	3	1	7	3	1	5	3
Spain	1	5	5	5	1	3	3
Cameroon	4	0	6	3	1	5	3
Gambia	1	1	7	4	1	5	3
Turkey	1	3	4	3	5	3	3
MALAW	1	2	7	3	1	5	3
Benin	2	5	6	1	1	2	3
Rwanda	1	2	4	3	3	3	3
West Bank			5	3	3	5	4

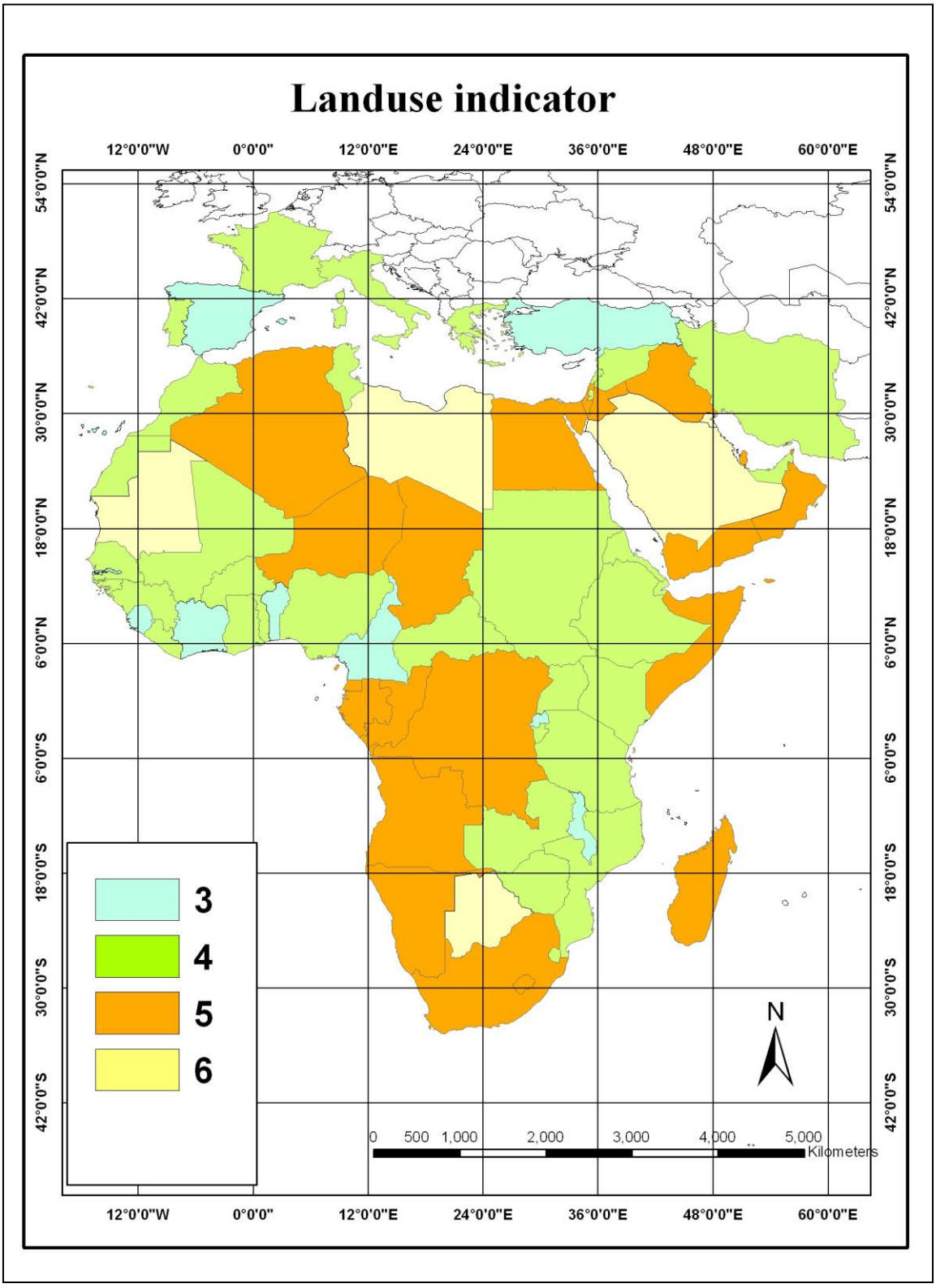


Figure 4.56. Evaluating Economic Indicator

Step 4: Assessing the Main Water Availability Capacity Characteristics of The Studied Countries.

WaA. Total Renewable Water Resources cu km
WaB. Fresh water Withdrawal Total Cu km/y
WaC. Fresh water Withdrawal agricultural %
WaD. Fresh water Withdrawal per Capita Cu km/y

The value for each character were studied and presented as in table (4.16), the evaluation of the main Population Capacity Characteristics for Studied Countries are shown in table (4.17), countries have been ranked from the lowest to highest capacity, (figure 4.57) .

Finally, the evaluation of the all capacity indicators are shown in (Table 4.18 and figure 4.58).

Table 4.16. Main Water Availability Capacity Characteristics for Studied Countries

Country	WaA	WaB	WaC	WaD
Algerian	14.3	6.07	65	185
Angola	184	0.35	60	22
Bahrain	0.1	0.3	57	411
Benin	25.8	0.13	45	15
Botswana	14.7	0.19	41	107
Burkina Faso	17.5	0.8	86	60
Burundi	3.6	0.29	77	38
Cameroon	273	1.18	73.7	601
Central Afr	144.4	0.03	4	7
Chad	43	0.23	83	24
Congo	832	0.03	12	8
Cote D'ivoire	81	0.93	65	51
Djibouti	0.3	0.02	16	25
D R. Congo	1,283	0.36	31	6
Egypt	86.8	68.3	86	800
Equatorial Guinea	26	0.11	1	220
Eritrea	6.3	0.3	97	68
Ethiopia	110	5.56	94	72
France	189	33.16	10	548
Gabon	164	0.12	42	87
Gambia, The	8	0.03	65	20
Ghana	53.2	0.98	66	44
Greece	72	8.7	81	782
Iran	137.5	72.88	91	1,048
Iraq	96.4	42.7	92	1482
Jordan	0.9	1.01	75	177
Kenya	30.2	1.58	64	46
Kuwait	0.02	0.44	52	164
Israel	1.7	2.05	62	305
Italy	175	41.98	45	723

Table 4.16Cont'd.

Country	WaA	WaB	WaC	WaD
Lebanon	4.8	1.38	67	385
Lesotho	5.2	0.05	20	28
Liberia	232	0.11	55	34
Libya	0.6	4.27	83	730
Madagascar	337	14.96	96	804\
Malawi	17.3	1.01	80	78
Mali	100	6.55	90	484
Mauritania	11.4	1.7	88	554
Morocco	29	12.6	87	400
Mozambique	216	0.63	87	32
Namibia	45.5	0.3	71	148
Niger	33.7	2.18	95	156
Nigeria	286.2	8.01	69	61
Oman	1	1.36	90	529
Portugal	73.6	11.09	78	1,056
Qatar	0.1	0.29	72	358
Rwanda	5.2	0.15	68	17
Saudi Arabia	2.4	17.32	89	705
Senegal	39.4	2.22	93	190
Sierra Leone	160	0.38	92	69
South Africa	50	12.5	63	264
Spain	111.1	37.22	68	864
Sudan	154	37.32	97	1,030
Somalia	15.7	3.29	100	400
Swaziland	4.5	1.04	97	1,010
Syria	46.1	19.95	95	1,048
Tanzania	91	5.18	89	135
Togo	14.7	0.17	45	28
Tunisia	4.6	2.64	82	261
Turkey	234	39.78	74	544
United Arab Emirates	0.2	2.3	68	511
Uganda	66	0.3	40	10
Yemen	4.1	6.63	95	316
Zambia	105.2	1.74	76	149
Zimbabwe	20	4.21	79	324

Table 4.17. Evaluation of the Water Availability Capacity Indicators

	WaA	**WaB**	**WaC**	**WaD**	WaALL
BURKINA FASO	7	7	7	7	7
ERITREA	7	7	7	7	7
MALAWI	7	7	6	7	7
NIGER	6	7	7	7	7
SENEGAL	6	7	7	7	7
CHAD	6	7	6	7	7
BURUNDI	7	7	5	7	7
JORDAN	7	7	5	7	7
TUNISIA	7	7	6	6	7
YEMEN	7	6	7	6	7
SOMALIA	7	7	7	5	7
ZIMBABWE	7	7	5	6	6
OMAN	7	7	7	4	6
MAURITANIA	7	7	7	4	6
RWANDA	7	7	3	7	6
SIERRA LEONE	3	7	7	7	6
TANZANIA	4	6	7	7	6
NAMIBIA	6	7	4	7	6
QATAR	7	7	4	6	6
GAMBIA, THE 20	7	7	3	7	6
Angola	7	7	2	7	6
MOZAMBIQUE	2	7	7	7	6
KUWAIT	7	7	2	7	6
Algerian	7	6	3	7	6
LEBANON	7	7	3	6	6
MOROCCO	6	5	7	5	6
LIBYA	7	7	6	3	6
SWAZILAND	7	7	7	2	6
ETHIOPIA 72	3	6	7	7	6
Benin	7	7	1	7	6
LESOTHO	7	7	1	7	6
TOGO	7	7	1	7	6
GHANA	5	7	3	7	6
KENYA	6	7	2	7	6
BOTSWANA	7	7	1	7	6
ZAMBIA	3	7	5	7	6
ISRAEL	7	7	2	6	6
SAUDI ARABIA	7	5	7	3	6
DJIBOUTI 25	7	7	1	7	6
COTE D'IVOIRE	4	7	3	7	5
BAHRAIN	7	7	2	5	5
MALI	3	6	7	5	5
MAURITIUS	7	7	2	5	5
UNITED ARAB EMIRATES	7	7	3	4	5
UGANDA	5	7	1	7	5
EQUATORIAL GUINEA	6	7	1	6	5
GREECE	5	6	6	3	5
SYRIA	6	5	7	2	5
CENTRAL AFR	3	7	1	7	5

Table 4.17 Cont'd

Countries	WaA	WaB	WaC	WaD	WaALL
LIBERIA	2	7	2	7	5
NIGERIA	2	6	3	7	5
GABON	3	7	1	7	5
SOUTH AFRICA	5	5	2	6	5
PORTUGAL	5	5	5	2	4
CONGO, D R	1	7	1	7	4
CAMEROON	2	7	4	3	4
MADAGASCAR	2	5	7	2	4
CONGO, R 8	1	7	1	7	4
SUDAN	3	3	7	2	4
IRAQ 1482	4	3	7	1	4
EGYPT	4	1	7	2	4
TURKEY	2	3	4	4	3
IRAN	3	1	7	2	3
FRANCE	3	4	1	4	3
SPAIN	3	3	3	2	3
ITALY	3	3	1	3	3

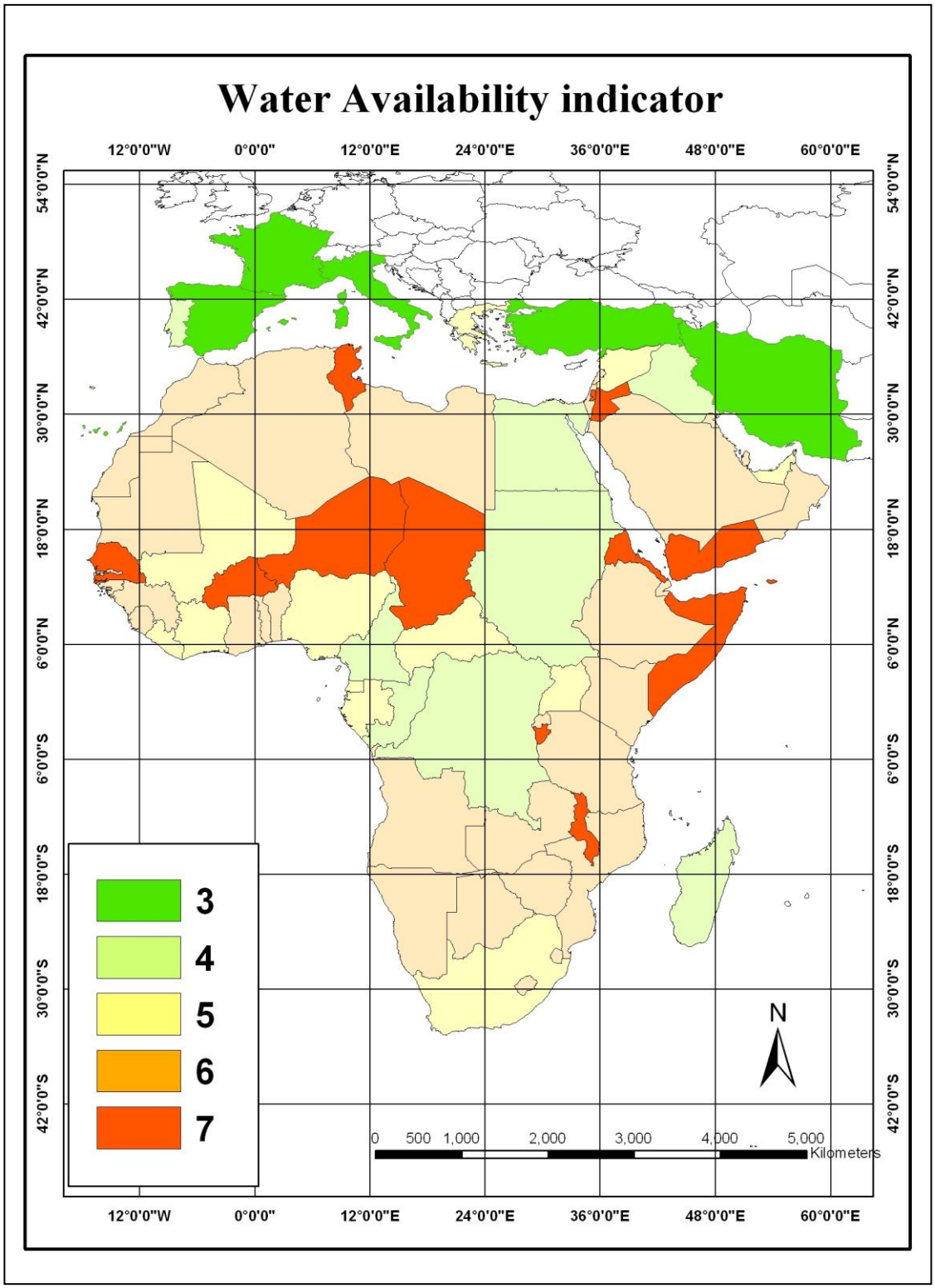


Figure 4.57. Evaluating of water Availability Indicator

Step 5: Ranking Countries According to Their Overall Resilience Capacities.

Table 4.18 Ranking Countries with their Capacity Level

Country	Ec ALL	Po ALL	Lu All	Wa All	Capacity Level	Capacity Level Description
Very Low Capacity Level with main limitation in						
Niger	6	3	5	7	7,Ec, Wa	Economy and water availability
Somalia	6	2	5	7	7,Ec, Wa	Economy and water availability
Cote D Lvoire	7	3	3	5	7, Ec	Economy
Burkina Faso	6	4	4	7	7, Wa, Lu	Land use and water availability
Burundi	6	3	4	7	7, Wa, Lu	Land use and water availability
Chad	6	3	5	7	7, Wa, Lu	Land use and water availability
Djibouti	5	3	4	6	7, Wa, Lu	Land use and water availability
Eritrea	6	2	4	7	7, Wa, Lu	Land use and water availability
Malawi	6	2	3	7	7, Wa, Lu	Land use and water availability
Jordan	3	2	5	7	7, Wa	water availability
Senegal	5	3	4	7	7, Wa	water availability
Tunisia	4	2	4	7	7,Wa	water availability
Yemen	4	3	5	7	7,Wa	water availability
Low Capacity Level with main limitation in						
Mauritania	6	3	6	6	6,Ec, Wa, Lu	Economy, Land use and water availability
Mozambique	6	3	4	6	6,Ec, Wa	Economy and water availability
Sierra Leane	6	3	3	6	6,Ec, Wa	Economy and water availability
Swaziland	6	2	4	6	6,Ec, Wa	Economy and water availability
Comoros	6	2	4		6, Ec	Economy
DR Of The Congo	6	3	5	4	6, Ec	Economy
Liberia	6	3	4	5	6, Ec	Economy
Botswana	4	2	6	6	6, Wa, Lu	Land use and water availability
Kuwait	1	2	6	6	6, Wa, Lu	Land use and water availability
Lesotho	6	1	5	6	6, Wa, Lu	Land use and water availability
Libya	4	3	6	6	6, Wa, Lu	Land use and water availability
Saudi Arabia	2	2	6	6	6, Wa, Lu	Land use and water availability
Bahrain	3	3	6	5	6,Lu	Land use
Tanzania	4	3	4	6	6,Wa	water availability
Togo	5	3	4	6	6,Wa	water availability
Zambia	5	3	4	6	6,Wa	water availability
Zimbabwe	6	4	4	6	6,Wa	water availability
Algeria	4	2	5	6	6, Wa	water availability
Angola	4	3	5	6	6, Wa	water availability
Benin	5	2	3	6	6, Wa	water availability
Ethiopia	5	3	4	6	6, Wa	water availability
Gambia	5	3	3	6	6, Wa	water availability
Ghana	4	2	4	6	6, Wa	water availability
Israel	2	3	5	6	6, Wa	water availability
Kenya	5	3	4	6	6, Wa	water availability
Lebanon	3	2	4	6	6, Wa	water availability

Table 4.18. Cont'd

Country	Ec ALL	Po ALL	Lu All	Wa All	Capacity Level	Capacity Level Description
Morocco	4	2	4	6	6, Wa	water availability
Namibia	5	2	5	6	6, Wa	water availability
Oman	3	2	5	6	6, Wa	water availability
Qatar	2	3	5	6	6, Wa	water availability
Rwanda	5	3	3	6	6, Wa	water availability
Moderate Capacity Level with main limitation						
Central Africa	5	3	4	5	5, Ec, Wa	Economy and water availability
Mali	5	3	4	5	5, Ec, Wa	Economy and water availability
Nigeria	5	3	4	5	5, Ec, Wa	Economy and water availability
Sudan	5	2	4	4	5, Ec, Wa	Economy and water availability
Cameroon	5	3	3	4	5, Ec	Economy
Congo	5	3	5	4	5, Ec	Economy
Iraq	5	2	5	4	5, Ec	Economy
Madagascar	5	3	5	4	5, Ec	Economy
Sao Tome And Principe	5	1	4		5, Ec	Economy
Eq Guinea	4	1	5	5	5, Lu, Wa	Land use and water availability
Gabon	4	2	5	5	5, Lu, Wa	Land use and water availability
South Africa	3	2	5	5	5, Lu, Wa	Land use and water availability
Egypt	3	2	5	4	5, Lu	Land use
Greece	4	3	4	5	5, Wa	Water availability
Syria	4	2	4	5	5, Wa	Water availability
UAE	2	3	4	5	5, Wa	Water availability
Uganda	5	3	4	5	5, Wa	Water availability
Mauritius	2	2	4	5	5, Wa	Water availability
Relatively Moderate to High Capacity Level without main limitation						
Iran	4	2	4	3	4	Relatively Moderate to High Capacity Level
Portugal	3	3	4	4	4	Relatively Moderate to High Capacity Level
Italy	2	2	4	3	4	Relatively Moderate to High Capacity Level
France	3	2	4	3	3	Relatively Moderate to High Capacity Level
Turkey	3	2	3	3	3	Relatively High Capacity Level
Spain	3	3	3	3	3	Relatively High Capacity Level

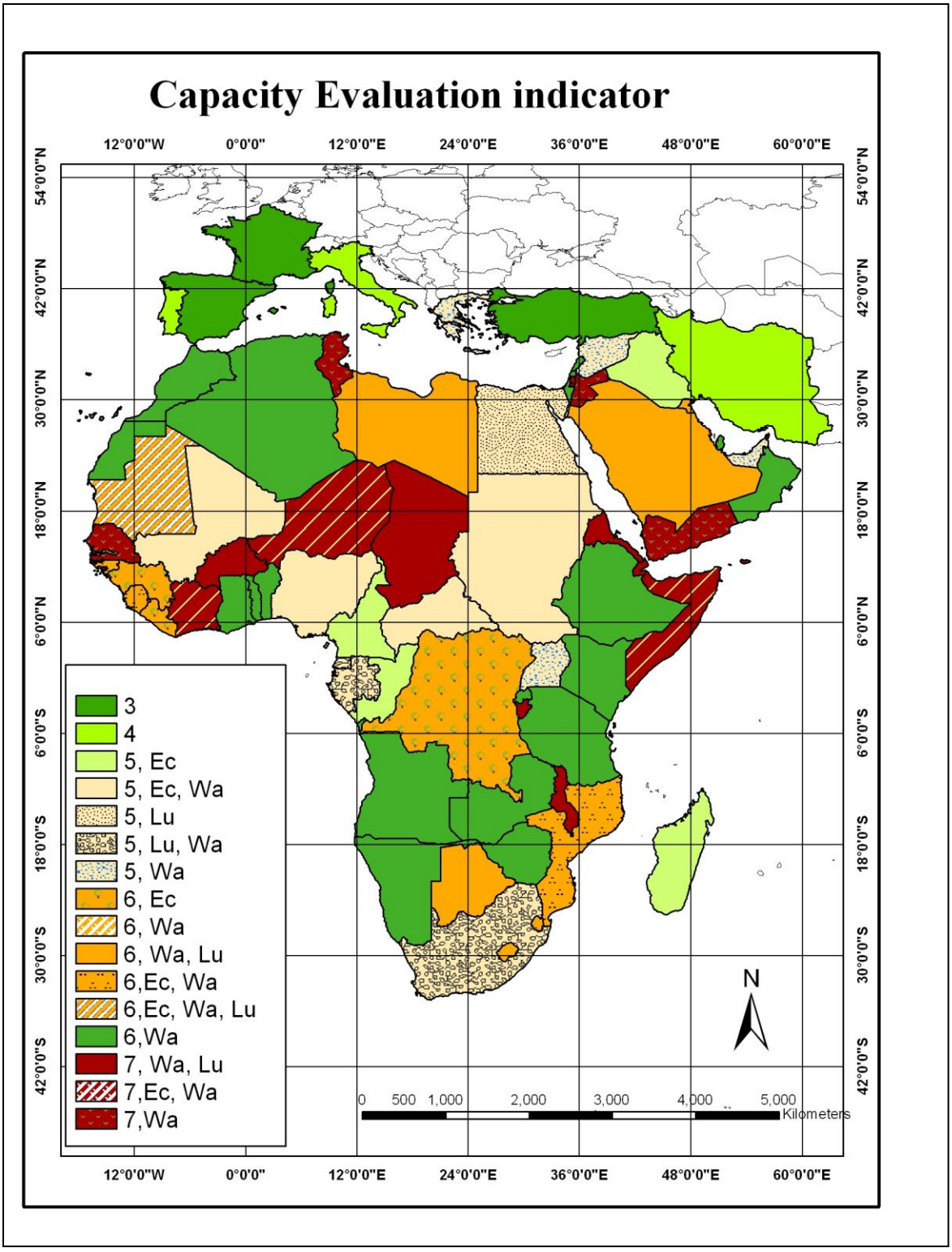


Figure 4.58 Countries Capacities limitations Map.

Step 6: Identifying the most ADH Vulnerable Countries and describe their Degree of Affection by ADH in rainfed croplands, rangelands, forestry and in land degradation.

Agriculture drought hazard has its different level of negative impacts on vegetation (rainfed croplands, rangelands, forestry and land degradation the ability to become vulnerable depends on the hazard coverage and severity and the level capacity related to each country. Countries have been grouped as shown in (table 4.19).

Table 4.19 Identifying the Most Vulnerable Countries to ADH.

Country	Agriculture Hazard				Capacity	Total Affected				LD Total	LD Hot Spots
						Rainfed	Rangeland	Forest	Veg. Cover		
	(H+M+S)	Coverage Class	(H+M)	Severity Class	Level	Area %	Area %	Area %	Area %	%	%
Class 7: Very High Coverage of ADH >85 %											
	High severity				Moderate Capacity Level,				Highly Affected Veg. Cover		
Greece	85.89	7	60.93	5	5, Wa	17.8	26.99	22.69	67.48	11.5	9.4
	Moderate Severity				Low Capacity Level				very High affected Veg. Cover		
Lebanon	89.62	7	39.83	3	6, Wa	1.07	18.32	63.45	82.84	9.5	7.1
	Moderate Severity				Low Capacity Level				Low Affected Veg. Cover		
Qatar	86.37	7	51.49	4	6, Wa	0	0.41	0.09	0.5	45.9	13.3
	Moderate Severity				Relatively Moderate to High Capacity Level				very High affected Veg. Cover		
Portugal	86.93	7	52.98	4	4	13.5	45.51	20.94	79.95	61.3	56.3
Class 6, High coverage of ADH 75 – 85%											
	High severity				Low Capacity Level				Low Affected Veg. Cover		
Kuwait	83.12	6	73.83	6	6, Wa, Lu		0.17	0.09	0.26	83	44.7
	Moderate Severity				Very Low Capacity Level				Moderately Affected Veg. Cover		
Eritrea	79.42	6	38.44	3	7, Wa, Lu	0	36.8	8.74	45.54	64.2	49.1
	Moderate Severity				Low Capacity Level				Moderately Affected Veg. Cover		
Morocco	84.22	6	34.04	3	6, Wa	0.22	17.6	22.28	40.1	14.5	3.6
	Moderate Severity				Moderate Capacity Level				Moderately Affected Veg. Cover		
Syria	79.79	6	49.89	4	5,Wa	0.23	16.77	19.64	36.64	63.1	51.6
Eq Guinea	77.17	6	35.82	3	5, Wa, Lu	52.77	0.07	5.99	58.83	53.5	49.2
Class 5, high to Moderate Coverage of ADH 60-75 %											
	Moderate Severity				Very Low Capacity Level				Moderately Affected Veg. Cover		
Tunisia	69.8	5	30.77	3	7,Wa	0.34	10.52	13.49	24.35	27.3	13
Djibouti	68.33	5	47.82	4	7, Wa, Lu		19.69	0.05	19.74	82.2	69.3
	Moderate Severity				Low Capacity Level				Moderately Affected Veg. Cover		
Namibia	61.41	5	58.99	4	6, Wa	0.05	47.81	0.4	48.26	23.5	19.5
					Moderate Capacity Level				Highly Affected Veg. Cover		
Gabon	70.53	5	40.05	3	5, Wa, Lu	55.99	3.18	3.87	63.04	47.4	42.3
	Moderate Severity								Moderately Affected Veg. Cover		
Iraq	68.87	5	49.26	4	5, Ec	0.02	13.43	8.29	21.74	64.1	51
	Moderate Severity				Relatively Moderate to High Capacity Level				Highly Affected Veg. Cover		
Italy	72.39	5	52.03	4	4	17.76	14.72	30.65	63.13	42	37.6
Spain	74.4	5	54.71	4	3	9.85	37.98	22.15	69.98	43.4	38.3
	Low Severity				Low Capacity Level				Moderately Affected Veg. Cover		
Israel	60.28	5	25.7	2	6, Wa	0.09	8.48	23.38	31.95	43.8	31.4
	Low Severity				Relatively Moderate to High Capacity Level				Moderately Affected Veg. Cover		
Iran	65.79	5	29.19	2	4	1.03	14.37	9.06	24.46	29.6	17.8

Country	Agriculture Hazard				Capacity	Total Affected				LD Total	LD Hot Spots
						Rainfed	Rangeland	Forest	Veg. Cover		
	(H+M+S)	Coverage Class	(H+M)	Severity Class	Level	Area %	Area %	Area %	Area %	%	%
Class 4, Moderate Coverage of ADH 45-60 %											
	Moderate Severity				Very Low Capacity Level with main limitation in				Moderately Affected Veg. Cover		
Somalia	56.53	4	52.57	4	7,Ec, Wa	0.11	37.47	11.04	48.62	50.2	39.1
Senegal	52.62	4	30.85	3	7, Wa	0.61	11.18	34.83	46.62	24.3	17.9
	Moderate Severity				Low Capacity Level				Moderately Affected Veg. Cover		
Kenya	49.26	4	41.16	3	6, Wa	0.5	33.2	5.07	38.77	48.9	42.8
	Moderate Severity				Relatively Moderate to High Capacity Level				Moderately Affected Veg. Cover		
France	56.45	4	49.15	4	3	8.47	6.14	10.81	25.42	74.6	69.6
	Moderate Severity								Highly Affected Veg. Cover		
Turkey	55.39	4	45.6	4	3	9.2	11.45	31.75	52.4	15.3	11.9
	Low Severity				Very Low Capacity Level				Highly Affected Veg. Cover		
Cote D Lvoire	55.78	4	22.57	2	7, Ec	22.99	8.58	22.87	54.44	40.8	35.4
	Low Severity				Low Capacity Level				Moderately Affected Veg. Cover		
Sierra Leane	48.31	4	13.47	1	6,Ec, Wa	14.8	2.22	28.14	45.16	80.1	74.5
Ghana	45.03	4	17.76	2	6, Wa	16.17	9.01	16.76	41.94	39.9	33.3
Liberia	51.05	4	12.52	1	6, Ec	23.66	0.08	17.6	41.34	66.6	61.7
	Low Severity				Moderate Capacity Level				Moderately Affected Veg. Cover		
Nigeria	53.83	4	23.57	2	5,Ec, Wa	10.86	15.25	22.84	48.95	57.4	49.2
Class 3, moderate to low Coverage ADH 30-45 %											
	Moderate Severity				Moderate Capacity Level with main limitation				Moderately Affected Veg. Cover		
South Africa	38.45	3	33.55	3	5,Lu, Wa	1.09	30.87	2.68	34.64	62.1	46.4
	Low Severity				Very Low Capacity Level				Moderately Affected Veg. Cover		
Burkina Faso	38.26	3	21.85	2	7, Wa, Lu	0.1	11.29	23.78	35.17	36.9	28.4
Chad	30.87	3	12.93	1	7, Wa, Lu	0.23	11.23	7.68	19.14	45.6	27
	Low Severity				Low Capacity Level				Moderately Affected Veg. Cover		
Benin	40.48	3	9.01	1	6, Wa	15.84	17.18	7.99	41.01	50.1	43.4
Togo	37.97	3	7.88	1	6,Wa	8.48	20.83	6.78	36.09	41.3	33.6
Ethiopia	41.68	3	29.76	2	6, Wa	0.36	27.75	6.58	34.69	66.3	59.4
Botswana	36.5	3	24.14	2	6, Wa, Lu	2.55	26.55	3.38	32.48	65.3	50.5
	Low Severity				Low Capacity Level				Low Affected Veg. Cover		
Saudi Arabia	39.71	3	15.59	2	6, Wa, Lu	0	0.47	0.14	0.61	68.7	28.9
	Low Severity				Moderate Capacity Level				Moderately Affected Veg. Cover		
Cameroon	32.02	3	12.08	1	5, Ec	20.15	1.48	7.24	28.87	57	49.7
Sudan	33.3	3	14.95	1	5,Ec, Wa	0.61	16.05	7.1	23.76	47.4	26.7
Mali	39.84	3	17.28	2	5,Ec, Wa	0.12	13.51	8.66	22.29	46.3	21.7
	Low Severity				Moderate Capacity Level				Low Affected Veg. Cover		
UAE	39.68	3	6.83	1	5,Wa		0.13	0.1	0.23	35.3	6

Country	Agriculture Hazard				Capacity	Total Affected				LD Total	LD Hot Spots
						Rainfed	Rangeland	Forest	Veg. Cover		
	(H+M+S)	Coverage Class	(H+M)	Severity Class	Level	Area %	Area %	Area %	Area %	%	%
Class 2, low Coverage of ADH 15-30 %											
	Low Severity				Very Low Capacity Level				Highly Affected Veg. Cover		
Jordan	28.73	2	10.09	1	7, Wa		33.2	25.13	58.33	29.1	9.3
	Low Severity				Very Low Capacity Level				Moderately Affected Veg. Cover		
Niger	29.11	2	12.24	1	7,Ec, Wa	0	15.08	1.69	16.77	48.7	17.9
	Low Severity				Very Low Capacity Level				Low Affected Veg. Cover		
Yemen	29.46	2	13.67	1	7,Wa	0	2.32	0.99	3.31	46.3	20.4
	Low Severity				Low Capacity Level				Low Affected Veg. Cover		
Mauritania	24.77	2	10.64	1	6,Ec, Wa, Lu		8.73	2.01	10.74	36.9	8.9
Algeria	25.52	2	12.75	1	6, Wa	0.1	3.8	3.6	7.5	40.5	2.9
Libya	16.8	2	3.46	1	6, Wa, Lu		0.62	0.22	0.84	45.8	6.2
Oman	19.43	2	3.58	1	6, Wa	0.01	0.55	0.17	0.73	38	9.5
	Low Severity				Moderate Capacity Level				Low Affected Veg. Cover		
Egypt	15.9	2	3.98	1	5, Lu		0.1	0.23	0.33	47.3	10.7
	Low Severity				Moderate Capacity Level				Moderately Affected Veg. Cover		
Congo	25.56	2	16.2	2	5, Ec	11.68	8.06	3.88	23.62		
Class 1, very low Coverage of ADH <15 %											
	Low severity				Very Low Capacity Level				Low Affected Veg. Cover		
Malawi	11.96	1	8.74	1	7, Wa, Lu	1.56	3.09	1.41	6.06	38.4	28.2
Burundi	3.44	1	2.6	1	7, Wa, Lu	0.31	0.02	0.15	0.48	41.1	24.2
					Low Capacity Level				Highly Affected Veg. Cover		
Angola	5.77	1	3.7	1	6, Wa	14.48	5.3	47.31	67.09	62.1	45.8
	Low severity				Low Capacity Level				Low Affected Veg. Cover		
Zimbabwe	13.73	1	10.16	1	6,Wa	0.77	7.56	4.12	12.45	67.5	36.7
Lesotho	7.11	1	3.11	1	6, Wa, Lu	0.65	5.07	0.57	6.29	92.7	61
Mozambique	6.86	1	5.01	1	6,Ec, Wa	1.63	2.72	1.09	5.44	53.4	22
Gambia	10.98	1	1.65	1	6, Wa	0.07	0.55	4.5	5.12	38.8	32.2
Tanzania	3.78	1	2.32	1	6,Wa	0.59	1.06	0.68	2.33	53.3	44
DR Congo	2.3	1	1.22	1	6, Ec	0.56	0.71	0.41	1.68	78.1	69.6
Zambia	1.73	1	0.56	1	6,Wa	0.35	0.55	0.17	1.07	79	56.6
Swaziland	1.05	1	0.7	1	6,Ec, Wa	0.32	0.3	0.13	0.75	73.7	51.4
Rwanda	1.84	1	1.35	1	6, Wa	0.43	0.05	0.07	0.55	54.9	49.5
	Low severity				Moderate Capacity Level				Moderately Affected Veg. Cover		
Guinea	13.58	1	1.62	1		7.76	5.33	7.82	20.91	66.7	59.1
	Low severity				Moderate Capacity Level				Low Affected Veg. Cover		
Guinea-Bissau	2.84	1	0.27	1		0.32	12.95	0.75	14.02	53	42.5
Madagascar	3.25	1	2.01	1	5,Ec	0.18	2.19	0.05	2.42	61.7	37.2
Uganda	3.77	1	2.59	1	5,Wa	0.19	0.89	0.42	1.5	59.2	53.8
Central Africa	1.32	1	0.07	1	5,Ec, Wa	0.06	0.66	0.48	1.2	58.1	48

From the results illustrated on the table above, levels of agriculture drought hazard vulnerability for the different studied countries could be classified as shown in (table 4.20). , and (figure 4.59)

Table 4.20 Vulnerability Classes to ADH

Vulnerability classes	**Countries**
High to Moderate Vulnerability: moderate coverage of ADH 45-60 %, moderate severity and **very Low to low** capacity	Somalia, Senegal and Kenya.
Moderate Vulnerability: high coverage of ADH 75 – 85%, moderate severity and moderate capacity	Eritrea, Morocco, Syria and Eq Guinea (Kuwait, has a very low vegetation cover).
Moderate Vulnerability: high to moderate coverage of ADH 60-75 %, moderate severity and high to moderate capacity	Tunisia, Djibouti, Namibia, Gabon, Iraq and Italy.
Moderate to Low Vulnerability: high to moderate coverage of ADH 60-75 %, moderate severity and moderate to high capacity	Spain, Portugal, Israel and Iran.
Moderate to Low Vulnerability: very high coverage of ADH >85 %, high severity and very high capacity	Greece and, Lebanon (Qatar, has a very low vegetation cover)
Moderate to Low Vulnerability: moderate coverage of ADH 45-60 %, low severity and very low to low capacity	Cote D Lvoire, Sierra Leanne, Ghana, Liberia and Nigeria
Moderate to Low Vulnerability: moderate to low coverage ADH 30-45 %, moderate to low severity and moderate to low capacity	South Africa, Burkina Faso, Chad, Benin, Togo, Ethiopia, Botswana, Cameroon, Sudan, Mali, Saudi Arabia and UAE (UAE has a very low vegetation cover).
Low Vulnerability: moderate coverage of ADH 45-60 %, moderate severity and high to moderate capacity	France and Turkey
Low Vulnerability: low coverage of ADH 15-30 %, low severity and high to moderate capacity	Jordan, Niger, Yemen, Mauritania, Algeria, Libya, Oman, Malawi, Burundi, Angola, Zimbabwe, Lesotho, Mozambique, Gambia, Tanzania, DR Congo, Zambia, Swaziland, and Rwanda
Low Vulnerability: low coverage of ADH 15-30 %, low severity and low capacity	Egypt, Congo, Guinea, Guinea-Bissau,
Low Vulnerability: low coverage of ADH less than 15 %, low severity and low capacity	Madagascar, Uganda, Central Africa

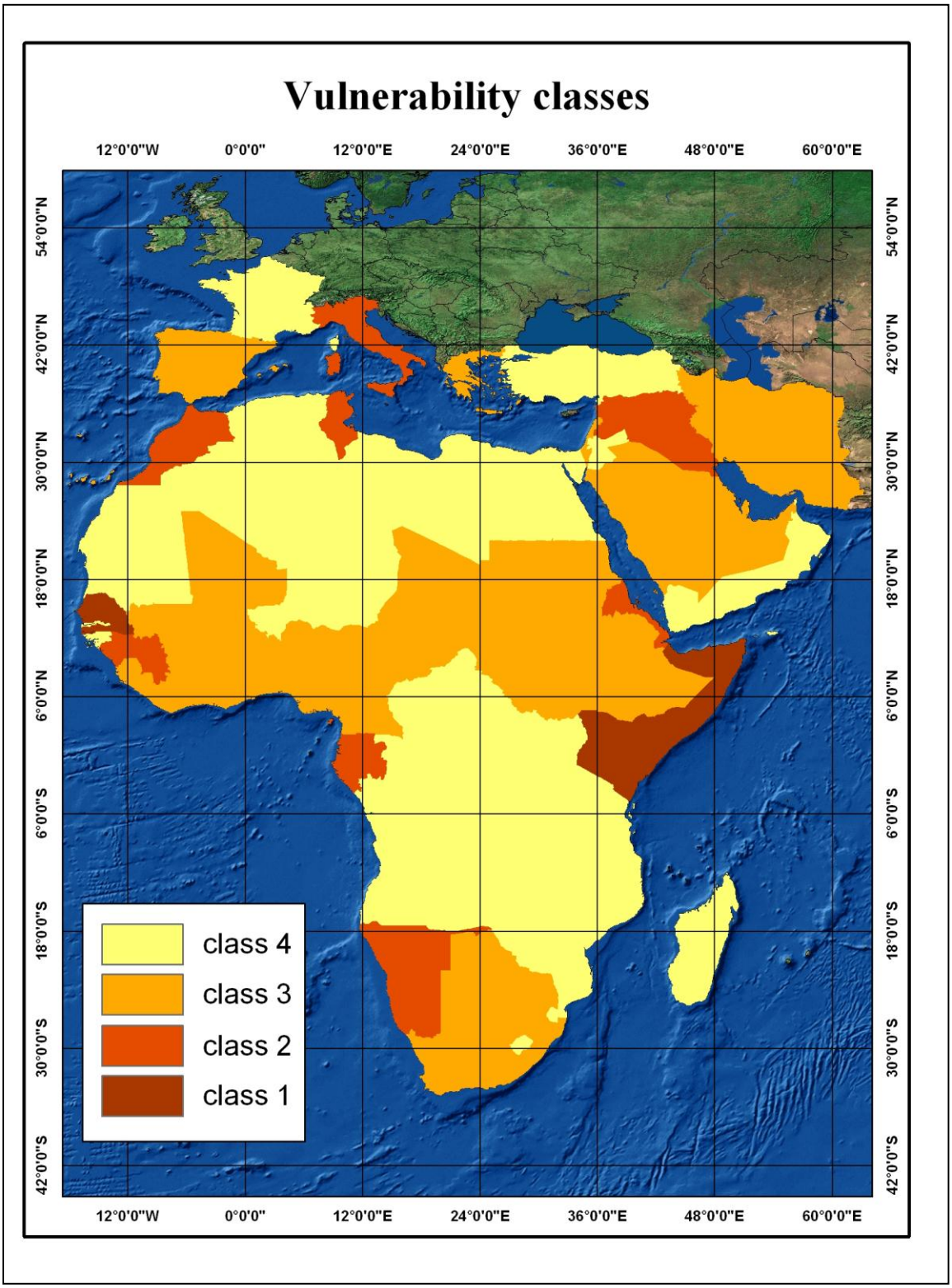


Figure 4.59. Vulnerability Classes

4.6. Agriculture Drought Hazard Risk

Disaster risk is defined as the likelihood over a specified time period of severe alterations in the normal functioning of a community or a society due to hazardous physical events interacting with vulnerable social conditions, leading to widespread adverse human, material, economic, or environmental effects that require immediate emergency response to satisfy critical human needs and that may require external support for recovery. Disaster risk derives from a combination of physical hazards and the vulnerabilities of exposed elements and will signify the potential for severe interruption of the normal functioning of the affected society once it materializes as disaster. Risk assessment using both quantitative and qualitative (social and psychological) measures is required to render a more complete description of risk and risk causation processes (Douglas and Wildavsky, 1982[239]; Cardona, 2004[240]; Wisner et al., 2004[241]; Weber, 2006[242]).

The obtained results show that when drought is the highlighted extreme event, we could agree with the concept that considers socioeconomic as the main drivers of future increases in economic losses (*medium confidence*, based on *medium agreement*, *limited evidence*), (IPCC 2012). Drought as one of the climate extremes is only one of the factors that affect risks, and there is high confidence that exposure and vulnerability are dynamic, varying across temporal and spatial scales. A few studies have specifically quantified the effects of changes in population, exposure of people and assets, and vulnerability as determinants of loss. It has greater impacts on sectors with closer links to climate, such as water, agriculture and food security, forestry and other important economic sectors.

In this study we could focus on crop losses, Land degradation and affected population as the part of the drought risk, but it is important to recognize that, drought is in many instances only one of the drivers and is not necessarily the only driver.

4.6.1. Crop Losses

A. Change in Crop Production:

The analysis of the major crops grown in the studied area such as Wheat, sorghum, Millet, Maize, Cassava, Potatoes, Sweet Potatoes, and green Maize were studied using the available data from 1999 – 2011 in FAO STAT[243], countries were grouped according to their vulnerability classes presented earlier, (Table 4.21).

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[239] Douglas, M. and A. Wildavsky, 1982: Risk and Culture: An Essay on the Selection of Technical and Environmental Dangers. University of California Press, Berkeley,CA.

[240] Cardona, O.D., 2004: The Need for rethinking the concepts of vulnerability and risk from a holistic perspective: A necessary review and criticism for effective risk management. In: *Mapping Vulnerability: Disa sters, Development and People* [Bankoff, G., G. Frerks, and D. Hilhorst (eds.)]. Earthscan Publishers, London, UK,pp. 37-51.

[241] Wisner, B., P. Blaikie, T. Cannon, and I. Davis, 2004: *At Risk: Natural Hazards, People'sVulnerability, and Disasters*, 2nd edition. Routledge, London, UK.

[242] Weber, E.U., 2006: Experience-based and description-based perceptions of long-term risk: why global warming does not scare us (yet). *Climatic Change*, 77, 103-120.

[243] FAO site, i.e. FAOSTAT (http://faostat.fao.org).

At the meantime all drought components such as intensity, frequency and consecutive were analyzed from the crop production changes shown in (table 4.22). The intensity were classified based on the range of sum of negative changes percent from average (less than (100%) = Slight, (100%)-(250%) = Moderate and more than (250%); the number of years with annual negative change correspond to Frequency; and the total continuous number of years with negative change correspond to Consecutive (duration). The relation also were made for each country with the percentage of affected rainfed croplands (presented earlier in table) by drought hazard and showing similar trend.

Table Crop Production in Million Ton

A. Under Areas with Low Vulnerability

Madagascar

CROP	Years	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Cassava	Ton	2461000	2463360	2510340	2366250	1992200	1949400	2964000	2982480	2993580	3021080	3019970	3008890
	Change in production in Ton	-183379	-181019	-134039	-278129	-652179	-694979	319621	338101	349201	376701	375591	364511
	Change in % from Ave.	-7	-7	-5	-11	-25	-26	12	13	13	14	14	14
Maize	Ton	175000	169800	179550	171950	317860	349646	391000	405344	416767	430334	425204	411914
	Change in production in Ton	-145364	-150564	-140814	-148414	-2504	29282	70636	84980	96403	109970	104840	91550
	Change in % from Ave.	-45	-47	-44	-46	-1	9	22	27	30	34	33	29
Potato	Ton	291000	286715	294755	296050	255000	280500	214650	216631	218627	220655	224683	224787
	Change in production in Ton	38996	34711	42751	44046	2996	28496	-37354	-35373	-33377	-31349	-27321	-27217
	Change in % from Ave.	15	14	17	17	1	11	-15	-14	-13	-12	-11	-11
Sweet Potato	Ton	520000	512640	525130	493030	492940	542234	878500	886518	894553	902665	910857	919127
	Change in production in Ton	-186516	-193876	-181386	-213486	-213576	-164282	171984	180002	188037	196149	204341	212611
	Change in % from Ave.	-26	-27	-26	-30	-30	-23	24	25	27	28	29	30

Central African Republic

CROP	Years	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Cassava	Ton	559000	560400	561700	563000	564300	565600	578200	572000	597843	621757	642897	678958
	Change in production in Ton	-29805	-28405	-27105	-25805	-24505	-23205	-10605	-16805	9038	32952	54092	90153
	Change in % from Ave.	-5	-5	-5	-4	-4	-4	-2	-3	2	6	9	15
Maize	Ton	**95000**	**100700**	**107000**	**113000**	**119000**	**125000**	**131000**	**131000**	**139776**	**146765**	**151168**	**150000**
	Change in production in Ton	**-30784**	**-25084**	**-18784**	**-12784**	**-6784**	**-784**	**5216**	**5216**	**13992**	**20981**	**25384**	**24216**
	Change in	**-24**	**-20**	**-15**	**-10**	**-5**	**-1**	**4**	**4**	**11**	**17**	**20**	**19**

Egypt

CROP	Years	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Wheat	**Ton**	6346640	6564050	6254580	6624870	6844690	7177860	8140960	8274230	7379000	7977050	8523000	7177400
	Change in production in Ton	-927054	-709644	-1019114	-648824	-429004	-95834	867266	1000536	105306	703356	1249306	-96294
	Change in % from Ave.	-13	-10	-14	-9	-6	-1	12	14	1	10	17	-1
Potato	**Ton**	**1808890**	**1769910**	**1903130**	**1985320**	**2039350**	**2546610**	**3167430**	**2312790**	**2760460**	**3567050**	**3659280**	**3643220**
	Change in production in Ton	**-788063**	**-827043**	**-693823**	**-611633**	**-557603**	**-50343**	**570477**	**-284163**	**163507**	**970097**	**1062327**	**1046267**
	Change in % from Ave.	**-30**	**-32**	**-27**	**-24**	**-21**	**-2**	**22**	**-11**	**6**	**37**	**41**	**40**

Uganda

CROP	Years	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Cassava	**Ton**	4875000	4966000	5265000	5373000	5450000	5500000	5576000	4926000	4973000	5072000	5179000	5282000
	Change in production in Ton	-328083	-237083	61917	169917	246917	296917	372917	-277083	-230083	-131083	-24083	78917
	Change in % from Ave.	-6	-5	1	3	5	6	7	-5	-4	-3	0	2
Sorghum	**Ton**	**413000**	**361000**	**423000**	**427000**	**421000**	**399000**	**449000**	**440000**	**456000**	**477000**	**497000**	**500000**
	Change in production in Ton	**-25583**	**-77583**	**-15583**	**-11583**	**-17583**	**-39583**	**10417**	**1417**	**17417**	**38417**	**58417**	**61417**
	Change in % from Ave.	**-6**	**-18**	**-4**	**-3**	**-4**	**-9**	**2**	**0**	**4**	**9**	**13**	**14**
Maize	**Ton**	**1053000**	**1096000**	**1174000**	**1217000**	**1300000**	**1080000**	**1170000**	**1258000**	**1262000**	**1266000**	**1272000**	**1373000**
	Change in production in Ton	**-157083**	**-114083**	**-36083**	**6917**	**89917**	**-130083**	**-40083**	**47917**	**51917**	**55917**	**61917**	**162917**
	Change in % from Ave.	**-13**	**-9**	**-3**	**1**	**7**	**-11**	**-3**	**4**	**4**	**5**	**5**	**13**
Potato	**Ton**	**449000**	**478000**	**508000**	**546000**	**557000**	**573000**	**585000**	**628000**	**650000**	**670000**	**689000**	**695000**
	Change in production in Ton	**-136667**	**-107667**	**-77667**	**-39667**	**-28667**	**-12667**	**-667**	**42333**	**64333**	**84333**	**103333**	**109333**
	Change in % from Ave.	**-23**	**-18**	**-13**	**-7**	**-5**	**-2**	**0**	**7**	**11**	**14**	**18**	**19**
Sweet Potato	**Ton**	2354000	2398000	2515000	2592000	2610000	2650000	2604000	2628000	2602000	2707000	2766000	2838000
	Change in production in Ton	-251333	-207333	-90333.3	-13333.3	4666.7	44666.67	-1333.33	22666.67	-3333.33	101666.7	160666.7	232666.7
	Change in % from Ave.	-10	-8	-3	-1	0	2	0	1	0	4	6	9
Millet	**Ton**	606000	534000	584000	590000	640000	659000	672000	687000	732000	783000	841000	850000
	Change in production in Ton	-75500	-147500	-97500	-91500	-41500	-22500	-9500	5500	50500	101500	159500	168500
	Change in % from Ave.	-11	-22	-14	-13	-6	-3	-1	1	7	15	23	25

Congo

CROP	Years	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Cassava	Ton	811890	828128	844690	861583	877776	932198	935000	1000000	950000	1112700	1148500	1148500
	Total Loss in Ton	-142357	-126119	-109557	-92664	-76471	-22049	-19247	45753	-4247	158453	194253	194253
	Loss % from Av.	-15	-13	-11	-10	-8	-2	-2	5	0	17	20	20

Jordon

CROP	Years	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Potato	Ton	96338	97075	101344	105334	122396	165332	172077	160028	97400	139787	118705	174931
	Change in production in Ton	-32891	-32154	-27885	-23895	-6833	36103	42848	30799	-31829	10558	-10524	45702
	Change in % from Ave.	-25	-25	-22	-18	-5	28	33	24	-25	8	-8	35

Niger

CROP	Years	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Sorghum	Ton	476119	370716	655729	636300	757600	599500	943900	929265	975223	1226250	738661	1304830
	Change in production in Ton	-325055	-430458	-145445	-164874	-43574	-201674	142726	128091	174049	425076	-62513	503656
	Change in % from Ave.	-41	-54	-18	-21	-5	-25	18	16	22	53	-8	63
Millet	Ton	2296230	1679170	2414390	2504000	2744900	2037700	2652400	3008580	2781930	3521730	2677860	3843350
	Change in production in Ton	-383957	-1001017	-265797	-176187	64713	-642487	-27787	328393	101743	841543	-2327	1163163
	Change in % from Ave.	-14	-37	-10	-7	2	-24	-1	12	4	31	0	43

Guinea

CROP	Years	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Cassava	Ton	812105	845488	836364	878360	922465	968785	1017430	1068520	1095350	1122170	989326	1030800
	Change in production in Ton	-153492	-120109	-129233	-87237	-43132	3188	51833	102923	129753	156573	23729	65203
	Change in % from Ave.	-16	-12	-13	-9	-4	0	5	11	13	16	2	7
Maize	Ton	295190	329025	356893	388679	423295	460994	502051	546765	595460	952170	565660	580100
	Change in production in Ton	-204500	-170665	-142797	-111011	-76395	-38696	2361	47075	95770	452480	65970	80410
	Change in % from Ave.	-41	-34	-29	-22	-15	-8	0	9	19	91	13	16
Green Maize	Ton	266289	276907	279188	303795	321057	330627	351551	270000	280000	285000	226620	297000
	Change in production in Ton	-24381	-13763	-11482	13126	30388	39958	60882	-20670	-10670	-5670	-64050	6331
	Change in % from Ave.	-8	-5	-4	5	10	14	21	-7	-4	-2	-22	2

Guinea-Bissau

CROP	Years	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Cassava	Ton	32627	32613	34000	35882	38000	39469	41305	40000	43397	47737	27721	88786
	Change in production in Ton	-9168	-9182	-7795	-5913	-3795	-2326	-490	-1795	1602	5942	-14074	46991
	Change in	-22	-22	-19	-14	-9	-6	-1	-4	4	14	-34	112
Sorghum	% from Ave.	14861	21096	15082	14703		15506	23359	24527	14633	18293	14560	17592
	Ton	-2795	3440	-2574	-2953	0	-2150	5703	6871	-3023	637	-3096	-64
	Change in production in Ton	-16	19	-15	-17		-12	32	39	-17	4	-18	0
Maize	Change in	24775	25673	28088	22113	20639	31868	39835	41827		16690		
	% from Ave.	-376	522	2937	-3038	-4512	6717	14684	16676		-8461		
	Ton	-1	2	12	-12	-18	27	58	66		-34		
Millet	Change in production in Ton	21100.0	21096.0	28604.0	24243.0	22669.0	31473.0	47209.0	49569.0	26169.0	31388.0		28062.0
	Change in	-9043.8	-9047.8	-1539.8	-5900.8	-7474.8	1329.2	17065.2	19425.2	-3974.8	1244.2		-2081.8
	% from Ave.	-30.0	-30.0	-5.1	-19.6	-24.8	4.4	56.6	64.4	-13.2	4.1		-6.9

Yemen

CROP	Years	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Wheat	Ton	139563	141884	152742	131733	103794	103265	112963	149173	218520	170446	222129	265432
	Change in production in Ton	-19741	-17420	-6562	-27571	-55510	-56039	-46341	-10131	59216	11142	62825	106128
	Change in % from Ave.	-12	-11	-4	-17	-35	-35	-29	-6	37	7	39	67
Sorghum	Ton	399208	375009	382495	289296	212780	263428	330330	484120	601040	376728	311504	507302
	Change in production in Ton	21438	-2761	4725	-88474	-164990	-114342	-47440	106350	223270	-1042	-66266	129532
	Change in % from Ave.	6	-1	1	-23	-44	-30	-13	28	59	0	-18	34
Potato	Ton	211121	210424	208597	210769	213324	197958	217759	226366	249010	263945	278022	303380
	Change in production in Ton	-21435	-22132	-23959	-21787	-19232	-34598	-14797	-6190	16454	31389	45466	70824
	Change in % from Ave.	-9	-10	-10	-9	-8	-15	-6	-3	7	13	20	30

Mauritania

CROP	Years	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Sorghum	Ton	95101	84910	53113	28694	77908	20729	81816	74057	79674	85595	93609	114249
	Change in production in Ton	20979.75	10788.75	-21008.25	-45427.25	3786.8	-53392.25	7694.75	-64.25	5552.75	11473.75	19487.75	40127.75
	Change in % from Ave.	28	15	-28	-61	5	-72	10	0	7	15	26	54
Maize	Ton		13651					12234	17285	16966	15461	11830	19910
	Change in production in Ton		-1683					-3100	1951	1632	127	-3504	4576
	Change in % from Ave.		-11					-20	13	11	1	-23	30
Potato	Ton	15322	13843	16350	13339	12359	11246	12777	11310	15367	14868	19828	17000
	Change in production in Ton	855	-624	1883	-1128	-2108	-3221	-1690	-3157	900	401	5361	2533
	Change in % from Ave.	6	-4	13	-8	-15	-22	-12	-22	6	3	37	18
Millet	Ton	6064	4587			5902						8081	
	Change in production in Ton	-95	-1572			-257						1923	
	Change in % from Ave.	-2	-26			-4						31	

Algeria

CROP	Years	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Wheat	Ton	1470000	760361	2039210	1501800	2964850	2730700	2414730	2687930	2318960	1111030	2953120	3100000
	Change in production in Ton	-701058	-1410697	-131848	-669258	793792	559642	243672	516872	147902	-1060028	782062	928942
	Change in % from Ave.	-32	-65	-6	-31	37	26	11	24	7	-49	36	43
Potato	Ton	996268	1207690	967232	1333470	1879920	1896270	2156550	2180960	1506860	2171060	2636060	3290000
	Change in production in Ton	-855594	-644172	-884630	-518392	28058	44408	304688	329098	-345002	319198	784198	1438138
	Change in % from Ave.	-46	-35	-48	-28	2	2	16	18	-19	17	42	78

Libya

CROP	Years	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Potato	Ton	138200	190000	195000	195000	211697	195000	310000	300000	290000	290000	311332	290000
	Change in production in Ton	-104819	-53019	-48019	-48019	-31322	-48019	66981	56981	46981	46981	68313	46981
	Change in % from Ave.	-43	-22	-20	-20	-13	-20	28	23	19	19	28	19

Oman

CROP	Years	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Sorghum	Ton	**8500**	**9000**	**10000**	**10800**	**11500**			**8775**	**10439**		**42000**	**53300**
	Total Loss in Ton	**-9757**	**-9257**	**-8257**	**-7457**	**-6757**			**-9482**	**-7818**		**23743**	**35043**
	Loss % from Av.	**-53**	**-51**	**-45**	**-41**	**-37**			**-52**	**-43**		**130**	**192**
Potato		**15600**	**18220**	**12688**	**15454**	**15454**	**15500**				**11100**	**10000**	
		-688	**1932**	**-3600**	**-834**	**-834**	**-788**				**-5188**	**-6288**	
		-4	**12**	**-22**	**-5**	**-5**	**-5**				**-32**	**-39**	

Zimbabwe

CROP	Years	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Wheat	Ton	260909	229775	197526	195000	247048	229089	241924	149110				
	Total Loss in Ton	42111	10977	-21272	-23798	28250	10291	23126	-69688				
	Loss % from Av.	19	5	-10	-11	13	5	11	-32				
Cassava	Ton	170000	175000	180624	174543	180000	190000	208952	212441	192000	206147	216149	203000
	Total Loss in Ton	-22405	-17405	-11781	-17862	-12405	-2405	16547	20036	-405	13742	23744	10595
	Loss % from Av.	-12	-9	-6	-9	-6	-1	9	10	0	7	12	6
Maize		**1519560**	**2108110**	**1466750**	**605000**	**1059000**	**1686150**	**915366**	**1484840**	**952600**	**496000**	**700000**	**1192400**
		337412	**925962**	**284602**	**-577148**	**-123148**	**504002**	**-266782**	**302692**	**-229548**	**-686148**	**-482148**	**10252**
		29	**78**	**24**	**-49**	**-10**	**43**	**-23**	**26**	**-19**	**-58**	**-41**	**1**

Zambia

CROP	Years	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Wheat	Ton	69226	75000	80000	75000	135000	82858	136833	93958	115843	113242	195456	172256
	Total Loss in Ton	-42830	-37056	-32056	-37056	22944	-29198	24777	-18098	3787	1186	83400	60200
	Loss % from Av.	-38	-33	-29	-33	20	-26	22	-16	3	1	74	54
Cassava	Ton	970823	815248	950000	918016	957000	957000	1056000	1059890	1059890	1185600	1160850	1151700
	Total Loss in Ton	-49345	-204920	-70168	-102152	-63168	-63168	35832	39722	39722	165432	140682	131532
	Loss % from Av.	-5	-20	-7	-10	-6	-6	4	4	4	16	14	13
Maize		**822056**	**1040000**	**802000**	**606172**	**1157860**	**1214000**	**866187**	**1424400**	**1366160**	**1211570**	**1887010**	**2795480**
		-444019	**-226075**	**-464075**	**-659903**	**-108215**	**-52075**	**-399888**	**158325**	**100085**	**-54505**	**620935**	**1529405**
		-35	**-18**	**-37**	**-52**	**-9**	**-4**	**-32**	**13**	**8**	**-4**	**49**	**121**

Congo Democratic Republic

CROP	Years	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Cassava	Ton	16500000	15959000	15435700	14929600	14944600	14950500	14974500	14989400	15004400	15013500	15034400	15049500
	Total Loss in Ton	1267908	726908	203608	-302492	-287492	-281592	-257592	-242692	-227692	-218592	-197692	-182592
	Loss % from Av.	8	5	1	-2	-2	-2	-2	-2	-1	-1	-1	-1
Maize		**1199000**	**1184000**	**1169190**	**1154570**	**1154800**	**1155030**	**1155260**	**1155490**	**1155720**	**1155950**	**1156180**	**1156410**
		36367	**21367**	**6557**	**-8063**	**-7833**	**-7603**	**-7373**	**-7143**	**-6913**	**-6683**	**-6453**	**-6223**
		3	**2**	**1**	**-1**	**-1**	**-1**	**-1**	**-1**	**-1**	**-1**	**-1**	**-1**

Burundi

CROP	Years	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Cassava	Ton	**617483**	**656656**	**712713**	**749938**	**720000**	**709574**	**700000**	**571114**	**558557**	**577063**	**235369**	**187901**
	Total Loss in Ton	**34452**	**73625**	**129682**	**166907**	**136969**	**126543**	**116969**	**-11917**	**-24474**	**-5968**	**-347662**	**-395130**
	Loss % from Av.	**6**	**13**	**22**	**29**	**23**	**22**	**20**	**-2**	**-4**	**-1**	**-60**	**-68**
Sorghum		**130000**	**123518**	**136612**	**141393**	**121000**	**145000**	**140000**	**145000**	**80000**	**75046**	**86080**	**100400**
		11329	**4847**	**17941**	**22722**	**2329**	**26329**	**21329**	**26329**	**-38671**	**-43625**	**-32591**	**-18271**
		10	**4**	**15**	**19**	**2**	**22**	**18**	**22**	**-33**	**-37**	**-27**	**-15**
Maize		**128706**	**117840**	**124395**	**126799**	**127000**	**123199**	**135000**	**116825**	**115507**	**117681**	**120379**	**126412**
		5394	**-5472**	**1083**	**3487**	**3688**	**-113**	**11688**	**-6487**	**-7805**	**-5631**	**-2933**	**3100**
		4	**-4**	**1**	**3**	**3**	**0**	**9**	**-5**	**-6**	**-5**	**-2**	**3**
Sweet Potato		734172	687382	780859	833470	833500	834394	880000	837311	873663	900415	484207	303432
		-14395	-61185	32292	84903	84933	85827	131433	88744	125096	151848	-264360	-445135
		-2	-8	4	11	11	11	18	12	17	20	-35	-59

Gambia, The

CROP	Years	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Cassava	Ton	**11630**	**7500**	**7690**	**8116**	**8674**	**9009**	**9428**	**10074**	**7800**	**8360**	**7370**	**7600**
	Total Loss in Ton	**3026**	**-1104**	**-914**	**-488**	**70**	**405**	**824**	**1470**	**-804**	**-244**	**-1234**	**-1004**
	Loss % from Av.	**35**	**-13**	**-11**	**-6**	**1**	**5**	**10**	**17**	**-9**	**-3**	**-14**	**-12**
Sorghum		**17970**	**25000**	**33418**	**15209**	**30130**	**28999**	**30499**	**30240**	**17951**	**25624**	**31882**	**39000**
		-9190	**-2160**	**6258**	**-11951**	**2970**	**1839**	**3339**	**3080**	**-9209**	**-1536**	**4722**	**11840**
		-34	**-8**	**23**	**-44**	**11**	**7**	**12**	**11**	**-34**	**-6**	**17**	**44**
Maize		**20400**	**22000**	**28988**	**18580**	**33353**	**29209**	**29002**	**27750**	**31408**	**44894**	**54625**	**66000**
		-13451	**-11851**	**-4863**	**-15271**	**-498**	**-4642**	**-4849**	**-6101**	**-2443**	**11043**	**20774**	**32149**
		-40	**-35**	**-14**	**-45**	**-1**	**-14**	**-14**	**-18**	**-7**	**33**	**61**	**95**
Millet		80900.0	94600.0	104972.0	84618.0	120342.0	132494.0	127563.0	125680.0	89186.0	125624.0	144868.0	158018.0
		-34838.8	-21138.8	-10766.8	-31120.8	4603.3	16755.3	11824.3	9941.3	-26552.8	9885.3	29129.3	42279.3
		-30.1	-18.3	-9.3	-26.9	4.0	14.5	10.2	8.6	-22.9	8.5	25.2	36.5

Malawi

CROP	Years	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Cassava	Ton	906430	2794620	3362400	1540180	1735070	2532080	2197640	2832140	338349	3491180	399387	3420100
	Total Loss in Ton	-1222701	665489	1233269	-588951	-394061	402949	68509	703009	-1790782	1362049	-1729744	1290969
	Loss % from Av.	-57	31	58	-28	-19	19	3	33	-84	64	-81	61
Maize		2479410	2501310	1713060	1556980	1983440	1608350	1225230	2611490	395908	2634700	436169	3800000
		567239	589139	-199111	-355191	71269	-21	-686941	699319	-1516263	722529	-1476002	1887829
		30	31	-10	-19	4	-16	-36	37	-79	38	-77	99
Potato		1840400	2037280	2852010	1403800	1884200	2182620	1485880	2309430	319802	2993820	410921	4706400
		-195147	1733	816463	-631747	-151347	147073	-549667	273883	######	958273	-1624626	2670853
		-10	0	40	-31	-7	7	-27	13	-84	47	-80	131

Mozambique

CROP	Years	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Cassava	Ton	5552930	5361970	5974590	5924550	6149900	6412770	4782420	6658710	5038620	4054590	5672370	5700000
	Change in production in Ton	-54022	-244982	367638	317598	542948	805818	-824532	1051758	-568332	-1552362	65418	93048
	Change in % from Ave.	-1	-4	7	6	10	14	-15	19	-10	-28	1	2
Sorghums	Ton	250000	193112	160000	138318	190820	152910		204986	169543	187265	384000	395000
	Change in production in Ton	29459	-27429	-60541	-82223	-29721	-67631		-15555	-50998	-33276	163459	174459
	Change in % from Ave.	13	-12	-27	-37	-13	-31		-7	-23	-15	74	79
Maize	Ton	1336080	1180430	1143260	1114770	1178790	1060400	942000	1417800	1152050	1284930	1932000	1878000
	Change in production in Ton	34371	-121279	-158449	-186939	-122919	-241309	-359709	116091	-149659	-16779	630291	576291
	Change in % from Ave.	3	-9	-12	-14	-9	-19	-28	9	-11	-1	48	44
Sweet Potato	Ton	400000	430000	450000	455950	877165	900000	915000	929896	875216	566050	900000	920000
	Change in production in Ton	-318273	-288273	-268273	-262323	158891.9	181726.9	196726.9	211622.9	156942.9	-152223	181726.9	201726.9
	Change in % from Ave.	-44	-40	-37	-37	22	25	27	29	22	-21	25	28

Angola

CROP	Years	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Cassava	Ton	3129730	4433030	5394320	6522760	6692160	6817230	8815010	9037020	9730260	10057400	12827600	13858700
	Change in production in Ton	-4979872	-3676572	-2715282	-1586842	-1417442	-1292372	705408	927418	1620658	1947798	4717998	5749098
	Change in % from Ave.	-61	-45	-33	-20	-17	-16	9	11	20	24	58	71
Maize	Ton	428045	394607	428769	546860	618684	577000	734372	526084	615894	702387	970231	1072740
	Change in production in Ton	-206594	-240032	-205870	-87779	-15955	-57639	99733	-108555	-18745	67748	335592	438101
	Change in % from Ave.	-33	-38	-32	-14	-3	-9	16	-17	-3	11	53	69
Potato	Ton			158388	179385	369204	241945	307296	295142	491216	402207	823266	841279
	Change in production in Ton			-252545	-231548	-41729	-168988	-103637	-115791	80283	-8726	412333	430346
	Change in % from Ave.			-61	-56	-10	-41	-25	-28	20	-2	100	105
Sweet Potato	Ton	182303	224043	353228	423141	543319	629573	663787	684756	949104	819772	982588	986563
	Change in production in Ton	-437878	-396138	-266953	-197040	-76862	9392	43606	64575	328923	199591	362407	366382
	Change in % from Ave.	-71	-64	-43	-32	-12	2	7	10	53	32	58	59
Millet	Ton	101736.0	105252.0	148016.0	161069.0	83090.0	123400.0	137864.0	144390.0	156434.0			
	Change in production in Ton	-27291.9	-23775.9	18988.1	32041.1	-45937.9	-5627.9	8836.1	15362.1	27406.1			
	Change in % from Ave.	-21.2	-18.4	14.7	24.8	-35.6	-4.4	6.8	11.9	21.2			

Swaziland

CROP	Years	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Maize	Ton	124057	112779	82536	67639	69273	68087	74540	67127		64012	60765	68000
	Change in production in Ton	45983	34705	4462	-10435	-8801	-9987	-3534	-10947		-14062	-17309	-10074
	Change in % from Ave.	59	44	6	-13	-11	-13	-5	-14		-18	-22	-13
Potato	Ton					6500			6000	6353	6757	7100	7200
	Change in production in Ton					-152			-652	-299	105	448	548
	Change in % from Ave.					-2			-10	-4	2	7	8

Lesotho

CROP	Years	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Sorghum	Ton	33340	26807	45350	11919	11954	11482	18527	11326	7837	10189	10151	23830
	Change in production in Ton	14781	8248	26791	-6640	-6605	-7077	-32	-7233	-10722	-8370	-8408	5271
	Change in % from Ave.	80	44	144	-36	-36	-38	0	-39	-58	-45	-45	28
Maize	Ton	124549	106800	158190	111110	82080	80996	78739	100815	60312	59651	57126	128213
	Change in production in Ton	28834	11085	62475	15395	-13635	-14719	-16976	5100	-35403	-36064	-38589	32498
	Change in % from Ave.	30	12	65	16	-14	-15	-18	5	-37	-38	-40	34
P[potato	Ton	85000	87000	88000	90000	81749	98340	96597	101795	93000	96500	83871	98200
	Change in production in Ton	-6671	-4671	-3671	-1671	-9922	6669	4926	10124	1329	4829	-7800	6529
	Change in % from Ave.	-7	-5	-4	-2	-11	7	5	11	1	5	-9	7

Turkey

CROP	Years	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Wheat	Ton	18008800	21008600	19007000	19508000	19008200	21000000	21500000	20010000	17234000	17782000	20600000	
	Change in production in Ton	-1506345.5	1493454.55	-508145.45	-7145.4545	-506945.5	1484854.55	1984854.55	494854.545	-2281145.5	-1733145.5	1084854.55	-19515145
	Change in % from Ave.	-8	8	-3	0	-3	8	10	3	-12	-9	6	
Potatoes	Ton	6000000	5370000	5000000	5200000	5300000	4800000	4090000	4397310	4246210	4196520	4397710	
	Change in production in Ton	######	552023	182023	382023	482023	-17977	-727977	-420667	-571767	-621457	-420267	
	Change in % from Ave.	25	11	4	8	10	0	-15	-9	-12	-13	-9	

France

CROP	Years	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Wheat	Ton	37050000	37353400	31540300	38939200	30474700	39692900	36885500	35363600	32763500	39006400	38332200	38207000
	Change in production in Ton	749275	1052675	-4760425	2638475	-5826025.0	3392175	584775	-937125	-3537225	2705675	2031475	1906275
	Change in % from Ave.	2	3	-13	7	-16	9	2	-3	-10	7	6	5
Maize	Ton	15356700	16018400	16408200	16440000	11990900	16372000	13687700	12775200	14357300	15818500	15288200	
	Change in production in Ton	400964	1062664	1452464	1484264	-2964836	1416264	-1268036	-2180536	-598436	862764	332464	
	Change in % from Ave.	3	7	10	10	-20	9	-8	-15	-4	6	2	
Potatoes	Ton	6645000	6434050	6077890	6874390	6348130	7255380	6604600	6362820	7183100	6871970	7174560	6582190
	Change in production in Ton	-56173	-267123	-623283	173217	-353043	554207	-96573	-338353	481927	170797	473387	-118983
	Change in % from Ave.	-1	-4	-9	3	-5	8	-1	-5	7	3	7	-2
Barley	Ton	9377600	9709330	9799110	10976000	9844290	11031500	10313400	10400600	9473570	12171600	12875800	10102000
	Change in production in Ton	-1128633	-796903	-707123	469767	-661943	525267	-192833	-105633	-1032663	1665367	2369567	-404233
	Change in % from Ave.	-11	-8	-7	4	-6	5	-2	-1	-10	16	23	-4

Rwanda

CROP	Years	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Cassava	Ton	316934	820992	788910	1031080	1003080	765748	781639	765000	779000	978541	2019740	2377210
	Change in production in Ton	-718722	-214664	-246746	-4576	-32576	-269908	-254017	-270656	-256656	-57115	984084	1341554
	Change in % from Ave.	-69	-21	-24	0	-3	-26	-25	-26	-25	-6	95	130
Sorghum	Ton	107566	155106	175904	184351	171587	163772	227927	187380	164000	144000	174499	161229
	Change in production in Ton	-60544	-13004	7794	16241	3477	-4338	59817	19270	-4110	-24110	6389	-6881
	Change in % from Ave.	-36	-8	5	10	2	-3	36	11	-2	-14	4	-4
Maize	Ton	54912	62501	80979	91686	78886	88209	97251	91813	102000	167000	285505	432404
	Change in production in Ton	-81184	-73595	-55117	-44410	-57210	-47887	-38845	-44283	-34096	30905	149410	296309
	Change in % from Ave.	-60	-54	-40	-33	-42	-35	-29	-33	-25	23	110	218
Potato	Ton	175889	957202	1012270	1038930	1099550	1072770	1314050	1285150	967000	1162000	1287400	1789400
	Change in production in Ton	-920912	-139599	-84531	-57871	2749	-24031	217249	188349	-129801	65199	190599	692599
	Change in % from Ave.	-84	-13	-8	-5	0	-2	20	17	-12	6	17	63
Sweet Potato	Ton	862562	1032920	1156360	1292360	868204	908306	885648	777034	841000	826000	801376	840072
	Change in production in Ton	-61758.2	108599.8	232039.8	368039.8	-56116.2	-16014.2	-38672.2	-147286	-83320.2	-98320.2	-122944	-84248.2
		-7	12	25	40	-6	-2	-4	-16	-9	-11	-13	-9

B. Under Areas with Moderate to Low Vulnerability

Saudi Arabia

CROP	Years	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Wheat	Ton	2046000	1787540	2081870	2436440	2524280	2775680	2648470	2630390	2558000	1985560	1152450	1300000
	Change in production in Ton	-114557	-373017	-78687	275883	363723	615123	487913	469833	397443	-174997	-1008107	-860557
	Change in % from Ave.	-5	-17	-4	13	17	28	23	22	18	-8	-47	-40
Sorghum	Ton	205000	212248	248153	240231	241982	283855	212720	248900	233000	251941	244065	275300
	Change in production in Ton	-36450	-29202	6703	-1219	532	42405	-28730	7450	-8450	10491	2615	33850
	Change in % from Ave.	-15	-12	3	-1	0	18	-12	3	-3	4	1	14
Potato	Ton	394000	380579	315891	315008	317939	387340	440974	468596	463000	446953	444138	495100
	Change in production in Ton	-11793	-25214	-89902	-90785	-87854	-18453	35181	62803	57207	41160	38345	89307
	Change in % from Ave.	-3	-6	-22	-22	-22	-5	9	15	14	10	9	22

Ethiopia

CROP	Years	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Wheat	Ton	1149670	1235270	1596020	1447650	1618090	2176600	2306860	2779060	2219100	2463060	3075640	3000000
	Change in production in Ton	-939248	-853648	-492898	-641268	-470828	87682	217942	690142	130182	374142	986722	911082
	Change in % from Ave.	-45	-41	-24	-31	-23	4	10	33	6	18	47	44
Sorghum	Ton	1334370	1188080	1548720	1546230	1784280	1717910	2200240	2313040	2173600	2316040	2971270	2997400
	Change in production in Ton	-673228	-819518	-458878	-461368	-223318	-289688	192642	305442	166002	308442	963672	989802
	Change in % from Ave.	-34	-41	-23	-23	-11	-14	10	15	8	15	48	49
Maize	Ton	2832070	2682940	3298330	2825560	2743880	2906310	3911870	4029630	3336800	3776440	3897160	4400000
	Change in production in Ton	-554679	-703809	-88419	-561189	-642869	-480439	525121	642881	-49949	389691	510411	1013251
	Change in % from Ave.	-16	-21	-3	-17	-19	-14	16	19	-1	12	15	30
Barley	Ton	962214	803904	1016940	1183540	1087370	1375520	1398400	1409690	1270680	1352150	1750440	1400000
	Change in production in Ton	-288690	-447000	-233964	-67364	-163534	124616	147496	158786	19776	101246	499536	149096
	Change in % from Ave.	-23	-36	-19	-5	-13	10	12	13	2	8	40	12

South Africa

CROP	Years	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Wheat	Ton	1733030	2428100	2503950	2437750	1546840	1687000	1905000	2105000	1905000	2130000	1958000	1464970
	Change in production in Ton	-250690	444380	520230	454030	-436880	-296720	-78720	121280	-78720	146280	-25720	-518750
	Change in % from Ave.	-13	22	26	23	-22	-15	-4	6	-4	7	-1	-26
Maize	Ton	7946000	11431200	7772000	10076000	9705000	9710070	11715900	6935060	7125000	12700000	12050000	12815000
	Change in production in Ton	-2052436	1432764	-2226436	77564	-293436	-288366	1717464	-3063376	-2873436	2701564	2051564	2816564
	Change in % from Ave.	-21	14	-22	1	-3	-3	17	-31	-29	27	21	28
Potato	Ton	1669000	1721000	1793000	1647000	1496000	1799620	1767730	1862860	1972390	2040000	1866650	2071930
	Change in production in Ton	-139932	-87932	-15932	-161932	-312932	-9312	-41202	53928	163458	231068	57718	262998
	Change in % from Ave.	-8	-5	-1	-9	-17	-1	-2	3	9	13	3	15
Green Maize	Ton	299203	299000	298000	296000	322000	320000	318966	310000	334199	363088	351595	402100
	Change in production in Ton	-26976	-27179	-28179	-30179	-4179	-6179	-7213	-16179	8020	36909	25416	75921
	Change in % from Ave.	-8	-8	-9	-9	-1	-2	-2	-5	2	11	8	23

Chad

CROP	Years	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Cassava	Ton	323200	256270	305956	322000	325000	327894	300000	280000	249564	161187	230000	230700
	Change in production in Ton	47219	-19711	29975	46019	49019	51913	24019	4019	-26417	-114794	-45981	-45281
	Change in % from Ave.	17	-7	11	17	18	19	9	1	-10	-42	-17	-16
Sorghum	Ton	456634	391714	497227	480686	564717	449427	582565	693579	576571	685430	600963	490300
	Change in production in Ton	-82517	-147437	-41924	-58465	25566	-89724	43414	154428	37420	146279	61812	-48851
	Change in % from Ave.	-15	-27	-8	-11	5	-17	8	29	7	27	11	-9
Maize	Ton	94151				117978		201305	183946	201257	225993	209030	208900
	Change in production in Ton	-26062				-2235		81092	63733	81044	105780	88817	88687
	Change in % from Ave.	-22				-2		67	53	67	88	74	74
Millet	Ton	361095	258828	397608	357425	516341	297529	578303	589754	495486	523162	708965	620900
	Change in production in Ton	-114355	-216622	-77842	-118025	40891	-177921	102853	114304	20036	47712	233515	145450
	Change in % from Ave.	-24	-46	-16	-25	9	-37	22	24	4	10	49	31

Benin

CROP	Years	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Cassava	Change in production in Ton	2112960	2350210	2703460	2452050	3054780	2955020	2861370	2524230	2849060	3611210	3996420	4147400
	Change in % from Ave.	-855221	-617971	-264721	-516131	86599	-13161	-106811	-443951	-119121	643029	1028239	1179219
	Ton	-29	-21	-9	-17	3	0	-4	-15	-4	22	35	40
Sorghum	Change in production in Ton	126440	155275	165342	195468	163276	163831	169235	156333	170695	142014	123960	127500
	Change in % from Ave.	-28507	328	10395	40521	8329	8884	14288	1386	15748	-12933	-30987	-27447
	Ton	-18	0	7	26	5	6	9	1	10	-8	-20	-18
Maize	Change in production in Ton	782974	750442	685902	622136	788320	842626	864698	671949	798356	978063	1205200	1235900
	Change in % from Ave.	-69240	-101772	-166312	-230078	-63894	-9588	12484	-180265	-53858	125849	352986	383686
	Ton	-8	-12	-20	-27	-7	-1	1	-21	-6	15	41	45

Togo

CROP	Years	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Cassava	Ton	693998	700697	678865	727709	778865	675475	678186	767366	773162	795371	895655	908755
	Change in production in Ton	-62177	-55478	-77310	-28466	22690	-80700	-77989	11191	16987	39196	139480	152580
	Change in % from Ave.	-8	-7	-10	-4	3	-11	-10	1	2	5	18	20
Sorghum	Ton	141658	700697		168983	155569	169782	206032	221155	210298	211257	237665	244674
	Change in production in Ton	-100867	458172		-73542	-86956	-72743	-36493	-21370	-32227	-31268	-4860	2149
	Change in % from Ave.	-42	189		-30	-36	-30	-15	-9	-13	-13	-2	1
Maize	Ton	493570	482055	537960	510084	537960	523647	509468	543342	546050	590106	651739	638129
	Change in production in Ton	-53439	-64954	-9049	-36925	-9049	-23362	-37541	-3667	-959	43097	104730	91120
	Change in % from Ave.	-10	-12	-2	-7	-2	-4	-7	-1	0	8	19	17
Millet	Ton	39337			51726	47136		42159	43747	45456	47401	49145	51264
	Change in production in Ton	-11927			5351	761		-4216	-2628	-919	1026	2770	4889
	Change in % from Ave.	-15			12	2		-9	-6	-2	2	6	11

Mali

CROP	Years	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Sorghum	**Ton**	**688830**	**564661**	**517748**	**641695**	**728717**	**664083**	**629127**	**769681**	**900791**	**1027200**	**1465620**	**1256810**
	Change in production in Ton	**-132417**	**-256586**	**-303499**	**-179552**	**-92530**	**-157164**	**-192120**	**-51566**	**79544**	**205953**	**644373**	**435563**
	Change in % from Ave.	**-16**	**-31**	**-37**	**-22**	**-11**	**-19**	**-23**	**-6**	**10**	**25**	**78**	**53**
Maize	**Ton**	**619896**	**214548**	**301931**	**363629**	**451018**	**459463**	**634464**	**706737**	**689918**	**695073**	**1476990**	**1403580**
	Change in production in Ton	**-48208**	**-453556**	**-366173**	**-304475**	**-217086**	**-208641**	**-33640**	**38633**	**21814**	**26969**	**808886**	**735476**
	Change in % from Ave.	**-7**	**-68**	**-55**	**-46**	**-32**	**-31**	**-5**	**6**	**3**	**4**	**121**	**110**
Millet	**Ton**	818905	759114	792548	795146	1260500	974673	1157810	1128770	1175110	1413910	1390410	1373340
	Change in production in Ton	-267781	-327572	-294138	-291540	173814	-112013	71124	42084	88424	327224	303724	286654
	Change in % from Ave.	-25	-30	-27	-27	16	-10	7	4	8	30	28	26

Burkina Faso

CROP	Years	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Sorghum	**Ton**	1178390	1016280	1371570	1373330	1610260	1399300	1552910	1515770	1507160	1875050	1521470	1990230
	Change in production in Ton	-314253	-476363	-121073	-119313	117616.7	-93343	60266	23126	14516	382406	28826	497586
	Change in % from Ave.	-21	-32	-8	-8	8	-6	4	2	1	26	2	33
Maize	**Ton**	**468948**	**423494**	**606291**	**653081**	**665508**	**481474**	**799052**	**866664**	**553874**	**1013630**	**894558**	**1133450**
	Change in production in Ton	**-244387**	**-289841**	**-107044**	**-60254**	**-47827**	**-231861**	**85717**	**153329**	**-159461**	**300295**	**181223**	**420115**
	Change in % from Ave.	**-34**	**-41**	**-15**	**-8**	**-7**	**-33**	**12**	**21**	**-22**	**42**	**25**	**59**
Millet	**Ton**	945001	725613	1009040	994661	1184280	937630	1196250	1175040	966016	1255190	970927	1147890
	Change in production in Ton	-97294	-316682	-33255	-47634	141985	-104665	153955	132745	-76279	212895	-71368	105595
	Change in % from Ave.	-9	-30	-3	-5	14	-10	15	13	-7	20	-7	10

Botswana

CROP	Years	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Sorghum	**Ton**	**13000**	**11322**	**15000**	**15805**	**32298**	**17050**	**18316**	**26125**	**26626**	**23633**	**37581**	**41000**
	Change in production in Ton	**-10146**	**-11824**	**-8146**	**-7341**	**9152**	**-6096**	**-4830**	**2979**	**3480**	**487**	**14435**	**17854**
	Change in % from Ave.	**-44**	**-51**	**-35**	**-32**	**40**	**-26**	**-21**	**13**	**15**	**2**	**62**	**77**
Maize	**Ton**		**9347**		**16447**			**10929**			**8967**	**13193**	**14100**
	Change in production in Ton		**-2817**		**4283**			**-1235**			**-3197**	**1029**	**1936**
	Change in % from Ave.		**-23**		**35**			**-10**			**-26**	**8**	**16**

Cameroon

CROP	Years	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Cassava	Ton	1889190	1918300	1947270	2003630	2047710	2092760	2393800	2652180	2767460	2882730	2950000	3024000
	Change in production in Ton	-491563	-462453	-433483	-377123	-333043	-287993	13048	271428	386708	501978	569248	643248
	Change in % from Ave.	-21	-19	-18	-16	-14	-12	1	11	16	21	24	27
Sorghum	Ton		420000	505000	541975	573951	607814	764485	852107	906222	931478	900000	900000
	Change in production in Ton		-298457	-213457	-176482	-144506	-110643	46028	133650	187765	213021	181543	181543
	Change in % from Ave.		-42	-30	-25	-20	-15	6	19	26	30	25	25
Maize	Ton	785000	741447	738627	861456	912280	966106	1050400	1249490	1322160	1394830	1450000	1674400
	Change in production in Ton	-310516	-354069	-356889	-234060	-183236	-129410	-45116	153974	226644	299314	354484	578884
	Change in % from Ave.	-28	-32	-33	-21	-17	-12	-4	14	21	27	32	53

Sierra Leone

CROP	Years	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Cassava	Ton	239597	240891	300000	260000	325000	290000	320000	350000	370000	396564	349618	361300
	Change in production in Ton	-77317	-76023	-16914	-56914	8086	-26914	3086	33086	53086	79650	32704	44386
	Change in % from Ave.	-24	-24	-5	-18	3	-8	1	10	17	25	10	14

Cote d'Ivoire, IC

CROP	Years	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Cassava	Ton	2113890	2100350	2086900	2073540	2060260	2074060	2197990	2267140	2342160	2531240	2262170	2450000
	Change in production in Ton	-99418	-112958	-126408	-139768	-153048	-139248	-15318	53832	128852	317932	48862	236692
	Change in % from Ave.	-4	-5	-6	-6	-7	-6	-1	2	6	14	2	11
Maize	Ton	569382	576910	584538	592267	600098	619831	640213	638753	531940	630188	637372	700000
	Change in production in Ton	-40742	-33214	-25586	-17857	-10026	9707	30089	28629	-78184	20064	27248	89876
	Change in % from Ave.	-7	-5	-4	-3	-2	2	5	5	-13	3	4	15
Green Maize	Ton	394584	410318	250000	254330	176576	182427	205910	210221	215231	202469	160995	185000
	Change in production in Ton	157246	172980	12662	16992	-60762	-54911	-31428	-27117	-22107	-34869	-76343	-52338
	Change in % from Ave.	66	73	5	7	-26	-23	-13	-11	-9	-15	-32	-22

Ghana

CROP	Years	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Cassava	**Ton**	7845440	8106800	8965840	9731040	10239300	9738810	9567000	9638000	10217900	11351100	12230600	13504100
	Change in production in Ton	-2249221	-1987861	-1128821	-363621	144639	-355851	-527661	-456661	123239	1256439	2135939	3409439
	Change in % from Ave.	-22	-20	-11	-4	1	-4	-5	-5	1	12	21	34
Sorghum	**Ton**	**302020**	**279800**	**279712**	**316070**	**337670**	**287000**	**305000**	**315000**	**330950**		**350550**	**324422**
	Change in production in Ton	**-9634**	**-31854**	**-31942**	**4416**	**26016.0**	**-24654**	**-6654**	**3346**	**19296**	**-311654**	**38896**	**12768**
	Change in % from Ave.	**-3**	**-10**	**-10**	**1**	**8**	**-8**	**-2**	**1**	**6**	**-100**	**12**	**4**
Maize	**Ton**	**1014450**	**1012700**	**937973**	**1400000**	**1288600**	**1157620**	**1171000**	**1189000**	**1219600**	**1470080**	**1619590**	**1871700**
	Change in production in Ton	**-264909**	**-266659**	**-341386**	**120641**	**9241**	**-121739**	**-108359**	**-90359**	**-59759**	**190721**	**340231**	**592341**
	Change in % from Ave.	**-21**	**-21**	**-27**	**9**	**1**	**-10**	**-8**	**-7**	**-5**	**15**	**27**	**46**

Nigeria

CROP	Years	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Cassava	**Ton**	**32697000**	**32010000**	**32068000**	**34120000**	**36304000**	**38845000**	**41565000**	**45721000**	**43410000**	**44582000**	**36804300**	**37504100**
	Change in production in Ton	**-5272200**	**-5959200**	**-5901200**	**-3849200**	**-1665200**	**875800**	**3595800**	**7751800**	**5440800**	**6612800**	**-1164900**	**-465100**
	Change in % from Ave.	**-14**	**-16**	**-16**	**-10**	**-4**	**2**	**9**	**20**	**14**	**17**	**-3**	**-1**
Sorghum	**Ton**	**476119**	**370716**	**655729**	**636300**	**757600**	**599500**	**943900**	**929265**	**975223**	**1226250**	**738661**	**1304830**
	Change in production in Ton	**-325055**	**-430458**	**-145445**	**-164874**	**-43574**	**-201674**	**142726**	**128091**	**174049**	**425076**	**-62513**	**503656**
	Change in % from Ave.	**-41**	**-54**	**-18**	**-21**	**-5**	**-25**	**18**	**16**	**22**	**53**	**-8**	**63**
Maize	**Ton**	**5476000**	**4107000**	**4596000**	**4890000**	**5203000**	**5567000**	**5957000**	**7100000**	**6724000**	**7525000**	**7338840**	**7305530**
	Change in production in Ton	**-506448**	**-1875448**	**-1386448**	**-1092448**	**-779448**	**-415448**	**-25448**	**1117553**	**741553**	**1542553**	**1356393**	**1323083**
	Change in % from Ave.	**-8**	**-31**	**-23**	**-18**	**-13**	**-7**	**0**	**19**	**12**	**26**	**23**	**22**
Millet	**Ton**	5960000	6105000	5530000	5884000	6260000	6699000	7168000	7705000	8090000	9064000	4884890	4124560
	Change in production in Ton	-496204	-351204	-926204	-572204	-196204	242796	711796	1248796	1633796	2607796	-1571314	-2331644
	Change in % from Ave.	-7.7	-5.4	-14.3	-8.9	-3.0	3.8	11.0	19.3	25.3	40.4	-24.3	-36.1

Qatar

CROP	Years	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Green Maize	**Ton**	**950**	**980**	**795**	**779**	**1466**	**1162**	**836**	**850**	**860**	**811**	**858**	**830**
	Change in production in Ton	**19**	**49**	**-136**	**-152**	**535**	**231**	**-95**	**-81**	**-71**	**-120**	**-73**	**-101**
	Change in % from Ave.	**2**	**5**	**-15**	**-16**	**57**	**25**	**-10**	**-9**	**-8**	**-13**	**-8**	**-11**

Liberia

CROP	Years	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Cassava	Ton	361300	440500	480000	506571	490000	508943	532614	500000	550000	560000	495300	493000
	Change in production in Ton	-131886	-52686	-13186	13385	-3186	15757	39428	6814	56814	66814	2114	-186
	Change in % from Ave.	-27	-11	-3	3	-1	3	8	1	12	14	0	0
Green Maize	Ton	29284	30452	30703	33409	35307	36359	38660	18000	19500	22960	18257	22400
	Change in production in Ton	1343	2511	2762	5468	7366	8418	10719	-9941	-8441	-4981	-9684	-5541
	Change in % from Ave.	5	9	10	20	26	30	38	-36	-30	-18	-35	-20

Lebanon

CROP	Years	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Potato	Ton	**281600**	**275000**	**257000**	**397100**	**416400**	**499000**	**511400**	**398000**	**514600**	**514600**	**515000**	**574100**
	Change in production in Ton	**-147883**	**-154483**	**-172483**	**-32383**	**-13083**	**69517**	**81917**	**-31483**	**85117**	**85117**	**85517**	**144617**
	Change in % from Ave.	**-34**	**-36**	**-40**	**-8**	**-3**	**16**	**19**	**-7**	**20**	**20**	**20**	**34**

Greece

CROP	Years	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Wheat	Ton	**1977000**	**2326000**	**2196000**	**2039000**	**1703000**	**2092100**	**2044150**	**1778170**	**1629070**	**1939300**	**1830000**	**1600000**
	Change in production in Ton	**47518**	**396518**	**266518**	**109518**	**-226483**	**162618**	**114668**	**-151313**	**-300413**	**9818**	**-99483**	**-329483**
	Change in % from Ave.	**2**	**21**	**14**	**6**	**-12**	**8**	**6**	**-8**	**-16**	**1**	**-5**	**-17**
Potato	Ton	**978000**	**1012000**	**959819**	**901000**	**955000**	**948361**	**818727**	**901705**	**943196**	**848000**	**848000**	**791500**
	Change in production in Ton	**69224**	**103224**	**51043**	**-7776**	**46224**	**39585**	**-90049**	**-7071**	**34420**	**-60776**	**-60776**	**-117276**
	Change in % from Ave.	**8**	**11**	**6**	**-1**	**5**	**4**	**-10**	**-1**	**4**	**-7**	**-7**	**-13**

Iran

CROP	Years	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Wheat	Ton	**8673200**	**8087760**	**9458620**	**12450000**	**13439600**	**14568500**	**14308000**	**14663700**	**15886600**	**7956650**	**13484500**	**15028800**
	Change in production in Ton	**-3660627**	**-4246067**	**-2875207**	**116172**	**1105772**	**2234672**	**1974172**	**2329872**	**3552772**	**-4377177**	**1150672**	**2694972**
	Change in % from Ave.	**-30**	**-34**	**-23**	**1**	**9**	**18**	**16**	**19**	**29**	**-35**	**9**	**22**
Potato	Ton	**3433110**	**3658040**	**3485810**	**3756000**	**4210640**	**4453790**	**4830120**	**4218520**	**4026410**	**4706720**	**4107630**	**4054490**
	Change in production in Ton	**-645330**	**-420400**	**-592630**	**-322440**	**132200**	**375350**	**751680**	**140080**	**-52030**	**628280**	**29190**	**-23950**
	Change in % from Ave.	**-16**	**-10**	**-15**	**-8**	**3**	**9**	**18**	**3**	**-1**	**15**	**1**	**-1**

Spain

CROP	Years	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Potato	Ton	3367400	3078060	2992420	3078140	2664960	2773570	2563460	2515000	2479580	2145170	2459800	2277900
	Change in production in Ton	667778	378438	292798	378518	-34662	73948	-136162	-184622	-220042	-554452	-239822	-421722
	Change in % from Ave.	25	14	11	14	-1	3	-5	-7	-8	-21	-9	-16

Portugal

CROP	Years	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Potato	Ton	949117	742588	694051	781287	735828	769767	576304	611200	638900	566600	435200	384000
	Change in production in Ton	292047	85518	36981	124217	78758	112697	-80766	-45870	-18170	-90470	-221870	-273070
	Change in % from Ave.	44	13	6	19	12	17	-12	-7	-3	-14	-34	-42

C. Under Areas with Moderate Vulnerability

Namibia

CROP	Years	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Maize	Ton						28244		60853	55523	58101	57320	58000
	Change in production in Ton						-24763		7846	2516	5094	4313	4993
	Change in % from Ave.						-47		15	5	10	8	9
Millet	Ton	47500	77000	65000	56055	52200	74400	47900	50000	44450	35512	37301	40000
	Change in production in Ton	-4777	24724	12724	3779	-77	22124	-4377	-2277	-7827	-16765	-14976	-12277
	Change in % from Ave.	-9	47	24	7	0	42	-8	-4	-15	-32	-29	-23

Iraq

CROP	Years	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Potato	Ton	730000	545000	623000	897000	872000	630000	808000	794000	598000	348773		
	Change in production in Ton	45423	-139577	-61577	212423	187423	-54577	123423	109423	-86577	-335804		
	Change in % from Ave.	7	-20	-9	31	27	-8	18	16	-13	-49		

Tunisia

CROP	Years	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Wheat	Ton	1390000	842000	1118000	422200	1984000	1722000	1626700	1250600	1442800	919000	1653600	822100
	Change in production in Ton	123917	-424083	-148083	-843883	717917	455917	360617	-15483	176717	-347083	387517	-443983
	Change in % from Ave.	10	-33	-12	-67	57	36	28	-1	14	-27	31	-35
Potato	Ton	**320000**	**290000**	**330000**	**310000**	**310000**	**375000**	**310000**	**365000**	**350000**	**370000**	**324000**	**380000**
	Change in production in Ton	**-16167**	**-46167**	**-6167**	**-26167**	**-26167**	**38833**	**-26167**	**28833**	**13833**	**33833**	**-12167**	**43833**
	Change in % from Ave.	**-5**	**-14**	**-2**	**-8**	**-8**	**12**	**-8**	**9**	**4**	**10**	**-4**	**13**

Gabon

CROP	Years	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Cassava	Ton	224000	228000	225000	226000	234000	228000	229000	235000	240000	243302	306897	270000
	Change in production in Ton	-16767	-12767	-15767	-14767	-6767	-12767	-11767	-5767	-767	2535	66130	29233
	Change in % from Ave.	-7	-5	-7	-6	-3	-5	-5	-2	0	1	27	12
Maize	Ton	**26800**	**25900**	**25150**	**24000**	**31000**	**31085**	**34686**	**32000**	**33000**	**34836**	**46005**	**39500**
	Change in production in Ton	**-5197**	**-6097**	**-6847**	**-7997**	**-997**	**-912**	**2689**	**3**	**1003**	**2839**	**14008**	**7503**
	Change in % from Ave.	**-16**	**-19**	**-21**	**-25**	**-3**	**-3**	**8**	**0**	**3**	**9**	**44**	**23**

Morocco

CROP	Years	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Wheat	Ton	2153540	1380700	3316380	3358680	5146840	5539840	3043080	6326760	1582630	3769450	6371430	4876140
	Change in production in Ton	-1751916	-2524756	-589076	-546776	1241384	1634384	-862376	2421304	-2322826	-136006	2465974	970684
	Change in % from Ave.	-45	-65	-15	-14	32	42	-22	62	-59	-3	63	25
Potato	Ton	1140780	1090350	1154600	1334380	1401470	1481800	1478540	1569100	1437220	1536560	1234470	1604620
	Change in production in Ton	**-231211**	**-281641**	**-217391**	**-37611**	**29479**	**109809**	**106549**	**197109**	**65229**	**164569**	**-137521**	**232629**
	Change in % from Ave.	**-17**	**-21**	**-16**	**-3**	**2**	**8**	**8**	**14**	**5**	**12**	**-10**	**17**

Eritrea

CROP	Years	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Wheat	Ton	27518	13776	36490				21559	21570	27274		26142	27300
	Change in production in Ton	2314	-11428	11286				-3645	-3634	2070		938	2096
	Change in % from Ave.	9	-45	45				-14	-14	8		4	8
Sorghum	Ton	207197	62005	78759	28434	64061	56745	183906	221613	302515	67980	59188	66700
	Change in production in Ton	90605	-54587	-37833	-88158	-52531	-59847	67314	105021	185923	-48612	-57404	-49892
	Change in % from Ave.	78	-47	-32	-76	-45	-51	58	90	159	-42	-49	-43
Potato	Ton	40000	46431	17415	15280	10850	16000	17488	11978				785800
	Change in production in Ton	-66805	-60374	-89390	-91525	-95955	-90805	-89317	-94827				678995
	Change in % from Ave.	-63	-57	-84	-86	-90	-85	-84	-89				636
Millet	Ton	23231.0		30267.0	5796.0	16935.0	11971.0	40571.0	33092.0	63254.0	12239.0	17217.0	17000.0
	Change in production in Ton	-1457.5		5578.5	-18892.5	-7753.5	-12717.5	15882.5	8403.5	38565.5	-12449.5	-7471.5	-7688.5
	Change in % from Ave.	-5.9		22.6	-76.5	-31.4	-51.5	64.3	34.0	156.2	-50.4	-30.3	-31.1
Barley	Ton	31835	25786	44934				56025	52345	39489		65084	67000
	Change in production in Ton	-15977	-22026	-2878				8213	4533	-8323		17272	19188
	Change in % from Ave.	-33	-46	-6				17	9	-17		36	40

Syrian Arab Republic

CROP	Years	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Wheat	Ton	2691500	3105490	4744620	4775440	4912990	4537460	4668750	4932000	4041100	2139300	3701780	3083100
	Change in production in Ton	-1252961	-838971	800159	830979	968529	592999	724289	987539	96639	-1805161	-242681	-861361
	Change in % from Ave.	-32	-21	20	21	25	15	18	25	2	-46	-6	-22
Potato	Ton	496503	484778	453435	513200	486600	541743	608400	603400	570128	720492	709601	673200
	Change in production in Ton	-75287	-87012	-118355	-58590	-85190	-30047	36610	31610	-1662	148702	137811	101410
	Change in % from Ave.	-13	-15	-21	-10	-15	-5	6	6	0	26	24	18

Equatorial Guinea

CROP	Years	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Cassava	**Ton**	45000	46433	47454	48825	49319	49758	54473	55469	57192	57979	73134	64300
	Change in production in Ton	-9111	-7678	-6657	-5286	-4792	-4353	362	1358	3081	3868	19023	10189
	Change in % from Ave.	-17	-14	-12	-10	-9	-8	1	3	6	7	35	19
Sweet Potato	**Ton**	36000	37703	44908	48969	56525	61966	65284	67611	82890	76884	92154	90200
	Change in production in Ton	-27425	-25722	-18517	-14456	-6900	-1459	1860	4187	19466	13460	28730	26776
	Change in % from Ave.	-43	-41	-29	-23	-11	-2	3	7	31	21	45	42

Kuwait

CROP	Years	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Potato	**Ton**	24446	17979	31850	17465	20811	20740	20740	20740	23500	23500	25229	26500
	Change in production in Ton	1654	-4813	9058	-5327	-1981	-2052	-2052	-2052	708	708	2437	3708
	Change in % from Ave.	7	-21	40	-23	-9	-9	-9	-9	3	3	11	16

D. Under Areas with High to Moderate Vulnerability

Senegal

CROP	Years	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Cassava	**Ton**	104009	132859	137893	106960	181721	401448	308312	920866	265533	920866	265533	181236
	Change in production in Ton	-223261	-194411	-189377	-220310	-145549	74178	-18958	593596	-61737	593596	-61737	-146034
	Change in % from Ave.	-68	-59	-58	-67	-44	23	-6	181	-19	181	-19	-45
Sorghum	**Ton**	147444	143750	149649	116929	126492	143989	121003	100704	251515	224956		162599
	Change in production in Ton	-6104	-9798	-3899	-36619	-27056	-9559	-32545	-52844	97967	71408	-153548	9051
	Change in % from Ave.	-4	-6	-3	-24	-18	-6	-21	-34	64	47		6
Maize	**Ton**			108546	116929	400907	400555	399958	181585	158266	397326	328644	186511
	Change in production in Ton			-159377	-150994	132984	132632	132035	-86338	-109657	129403	60721	-81412
	Change in % from Ave.			-59	-56	50	50	49	-32	-41	48	23	-30
Millet	**Ton**	675000	600221	556655	414820	628426	323752	608551	494345	318822	678171	810121	813295
	Change in production in Ton	98152	23373	-20193	-162028	51578	-253096	31703	-82503	-258026	101323	233273	236447
	Change in % from Ave.	17	4	-4	-28	9	-44	5	-14	-45	18	40	41

Somalia

CROP	Years	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Cassava	Ton	65000	70000	75000	80000	75286	85000	93479	82000	73341	78745	82566	78000
	Change in production in Ton	-13201	-8201	-3201	1799	-2915	6799	15278	3799	-4860	544	4365	-201
	Change in % from Ave.	-17	-10	-4	2	-4	9	20	5	-6	1	6	0
Sorghum	Ton	130000	123518	136612	141393	121000	145000	140000	145000	80000	75046	86080	100400
	Change in production in Ton	11329	4847	17941	22722	2329	26329	21329	26329	-38671	-43625	-32591	-18271
	Change in % from Ave.	10	4	15	19	2	22	18	22	-33	-37	-27	-15
Maize	Ton	165615	265930	287500	287500	268860	202470	200000	97000	99000	100000	111838	141600
	Change in production in Ton	-19994	80321	101891	101891	83251	16861	14391	-88609	-86609	-85609	-73771	-44009
	Change in % from Ave.	-11	43	55	55	45	9	8	-48	-47	-46	-40	-24

Kenya

CROP	Years	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Maize	Ton	2322140	2160000	2790000	2408600	2710850	2607140	2905560	3247200	2928790	2367240	2439000	3222000
	Change in production in Ton	-353570	-515710	114290	-267110	35140	-68570	229850	571490	253080	-308470	-236710	546290
	Change in % from Ave.	-13	-19	4	-10	1	-3	9	21	9	-12	-9	20
Potato	Ton	1047570	670303	1112850	861566	1223530	1084410	980163	783783	850000	600000		450000
	Change in production in Ton	169009	-208258	234289	-16995	344969	205849	101602	-94778	-28561	-278561		-428561
	Change in % from Ave.	19	-24	27	-2	39	23	12	-11	-3	-32		-49
Sweet Potato	Ton									811531	894781	930784	
	Change in production in Ton									811531	15749	51752	
	Change in % from Ave.									-8	2	6	

B. Economic Crop losses

Although the prices of agricultural commodities started to rise from as early as 2001, the sharpest increase occurred in the years 2006-08,(ICRISAT 2008[244]), (Figure 4.60). The rise in prices can be attributed to a multitude of factors both on the demand and supply side. Fuelled by technological change, the real prices of agricultural commodities witnessed a secular decline until 2000, at an annual rate of about 2% a year between 1970 and 2005, with some minor intermittent ups and downs, both absolutely and relative to the manufactured products (FAO 2004[245]).

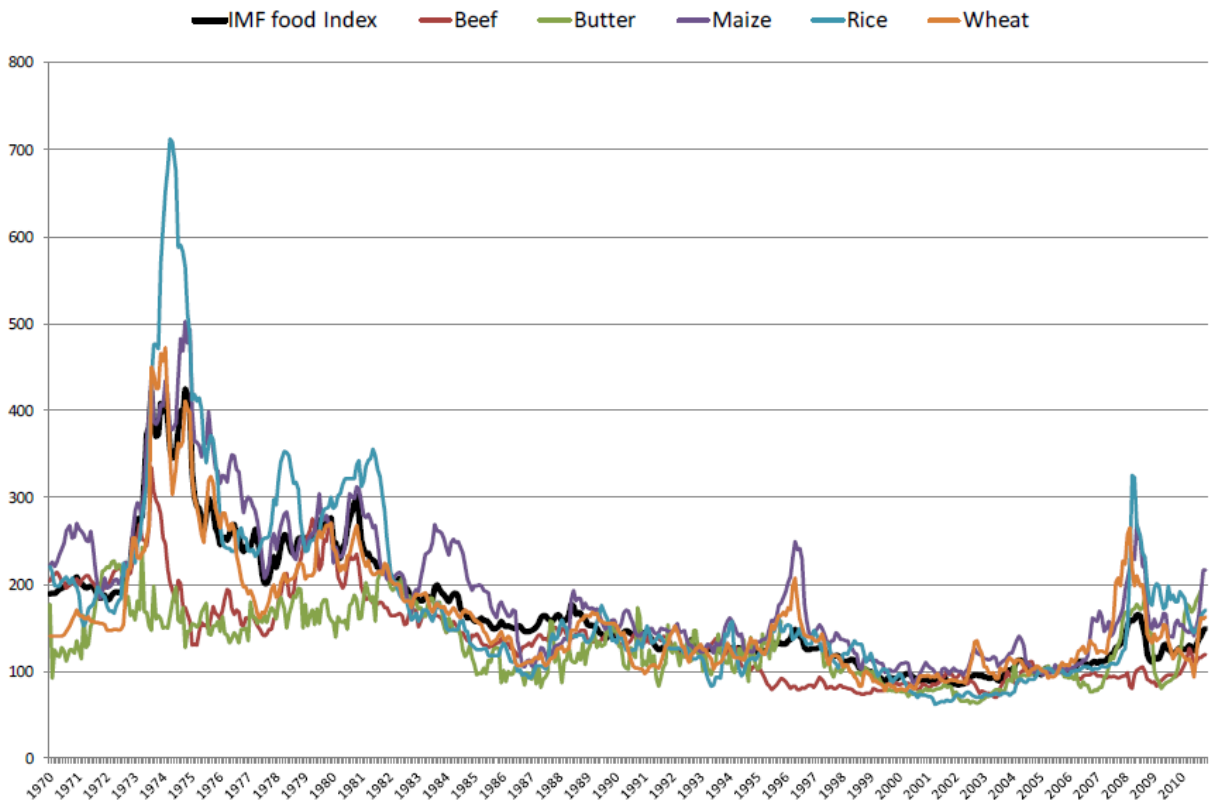


Figure.4.60 Agricultural commodity prices in real terms (2005=100)

While much has been written about the price trends of fine cereals and commercial crops, very little is known about the trends in crops like sorghum and millet that are both staples and an important source of income for the small-scale farmers in the semi-arid tropics, as in sub-Saharan Africa,(ICRISAT 2008), Trend in real export prices of sorghum, millets and maize 1970-2008, is shown in (figure 4.61).

[244] ICRISAT 2008. Strategic Assessments and Development Pathways for Agriculture in the Semi-Arid Tropics Policy Brief No. 13

[245] FAO. 2004. The state of agricultural commodity market. Rome, Italy: FAO.

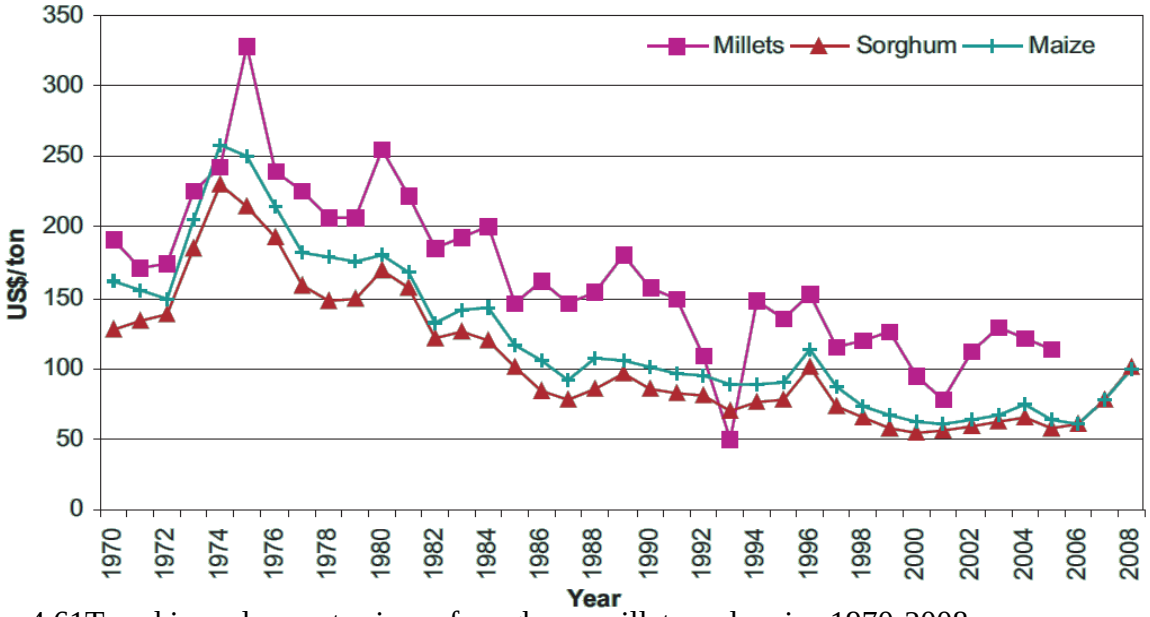


Figure 4.61Trend in real export prices of sorghum, millets and maize 1970-2008,
Source of data: World Bank 2008.

The economical crop losses were studied and calculated from the data illustrated above in table (4.23), and the results are presented in (Table 4.24). The results show the following Crop Losses classes:

- Class 1: Loss in US$ of more than 7 billion US$ in 12 years, as in Nigeria
- Class 2: Loss in US$ range between 5- 7 billion US$ in 12 years, as in France, Iran and Angola
- Class 3: Loss in US$ range between 2.5- 5 billion US$ in 12 years, as in Malawi, Morocco and Turkey
- Class 4: Loss in US$ range between 1- 2,5 billion US$ in 12 years, as in Egypt, Ghana, Algeria, Syrian Arab Republic, South Africa, Ethiopia, Rwanda, Mozambique, Iraq and Italy
- Class 5: Loss in US$ range between 0.75- 1.0 billion US$ in 12 years, Benin, Saudi Arabia and Cameroon
- Class 5: Loss in US$ range between 0. 5- 0.75 billion US$ in 12 years, Madagascar, Tunisia, Congo Democratic Republic, Uganda, Kenya and Spain,
- Class 6: Loss in US$ range between 0.25- 0.5 billion US$ in 12 years, Senegal, Greece, Zambia, Mali, Niger and Cote d'lvoire, IC
- Class 7: Loss in US$ range between 0.1- 0.25 billion US$ in 12 years, Burundi, Burkina Faso, Portugal, Guinea, Zimbabwe, Congo, Lebanon, Togo, Chad and Yemen
- Class 8: Loss in US$ range between 0.05 - 0.1 billion US$ in 12 years, Libya, Comoros, Sierra Leone, Central African Republic and Liberia
- Class 9: Loss in US$ less than 0.05 billion US$ in 12 years, Jordon, Somalia, Lesotho, Gabon, Guinea-Bissau, Gambia, Mauritania, Eritrea, Equatorial Guinea, Oman, Swaziland, Namibia, Kuwait, Botswana, and Sao Tome and Principles

The real crop losses figures related to the severity of drought hazard are wider than obtained from the studied crops and could be improved in more detailed studies for each country using similar technique like the one used in this study.

Table 4. 23Rainfed Drought Hazard Impacts on Crop Production

Country	Total Rainfed		Total Affected Rainfed %	Crop	Intensity	Frequency	Consecutive
	in Ha	%					
Algeria	9345798.74	4.19	3.6	Wheat	Moderate	5	4
				Maize	Moderate	8	6
				Potatoes	Moderate	5	4
Angola	9677668.03	8.36	0.4	Cassava	Moderate	**6**	**6**
				Potatoes	Moderate	7	6
				Millet	Slight	4	2
Benin	2962110.62	26.30	7.99	Cassava	Slight	7	4
				Sorghum	Slight	4	3
				Maize	Moderate	8	6
Botswana	10151616.53	17.45	3.38	Sorghum	High	6	4
				Maize	Slight	2	1
Burkina Faso	6524165.64	23.79	23.78	Sorghum	Slight	5	4
				Maize	Moderate	7	6
				Millet	Slight	7	4
Burundi	881116.20	31.66	0.15	Cassava	Moderate	**5**	**5**
				Sorghum	Slight	5	5
				Maize	Slight	5	4
Cameroon	6932213.44	14.58	7.24	Cassava	Moderate	**6**	**6**
				Sorghum	Moderate	5	5
				Maize	Moderate	7	7
C African R	2706937.63	4.35	0.48	Cassava	Slight	8	8
				Maize	Slight	6	6
Chad	17234489.77	13.42	7.68	Cassava	Slight	**5**	**4**
				Sorghum	Slight	6	4
				Maize	Slight	2	1
				Millet	Moderate	5	4
Congo	3190778.50	9.33	3.88	Cassava	Slight	**9**	**9**
				Maize	Slight	9	9
Congo, DRC	36702941.92	15.65	0.41	Cassava	Slight	**7**	**7**
Cote d'Ivory	10852221.01	33.65	22.87	Cassava	Slight	**7**	**7**
				Maize	Slight	**6**	**5**
				Green Maize	Moderate	8	8
Egypt	443831.90	0.44	0.23	Wheat	Slight	6	5
				Potatoes	Moderate	7	6
Eq. Guinea	182120.73	6.49	5.99	Cassava	Slight	**6**	**6**
Eritrea	1227487.52	10.44	8.74	Barley	Slight	6	6
				Sorghum	High	8	5
				Potatoes	High	8	8
				Millet	Moderate	7	3
Ethiopia	34810466.07	31.52	6.58	Wheat	Moderate	5	5
				Barley	Slight	6	6
				Sorghum	Mod	6	6
				Maize	Slight	**7**	**6**

Table 4. 23Cont'd

Country	Total Rainfed		Total Affected Rainfed %	Crop	Intensity	Frequency	Consecutive
	in Ha	%					
France	9654533.38	17.51	10.81	Wheat	Slight	4	2
				Barley	Slight	6	6
				Maize	Slight	4	3
				Potatoes	Slight	7	3
Gabon	1482186.97	5.54	3.87	Cassava	Slight	**9**	**9**
Gambia	532274.29	47.12	4.5	Cassava	Slight	**6**	**3**
				Sorghum	Moderate	5	2
				Maize	Moderate	9	9
				Millet	Moderate	5	4
Ghana	6819500.04	28.59	16.76	Cassava	Slight	**7**	**4**
				Sorghum	Slight	5	3
				Maize	Slight	**7**	**4**
Greece	3350487.81	25.39	22.69	Wheat	Slight	5	2
				Potatoes	Slight	5	3
Guinea	4166644.33	31.58	7.82	Cassava	Slight	**5**	**5**
				Maize	Moderate	6	6
				Green Maize	Slight	7	4
Guinea-Bissau	709141.99	19.63	0.75	Cassava	Moderate	**9**	**8**
				Sorghum	Slight	6	2
				Maize	Slight	4	2
				Millet	Moderate	7	5
Iran	20769014.56	12.60	9.06	Wheat	Moderate	4	3
				Potatoes	Slight	6	4
Iraq	4390931.09	10.02	8.29	Wheat	Moderate	5	2
				Potatoes	Slight	5	2
Israel	655916.55	31.58	23.38	Potatoes	Moderate	5	5
Italy	12579587.11	41.75	30.65	Wheat	Slight	6	2
Jordan	4111.61	1.21	25.13	Potatoes	Moderate	7	5
Kenya	14837964.78	25.57	5.07	Wheat	Slight	3	2
				Cassava	Slight	**4**	**2**
				Maize	Slight	6	3
				Potatoes	Moderate	6	3
Kuwait	1507.59	0.08	0.09	Potatoes	Slight	6	5
Lebanon	724137.49	69.63	63.45	Potatoes	Moderate	6	5
Lesotho	690548.76	22.75	0.57	Wheat	High	5	5
				Sorghum	High	8	8
				Maize	Moderate	6	3
				Potatoes	Slight	6	5
Liberia	3442633.10	30.91	17.6	Cassava	Slight	**4**	**3**
				Green Maize	Moderate	5	5
Libya	452755.12	0.26	0.22	Potatoes	Moderate	6	6
Madagascar	6373006.91	10.86	0.05	Cassava	Slight	**6**	**6**
				Maize	Moderate	6	6
				Potatoes	High	6	6
Malawi	2283400.80	19.27	1.41	Cassava	High	**5**	**2**
				Maize	High	6	2
				Potatoes	High	6	2

Table 4. 23Cont'd

Country	Total Rainfed		Total Affected Rainfed %	Crop	Intensity	Frequency	Consecutive
	in Ha	%					
Mali	19161916.91	15.45	8.66	Sorghum	Moderate	8	8
				Maize	High	6	6
				Millet	Moderate	5	4
Mauritania	2493309.44	2.42	2.01	Sorghum	moderate	4	2
				Maize	Slight	3	1
				Millet	Slight	3	2
Morocco	11153532.35	24.98	22.28	Wheat	High	7	4
				Potatoes	Slight	5	4
Mozambique	12759199.11	15.96	1.09	Cassava	Slight	**5**	**2**
				Sorghum	Moderate	8	5
Namibia	3857952.19	4.68	0.4	Maize	Slight	1	1
				Millet	Moderate	7	6
Niger	3877142.13	3.06	1.69	Sorghum	Moderate	6	6
				Millet	Slight	7	4
Nigeria	39908867.19	43.20	22.84	Cassava	Slight	**7**	**5**
				Sorghum	Slight	6	4
				Maize	Moderate	6	6
				Millet	Moderate	7	5
Oman	113031.56	0.37	0.17	Sorghum	High	7	5
				Potatoes	Moderate	7	4
Qatar	2053.71	0.18	0.09	Green Maize	Slight	8.0	6.0
Rwanda	1250227.87	47.47	0.07	Cassava	High	**9**	**9**
				Sorghum	Slight	5	2
				Maize	High	**9**	**9**
				Potatoes	Moderate	6	4
S.Tome&Principe	675.64	0.70	0.14	Cassava	Slight	**7**	**7**
				Maize	Moderate	7	6
Saudi Arabia	566390.72	0.26	0.14	Wheat	Moderate	6	3
				Sorghum	Slight	5	2
				Potatoes	Slight	6	6
Senegal	10225013.85	51.98	34.83	Cassava	High	**8**	**5**
				sorghum	Moderate	8	8
				Maize	Moderate	4	2
				Millet	Moderate	5	2
Sierra Leone	3766123.30	52.50	28.14	Cassava	Slight	**5**	**4**
Somalia	14684302.83	23.03	11.04	Cassava	Slight	**4**	**3**
				Sorghum	Moderate	4	4
				Maize	High	6	5
South Africa	23310821.05	19.12	2.68	Wheat	Slight	7	3
				Maize	Moderate	6	2
				Potatoes	Slight	7	7
				Green Maize	Slight	8	8
Spain	15550661.59	30.77	22.15	Potatoes	Slight	7	6
Swaziland	381572.08	21.97	0.13	Maize	Moderate	8	5
				Potatoes	Slight	3	2
Syria	3905505.49	21.09	19.64	Wheat	Moderate	5	3

Table 4.23. Cont'd

Country	Total Rainfed		Total Affected Rainfed %	Crop	Intensity	Frequency	Consecutive
	in Ha	%					
Togo	1007215.74	17.74	6.78	Cassava	Slight	**6**	**4**
				Sorghum	Moderate	9	8
				Maize	Slight	**8**	**8**
				Millet	Slight	4	3
Tunisia	2902603.70	17.74	13.49	Wheat	Moderate	6	3
				Potatoes	Slight	7	5
Turkey	46864020.92	59.81	31.75	Wheat	Slight	5	2
				Potatoes	Slight	5	5
Uganda	11067245.84	45.91	0.42	Cassava	Slight	**5**	**3**
				Sorghum	Slight	6	6
				Maize	Slight	5	3
				Millet	Slight	7	7
Yemen	875599.55	1.66	0.99	Wheat	Moderate	8	8
				Sorghum	moderate	6	4
				Potatoes	Slight	8	8
Zambia	8254288.53	10.97	0.17	Wheat	Moderate	6	4
				Cassava	Slight	**6**	**6**
				Maize	Moderate	8	7
Zimbabwe	13099138.64	33.52	4.12	Wheat	Slight	3	2
				Cassava	Slight	**6**	**6**
				Maize	Moderate	5	3

Table 4.24. Economical Total Crop Loss in Million US$

Country	Duration	Potatoes		Wheat		Maize		Sorghum		Millet		Cassava		Crops Total Losses
	1999-2011	Million		Million		Million		Million		Million		Million		
		Ton	US$	Ton	US$	Ton	US$	Ton	US$	Ton	US$	Ton	US$	US$
France	Average	6.70	2010.35	36.30	10890.22	14.96	1121.68							
France	Crop Loss	-1.85	-556.06	-15.06	-4518.24	-7.01	-525.89							-5600.19
France														
Spain		2.70	809.89											
Spain		-1.79	-537.44											-537.44
Spain														
Portugal		0.66	197.12											
Portugal		-0.73	-219.07											-219.07
Portugal														
Algeria		1.85	555.56	2.17	651.32									
Algeria		-3.25	-974.34	-2.91	-873.87									-1848.21
Algeria														
Morocco		1.37	411.6	3.91	1171.64									
Morocco		-0.91	-271.61	-8.73	-2620.12									-2891.73
Morocco														
Tunisia		0.34	100.85	1.27	379.83									
Tunisia		-0.16	-47.75	-2.22	-666.78									-714.53
Tunisia					-0.05									
Libya		0.24	72.91											
Libya		-0.33	-99.97											-99.97
Libya														

Table 4.24 Cont'd

Country	Duration	Potatoes		Wheat		Maize		Sorghum		Millet		Cassava		Crops Total Losses
	1999-2011	Million		Million		Million		Million		Million		Million		
		Ton	US$	Ton	US$	Ton	US$	Ton	US$	Ton	US$	Ton	US$	US$
Italy				7.35	2205.04									
Italy				-3.41	-1024.49									-1024.49
Italy														
Greece		0.91	272.63	1.93	578.84									
Greece		-0.34	-103.12	-1.11	-332.15									-435.27
Greece														
Turkey		4.82	1445.39	19.52	5854.54									
Turkey		-2.78	-834.03	-6.54	-1960.72									-2794.75
Turkey														
Jordon		0.13	38.77											
Jordon		-0.17	-49.8											-49.8
Jordon														
Syrian Arab Republic		0.57	171.54	3.94	1183.34									
Syrian Arab Republic		-0.45	-136.34	-5.00	-1500.34									-1636.68
Syrian Arab Republic														
Lebanon		0.43	128.85	0.14	41.19									
Lebanon		-0.55	-165.54	-0.02	-5.49									-171.03
Lebanon					0									
Iraq		0.68	205.37	1.88	563.85									
Iraq		-0.68	-203.43	-2.91	-872									-1075.43
Iraq					-0.05									

Table 4.24 Cont'd

Country	Duration	Potatoes		Wheat		Maize		Sorghum		Millet		Cassava		Crops Total Losses
	1999-2011	Million		Million		Million		Million		Million		Million		
		Ton	US$	Ton	US$	Ton	US$	Ton	US$	Ton	US$	Ton	US$	US$
Iran		**4.08**	**1223.53**	**12.33**	**3700.15**									
Iran		**-2.03**	**-609.85**	**-15.16**	**-4547.72**									**-5157.57**
Iran														
Oman		**0.02**	**4.89**					**0.02**	**1.37**					
Oman		**-0.02**	**-5.47**					**-0.06**	**-4.41**					**-9.88**
Oman														
Yemen		**0.23**	**69.77**	**0.16**	**47.79**			**0.38**	**28.33**					
Yemen		**-0.16**	**-49.24**	**-0.24**	**-71.79**			**-0.49**	**-36.4**					**-157.43**
Yemen					**-0.05**									
Saudi Arabia		**0.41**	**121.74**	**2.16**	**648.17**			**0.24**	**18.11**					
Saudi Arabia		**-0.32**	**-97.2**	**-2.61**	**-782.98**			**-0.10**	**-7.8**					**-887.98**
Saudi Arabia														
Kuwait		**0.02**	**6.84**											
Kuwait		**-0.02**	**-5.48**											**-5.48**
Kuwait														
Egypt		**2.60**	**779.09**	**7.27**	**2182.11**									
Egypt		**-3.81**	**-1143.8**	**-3.93**	**-1177.73**									**-2321.53**
Egypt														
Ethiopia				**2.09**	**626.68**	**3.39**	254.01	**2.01**	**150.57**					
Ethiopia				**-3.40**	**-1019.37**	**-3.08**	-231.1	**-2.93**	**-219.45**					**-1469.92**
Ethiopia														
Eritrea		**0.11**	**32.04**	**0.03**	**7.56**	**0.02**	**1.85**	**0.12**	**8.74**					
Eritrea		**0.11**	**32.04**	**-0.02**	**-5.61**	**-0.07**	**-5.13**	**-0.45**	**-33.66**					**-12.36**
Eritrea					**-0.02**									

Table 4.24 Cont'd

Country	Duration	Potatoes		Wheat		Maize		Sorghum		Millet		Cassava		Crops Total Losses
	1999-2011	Million		Million		Million		Million		Million		Million		
		Ton	US$	Ton	US$	Ton	US$	Ton	US$	Ton	US$	Ton	US$	US$
Uganda		0.59	175.7			1.21	90.76	0.44	32.89	0.68	51.11	5.20	1561	
Uganda		-0.40	-121.1			-0.48	-35.81	-0.19	-14.06	-0.49	-36.41	-1.20	-361	-568.38
Uganda														
Somalia						0.19	13.92	0.12	8.9			0.08	23	
Somalia						-0.40	-29.9	-0.13	-9.99			-0.03	-9	-48.89
Somalia														
Kenya		0.88	263.57	0.41	122.92	2.68	200.68					0.68	204	
Kenya		-1.06	-316.71	-0.10	-30.68	-1.75	-131.26					-0.21	-63	-541.65
Kenya					-0.01									
Rwanda		1.10	329.04			0.14	10.21	0.17	12.61			1.04	311	
Rwanda		-1.36	-407.02			-0.48	-35.75	-0.11	-7.96			-2.27	-681	-1131.73
Rwanda														
Burundi						0.12	9.3	0.07	5.55			0.58	175	
Burundi						-0.01	-0.4	-0.04	-2.67			-0.79	-236	-239.07
Burundi														
Chad						0.12	9.02	0.54	40.44	0.48	35.66	0.28	83	
Chad						-0.03	-2.12	-0.47	-35.17	-0.70	-52.86	-0.25	-76	-166.15
Chad													0	
Niger								0.80	60.09	2.68	201.01			
Niger								-1.31	-98.33	-2.50	-187.47			-285.8
Niger														

Table 4.24 Cont'd

Country	Duration	Potatoes		Wheat		Maize		Sorghum		Millet		Cassava		Crops Total Losses
	1999-2011	Million		Million		Million		Million		Million		Million		
		Ton	US$	Ton	US$	Ton	US$	Ton	US$	Ton	US$	Ton	US$	US$
Mali						**0.67**	**50.11**	**0.82**	**61.59**	**1.09**	**81.5**			
Mali						**-1.58**	**-118.77**	**-1.37**	**-102.41**	**-1.29**	**-96.98**			**-318.16**
Mali														
Mauritania		**0.01**	**4.34**			**0.02**	**1.15**	**0.07**	**5.56**	**0.01**	**0.46**			
Mauritania		**-0.01**	**-3.58**			**-0.01**	**-0.62**	**-0.12**	**-8.99**	**0.00**	**-0.14**			**-13.33**
Mauritania														
Senegal						**0.27**	**20.09**	**0.15**	**11.52**	**0.58**	**43.26**	**0.33**	**98**	
Senegal						**-0.51**	**-37.98**	**-0.18**	**-13.38**	**-0.78**	**-58.19**	**-1.24**	**-373**	**-482.55**
Senegal														
Burkina Faso						**0.71**	**53.5**	**1.49**	**111.95**	**1.04**	**78.17**			
Burkina Faso						**-1.14**	**-85.55**	**-1.12**	**-84.33**	**-0.75**	**-56.04**			**-225.92**
Burkina Faso														
Sierra Leone												**0.32**	**95**	
Sierra Leone												**-0.25**	**-76**	**-76**
Sierra Leone														
Liberia												**0.49**	**148**	
Liberia												**-0.20**	**-60**	**-60**
Liberia														
Benin						**0.85**	**64**	**0.15**	**11.62**			**2.97**	**890**	
Benin						**-0.88**	**-66**	**-0.10**	**-7.49**			**-2.92**	**-877**	**-950.49**
Benin														

Table 4.24 Cont'd

Country	Duration	Potatoes		Wheat		Maize		Sorghum		Millet		Cassava		Crops Total Losses
	1999-2011	Million		Million		Million		Million		Million		Million		
		Ton	US$	Ton	US$	Ton	US$	Ton	US$	Ton	US$	Ton	US$	US$
Togo						0.55	41.03	0.24	18.19	0.05	3.48	0.76	227	
Togo						-0.24	-17.85	-0.46	-34.52	-0.02	-1.48	-0.38	-115	-168.85
Togo														
Nigeria						5.98	448.68	7.83	586.97	6.46	484.22	37.97	11391	
Nigeria						-6.08	-456.08	-7.06	-529.24	-6.44	-483.37	-24.28	-7283	-8751.69
Nigeria														
Cameroon						1.10	82.2					2.38	714	
Cameroon						-1.61	-121					-2.39	-716	-837
Cameroon														
Equatorial Guinea												0.05	16	
Equatorial Guinea												-0.04	-11	-11
Equatorial Guinea														
Congo												0.95	286	
Congo												-0.59	-177	-177
Congo													0	
Cote d'Ivoire, IC						0.61	45.76					2.21	664	
Cote d'Ivoire, IC						-0.21	-15.42					-0.79	-236	-251.42
Cote d'Ivoire, IC							0							
Gabon						0.03	2.4					0.24	72	
Gabon						-0.03	-2.1					-0.10	-29	-31.1
Gabon							-0.01							

Table 4.24 Cont'd

Country	Duration	Potatoes		Wheat		Maize		Sorghum		Millet		Cassava		Crops Total Losses
	1999-2011	Million		Million		Million		Million		Million		Million		
		Ton	US$	Ton	US$	Ton	US$	Ton	US$	Ton	US$	Ton	US$	US$
Gambia, The						0.03	2.54	0.03	2.04	0.12	8.68	0.01	3	
Gambia, The						-0.06	-4.8	-0.03	-2.55	-0.12	-9.33	-0.01	-2	-18.68
Gambia, The							-0.01							
Ghana						1.28	95.95	0.31	23.37			10.09	3028	
Ghana						-1.25	-93.99	-0.10	-7.86			-7.07	-2121	-2222.85
Ghana														
Guinea						0.50	37.48					0.97	290	
Guinea						-0.74	-55.8					-0.53	-160	-215.8
Guinea														
Guinea-Bissau						0.03	1.89	0.02	1.32	0.03	2.26	0.04	13	
Guinea-Bissau						-0.02	-1.23	-0.02	-1.25	-0.04	-2.93	-0.05	-16	-21.41
Guinea-Bissau							0							
Congo Democratic Republic						1.16	87.2					15.23	4570	
Congo Democratic Republic						-0.06	-4.82					-2.20	-660	-664.82
Congo Democratic Republic													0	
Malawi		2.04	610.66			1.91	143.41					2.13	639	
Malawi		-4.87	-1460.48			-4.54	-340.3					-5.73	-1718	-3518.78
Malawi														
Mozambique							97.63	0.22	16.54			5.61	1682	
Mozambique							-101.78	-0.37	-27.55			-3.24	-973	-1102.33
Mozambique														
Central African Republic						0.13	9.43					0.59	177	

Table 4.24 Cont'd

Country	Duration	Potatoes		Wheat		Maize		Sorghum		Millet		Cassava		Crops Total Losses
	1999-2011	Million		Million		Million		Million		Million		Million		
		Ton	US$	Ton	US$	Ton	US$	Ton	US$	Ton	US$	Ton	US$	US$
Central African Republic						-0.10	-7.13					-0.19	-56	-63.13
Central African Republic							-0.01							
Angola		0.41	123.28			0.63	48			0.13	9.68	8.11	2433	
Angola		-0.92	-276.89			-0.94	-71			-0.10	-7.7	-15.67	-4701	-5056.59
Angola														
Zambia				0.11	33.62	1.27	94.96					1.02	306	
Zambia				-0.20	-58.89	-2.41	-180.66					-0.55	-166	-405.55
Zambia					-0.05								0	
Swaziland		0.01	2			0.08	5.86							
Swaziland		0.00	-0.33			-0.09	-6.39							-6.72
Swaziland														
Zimbabwe				0.22	65.64	1.18	88.66					0.19	58	
Zimbabwe				-0.11	-34.43	-1.79	-134.08					-0.08	-25	-193.51
Zimbabwe					-0.02								0	
Namibia						0.05	3.98			0.05	3.92			
Namibia						-0.02	-1.86			-0.06	-4.75			-6.61
Namibia														
South Africa		1.81	542.68	1.98	595.12	10.00	749.88							
South Africa		-0.77	-230.75	-1.69	-505.86	-10.80	-809.81							-1546.42
South Africa														
Lesotho		0.09	27.5	0.01	4.28	0.10	7.18	0.02	1.39					
Lesotho		-0.03	-10.32	-0.04	-10.89	-0.16	-11.65	-0.06	-4.13					-36.99
Lesotho					-0.08									

Table 4.24 Cont'd

Country	Duration	Potatoes		Wheat		Maize		Sorghum		Millet		Cassava		Crops Total Losses
	1999-2011	Million		Million		Million		Million		Million		Million		
		Ton	US$	Ton	US$	Ton	US$	Ton	US$	Ton	US$	Ton	US$	US$
Botswana						**0.01**	**0.91**	**0.02**	**1.74**					
Botswana						**0.00**	**-0.3**	**-0.05**	**-3.63**					**-3.93**
Botswana														
Comoros						**0.00**	**0.34**	**0.72**	**53.88**			**0.06**	**17**	
Comoros						**0.00**	**-0.27**	**-0.94**	**-70.77**			**-0.02**	**-5**	**-76.04**
Comoros													**0**	
Madagascar		**0.25**	**75.6**			**0.32**	**24.03**					**2.64**	**793**	
Madagascar		**-0.19**	**-57.6**			**-0.56**	**-41.88**					**-2.12**	**-637**	**-736.48**

5. LESSONES LEARNED AND RECOMENDATIONS:

5.1. LESSONES LEARNED

5.1.1. Drought Hot Spots Areas

- Most studies analyze changes in drought, under the future projections, showed decreases in soil moisture globally for all scenarios with a corresponding doubling of the spatial extent of severe soil moisture deficits and frequency of droughts from the mid-twentieth century to the end of the twenty-first. Long-term droughts become three times more common.
- Regionally, the only regions where there is a consistent increase in drought most notably for long-term frequencies across all indices and ensembles are those where the annual average precipitation decreases as found for the Mediterranean, Amazonia, and Southern Africa.
- Regional climate simulations highlight the Mediterranean region as being affected by more severe droughts, consistent with available global projections.
- the Mediterranean and Northeastern Europe regions as the most prominent climate response Hot-Spots, followed by high latitude Northern hemisphere regions and Central America. The latter appears to be the primary Hot-Spot in the tropics, immediately followed by Southern Equatorial Africa and Southeast Asia. Other prominent mid-latitude Hot-Spot regions are Eastern North America and Central Asia.
- Major Key Massage related to drought, (IPCC 2012),

> *"..There is medium confidence that since the 1950s some regions of the world have experienced trends toward more intense and longer droughts, in particular in Southern Europe and West Africa, but in some regions droughts have become less frequent, less intense, or shorter, for example, central North America and northwestern Australia…".*
>
> *"..There is medium confidence that anthropogenic influence has contributed to some changes in the drought patterns observed in the second half of the 20th century, based on its attributed impact on precipitation and temperature changes (though temperature can only be indirectly related to drought trends)…"*
>
> *"…. there is low confidence in the attribution of changes in droughts at the level of single regions due to inconsistent or insufficient evidence…"*
>
> *"….Post-AR4 studies indicate that there is medium confidence in a projected increase in duration and intensity of droughts in some regions of the world, including Southern Europe and the Mediterranean region, central Europe, central North America, Central America and Mexico, northeast Brazil, and Southern Africa. Elsewhere there is overall low confidence because of insufficient agreement of projections of drought changes (dependent both on model and dryness index)……"*

Note: It is important to mention that definitional issues and lack of data preclude higher confidence than medium in observations of drought changes, while these issues plus the inability of models to include all the factors likely to influence droughts preclude stronger confidence than medium in the projections.

5.1.2. Agriculture Drought Hazard Impacts

A. Land Cover

- The overall countries affected land cover types areas in percent shows that Lebanon and Portugal are very high affected land cover areas in more than 75% of their areas, followed by Spain, West Bank, Greece, Italy, Albania, Gabon, Macedonia, Equatorial Guinea, Jordan, Cote d'Ivory and Turkey they are high affected land cover areas in 50- 75% of their areas, followed by Croatia, Nigeria, Serbia, Somalia, Namibia, Senegal, Eritrea, Sierra Leone, Ghana, Liberia, Benin, Morocco, Kenya, Syria, Togo, Burkina Faso, Bosnia & Herzegovina, Ethiopia, South Africa, Botswana, Israel, Armenia, Cameroon, Montenegro and France they are moderately affected land cover areas in 25- 50%. Countries like Iran, Tunisia, Sudan, Congo, Mali, Iraq, Guinea, Djibouti, Chad, Niger, Guinea-Bissau, Zimbabwe, and Mauritania, with relatively low affected land cover areas in10- 25%. And the rest of the countries are affected with less than 10% of their areas.
- The most affected countries' rainfed croplands areas are Lebanon, West Bank, Albania, Senegal, Macedonia, Serbia, Turkey, Italy, Croatia, Sierra Leone and Jordan. They are affected in more than 25% of their croplands areas, followed by countries like Burkina Faso, Israel, Cote d'Ivory, Nigeria, Greece, Morocco' Spain, Portugal, Armenia, Syria, Liberia, Bosnia & Herzegovina, Ghana, Montenegro, Tunisia, Somalia and France. It is recognized that the most affected rainfed croplands are Mediterranean countries except for few countries like, Senegal, Sierra Leone, Burkina Faso, Cote d'Ivory, Nigeria in Sub Sahara and West Africa, Liberia In the South of Africa and Somalia in the horn of Africa. The rest of the countries are affected with less than 10% of their areas.
- The most affected countries' rangelands are Namibia, Portugal, Spain, Somalia, Eritrea, Jordan, Kenya, South Africa, Ethiopia, Greece, and Botswana. They are affected in more than 25% of their areas, followed by countries like West Bank, Togo, Djibouti, Lebanon, Morocco, Benin, Syria, Sudan, Nigeria, Niger, Italy, Iran, Mali, Iraq, Guinea-Bissau, Turkey, Burkina Faso, Chad, Senegal and Tunisia with relatively low affected land cover areas in10-25%. The rest of the countries are affected with less than 10% of their areas.
- The most affected countries' Forests areas are Gabon and Equatorial Guinea They are affected in more than 50% of their areas, followed by countries like Liberia, Macedonia, Cote d' Ivory, Cameroon, Greece, Italy, Ghana, Benin, Croatia, Sierra Leone, Albania, Portugal, Bosnia & Herzegovina, Serbia, Congo and Nigeria with relatively low affected land cover areas in10- 25%. The rest of the countries are affected with less than 10% of their areas.

Drought is extremely serious problem in many countries in the studied area:

- <u>In Arab region:</u>
  - Drought will increase causing serious threat for all Arab countries that already are suffering from fragility ecosystems, and facing severe risks of depletion of soil, vegetation, and water resources on daily basis. The strong seasonal and inter-annual variability of vegetation in most semi-arid regions is a subject of particular interest due to the ecological and economic impacts. The high sensitivity of vegetation to climate forcing may result in rapid land use changes and high vulnerability to land degradation, as result of human action.

- When drought conditions end, recovery of vegetation may follow but such recovery process may last for longer periods of time. This is coupled with a population increase within this region rushing at scary rates further increase stresses on natural resources.
- Since the 80's rangelands annually declined by 1.67% (from 495 million ha in1986 to 205 million ha at 2009 and forests by declined by 1.1% (from 95.4 million ha in 1986 to 60.1million ha in 2009).

- Dry conditions during the plantation period cause crops failure due to lack of water during the germination of the seeds. Inter-annual variability of cereal production is depicted in figure (4.62) with wheat and barley productions for Iran, Iraq and Syria from 1980 to 2009. Values of annual production were obtained from the appropriate FAO site, i.e. FAOSTAT (http://faostat.fao.org).
- In fertile crescent area FC: that includes Syria, Iraq and Iran The impact of drought is clearly visible during the years 2000 and 2008 in both wheat and barley productions, with significant socio-economic losses in the affected countries (Shean, 2008a[246],b[247],c[248]).

  The exceptionality of the 1999–2000 and 2008–2009 drought events is once again evident with larger than usual dips in production curves during these two-year events. These declines are obviously associated with both the extension and persistence of the drought, and the fact that both prolonged droughts affected vast amounts of cultivated area, including those responsible for the most relevant cereal productions in the FC (wheat and barley).

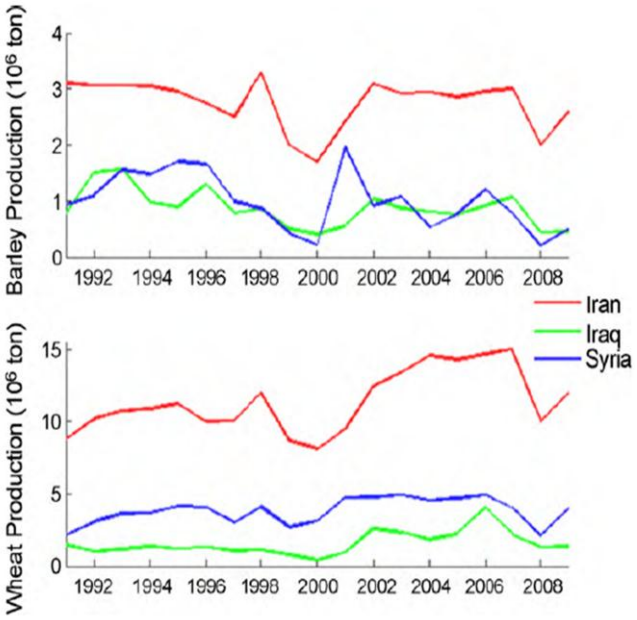


Figure.4.62. Inter-annual variability of cereal production between 1980 and 2009 for wheat (bottom panel) and barley (top panel) productions.

- When the whole two-year events are considered, the agricultural impacts of the 2007–2009 drought emerges especially severe in Iraq compared to the 1999–2000 drought, and more acute in barley production, whereas Syria and Iran production levels remained similar or even higher than those for the 1998–2000 drought. During the agriculture season 2007–2008 and due to severe drought in the Syria, 75% of the country's farmers suffered total crop failure, where, wheat production dropped by 39.8% from 0.43 to 0.25 million ton from the year 2000 to the year in Al-Hassakehh governorate in the eastern part; Kattana,

[246] Shean, M., 2008a. Iran: 2008/09 wheat production declines due to drought. United States Department of Agriculture, Foreign Agricultural Service. May 9. Accessed 30.05.08.
[247] Shean, M., 2008b. Iraq: drought reduces 2008/09 winter grain production. United States Department of Agriculture, Foreign Agricultural Service. May 9. Accessed 30.05.08.
[248] Shean, M., 2008c. Syria: wheat production in 2008–09 declines owing to season-long drought. United States Department of Agriculture, Foreign Agricultural Service.May 9. Accessed 30.05.08.

2011[249]. Barley production which considered an important crop for rainfed areas in the country, and used as fodder for animals has decreased in the last years 2005-2009 up to 40%, beside the absence of natural pastures and at the same time feed prices have doubled, which resulted in the sale of animals, accompanied by a large fall in price of ewes sold or slaughtered as well as young animals in the market; animals weight loss in beside physical deterioration; lower in the amount of newly born young because of Low fertility rate, declining birth rate, low rate hike to zero; and. breeders forced to sell a large proportion of female babies beside the high mortality rate of adult ewes and young animals; FAO 2011. The estimated number of sheep population has dropped from 2.47 million head at the year 2005 to 1.5 million head at the year 2009 and the livestock population was 50 percent below the pre-drought level more than a year after the drought ended; (Kattana, 2011; Erian et al, 2011[250]).

– In the Horn of Africa:
  - Spring and summer rains in parts of Ethiopia have declined by 15–20 percent since the mid-1970s and substantial warming across the entire country has exacerbated the dryness. An important pattern of observed existing rainfall declines coincides with heavily populated areas of the Rift Valley in south-central Ethiopia, and is likely already adversely affecting crop yields and pasture conditions. The rapid population growth and the expansion of farming and pastoralism under a drier, warmer climate regime could dramatically increase the number of at-risk people in Ethiopia during the next 20 years. Accordingly, in many areas of Ethiopia will maintain moist climate conditions, and agricultural development in these areas could help offset rainfall declines and reduced production in other areas. We could recognize that the spatial patterns and quantities of projected future rainfall reductions and temperature increases, by extending the rate of observed 1960–2009 changes for each season, through 2010–2039, based on an assumed persistence of the observed trends. For the Belg rains, rainfall declines range from -150 to -50 mm across the south-central and eastern parts of the country, and will be associated with lower Belg harvests and poorer pastoral rangelands during the summer and early fall. This may be particularly disruptive for pastoralists and agro-pastoralists living in Southern Oromia and western Somali regions who currently (2012) rely upon meager Belg rains for their livelihoods. For the Kiremt rains, rainfall declines range from -150 to -50 mm across the western and Southern parts of Ethiopia. The combined Belg and Kiremt rainfall reductions total a loss of more than 150 mm of rainfall per year in the most densely populated long cycle crop growing area of the country. If recent warming trends continue, most of Ethiopia will experience more than a 1.0° Celsius (°C) increase in air temperature, with the warming tendency projected to be greatest in the south-central part of the country. This warming will intensify the impacts of droughts, and could particularly reduce the amount of productive crop land for coffee, since coffee plants typically prefer temperatures cooler than 22°C. A decline in rainfall of

[249] Kattana, H. , 2011. Agriculture Production Indicators In North Eastern Part of Syria. WB, MAAR and ACSAD Workshop on: Reducing Vulnerability to climate change in Agricultural Systems in Syria, March 23-24, El-Hassakeh governorate, Syria.

[250] Erian, W., Katlan, B. and Babah, O., 2011. Drought Vulnerability in the Arab Region, Case Study-Drought in Syria Ten Years of Scarce Water (2000 – 2010), ACSAD and UNISDR publication Giorgi, F., 2006: Climate change hot-spots. Geophysical Research Letters, 33(L08707)

approximately 0.5standard deviation, and an increase in the frequency of droughts of approximately 40 percent, is sufficient to markedly increase the number of poor harvests that can be expected. The impacts of increasingly frequent droughts could be offset by improved water and agricultural management practices. Raising yields in the more agriculturally viable areas may be a better option than extending agriculture into ever more marginal areas; however, rapid population growth may make it difficult to slow the process of agricultural extensification into those more marginal areas

- Long rains in central Kenya have declined more than 100 millimeters since the mid-1970s. This decline is probably linked to warming in the Indian Ocean, and seems likely to continue. A warming of more than 1° Celsius may exacerbate drying impacts, especially in lowland areas. The drying trends could particularly impact densely populated areas to the east, north, and north-west of Nairobi. Critical surplus crop growing areas in Central Kenya are threatened, and the amount of prime arable land could diminish substantially. Kenya's marginal growing areas currently (2010) are, and in the future likely will be, facing less rainfall and more crop water loss because of greater evaporation
- In 2008, some 26 million people lived in central Kenya, and this number will likely increase to 34 million by 2025. Average 2001–2006 yields and per capita harvested area are both low (1,100 kilogram per hectare [kg/ha], and 0.03 hectare per person), and the annual per capita crop production also is low at 34 kg per person. By examining trends in area and yield, an imprecise, but potentially useful projection of the country's future food availability can be provided. The per capita harvested area trend is negative, as population is growing faster than cultivated land area. Maize yields, although quite low compared to what they might be with improved practices, are actually increasing, despite increasing dryness and temperatures. If both these trends continue through 2025, the analysis indicates that per capita harvested area will drop slightly (approximately 7 percent), but yields may increase by 50 percent (to 1,850 kg/ha) in 2025. The result indicates future maize production may actually ***increase*** by approximately 40 percent from current levels.
- Long-rains precipitation has declined in much of Kenya and Ethiopia in the past 30 years. These rainfall declines have been particularly strong in central and eastern Ethiopia and Kenya, with rainfall totals declining by 35–45 percent of the 1950–79 mean rainfall throughout much of the area south and east of the Ethiopian Highlands. The long rains of 2009 were the driest in at least 60 years throughout much of this region.
- Summer rains in western and Southern Sudan have declined by 10–20 percent since the mid- 1970s. Observed warming of more than 1 degree Celsius is equivalent to another 10–20 percent reduction in rainfall for crops. The warming and drying have impacted Southern Darfur and areas around Juba. Rainfall declines west of Juba threaten Southern Sudan's future food production prospects.

– Sub-Sahara and Central Africa
  - In Uganda, smoothed time series of 1900–2009 rainfall, extracted for crop growing regions in Uganda, indicate that 2000–2009 rainfall has been, on average, about 8% lower (-0.65 standard deviation) than rainfall between 1920 and 1969. Observed rainfall reductions of the 1960–2009 period are projected to the 2010–2039 period, assuming a persistence of the observed trends. The projected rainfall declines range from -150 to -50 mm across the Northern part of the country. Uganda is becoming drier and hotter, during

the March–June and June–September rainy seasons, such warming in regions with high average air temperatures can amplify the impact of water shortages on agriculture. Warming temperatures may adversely affect coffee production, which is an important cash commodity in Uganda. Crop statistics from the FAO indicate that per capita cereal production in Uganda is low (150 kilograms per person per year). While yields have been improving, the amount of farmland per person has been declining twice as fast. If these trends persist, then per capita cereal production could decline by 35 percent by 2025. This level of food production could leave hundreds of thousands more Ugandans exposed to hunger and under nourishment.

- In Mozambique, warmer temperatures earlier in the season threaten maize yields by exposing the plant at sensitive crop phases to increased heat and drought, and shortening the crop's growth cycle, thus reducing the size of the plant and the weight of its grains, continued warming could increase the risk of these hazards and affect crop production, regardless of any changes in rainfall.
- Burkina Faso's agriculture is mainly rainfed, making it highly dependent upon rainfall amounts and distribution. In good seasons, the country's coarse grain production covers domestic consumption needs, and cereal imports are limited to rice and wheat. The Northern part of the country, namely the regions of Nord, Centre-Nord, and Sahel is characterized by a shorter growing season, higher rainfall variability, and less diversified agriculture. This area, therefore, is the most vulnerable to food insecurity. The amount of farmland per person is low, and declining.
- Rainfall in Niger declined rapidly between 1950 and the mid-1980s and partially recovered during the 1990s and 2000s. Between 2000 and 2009, the average rainfall in Niger's crop growing districts was about 8 percent lower than the 1920–69 mean. In Niger Over longer periods, small changes may have a considerable impact on the viability of agricultural and pastoral systems. In this environment, natural vegetation and non-irrigated crops are crucially dependent on soil moisture provided by seasonal rains or springtime snowmelt. This dependence leads to quite different vegetation activity levels on seasonal and inter-annual time scales. Consequently, opportunistic annual species may appear rapidly in response to humid condition of the soil and their greenness is mainly related to recent precipitation. On the other hand, winter crops and persistent vegetation are dependent on deeper reserves of soil moisture and their vegetative cycle is the result of the combined effect of precipitation (over weeks and months), evaporation and in some regions, of temperature.

– In Mediterranean

- The strong dependence of vegetation dynamics on water availability has been for long recognized in the Mediterranean and other semi-arid regions. A combined effect of lack of precipitation[251] over a certain period with other climatic anomalies, such as high temperature, high wind and low relative humidity over a particular area may result in reduced green vegetation cover. Agriculture in Spain is considered one of the most affected countries by Drought. Agriculture is now experiencing limited developments

[251]Several indicators can be taken into account in order to illustrate the severity of a drought event. The level of precipitation may be one of these indicators. Tables available on http://forum.europa.eu.int/Public/irc/env/wfd/library?l=/framework_directive/scarcity_droughts (public library of CIRCA, file entitled "scope of droughts in some Member States") present an overview of drought events at national level for Member States that provided information.

since, extraction costs are increasing, agricultural margins are reducing and a greater uncertainty is being put on production, leading to loss of competition.

- The following figure (4.63) illustrates that droughts affected more than 800 000 km² of the EU territory and 100 million inhabitants in 1989, 1990, 1991 and more recently in 2003. **The change in % of EU affected area** was as follows 5, 3, 10, 17, 5, 15 for the years 1976-1980, 1981-1985, 1986-1990, 1991-1995, 1996-2000 and 2000-2006 respectively. This figures show a significant increase in annual average EU area (from 6% to 13%) affected by droughts between 1976-1990 period and 1991-2006 period.

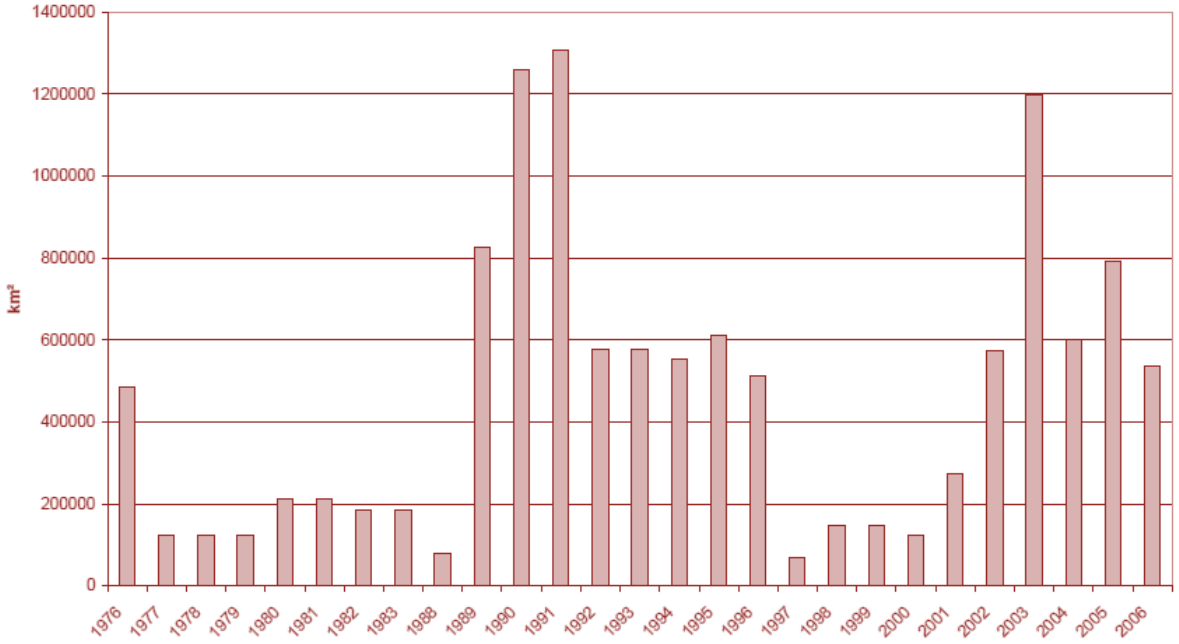


Figure 4.63. EU area affected by droughts in the last 30 years Source: Member State data, Commission, November 2006

B. Increase in Land Degradation and decline in Biodiversity.

B.1. Increase in Land Degradation

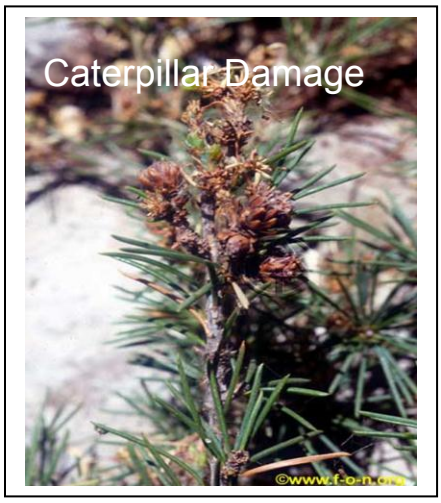
- The overall countries affected areas by land degradation in percent shows that Lesotho, Kuwait, Djibouti, Sierra Leone, Zambia, D R Congo and Andorra are very high affected in more than 75% of their areas,
- France, Swaziland, Gaza Strip, Saudi Arabia, R Congo, Zimbabwe, San Marino, Guinea, Liberia, Ethiopia, Botswana, Comoros, Eritrea, Iraq, Syria, South Africa, Angola, Madagascar, Portugal, Mauritius, Uganda, C A Republic, Nigeria, Cameroon, Rwanda, Croatia, Equatorial Guinea, Mozambique, Tanzania, Guinea-Bissau, Burundi, Somalia and Benin they are high affected land cover areas in 50- 75% of their areas,
- Followed by Kenya, Niger, Gabon, Sudan & South Sudan, Egypt, Mali, Yemen, Qatar, Libya, Chad, Israel, Spain, Italy, Togo, Bahrain, Cote d'Ivoire, Algeria, Ghana, Gambia, Malawi, Oman, Cyprus, West Bank, S. T. & Principe, Burkina Faso, Mauritania, U A Emirates, Georgia, Iran, Jordan and Tunisia they are moderately affected areas in 25- 50%.
- And countries like Senegal, Namibia, Turkey, Morocco, Bulgaria, Albania and Greece, with relatively low affected land cover areas in10- 25%. And the rest of the countries are affected with less than 10% of their areas.

- Drought will increase causing serious threat for most studied countries that already are suffering from fragility ecosystems, and facing severe risks of depletion of soil, vegetation, and water resources on daily basis. The strong seasonal and inter-annual variability of vegetation in most semi-arid regions is a subject of particular interest due to the ecological and economic impacts. The high sensitivity of vegetation to climate forcing may result in rapid land use changes and high vulnerability to land degradation, as result of human action.
- When drought conditions end, recovery of vegetation may follow but such recovery process may last for longer periods of time. This is coupled with a population increase within this region rushing at scary rates further increase stresses on natural resources.
- In Arab region and similar to many other areas, since the 80's rangelands annually declined by 1.67% (from 495 million ha in1986 to 205 million ha at 2009 and forests by declined by 1.1% (from 95.4 million ha in 1986 to 60.1million ha in 2009).

B.2. Drought's Impacts on Biodiversity.

- Due to frequent drought cycles, it has been recognized in Tanourine Natural Reserve, in Lebanon that the insect pests caterpillars, moth larvae's *"Cephalcia Tannourinensis"* is causing a damage, that first observed in 1998, major defoliator of Cedar trees (Lebanon National Symbol), at altitudes of 1,700 m. First, second and third larval instars chew on the needles in sprin, attacked trees turn rusty-brown and look as if they were devastated by fire. Damage may lead to death of the trees, (Farah, P. 2012[252]).

[252] Farah, P. 2012. Climate Change Impacts on Forest Land in Lebanon, presentation of the Ministry of Environment Service of Planning and Programming, presented at ACSAD Workshop on Agriculture Drought Impacts on Trans-boundary river basins, Orontes and Euphrates, Beirut, 02- 04 May 2012





C. Population Affected by Drought.

- The overall countries population affected areas by drought in percent shows that Gaza Strip, Greece, Lebanon, Morocco, Portugal, Kuwait, Qatar, West Bank, Albania, Syria, Spain, Italy and Eritrea are very highly affected countries in more than 75% of their total population, the total affected population in that level are estimated by 0.17 billion represent 80.6% of the country's population.
- Gaza Strip, Greece, Lebanon, Morocco, Portugal, Kuwait, Qatar, West Bank, Albania, Syria, Spain, Italy and Eritrea are high affected countries in 50- 75% of their total population, the total affected population in that level are estimated by 0.41 billion that represent 67.4 % of the country's population.
- Followed by Burkina Faso, Sudan, Senegal, Mali, Somalia, Mauritania, Namibia, Botswana, Saudi Arabia, Congo, Yemen, Cameroon, Bosnia & Herzegovina, Togo, Libya, Armenia, Chad, Oman, Ethiopia and Egypt they are moderately affected areas in 25- 50% of their total population, the total affected population in that level are estimated by 0.14 billion that represent 35.8% of the country's population..
- And countries like Guinea, Comoros, Kenya, Sao Tome and Principe, South Africa, Gambia, The Malawi, Zimbabwe, Angola, Congo D.R., Mozambique, Tanzania, Lesotho, Guinea-Bissau, Uganda, Burundi, Madagascar, Zambia, Rwanda, Swaziland and Central African Republic, with relatively low affected land cover areas of less than 25% of their total population, the total affected population in that level are estimated by 0.034 billion represent 8.5% of the country's population.

Figure (4.64), illustrates that droughts affected more than 100 million inhabitants in 1989, 1990, 1991 and more recently in 2003.. **The change in % of EU affected population** was as follows 6, 3, 10, 11, 4, 17 for the years 1976-1980, 1981-1985, 1986-1990, 1991-1995, 1996-2000 and 2000-2006 respectively. This figures show a significant increase in annual average EU population (from 6% to 13%) affected by droughts between 1976-1990 period and 1991-2006 period.

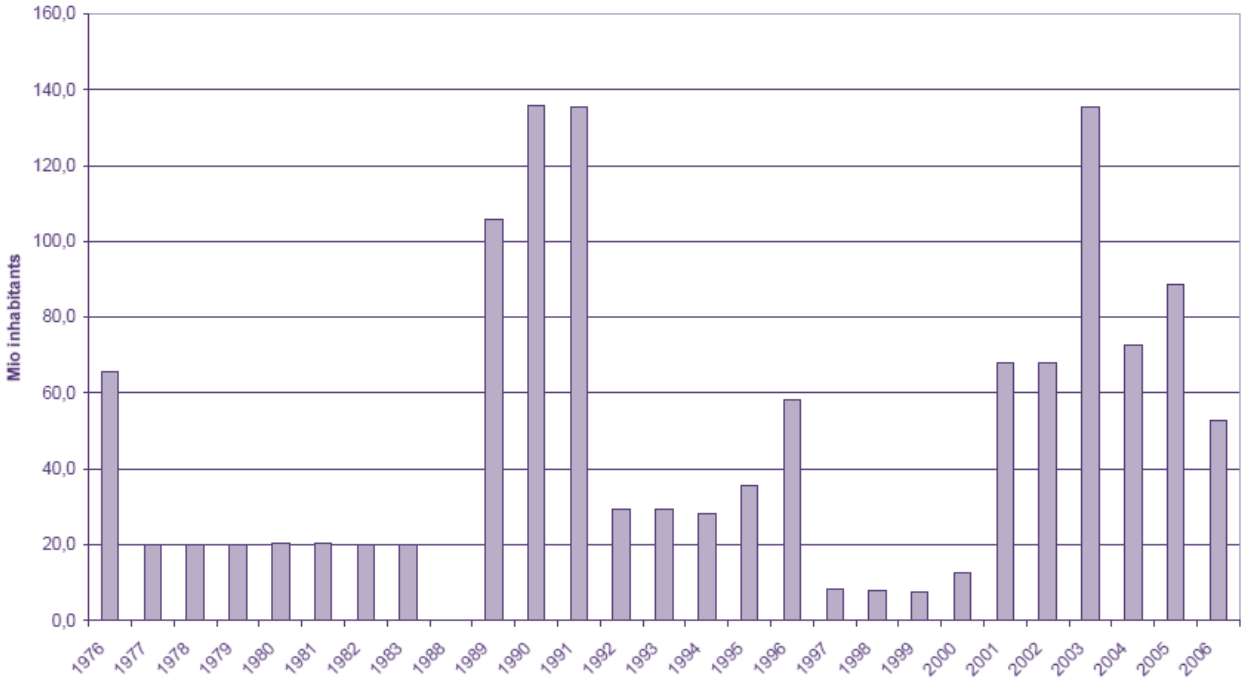


Figure 4.64. EU population affected by droughts in the last 30 years Source: Member State data, Commission, November 2006

D. Water resources

- Water resources are stressed in some areas around the world and therefore highly vulnerable, especially with respect to competition for water supply between agriculture, power generation, urban areas, and environmental flows (high confidence) and salinization. Increased evaporation and possible decreases in rainfall in many areas would adversely affect water supply, agriculture, and the survival and reproduction of key species in parts of the world that depend on uncertain sources.
- There is many clear evidence that rainfall has declined in many places in Mediterranean by 20% during the last 50 years, projections of rainfall and stream-flow in the 'Fertile Crescent' of the Middle East. They found that the annual discharge of the Euphrates River will decrease significantly (29%–73%), as will the stream-flow in the Jordan River. Thus countermeasures for water shortages will become much more difficult. This negative trend of precipitation during the past century and beginning of 21 century is of a similar magnitude as that predicted by most of the GCM for the Mediterranean Region in the coming decades.
- In few areas in Europe, winter droughts are caused by precipitation being stored in the catchment in the form of snow and ice, preventing any recharge of rivers or aquifers until air

temperatures rise again and snow melting starts, or to the timing (i.e. principal season of occurrence, delays in the start of the rainy season, occurrence of rains in relation to principal growth stages) and the effectiveness of the precipitation (i.e. rainfall intensity, number of rainfall events). Climate change is expected to reduce water availability and increase irrigation withdrawals.

- In Mediterranean river basins. Under mid-range assumptions on temperature and precipitation changes, water availability is expected to decline in southern and south-eastern Europe (by 10 % or more in some river basins by 2030).
- Droughts usually have long-term impacts, on natural water resources, as the water reservoirs, both surface and subsurface, need several rainy periods to be restored. As they are climate risks (rainfall deficiencies in relation to the annual or seasonal average) with hydrological consequences, that is to say consequences on renewable water resources, droughts are quite naturally the principal cause of random water shortage due to lack of water resources in all places where water demands are close in quantity to average annual water "blue water" resources; this is moreover because "green water" deficits (soil humidity) increase irrigation water demand: the drought both reduces available water resources, while increasing the demands for natural water. As they are climate risks (rainfall deficiencies in relation to the annual or seasonal average) with hydrological consequences, that is to say consequences on renewable water resources, droughts are quite naturally the principal cause of random water shortage due to lack of water resources in all places where water demands are close in quantity to average annual water "blue water" resources; this is moreover because "green water" deficits (soil humidity) increase irrigation water demand: the drought both reduces available water resources, while increasing the demands for natural water
- Better agreement on triggers for early warning and actions to improve preparedness within particularly vulnerable areas by changing land use and crop patterns, introducing new seed varieties more tolerant for drought, improve community socio-economical preparedness (assets, governance and technology) and create alternative economic opportunities

There is an increasing body of evidence of the ongoing global warming. Each of the five years since 2001 belongs to the six globally warmest years in the 165-year observation period and the two warmest years on record are 1998 and 2005. The future warming will depend on scenarios of socio-economic development and on adopted mitigation policies (curbing the greenhouse gas emissions). Different climate models and scenarios foresee that the temperature in 2011-2030 is to be higher than the temperature in 1980-1999 by 0.64-0.7oC. In 2100, the 65% probability range of warming for various SRES scenarios is 1.5-5.8oC, compared to 1980-1999.

Climate change models project more frequent and intense summer droughts, due to a joint effect of a rise in temperature and a drop in precipitation across many part of Europe, particularly in the Southern part (Goodess et al., 2007), (figure 4.65). Often the presently dry areas are likely to become drier, and those presently wet - wetter. Mean annual precipitation is likely to decrease over much of Europe (in particular, over the 15 Southern and the Central Europe). However, intensity of rainfall events is projected to increase even in regions where the mean annual precipitation is likely to decrease. Changes in extremes are likely to be more dramatic than in the means.

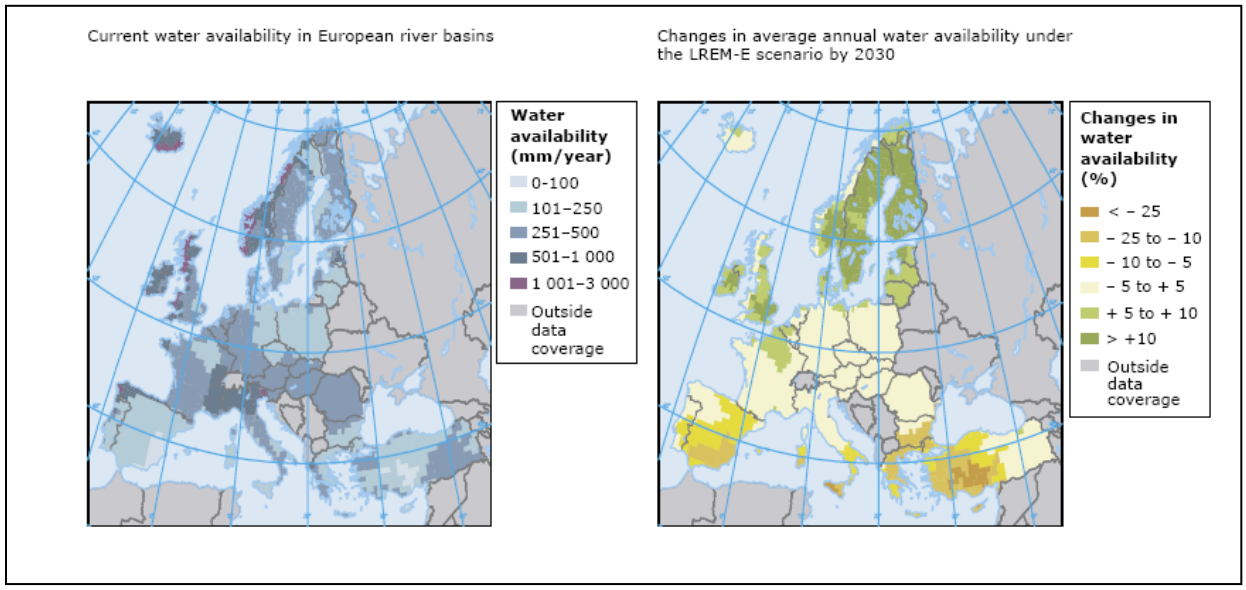


Figure 4.65. Change in average annual water availability in Europe by the year 2030, Source: EEA Report – European environment outlook, N°4/2005

- The growing impacts of water scarcity and droughts in the European Union and the expected worsening of the problem due to climate change, require the identification of appropriate options to address the challenge efficiently. the overall economic impacts of drought events in the past thirty years to a total of 100 billion € at EU level. Results show that the annual average impact has doubled between the 1976-1990 periods and the next 1991-2006 period. It reached an average of 6.2 billion €/year in the most recent years, with an exceptional cost of 8.7 billion € in 2003. These estimations only cover economic costs. They do not include social and environmental costs due to an absence of data.
- These challenges include the ongoing need to fully implement the Water Framework Directive[253] (WFD); moving towards sustainable land use planning; giving priority to water savings and water efficiency measures over any other alternatives and assessing the environmental impact of such alternatives as a last resort; further integrating water issues into all sectoral policies.
- Average run-off in Southern Europe rivers is projected to decrease with increasing temperatures and decreasing precipitation. In particular, some river basins in the Mediterranean region, which often already face low levels of water availability, may see decreases of 10% or more below today's levels by 2030. In the longer term, changes in water availability are likely to develop more noticeably. Changing temperatures and precipitation patterns may also change the frequency and intensity of droughts, particularly in Southern and parts of Central Europe.
- The impact of climate change on drought intensity and frequency attracts great attention and raises questions among EU Member States. thirteen Member States of EU provided a list of river basins particularly affected by water scarcity3. The thirty three river basins where water

[253] Directive 2000/60/EC of the European Parliament and the Council establishing a framework for Community action on water policy, OJ L 327, 22.12.2000.

scarcity has been identified represent 11% of the EU territory and 17% of the EU population. Agriculture represents the major water use (abstractions) in 17 of the all basins, followed by public water supply which is the major use in 4 basins. Most affected river basins are located in Southern Europe (Cyprus, Malta, Italy, Portugal, Spain, France). However, Northern and Eastern countries (Belgium, Denmark, Germany, Hungary, United Kingdom) also specified river basins. Water scarcity impacts are difficult to estimate due to a lack of information at EU, national and river basin levels. For the time being, research projects have not yet delivered any data and most inputs coming from Member States have been qualitative information. Cyprus, France and Spain provided information on the amount of investments carried out in order to face water scarcity, particularly the economic costs of new water supply infrastructures.

- Agriculture in Spain is considered one of the most affected countries y by Drought; agriculture I s now experiencing limited developments: extraction costs are increasing, agricultural margins are reducing and a greater uncertainty is being put on production, leading to loss of competition, (EU 2007). Employment in the farming sector seems to decrease in water scarcity areas (Spain, Cyprus). But this information needs to be further addressed, notably by comparing this evolution with evolutions in other areas and with future mid-term or long-term evolutions in areas where production is profitable but water is being used unsustainably.
- Drought is also related to the timing (i.e. principal season of occurrence, delays in the start of the rainy season, occurrence of rains in relation to principal growth stages) and the effectiveness of the precipitation (i.e. rainfall intensity, number of rainfall events). Portugal has an average annual precipitation between 800-1000 mm similar to most of EU Member States. However, the temporal precipitation variability within the year frequently leads to serious problems of water scarcity in some regions, during the dry season (6 months). In this season the amount of precipitation is only 25% of yearly amount. Analyzing the whole country, the temporal precipitation distribution in an average hydrological year in Portugal is given by the following figure (4.66), (European Commission 2007)[254].

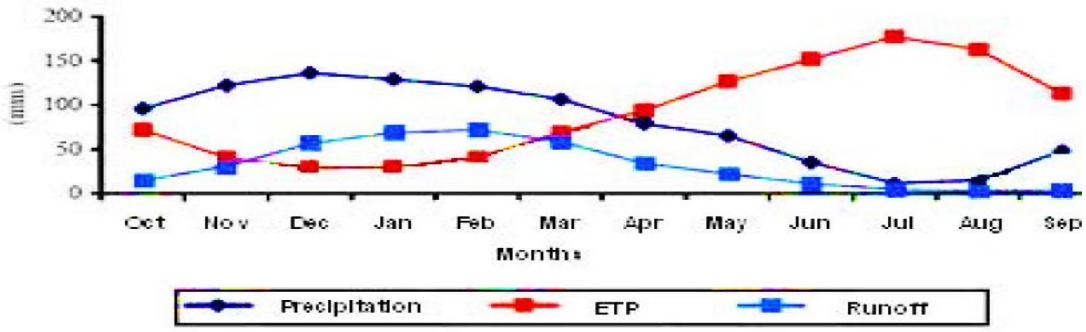


Figure 4.66 Yearly distribution of average precipitation, evapotranspiration and runoff

As it can be observed, in the summer season the precipitation values are significantly reduced and the evapotranspiration values very important. This leads to low runoff levels in this

[254] European Commission 2007, Water Scarcity & Droughts In-Depth Assessment, DG Environment, Second Interim Report

season and creates important problems in some regions in terms of water availability. If precipitation has in Portugal a large variability, the runoff case is more dramatic.

The average runoff in dry semester is in some basins less than 10% of the average annual runoff. It is in general less than 20% or 25%. The variability between dry and wet years is also very high, as illustrated in figure (4.67), Therefore indicators defined on an annual basis are clearly inefficient to demonstrate the problem of water availability, the inter-seasonal variability and the inter-annual variability particularly due to the runoff variability during the year and along the years.

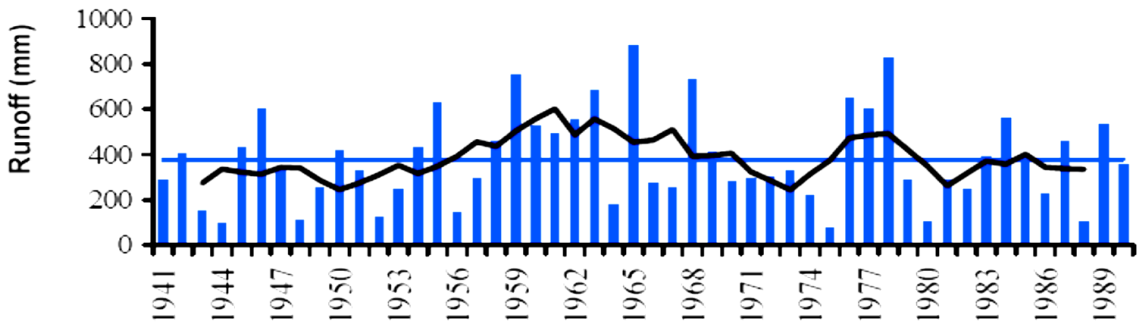


Figure 4.67 variability between dry and wet years

- Cyprus has a semi-arid climate and limited water resources which almost entirely depend on rainfall. Rainfall is highly variable with considerable regional variations. Two or three, or sometimes up to six consecutive dry years are observed. Statistical analysis of rainfall in Cyprus reveals a stepped drop in the early 70s, which has persisted. An analysis of the situation indicates a reduction of approximately 20% in the precipitation, which results in a 40% reduction in surface runoff. Furthermore, Cyprus has small catchments that do not provide any perennial flows, (European Commission 2007),

E. Socio-economy

- The African continent is predominantly semi-arid land which is highly sensitive to both climatic fluctuations and human encroachment on the natural environment. In recent years, the combined effects of drought and human-induced land degradation have taken an immense toll on the environment, e.g. in sub-Sahara areas, where drought conditions have been most severe, there is increasing evidence that these two factors may be related, that land surface conditions may help to reinforce and sustain the drought.
- Africa rural counties are composed mostly of populations disadvantaged by poverty, race, ethnicity, age, and gender. The factors of social vulnerability common in rural counties are more homogenous and reflect clear indicators through socio-economic status. Combined with potential climate impacts, specially increased drought cycles, a picture emerges of areas of extreme risk that demand proactive attention.
- The effects of natural disasters and climate change vary widely by state, county, and community. Although social variables such as income and age do not determine who will be hit by a natural disaster, they do determine a population's ability to prepare, respond, and recover when disaster does strike.

- The poor, who are net buyers of food, were able to access more and better quality food due to declining prices. However, the declining prices have negatively impacted farm incomes in many of the developing countries and worsened their terms of trade since agricultural products comprise a significant portion of their trade basket. Consequently, this has led to higher import bills and the conversion of short term borrowing to long-term debt in most developing countries (IMF/World Bank 2002). Higher prices and the consequent inflation do affect the poor consumers/net food importing countries. This was reflected in riots in several such countries during the last couple of years, coupled with this drought stricken developing countries. These developing countries now face higher than anticipated food prices and are increasingly finding it difficult to meet their food distribution goals (Walt 2008 , Kilman 2007).
- In many developing countries, smallholders commonly face price fluctuations. These can be partly seasonal and relatively predictable. They mostly result from the fact that most poor farmers have to sell their produce right after harvest, fetching lower prices, and then buy food during lean periods, contributing to driving prices up. Poor rural households are in turn two-thirds of the global population living below USD 1.25 a day per capita. Smallholder agriculture however, provides up to 80 percent of food consumed in some developing regions – notably Sub-Saharan Africa. It is thus a key sector for food security for multiple reasons: as a source of income for vast numbers of poor people, and as the main source of food in the developing world. It is also a sector that can play a major role in mitigating food price volatility (volatility refers to variations in economic variables over time) and its impact in developing countries, both in the short and in the longer term. Since 1990, as shown in Figure (4.68), the implied volatility for major crops has increased significantly. Implied volatility reflects the expectations of market participants on how volatile prices will be and is measured as a percentage of the deviation in the futures price (six months ahead) from underlying expected value. (Policy Report including contributions 2011 by FAO, IFAD, IMF, OECD, UNCTAD, WFP, the World Bank, the WTO, IFPRI and the UN HLTF).

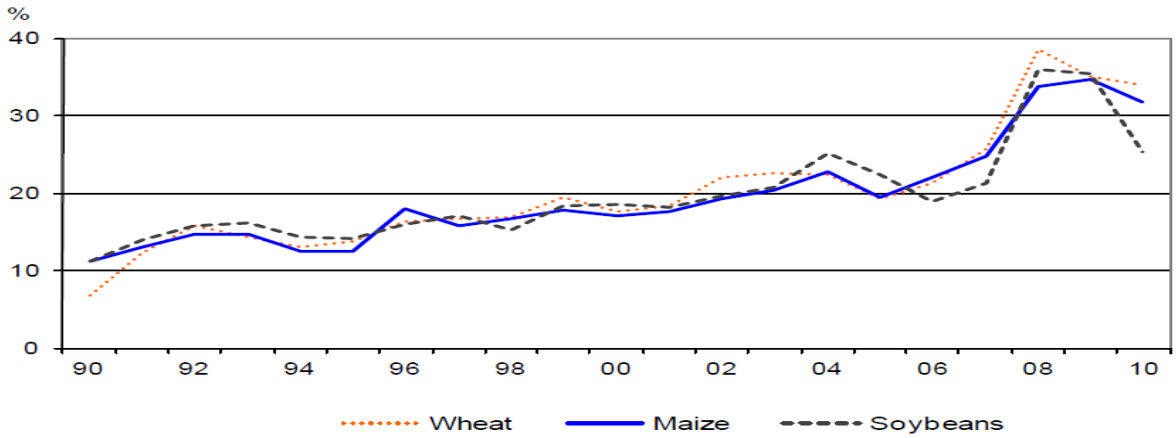


Figure 4.68. Evolution of Annual Volatilities 1990-2010. Source: FAO (2010), *Food Outlook*

- Growing population and income in emerging and developing countries will add significantly to the demand for food in the coming decades. By 2050 the world's population is expected to have reached about 9 billion people and the demand for food to have increased by between 70% and 100%. This alone is sufficient to exert pressure on commodity prices. According to

the latest OECD/FAO medium term outlook projections, prices of crops and most livestock products will be higher in both real and nominal terms during the decade to 2019 than they were in the decade before the 2007/08 price spikes. If the rate of growth of agricultural production does not keep pace with demand, upward pressure on prices will result.

- Food insecurity is likely to increase under climate change. Between 1961 and 1986, global total cereal yield increased by 89%, harvested area expanded by 11% and global per capita cereal production increased enormously, with a maximum in about 1986. Population, meanwhile, grew by 60% over those 25 years, resulting in an increase in per capita cereal production from 284 to 372 kg of grain per person per year. The last 21 years (1987–2007) have seen slower population growth (34% increase) accompanied by slower yield improvements (31% increase) and a 2% reduction in the total area harvested. Surprisingly, over this period according to FAO and UN data, per capita harvested area, fertilizer and seed use have all declined by 20–30%.
- Producers are more concerned about low income due to lower prices, which may threaten their living standards as well as their longer term viability when income is too low to provide for the farm family or for the operational needs of the farm. Agriculture uncertainty may result in less than optimal production and investment decisions, keeping in mind that higher price for agriculture inputs over time may also result in higher expected profits losses for farmers. In developing countries, many households are both producers and purchasers of agricultural products. For this group the impacts of price volatility are complex, with net outcomes depending on a combination of many factors, Rapsomanikis (2009) .The increased agriculture uncertainty becomes common mainly in highly variable rainfall areas that receive annual rainfall of less than 450 mm, (**ACSAD, 2008**[255]), and were drought hazard becomes more frequent.

- It has been recorded in United Nations humanitarian publications that drought contributed in countries' socio economy instability, particular cases could be described, as follows:
  - In Syria and since 2006, three consecutive years of drought have affected Syria. The 2007/2008 drought was the worst in 40 years and had a wider geographical reach. Sharp impoverishment in recent years has resulted in the migration within the country of entire families from 160 villages to the periphery of cities. Since early 2009, the migration pattern has increased dramatically: 65,000 families have already left their villages. From this total, 35,000 are from Al-Hassake and 30,000 from Dayr az Zawr, Ar-Raqqa and Aleppo. This drastic move has not saved these internally displaced families from further hardship and destitution. Instead, they have lost their social ties and are often exploited at below-market labour rates. It has also further increased the strain on the limited job market, resources and public services, which were already affected by the presence of approximately one million Iraqi refugees, (UN 2010a)[256],
  - In Somalia, the number of people living in crisis conditions had jumped from 2.4 million at the start of the year to four million by September 2011. The deterioration in the humanitarian situation is principally due to failed rains , OCHA 2011). The number of people in crisis increased From June 2010 to January 2011 by two million to 2.4 million,

[255] ACSAD 2008, Potential Land Use Map of Sudan, Part one – Eastern Sudan.

[256] United Nations, 2010a. Syria Drought Response Plan 2009-2010 MID-TERM REVIEW, (www.reliefweb.int/fts).

a 20% jump in just six months. The drought had intensified by April because of the delayed start of the Gu rains. When the rains began, they were below normal and haphazard, resulting in crop failure in the southern regions. Food prices increased by over 200% in some regions, pushing 100,000 more people into crisis – by the end of May the number of people in crisis had increased to 2.5 million. The poor rains also resulted in a significant number of livestock deaths and reduced the value of livestock for the pastoralists. It was also around this time that mass movements of people began into Mogadishu and across borders, mainly into Kenya and Ethiopia, in search of assistance. Large-scale displacement and significant limitations on humanitarian access further exacerbated the situation.

- In Kenya, alongside other countries in the Horn of Africa, has for most of 2011 faced a severe food crisis, due to a climatic disaster that has become a recurring phenomenon in shorter cycles, negating efforts to reduce vulnerability. A combination of drought-induced crop failure, poor livestock conditions, rising food and non-food prices and eroded coping capacities are some of the key factors contributing to the food crisis, which has made 3.75 million people in Kenya food-insecure. In addition, those areas that experienced the worst effects of drought also face entrenched poverty, limited investment, and intermittent conflict which have further compounded the food security situation, (UN 2012b)[257].
- In Zimbabwe, uneven rainfall distribution and a dry spell in the 2011 agricultural season affected six of the country's ten provinces and forestalled a potential good harvest that could have reversed the food aid needs. The increasingly uncertain pattern of weather, characterized by droughts and poor rains, is making farming difficult and unpredictable. Due to economic hardships fuelled partly by the over-60% unemployment rate in the country, an estimated three million Zimbabweans live abroad, the majority in Botswana and the Republic of South Africa, mostly on irregular status, (UN 2012c)[258].
- In Eritrea, and five years after the 1998-2000 border war with Ethiopia that caused displacement of persons from their homes, loss of assets and economic impoverishment a chronic drought resulting in five consecutive failed harvests and major losses in livestock. Repeated poor seasonal rains in 2004, culminating in food insecurity, indicate another year of crisis, the scale of which is larger than last year's and is further exacerbated by diminishing coping assets in both rural and urban areas. Some 2.2 million persons out of a total population of 3.8 million1 are unable to feed themselves. In 2004, of the 1.9 million vulnerable persons requiring food aid, (UN 2005)[259].

- In European Countries, The information provided by member States of EU, (European Commission 2007) made it possible to identify severe events that on annual basis affected more than 800 000 km² of the EU territory (37%) and 100 million inhabitants (20%) in 1989, 1990, 1991 and more recently in 2003. Information also revealed that at least Austria, Belgium, Cyprus, France, Hungary, Italy, Lithuania, Malta, Netherlands, Norway, Portugal, Spain and United Kingdom have been affected by droughts in the last thirty years, but with different degrees of intensity. Italy, Portugal, Cyprus, Spain and France have registered the highest frequency of droughts from 1976 to nowadays, with 8 to 21 events per country.

[257] United Nations, 2010b. . Kenya Emergency Humanitarian Response Plan http://fts.unocha.org.
[258] United Nations, 2012c Zimbabwe Consolidated Appeal http://fts.unocha.org
[259] United Nations, 2005 Eritrea Consolidated Appeal Process (CAP) www.reliefweb.int/fts

However, several Northern and Eastern countries (Belgium, UK, Finland, Germany, Hungary, Lithuania, Netherlands, Norway, Slovakia,) have also experienced severe droughts, particularly in recent years.

- Some countries have a large part of their territory being affected whenever droughts occur (Cyprus, Finland, France, Italy, Malta, Portugal, Spain), while some other countries may be frequently affected on a specific part of their territory (Belgium, Austria). Drought duration is largely variable from one country to another.

- In Cyprus, Italy, Portugal, Spain, droughts may last one or several years. In other countries, droughts have been predominant during one month (Hungary, Germany, Lithuania) or from two to six months (Austria, Belgium, France). Finland was affected by a 270 day drought from August 2002 to April 2003. Figures stress a significant increase in annual average EU territory (from 6% to 13%) and population (from 6% to 13%) affected by droughts between the 1976-1990 period and 1991-2006 period.

- Information from Member States provides a first estimation of the main drought impacts. Some countries provided economic costs incurred due to specific drought events. The compilation of this data and the translation in unit costs made it possible to estimate the overall economic impacts of drought events in the past thirty years to a total of 100 billion € at EU level. Results show that the annual average impact has doubled between the 1976-1990 period and the next 1991-2006 period. It reached an average of 6.2 billion €/year in the most recent years, with an exceptional cost of 8.7 billion € in 2003. These estimations only cover economic costs. They do not include social and environmental costs due to an absence of data. Therefore, attention will have to be paid in a near future to the enhancement of data collection at EU and national levels, in order to improve the economic, social and environmental impact assessment.
- Agriculture in **Spain**, impacts are being notable on agriculture. Some irrigated areas have been reconverted due to water scarcity. Agriculture is now experiencing limited developments: extraction costs are increasing, agricultural margins are reducing and a greater uncertainty is being put on production, leading to loss of competition.
- Employment in the farming sector seems to decrease in water scarcity areas (Spain, Cyprus). But this information needs to be further addressed, notably by comparing this evolution with evolutions in other areas and with future mid-term or long-term evolutions in areas where production is profitable but water is being used unsustainably.

The major vulnerability classes could be as follows:

- High to Moderate Vulnerability: moderate coverage of ADH 45-60 %, moderate severity and very Low to low capacity that includes countries like Somalia, Senegal and Kenya.
- Moderate Vulnerability: high coverage of ADH 75 – 85%, moderate severity and moderate capacity that includes countries like Eritrea, Morocco, Syria, Equatorial Guinea and Kuwait (it is important to note that Kuwait, has a very low vegetation cover).
- Moderate Vulnerability: high to moderate coverage of ADH 60-75 %, moderate severity and high to moderate capacity that includes countries like Tunisia, Djibouti, Namibia, Gabon, Iraq and Italy.

- Moderate to Low Vulnerability: high to moderate coverage of ADH 60-75 %, moderate severity and moderate to high capacity that includes countries like Spain, Portugal, Israel and Iran.
- Moderate to Low Vulnerability: very high coverage of ADH >85 %, high severity and very high capacity that includes countries like Greece, Lebanon and Qatar, (it is important to note that Qatar has a very low vegetation cover)
- Moderate to Low Vulnerability: moderate coverage of ADH 45-60 %, low severity and very low to low capacity that includes countries like Cote D Lvoire, Sierra Leanne, Ghana, Liberia and Nigeria
- Moderate to Low Vulnerability: moderate to low coverage ADH 30-45 %, moderate to low severity and moderate to low capacity that includes countries like South Africa, Burkina Faso, Chad, Benin, Togo, Ethiopia, Botswana, Cameroon, Sudan, Mali, Saudi Arabia and UAE , (it is important to note that UAE has a very low vegetation cover).
- Low Vulnerability: moderate coverage of ADH 45-60 %, moderate severity and high to moderate capacity that includes countries like France and Turkey
- Low Vulnerability: low coverage of ADH 15-30 %, low severity and high to moderate capacity that includes countries like Jordan, Niger, Yemen, Mauritania, Algeria, Libya, Oman, Malawi, Burundi, Angola, Zimbabwe, Lesotho, Mozambique, Gambia, Tanzania, DR Congo, Zambia, Swaziland, and Rwanda
- Low Vulnerability: low coverage of ADH 15-30 %, low severity and low capacity that includes countries like Egypt, Congo, Guinea, Guinea-Bissau,
- Low Vulnerability: low coverage of ADH less than 15 %, low severity and low capacity that includes countries like Madagascar, Uganda, Central Africa.

Special Case Study:

Agriculture Drought and Land Degradation in Arab Region Trans-boundary River's Basin:

Hazards and Exposure



2012

1. INTRODUCTION

1.2. An International Over View About Cooperation Over Shared Waters

landmark study released in June 2003 by two United Nations agencies and Oregon State University[260] warned that cooperation over shared waters was "inconsistent or absent." they added *"We have found that cooperation between countries over the past 50 years has outnumbered conflicts by more than 2:1* But things can go wrong,…. Since 1948, there have been only 37 incidents worldwide involving water resources that led to actual violence most of them in middle east*."* says Professor Aaron T. Wolf of Oregon State University. However, tensions are rising in less developed regions —especially in Asia and Africa— as economic development furthers the growth of intensive agriculture and imposes severe population pressures.

The International Water Management Institute (IWMI) has predicted that 2.7 billion people, or one third of the world's projected population, will not have access to enough water by 2025". It is estimated that irrigation and other forms of farm use will have to increase by 15-20% in the next 25 years to maintain food security, while water consumption will need to be reduced by 10% to protect natural watercourses. If current trends continue, the shortage of water will extend well beyond the semi-arid and arid regions.

Expanding demand for water will drain some of the world's major rivers, leaving them dry throughout most of the year, IWMI [261]. Urban centers will experience severe water shortages, but the rural poor will suffer the most serious consequences.

Climatic changes linked to global warming, including shorter rainy seasons and longer droughts, will affect other areas during coming decades, provoking new economic, social and health crises. In a foretaste of the climatic upheavals that may be expected.

The countries suffering the worst shortages are likely to be those that are already near the bottom of the socio-economic scale, partly because **they do not have enough** storage facilities. most inadequate water management, all face formidable investment challenges due to a low availability of water resources, insufficient storage capacity and the deterioration of environmental conditions.

Also many of people are living in economically important urban areas that will experience a doubling of their populations over the next 25 years. To meet the needs of a larger world population, the area of irrigated land will have to increase by 22%, and water withdrawals by 14%. Compounding the problem of water quantity is one of quality:

1.3. Trans-Boundary Water and Security.

The growing demand for finite freshwater resources heightens the risk of future conflicts. Globally, the sustainable management of the 263 trans-boundary rivers or lakes and many hundreds of aquifers, the basins of which contain more than half the territory and population of the world, presents major challenges and is of strategic importance in the immediate and long-

[260] http://www31.brinkster.com/induspak/General.htm By Alan Boyd, in Indus Pak Resource Centre for South Asian and Pakistani Affairs, Editor Ayaz Latif Palijo Sindh. Research Council, Tuesday 3 June 2003.
[261] Professor Frank Rijsberman, the Director-General of the IWMI

term future[262]. There are 59 trans-boundary river basins in Africa alone, accounting for 80% of the continent's surface water resources, (Figure 1.1). Management of these essential shared resources is crucial.



Figure 1.1. Major River Basins of the World
Source: UNEP 2001

At a basin level, the study at the University of Oregon found that few treaties had adequate reference to "*water quality management, monitoring and evaluation, conflict resolution, public participation and flexible allocation methods…As a result, most existing international water agreements continue to lack the tools necessary to promote long-term holistic water management,*".

More than 260 river basins may be qualified as international watercourses, being shared by two or more states. In the last century the world population has more than tripled. Meanwhile, because of pollution and over-exploitation, freshwater resources have been seriously depleted.

As these factors place a greater strain on the earth's natural resources, disputes over freshwater will pose an ever greater threat to the peace and security of our planet. Although there has been a great deal of talk in international fora and media about the looming world water crisis in the last decade, not enough has been said about how conflicts over scarce water resources could be averted or dealt with effectively when they arose.

Trans-boundary water resources are simultaneously local and international in scope, and vital to both community and commerce across every region of the planet. The proposal proposed by

[262] United Nations Environment Programme UNEP 2001; World Conservation Monitoring Centre WCMC; World Resources Institute WRI; American Association for the Advancement of Science AAAS; Atlas of Population and Environment,.

several International organizations[263] to urge member of the group of eight leaders, to allocate funds to promote cooperation over trans-boundary waters, International Rivers and Lakes. The proposal stressed that Sustainable trans-boundary water resources management requires*:*

(a) Sharing water-related benefits among nations for regional economic integration rather than polarized claims for water;

(b) balancing competing uses of basin and aquifer resources, especially upstream and downstream uses, in a transparent and participative way for local and regional sustainable development;

(c) Focusing on poverty reduction, public participation and gender balance to ensure equitable access to water for livelihoods;

(d) Recognizing the fundamental need of freshwater ecosystems for resource protection and natural risk prevention;

(e) Protecting watercourses during wars and conflicts and post-conflict rehabilitation of water resources;

(f) Improving our knowledge about the causes of conflicts and potential policy responses to prevent conflicts triggered by competition for the resource among different uses and users, and environmental concerns such as pollution; and

(g) Developing capacity building on integrated water resources management (IWRM).

Unfortunately, international law and development support for cooperation in trans-boundary river, lake and aquifer basins are currently insufficient to meet these challenges.

The vast majority of countries did not take the opportunity to reconfirm their commitment to cooperate over trans-boundary water basins by either including this goal in the outcomes of the World Summit on Sustainable Development that took place in Johannesburg - 2002, or in the Ministerial Declaration of the 3rd World Water Forum that took place in Kyoto - 2003. Greater political will and actions are urgently needed, as manifested in earlier declarations, such as those signed in Rio -1992, Paris -1998, The Hague - 2000 and Bonn- 2001. The implementation of IWRM (integrated water resources management) needs political will and long-term financial commitment.

[263] Quoted from the A Newsletter of several International organizations that including:

- Right to Water (rightwater@iatp.org).
- Global Water Partnership,
- Green Cross International,
- The World Conservation Union (IUCN),
- International Network of Basin Organizations,
- International Secretariat for Water,Programme Solidarit @ Eau,
- World Water Council and
- World Wide Fund for Nature. Posted: 05/28/2003 by svarghese@iatp.org.

The Newsletter prepared jointly by the Department for Economic and Social Affairs, United Nations, New York and the Economic Commission for Latin America and the Caribbean, Santiago, Chile No. 39

1.4. Integrated trans-boundary water resources and basin management

The watercourse/blue water –water of rivers, lakes and ground water used for production and development aspects- and the river basin/green water - precipitation that serve rainfed agriculture, natural green vegetation (rangelands and forests)- could be illustrated as in (figure 1.2), after (SIWI 2011)[264] . Abu-Zeid, (2011) [265] approach for achieving a win-win trans-boundary solutions requires a good understanding of the water sources distribution and uses in production globally, not only but also, the most important within each trans-boundary river and its basin.

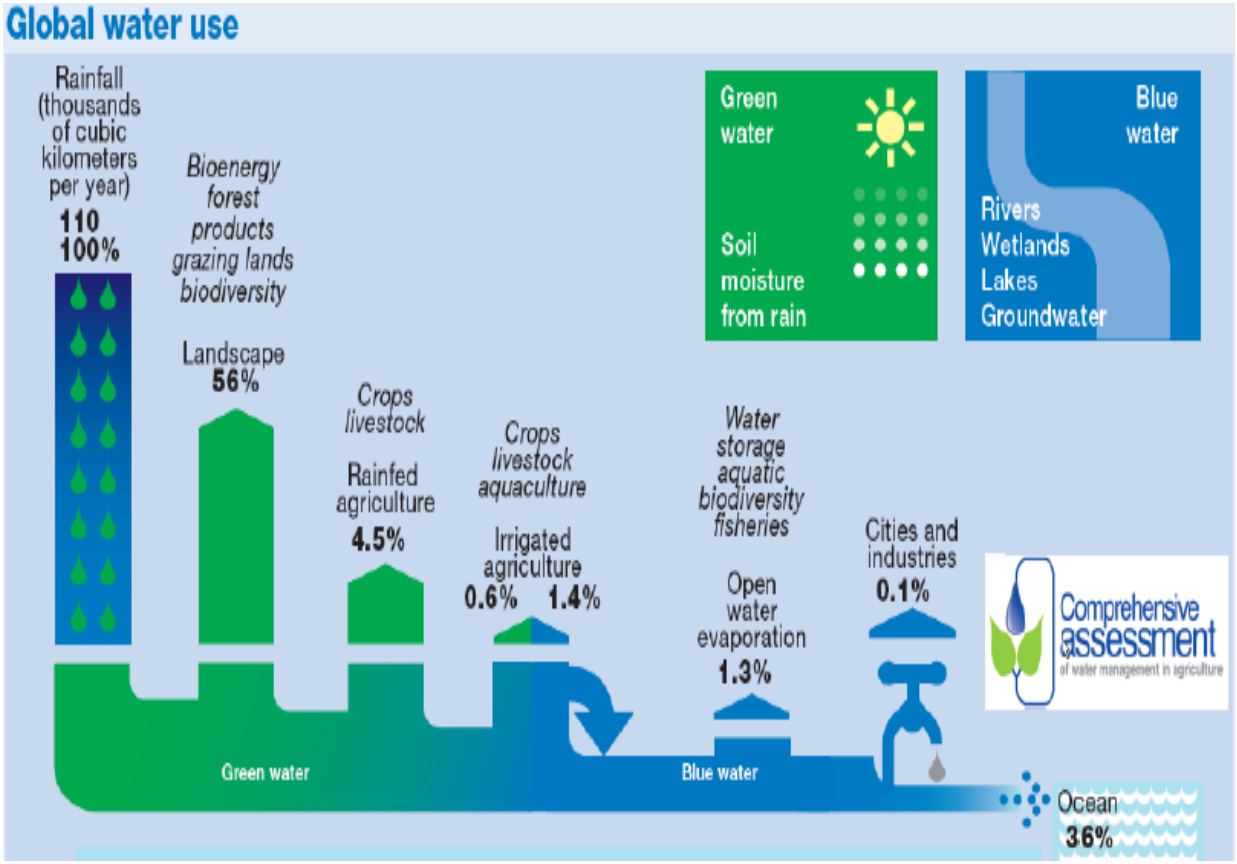


Figure 1.2. Global Green and Blue water use, after, Abu-Zeid, (2011)

As a resource that transcends political and administrative boundaries, the world's freshwater resources must be shared amongst individuals, economic sectors, intra-state jurisdictions and sovereign nations, while respecting the need for environmental sustainability. The win-win situation of sharing and cooperation will bring benefits to all basin countries if achieved. The benefits should go beyond the river (blue water) to include both (blue and Green water) the basin as all that should cover all environmental, social, economic and finally, political aspects, it

[264] SIWI 2011, Strengthening Water Diplomacy in Trans-boundary Basins - Nile Basin Case Study, World Water Week in Stockholm

[265] Abu-Zeid, K 2011. The Watercourse/Blue Water & the River Basin/Green Water Approach to Win-Win Trans-boundary Solutions, C2nd Arab Water Forum, 20-23 November, Cairo-Egypt

should be concerned more with people needs. water footprint of production –green and blue water use are shown in Figure (1.3), after (SIWI 2011).

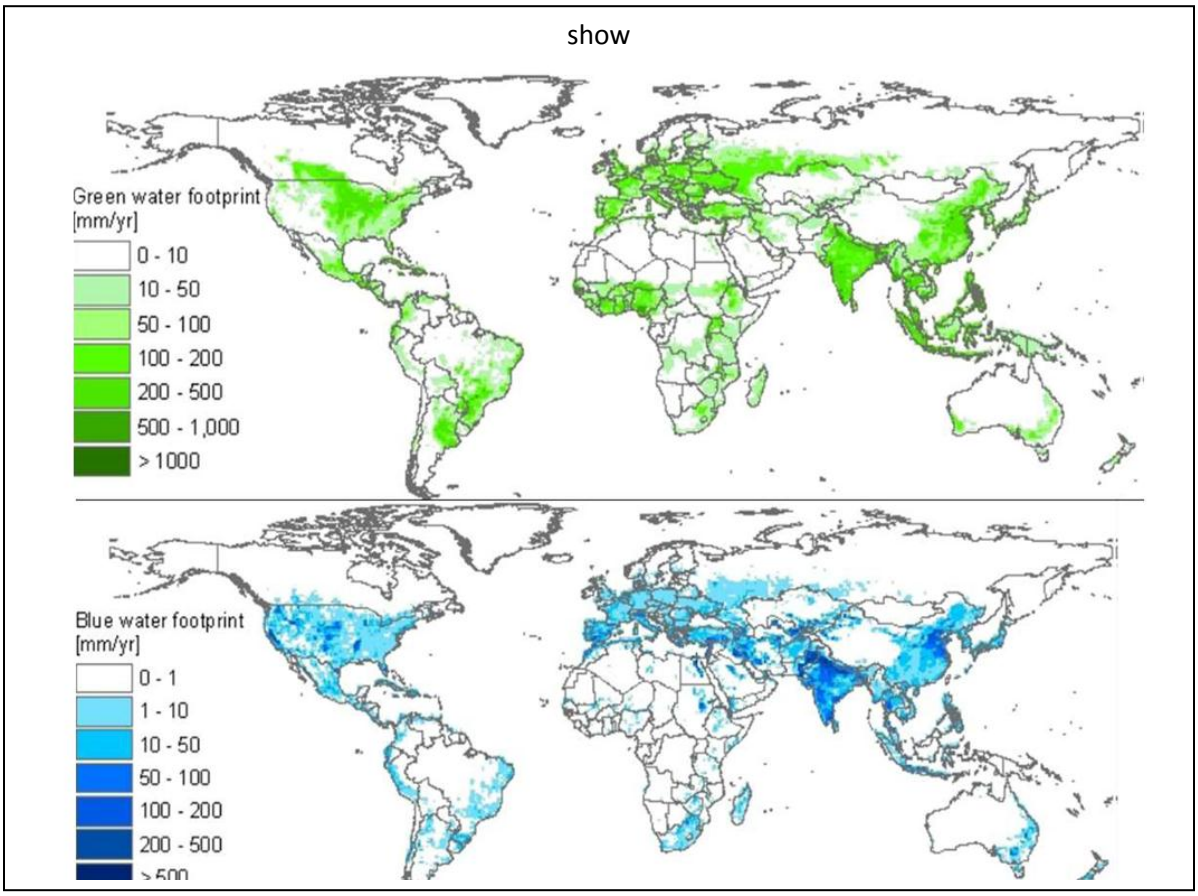


Figure 1.3. Water Footprint of Production –Green and Blue Water Use
Source: SIWI 2011,

The establishment of trans-boundary basin organizations has been a success in many basins at the international and sub national levels, such as the Rhine, Lake Geneva, the Great Lakes and St Lawrence (US/Canada), the Senegal, but many trans-boundary basin institutions do not have sufficient authority, capacity or resources.

What is worse, the majority of trans-boundary basins have no interstate water institutions at all. The need for widespread establishment and reinforcement of basin organizations to improve governance and facilitate stakeholder participation is in line with recommendations of the international community to elaborate a common vision for basin management, as shown in (figure 1.4). .



Figure 1.4. Benefit Sharing – from theory to practice

1.5. **Arab Countries Have Warmed And Most Have Become Drier.**

The so-called Win-Win situation within trans-boundary basins in Arab countries requires understanding of the water sources distribution and uses in production, not only but also, the most important within each trans-boundary river and its basin.

Rainfall could be considered the critical climate variable for human settlement patterns in the Arab region, most of it could be considered desert regions that receive annual rainfall totals of less than 200 millimeters, while, the central parts of the Sahara receive less than 50 millimeters. In a region ranging from southwestern Algeria to western Egypt, no rain at all was observed during the twentieth century, (World Bank 2012)[266]. Mediterranean zones receive above 500 millimeters of rainfall per year, whereas the annual rainfall in south Sudan and the Comoros is more than 1,000 millimeters.

Rainfall in most of the Arab countries depends partly on the state of the NAO[267], which is the dominant source of climate variability in the Atlantic/European/Mediterranean and Middle East region, (World Bank 2012). Cullen et al. (2002)[268] identified two components of Middle Eastern stream flow variability. The first reflects rainfall-driven runoff and explains 80 percent of the variability in river flows from December to March. In a positive NAO phase, the climate in the Middle East is cooler and drier than average and vice versa for the negative phase. The second principal component (the so-called Khamsin) is related to spring snow melt in the mountains and explains more than half of the stream-flow variability from April to June. A prevailing positive NAO phase, as in the 1990s and 2000s, can therefore result in drought conditions in the region, including in the Euphrates-Tigris and Jordan Rivers Basins.

In general the Arab countries are situated in the most semi-arid and arid region in the world with an uneven geographical distribution of water resources. And an increasing population water demand. The Arab countries are rated among nations facing extreme and high water security risks as having least secure supplies of water, less than 500 cubic meters per person per year in some of the Arab countries and characterized by its aridity, causing the formation of the vast Sahara and Arabian deserts. Deep in the Sahara and Arabian deserts several oases spring up creating microclimatic conditions where limited agriculture could be practiced. High evapo-transpiration rates greatly reduce the amount of water that turn into surface runoff or percolate through the soil to recharge aquifers. For example, it is estimated that in Jordan over 90 percent of the rain evaporates leaving a fraction to recharge aquifers and feed surface runoff (ESCWA 2005) [269].

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[266] World Bank 2012." Adaptation to a Changing Climate in the Arab Countries MNA", Flagship Report, Sustainable Development Department Middle East and North Africa Region, Report N° 64635 – MNA

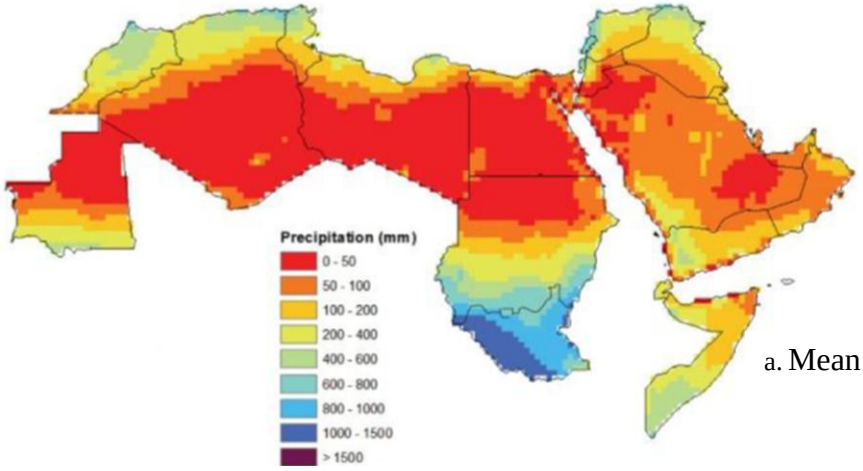
[267] **North Atlantic Oscillation (NAO):** The North Atlantic Oscillation consists of opposing variations of barometric pressure between areas near Iceland and near the Azores. It affects the strength and position of the main westerly winds across the Atlantic into Europe and the Mediterranean. When the pressure difference is high (NAO+), the westerlies are stronger and track more to the north leading to cool summers and mild wet winters in Europe, but drier conditions in the Mediterranean. In the opposite phase, the westerlies and the storms they bring track further south leading to cold winters in Europe, but more storms in the Mediterranean and more rain in North Africa.

[268] Cullen, H. M., A. Kaplan, P. A. Arkin, and P. B. de Menocal. 2002. —Impact of the NAO on Middle Eastern Climate and Streamflow. *Climate Change* 55: 315–38.

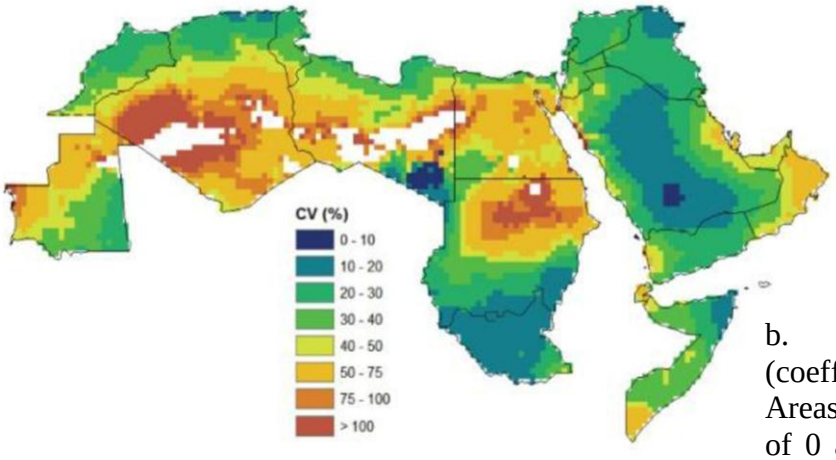
[269] ESCWA (2005). "Regional Cooperation Between Countries in the Management of Shared Water Resources: Case Studies of Some Countries in the ESCWA Region." E/ESCWA/SDPD/2005/15.

Mean annual temperature is vary between 20°C and 25°C in the desert regions, up to 28°C on the Arabian Peninsula, between 15°C and 20°C in the Mediterranean and subtropical zones, and close to 25°C in the tropical regions. In tropical zones, the annual amplitude is very small, whereas variability increases further north. In the mountainous regions of Morocco, Iraq and Lebanon, it is sometimes even cold enough for occasional snowfall. Often, monthly mean summer temperatures exceed 30°C and in a few places even 35°C, (World Bank 2012).

Consequently, most of the Arab countries are classified as Hyper arid and arid desert. As in other arid regions, rainfall varies greatly between years with the coefficient of variation 21 exceeding 100% in the deserts. This means that there can be years with little or no rainfall and years in which the rainfall greatly exceeds the average, but also that it is difficult to identify trends in the amount of rainfall, figure (1.5), after, (World Bank 2012).



a. Mean Annual rainfall in mm



b. inter-annual variability (coefficient of variation in %) Areas with mean annual rainfall of 0 are shown in white in the right panel.

Figure 1.5 (a and b), Mean Annual rainfall in mm and its coefficient of variation in %
***Source*: Westphal 2010.**

Despite some local deviations, the available evidence clearly indicates a warming trend within the last 100 years or more. Most of them show an overall temperature increase of 0.2 to 0.3°C per decade, mainly in the Maghreb and in Sudan. In the Mashreq, In larger cities, temperature decrease for 1961-1990, notably Damascus (Syria) and Kuwait City (Kuwait). For the more recent period 1991-2011, however, a significant positive trend of 0.3 to 0.4°C per decade. The fact that temperatures rose only slightly or even decreased prior to 1990 may be related to the generally positive NAO phase during this period. Metrological records suggest that rainfall has decreased over the past century,(World Bank 2012).

Temperature varies between summer's and winter's months, in most countries as shown in figure (1.6, a, b, c),- produced by NCRS , ACSAD and GTZ using FAO data – shows that during summer temperature rise in most Arab countries and become more mild in Northern parts and heights. But during winter time temperature increase only in Southern parts as they become closeer to equator, and gets cooler in internal parts far from sea water.

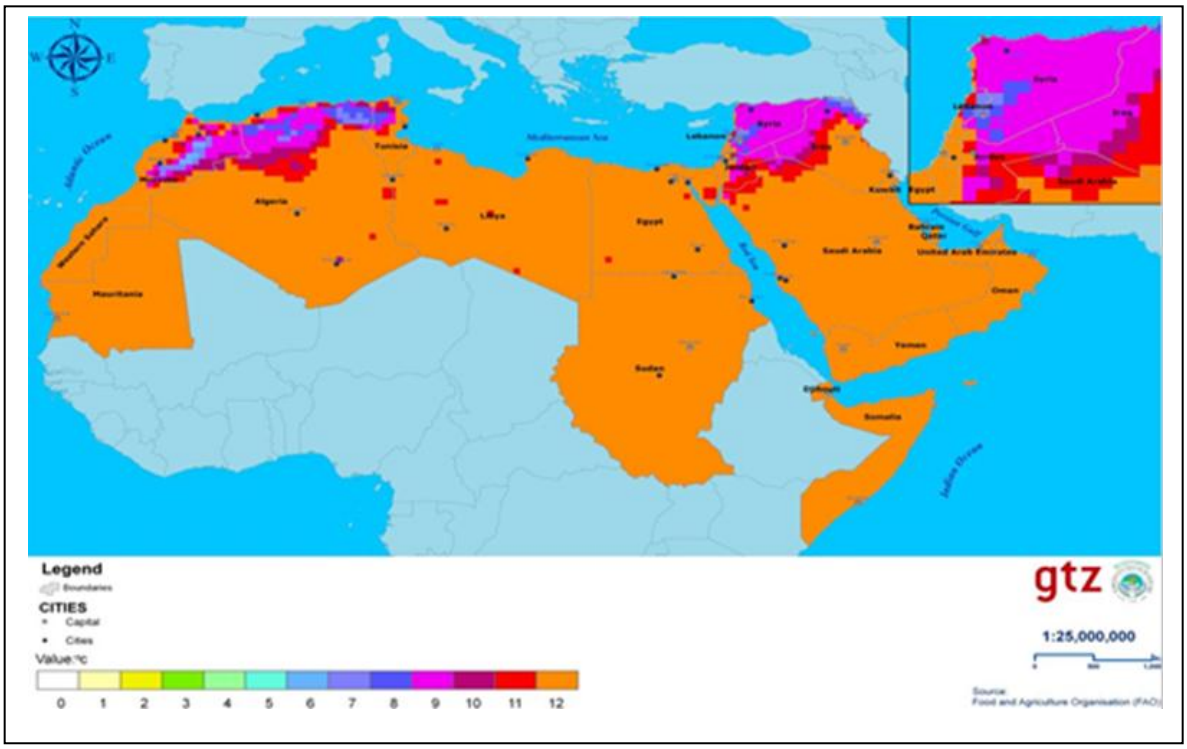


Figure 1.6-a. Number of Months with Temperature Exceeding 10C^{o}

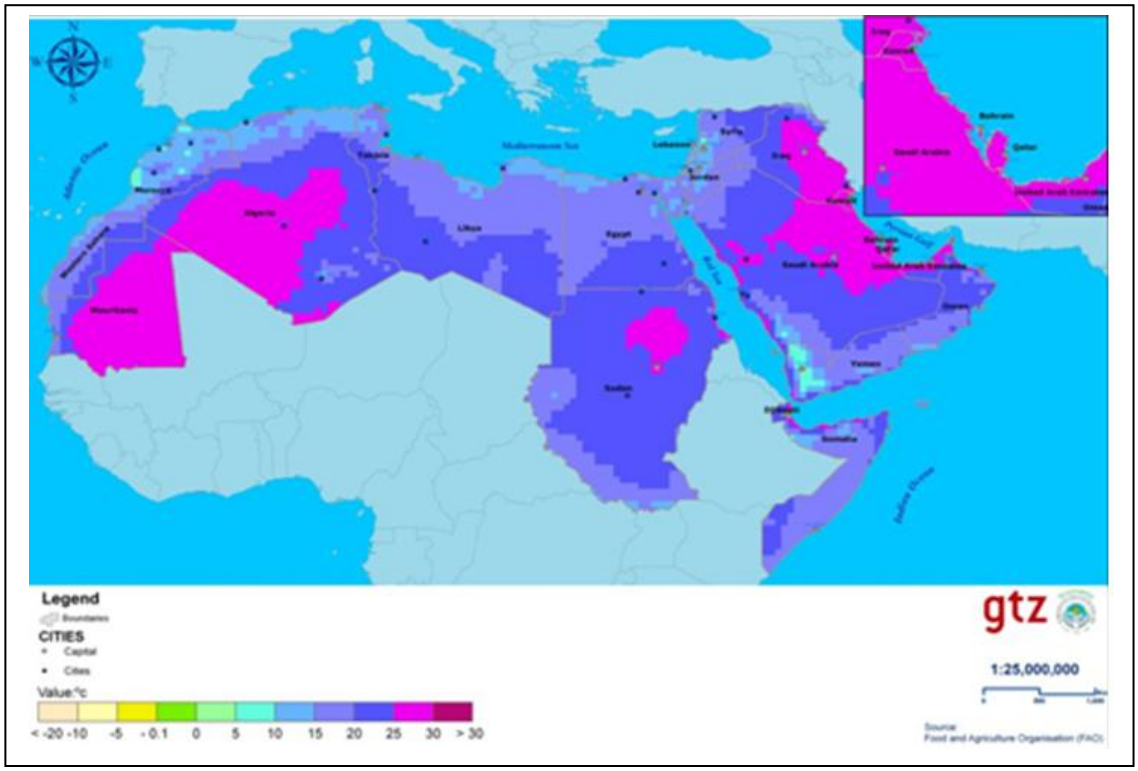


Figure 1.6-b. Mean Monthly Temperature of Warmest Month

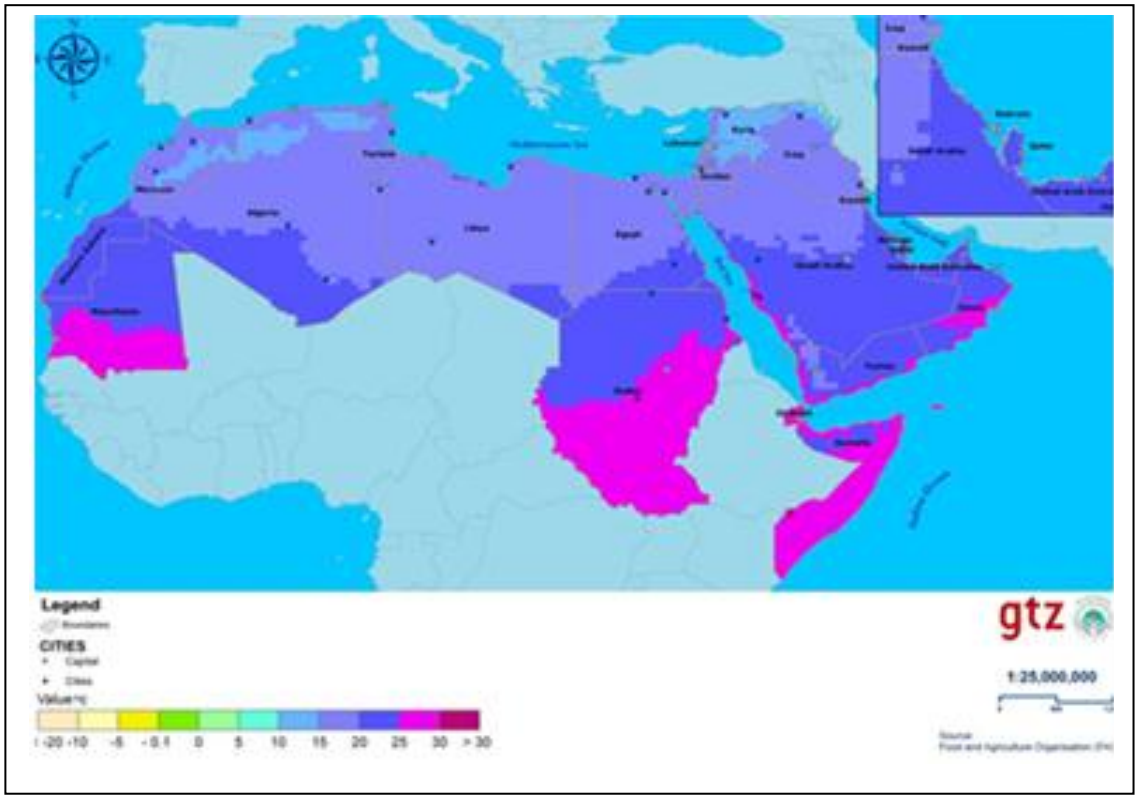


Figure 1.6-c. Mean Monthly Temperature of Coldest Month

The mean average values of Potential evapo-transpiration considered to be the highest if compared with other countries in the world. In June, July and August it reaches the maximum to come close to 15mm/day or more on few places especially in desert areas, as shown in figure (1.7), evaporation along the Mediterranean coastal areas (southern and eastern sides) vary between 750-1000 mm/year or more, in desert areas it could reaches 3000 mm/year or more and gradually reduced in South Sudan with the increase of humidity to reaches to 1500 mm/year. Due to the scarce of water on most of the Arab countries the annual actual evapo-transpiration doesn't exceeds 100 mm in most of Arab countries and might reaches to 300 mm on the North Western parts and could reaches 600 mm in South Sudan.

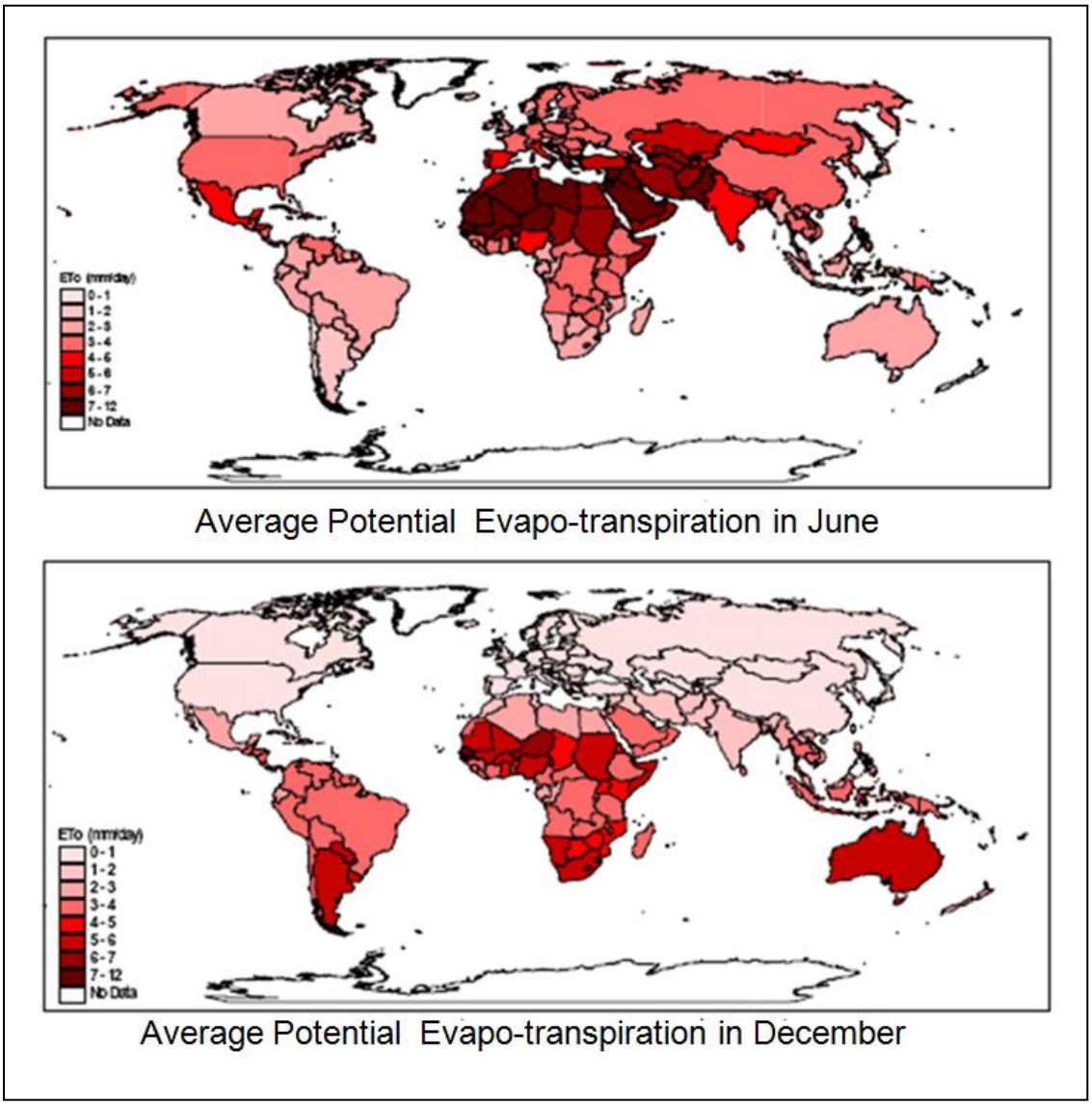


Figure 1.7. Comparing Average Potential Evapo-Transpiration in Arab Countries for the rest of the World

1.6. Drought in Mediterranean and Arab Countries:

Droughts are the world's costliest natural disasters, causing an average $6–$8 billion in global damages annually and collectively affecting more people than any other form of natural disaster (Wilhite 2000)[270]. Given the consequences and pervasiveness of drought, it is important to assess drought severity, but the precise quantification of drought is a difficult geophysical endeavor. Numerous specialized indices have been proposed to do this; for an extensive listing of available indices, the reader is referred to WMO (1975)[271] and Heim (2000)[272].

Mediterranean countries are experiencing an increased drought frequency, intensity and duration that have resulted in increased drought losses and impacts on agricultural production, rural livelihoods, migration, urban, economic sectors and ecosystem decline.

The Study that has been conducted by Burke and Brown, (2007)[273] using different indices related to moisture (Palmer drought severity index PDSI, and soil moisture anomaly SMA), shows increases in the proportion of the overall increase in areas affected by drought. The study also showed that all indices that include some measure of the atmospheric demand for moisture (PPEA, PDSI, and SMA) show increases in the proportion of the global land surface in drought ranging from an additional 5%–45%. SPI, based solely on precipitation, shows much smaller global changes ranging from 5% less to 10% more of the land surface. In addition to the overall increase in area affected by drought, the area in more severe drought increases much more than the area in less severe drought. This could have serious consequences as the impact of drought on socioeconomics increases with the severity of drought. They added that regionally, there is a very large range in the sign and magnitude of drought changes. The only regions where there is a consistent increase in drought across all indices and ensembles are those where the annual average precipitation decreases as found for the Mediterranean, Amazonia, and southern Africa. In other regions the sign and magnitude of the change in drought is dependent on index definition and ensemble member. The impact of change in drought will be felt at the regional scale. Therefore, in order to perform optimum impact assessments of changes in drought, regional studies are required using locally appropriate drought indices. For example, a soil-moisture-based drought index on a daily basis over the growing season will be most relevant for studying the impacts in agriculture.

Regional climate simulations highlight the Mediterranean region as being affected by more severe droughts, consistent with available global projections; Giorgi, (2006)[274], calculated the Regional Climate Change Index RCCI using wet season (WS) and dry season (DS) as defined by Giorgi and Bi, (2005)[275], temperature and precipitation over 26 land regions of the world and out of 20 global model simulations the RCCI for the different regions showed that the most

[270] Wilhite, D. A., 2000: Drought as a natural hazard: Concepts and definitions. *Drought: A Global Assessment,* D. A. Wilhite, Ed., Routledge, 3–18.
[271] WMO, 1975: Drought and Agriculture. WMO Tech. Note 138, 127 pp.
[272] Heim, R. R., Jr., 2000: Drought indices: A review. *Drought: A Global Assessment,* D. A. Wilhite, Ed., Routledge, 159–167.
[273] Burke, E.J., and S.J. Brown, 2008: Evaluating uncertainties in the projection of future drought. Journal of Hydrometeorology, 9(2),292-299
[274] Giorgi, F., (2006): Climate change hot-spots. Geophysical Research Letters, 33(L08707).
[275] Giorgi, F., and X. Bi (2005), Updated regional precipitation and temperature changes for the 21st century from ensembles of recent AOGCM simulations, Geophys. Res. Lett., 32, L21715, doi:10.1029/2005GL024288.

prominent Hot-Spots emerging from the RCCI analysis are the Mediterranean and North Eastern Europe (NEE) regions, Mediterranean was identified as the most prominent Hot-Spots emerging from the Regional Climate Change Index RCCI analysis, a large decrease in mean precipitation and an increase in precipitation variability during the dry (warm) season, which makes the Mediterranean one of the most responsive regions to global change,; (Giorgi 2006). the analysis presented here identifies the Mediterranean and Northeastern Europe regions as the most prominent climate response Hot-Spots, followed by high latitude northern hemisphere regions and Central America. The latter appears to be the primary Hot-Spot in the tropics, immediately followed by Southern Equatorial Africa and Southeast Asia. Other prominent mid-latitude Hot-Spot regions are Eastern North America and Central Asia.

Mariotti et al., *(*2008)[276] Used the CMIP3 multi-model simulations to show how individual hydro-climatic changes will concur to determine even greater alterations of 21st century Mediterranean water cycle characteristics, with contrasting behavior over land and sea. The study reflected that by 2070–2099, the average of the models predicts a 20% decrease in land surface water availability and a 24% increase in the loss of fresh water over the Mediterranean Sea due to precipitation reduction and warming-enhanced evaporation, with a remarkably high consensus among analyzed models. The projected decrease in river runoff from the surrounding land will further exacerbate the increase in Mediterranean Sea fresh water deficit. 20th century simulations indicate that the 'transition' toward drier conditions has already started to occur and has accelerated around the turn of the century towards the larger rates projected for the 21st century. These tendencies are supported by observational evidence of century-long negative trends in regionally averaged precipitation, PDSI and discharge from numerous rivers; and are consistent with reported increases in Mediterranean sea water salinity

The southeastern Mediterranean Sea during the wet season will see the greatest overall $P - E$ decrease, as this is where most of the precipitation decrease and evaporation increase occurs. The wet season $P - E$ decrease over land is mostly driven by precipitation decrease. During the dry season, decrease in land evaporation over southern parts leads to smaller $P – E$ decrease over these regions. Central and northwestern parts of the Mediterranean region will experience maximum surface fresh water loss during this season, after (Mariotti et al., 2008).

The study of the standardized precipitation index SPI, for the east MED shows that, over the last century the SPI has dropped by around 0.5 to 1 points with the exception of a part of Iraq, the entire region has negative trends of annual SPI and annual precipitation, and countries most affected by the decrease are Jordan, Syria, Lebanon and Palestine; (Göbel and De Pauw, 2010)[277].

[276] Mariotti, A., N. Zeng, J.H. Yoon, V. Artale, A. Navarra, P. Alpert, and L.Z.X. Li, 2008: Mediterranean water cycle changes: transition to drier 21st century conditions in observations and CMIP3 simulations. Environmental Research Letters, 3(4), Art. 044001 (8 pp.)

[277] Göbel, W and De Pauw, E, 2010. Climate and Drought Atlas for parts of the Near East A baseline dataset for lanning adaptation strategies to climate change". .International Center for Agricultural Research in the Dry Areas, ICARDA

Simulated precipitation regimes depict a globally drier Mediterranean in 2030–2060, with a 10–20% drop in annual rainfall, a drier Mediterranean in 2031– 2060 translates into about 1 week of additional dry days along the coast and in the already dry southeast basin; Over land areas in the northern part, up to and over 3 weeks of additional dry days; thus, if the effects of ozone are to be included in an assessment of crop yields in the Mediterranean under a future climate scenario, the results are likely to be greater yield reductions; (figure 12), (Giannakopoulos et al, 2009[278] and Dai, 2010[279]).

speed used in the IPCC AR4 from the 20th century and SRES A1B 21st century simulations.128

Red to pink areas are extremely dry (severe drought) conditions while blue colors indicate wet areas relative to the 1950–1979 mean.

The region is subject to frequent agriculture (soil moisture) droughts and rainfed crops are strongly affected by precipitation fluctuations; mainly in the areas were annual rainfall range between 120/150 – 400 mm, they are considered moderately to sever vulnerable areas to drought; figure (1.8) (Erian et al, 2006)[280].

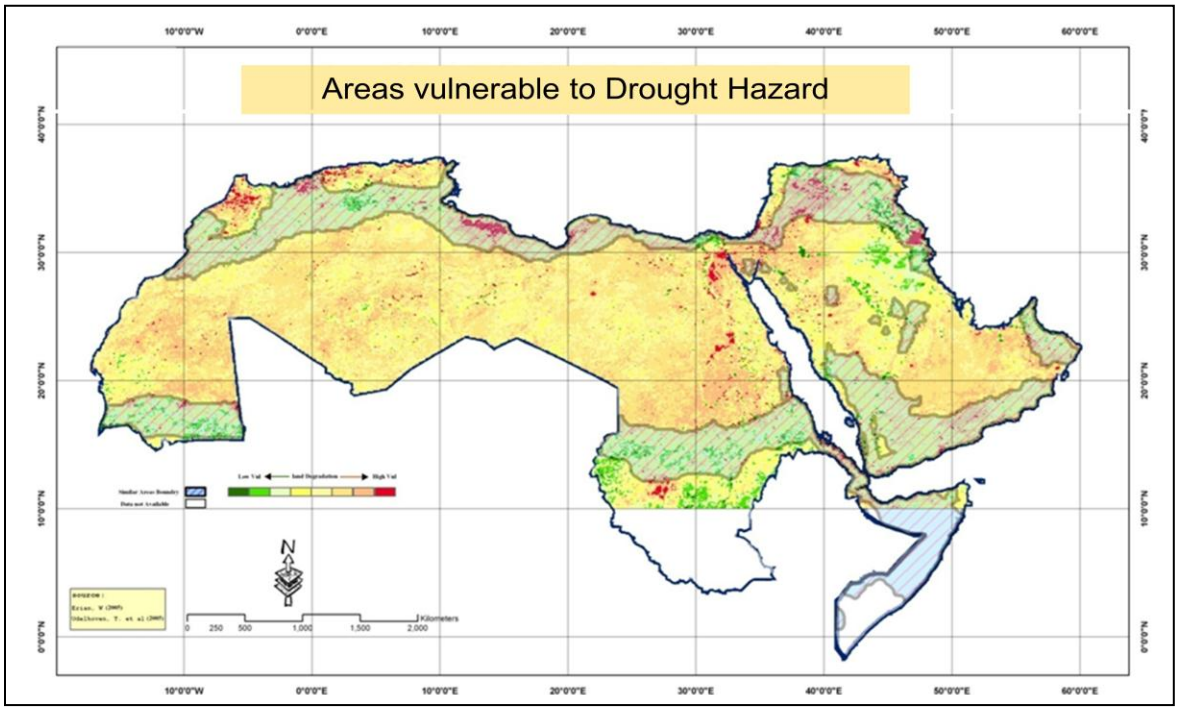


Figure 1.8. Areas Vulnerable to drought Hazard

[278] Giannakopoulos, C., P. Le Sager, M. Bindi, M. Moriondo, E. Kostopoulou, and C.M. Goodess, 2009: Climatic changes and associated impacts in the Mediterranean resulting from a 2°C global warming. Global and Planetary Change, 68(3), 209-224

[279] Dai, A., 2011: Drought under global warming: a review. Wiley Interdisciplinary Reviews: Climate Change, (in press, doi: 10.1002/wcc.81)

[280] Erian, W.F., F.S. Fares, T. Udelhoven and B. Katlan, (2006). "Coupling Long-term NDVI for Monitoring Drought in Syrian Rangelands", The Arab Journal for Arid Environments, volume (1), pp 77-87, Published by ACSAD.

1.7. Major Economic Characteristics of Arab Countries, after, (World Bank 2012).

The Arab World stretches across more than 14 million square kilometers (8.6 million square miles) of North Africa and the part of North-East Africa and South-West Asia called the Middle East. The Asian part of the Arab region is called the Mashriq. The North African part of the Arab World to the west of Egypt and Sudan is known as the Maghreb. The status of Egypt itself, geographically in the center of the Arab world, is disputed; although on the African continent, it has stronger cultural connections to the Mashriq.

The populations in Arab countries are growing; in some places they are increasing at unprecedented rates. The total population in Arab region recorded as 76 million people at the middle of last century with annual increase rate of about 2.5%, the total population increased to 144 million people at the year 1975, and reached 284 million people by the end of the 20th century with annual increase rate of about 2.7%, (figure 1.9). In Qatar and Yemen there is an annual population growth rate of 6.8 and 2.8 percent, respectively. The total population of the Arab region crossed 350 million people in 2010 and is likely to hit 700 million people by 2050; this is roughly twice the size of today's population. The distribution of population density in Arab countries could be shown as in figure (1.10) and shows high matching with areas that contain relatively suitable natural resources for development and agriculture areas. .

This growth will increase the demand for scarce resources, including water and land. Climate change and the increased demand for food will affect food prices. According to Oxfam (2011), food prices may double worldwide by the year 2030.

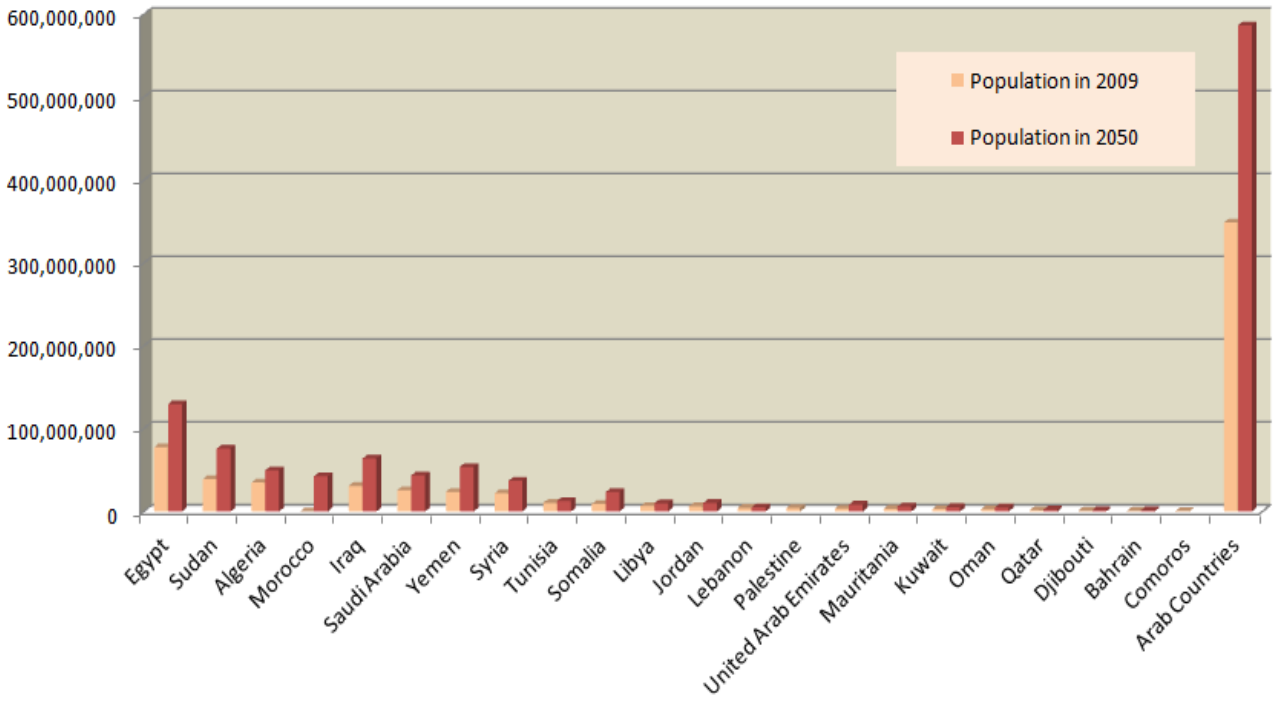


Figure 1.9. Total Population in Arab Countries as in 2009 and expected in 2050

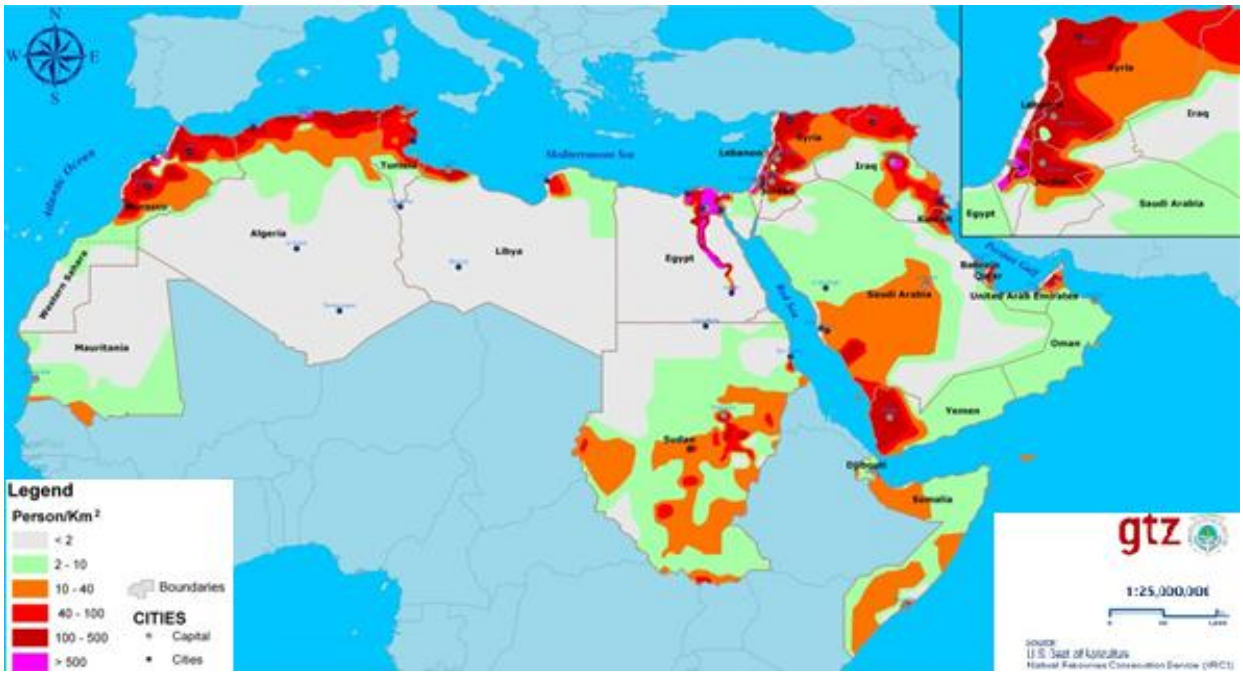


Figure 1.10. Distribution of Population Density in Arab Countries

The Arab Region varies greatly in climate, culture, education, literacy, in access to resources and thus in vulnerability. The GDP and GNI increased in most of the Arab countries during the last decade. Arab countries as shown in (Table 1.1 and 1.2) could be classified by the change in GDP/capita as USA for the year 2009 as follows:

- Countries with relatively high GDP/capita (more than 50000) includes Qatar and Kuwait
- Countries with relatively moderate GDP/capita (10000 - 30000) includes UAE, Oman, Bahrain, Saudi, and Sudan.
- Countries with relatively low GDP/capita (2000-10000) includes Libya, Lebanon, Jordan Algeria, Tunisia, Morocco, Syria, Egypt, Egypt and Iraq.
- Countries with relatively very low GDP/capita (less than 2000) includes Djibouti, Yemen, Mauritania, Comoros and Somalia.

Six IDA countries with annual GDP per capita as low as less than US$1,000 (Comoros and Somalia). These countries with the exception of Djibouti contain large rural populations of over 50 percent and agricultural sectors contributing to approximately 20 percent or more of total GDP. By comparison, the annual GDP in Qatar, Kuwait, and the UAE is more than US$50,000 per capita, and 80 to 90 percent of the people live in cities. Literacy rates of adult women are below 50 percent in Morocco and Yemen, while in Lebanon and Libya over 50 percent of young women are enrolled in tertiary education; more than similar aged men, (Table 1.3).

Table 1.1. Arab Countries Ranked by Total GDP

Countries	Gross Domestic Product GDP (Millions of USD)				Gross National Income GNI per capita (USD)			
	1994	1999	2004	2009	1994	1999	2004	2009
Sudan	170000	150000	220000	570000	300	390	500	1200
Saudia	130000	160000	250000	390000	7000	7000	11000	17500
UAE	40000	51000	100000	225000	19000	19000	25000	50000
Egypt	50000	95000	78000	195000	800	1300	1200	2100
Kuwait	22000	22000	45000	150000		19000	20000	59000
Algeria	40000	43000	80000	140000	1900	1700	2100	4500
Qatar	9000	18000	30000	100000	18000	20000	40000	70000
Morocco	30000	40000	59000	90000	1100	1300	1750	1800
Iraq		19000	21000	68000		750	750	2300
Libya	30000	30000	35000	62000	6000	6000	5000	12000
Syria	10000	15000	25000	54000	1000	998	1498	2499
Oman	12000	15000	24000	45000	6000	6000	9000	16000
Tunisia	15000	21000	29000	40000	1998	2100	2250	3997
Lebanon	10000	17500	22000	35000	2300	4300	5900	8000
Yemen	4900	7250	14900	25100	210	390	590	1050
Jordan	6000	9000	11000	25000	1500	1700	2100	4000
Bahrian	5000	5300	10200	20000	9900	10000	15000	25200
Mauritania	1400	1200	1500	3000	600	580	580	1000
Djibouti	500	550	650	1100	820	790	990	1300
Comoros	200	220	390	590	500	400	590	800

Table 1.2. Arab Countries Ranking by GDP/Capita.

Country	Total Population	GDP Millions of USD2009	GDP/capita USD 2009	GNI/capita USD 2009
Qatar	1,758,793	100000	56857	70000
Kuwait	2,736,732	150000	54810	59000
UAE	7,511,690	225000	29953	50000
Oman	2,782,435	45000	16173	16000
Bahrian	1,261,835	20000	15850	25200
Saudia	27,448,086	390000	14209	17500
Sudan	43,551,941	570000	13088	1200
Libya	6,355,112	62000	9756	12000
Lebanon	4,227,597	35000	8279	8000
Jordan	6,047,000	25000	4134	4000
Algeria	35,468,208	140000	3947	4500
Tunisia	10,549,100	40000	3792	3997
Morocco	31,951,412	90000	2817	1800
Syria	20,446,609	54000	2641	2499
Egypt	81,121,077	195000	2404	2100
Iraq	32,030,823	68000	2123	2300
Djibouti	888,716	1100	1238	1300
Yemen	24,052,514	25100	1044	1050

Mauritania	3,459,773	3000	867	1000
Comoros	734,750	590	803	800

Table 1.3. Socio-Economic Information for Arab Countries, after, (World Bank 2012)*.

Sub regional countries	Land area	1	2	3	4	5	6	7	8	9	10
	sq. km	%	%	person	%	(con 2005 int. $)	HDI 2011	%	person	%	%
Maghreb											
Algeria	2,381,740	17.4	0.6	35,468,208	1.47	7,521	0.698	6.8	14,844,724	20.7	11.7
Libya	1,759,540	8.8	0.1	6,355,112	1.47	15,361	0.760	--	2,304,613	19.7	1.9
Morocco	446,300	67.3	11.5	31,951,412	1.00	4,227	0.582	2.5	11,845,622	40.9	15.4
Tunisia	155,360	63.0	6.5	10,549,100	1.04	8,566	0.698	2.6	3,821,103	25.8	8.0
Mashreq											
Egypt	995,450	3.7	0.1	81,121,077	1.75	5,544	0.644	2.0	26,536,263	31.6	14.0
Iraq	434,320	20.1	1.9	32,030,823	3.02	3,195	0.573	4.0	7,275,555	23.4	8.6
Jordan	88,780	11.5	1.1	6,047,000	2.21	5,157	0.698	0.4	1,817,540	3	2.9
Lebanon	10,230	67.3	13.4	4,227,597	0.73	12,619	0.739	--	1,444,266	--	6.4
Syria	183,630	75.7	2.7	20,446,609	2.04	4,741	0.632	1.7	6,311,814	19.1	22.9
Countries - International Development Association IDA											
Comoros	1,860	83.3	1.6	734,750	2.62	984	0.433	46.1	327,568	--	46.3
Djibouti	23,180	73.4	0.3	888,716	1.89	2,087	0.430	18.8	389,680	--	3.9
Mauritania	1,030,700	38.5	0.2	3,459,773	2.40	1,744	0.453	21.2	1,415,617	--	20.2
Sudan	2,376,000	57.5	29.4	43,551,941	2.50	2,023	0.408	--	13,246,649	--	23.6
Somalia	627,340	70.2	10.8	9,330,872	2.29	--	--	--	3,531,417	--	65.5
Yemen	527,970	44.4	1	24,052,514	3.06	2,267	0.462	--	6,053,143	54.1	14.3
Gulf											
Bahrain	760	9.2	1.3	1,261,835	7.59	23,755	0.806	--	591,876	1.5	0.9
Kuwait	17,820	8.5	0.3	2,736,732	3.36	49,542	0.760	--	1,334,479	2.7	0.5
Oman	309,500	5.9	0	2,782,435	2.56	24,226	0.705	--	1,092,450	6.4	1.9
Qatar	11,590	5.6	0	1,758,793	9.60	73,196	0.831	--	1,158,535	2.3	--
Saudi Arabia	2,149,690	80.7	0.5	27,448,086	2.36	20,374	0.770	--	10,109,647	4.8	2.6
UAE	83,600	6.8	3.8	7,511,690	7.93	42,353	0.846	--	4,455,171	4.2	1.0

1	Agricultural land of land area	6	Human Development Index (HDI)
2	Forest land of land area	7	Poverty ratio at $1.25 a day (PPP)
3	Population	8	Labor force, total
4	Population annual gross	9	Employ. in agriculture % of total employment
5	GDP/ capita, PPP	10	Agriculture, value added% of GDP)

Data from World Bank World Development Indicators (December 2011 version) and UNEP Human Development Report 2011. Data are the most recently available and most apply to 2010 or a few years prior *.

1.8.Water in Arab Countries:

The Arab region is characterized by uneven topographical and climatic conditions; the bulk of the region is very arid, but arid areas are flanked by more humid mountainous and coastal plains. Precipitation levels are low and highly variable in time and location. Globally, Arab countries have the least favorable combination of the lowest levels of precipitation and the highest level of variability, figure (1.11), after *(*World Bank 2007)[281].

The Arab region has the highest reliance on external water resources; more than 65% of the annually renewable resources originate outside the boundaries of the Arab region the major rivers in the region are the Nile River, the Euphrates and Tigris Rivers and the Senegal River. All these challenges in the region lead to a complicated hydro-political problem facing many Arab countries.

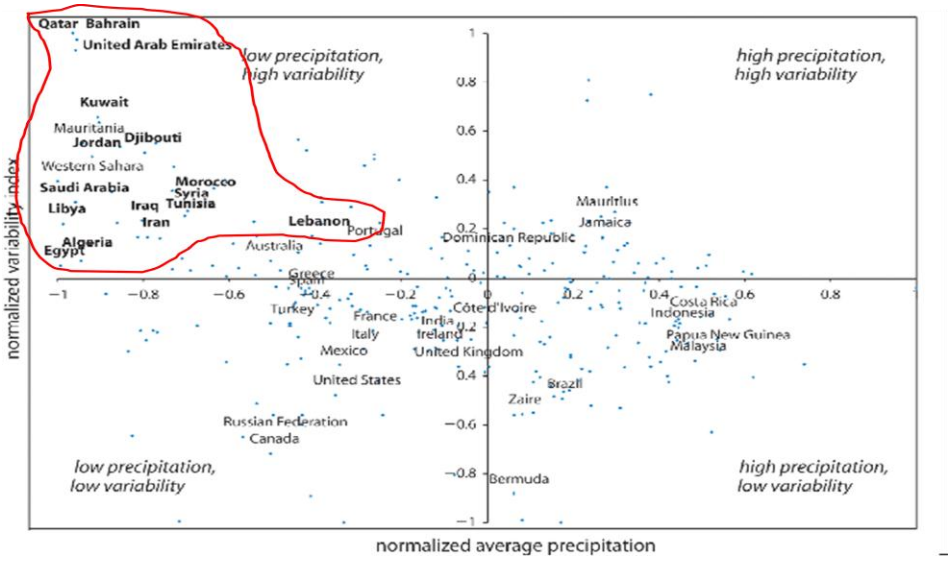


Figure 1.11. Precipitation in Arab countries is both lower and more variable than other countries worldwide, *Source*: World Bank 2007.

The vulnerability that comes from this high reliance on external and shared resources leads to political instability, and to serious problems and this is a limiting factor to achieve effective water management and sustainable development in the region. The region receives substantial runoff from neighboring regions, (figure 1.12). The Taurus and Zagros mountains to the north and east are the main headwaters of the Euphrates and Tigris. Egypt relies virtually exclusively on runoff from the Nile's headwaters in the Ethiopian and Equatorial Highlands several thousands of kilometers south. Water shortage for the individual countries will vary substantially. Many countries that are currently not facing any shortages will be confronted with huge deficits in the near and distant future, (World Bank 2012)[282].

[281] World Bank (2007). "Making the Most of Scarcity - Accountability for Better Water Management Results in the Middle East and North Africa." International Bank for Reconstruction and Development, Washington, D.C..

[282] World Bank 2012." Adaptation to a Changing Climate in the Arab Countries MNA", Flagship Report, Sustainable Development Department Middle East and North Africa Region, Report N° 64635 – MNA

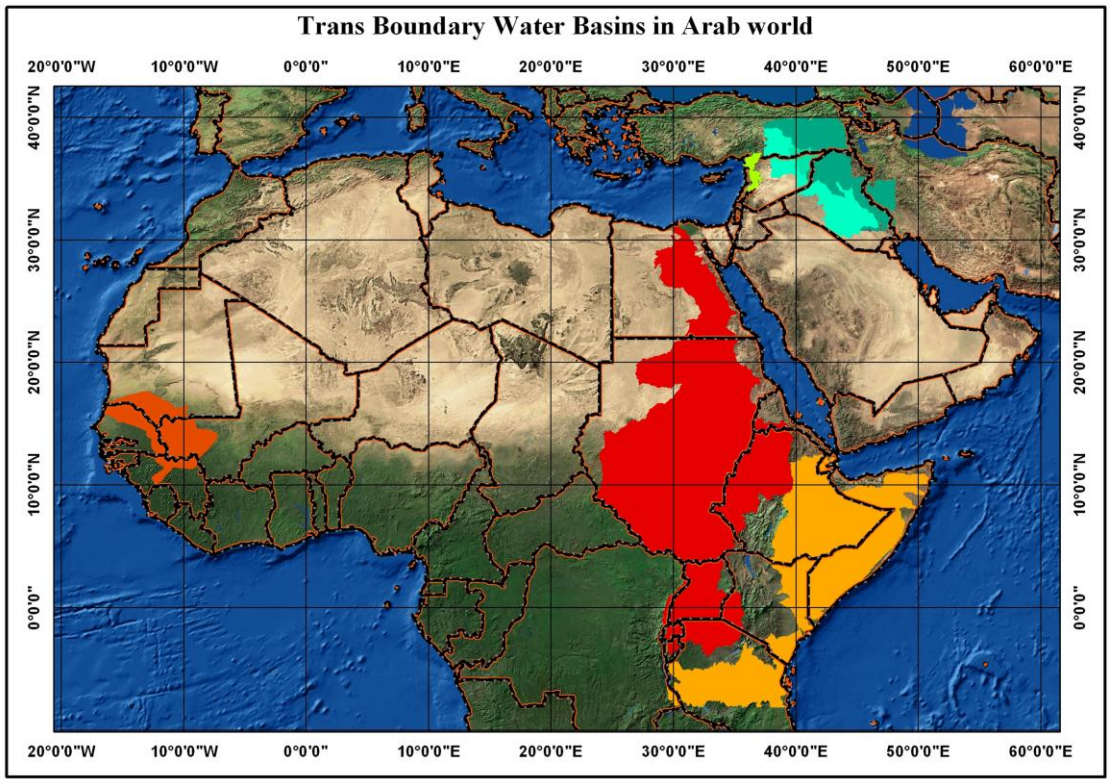


Figure 1.12. Major trans-boundary river's basins in Arab Region.

The level of cooperation with neighboring countries, non members in the Arab League is very weak and challenging, and there is an urgent need for the riparian neighboring countries to take the appropriate, tangible and concrete measures with the Arab concerned countries to improve and promote cooperation on sustainable use and protection of International shared water resources through: coordinated actions, the adoption of permanent agreements on a fair and equitable basis in conformity with the principles of International Law and Rules and existing agreements and preserve Arab water rights.

The majority of Arab countries are already experiencing water deficits in terms of internal and external renewable water resources. By midcentury all Arab countries will face serious water deficits as demand and supply continue to diverge. Total regional renewable water shortage will be about 200 cubic kilometers per year in 2040–2050 based on the average climate change projection, Uncertainty in the climate change projections was considered and the 10% and 90% range in water shortage is between 90 and 280 km^3 per year in the dry and wet scenarios considered in the World Bank study. The 2000-2009 supply-demand gap is filled by non-renewable water resources including fossil groundwater and desalination as well as through reuse. The demand is expected to rise by about 25 percent in 2020–2030 and up to 60 percent in 2040–2050 while renewable supply will drop by more than 10 percent over the same time period in the region. This will result in an unmet demand for the entire Arab region, expressed as percentage of total demand, which will increase from 16 percent currently to 37 percent in 2020–2030 and 51 percent in 2040–2050, figure (1.13), after (World Bank 2011) [283].

[283] World Bank (2011). "Middle-East and Northern Africa Water outlook.".

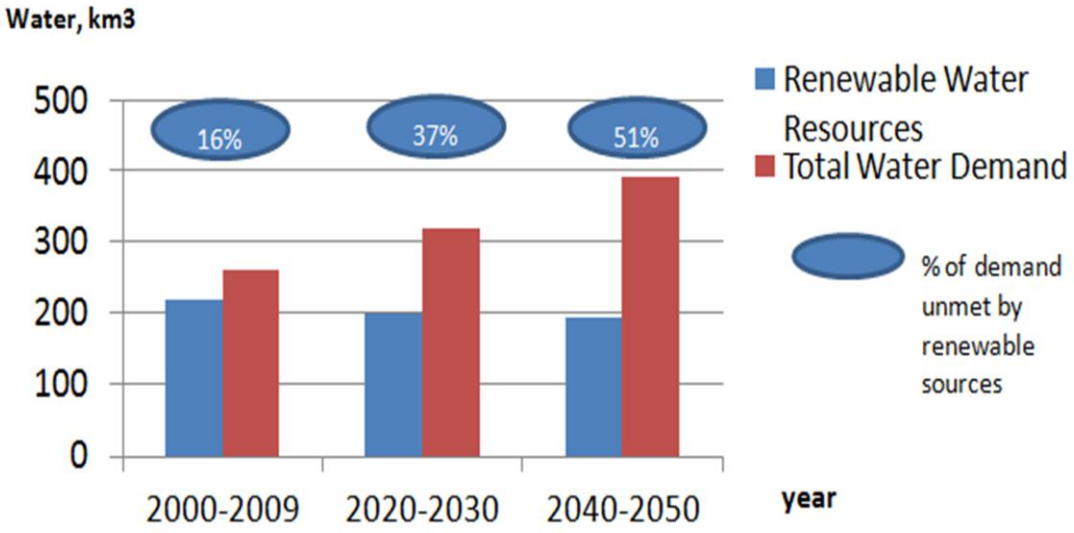


Figure 1.13. Renewable Water Resources versus Total Water Demand Through 2050,
***Source*: World Bank, 2011.**

Evans (2009)[284] analyzed the impact of climate change on an area covering the Levant, Northern Arabia, Iran, and Turkey using simulation results from 18 GCMs under the SRES A2 emissions scenarios which represents a high emission pathway. His analysis shows that most of the Arab region, will become warmer and undergo significant reduction in precipitation. The 200 millimeter isohyet—a threshold for viable rainfed agriculture—will move northward as climate warm. By mid century, 8,500 square kilometers of rainfed agricultural land will be lost. By end of century, the 200 millimeter isohyets is projected to move northward by about 75 kilometers resulting in the loss of 170,000 square kilometers of rainfed agricultural land over an area covering Palestine, Lebanon, Syria, Iraq, and Iran. Evans has also indicated that the dry season will grow longer by about two months, reducing the grazing rangelands in Iraq and Syria and necessitating the reduction of herd sizes or increasing water requirements and imports of feedstuff.

Finally, through this work we are looking forward to understand better the situation toward Arab water rights and find more coordination at the regional and international level to find effective solutions to challenges related to share water resources.

[284] Evans, J.P. (2009). "21st Century Climate Change in the Middle East." Climatic Change (2009), 92:417–432.

2. DESCRIPTION OF TRANS-BOUNDARY RIVER'S BASINS IN ARAB REGION

2.1. The Euphrates and Tigers River's basins

The Euphrates and Tigris rivers both rise I highlands of southeastern Turkey and after passing through the territory and along the border of Syria they join north of the Iraqi town of Basra to form the Shatt al-Arab water way, which empties into the Arab Gulf, (Figure 2.1). Even though the waters of the two rivers flow most of their long journey to sea in two separate streams they are regarded as forming one system. Turkey, Syria, Iran and Iraq are the four main riparian countries.

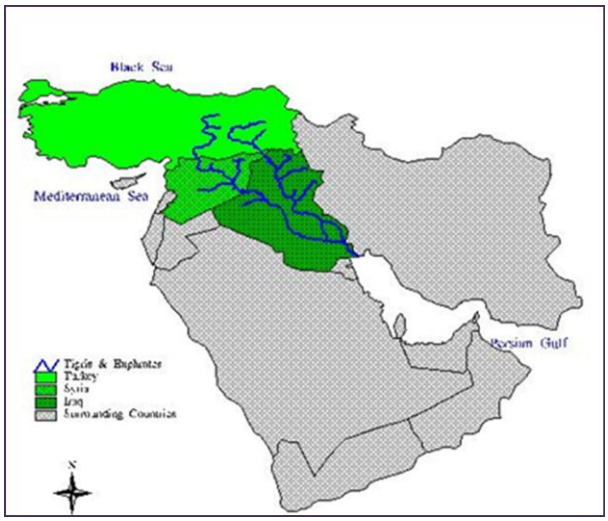


Figure 2.1 Location Map of Euphrates and Tigers Rivers

Most of the waters in the two rivers are drawn from Turkey. The Euphrates River is formed by two rivers, the Kara and Murat Rivers, at their confluence in Kharput, Turkey.

Turkey contributes 95% of its waters; the remaining 5% derive from Syrian territory, where two main tributaries the Khabur and Balikh join the main river bed.

Iraq, which controls 1,060 km of the approximately 2,800 km long main channel of the Euphrates River, does not contribute any measurable quantities of water.

The Tigris River also draws a large part of its total discharge (about 58%) from the Turkish highlands. It rises near Diyarbakir and is joined by the Batman River on its 100 km journey through Southeastern Turkey; it forms the border between Syria and Turkey for about 44 km before it enters Iraq, and finally joins the Euphrates River to form the Shatt al-Arab. Its total length is about 1,750 km.

Iraq contributes about 30% of the Tigris discharge. Most of Iran's contributions to the system take place after the two rivers united through discharge from the Kharun River, which adds about 20-25 km3 annually to the Shatt al-Arab.

Annual mean flow of the entire system is about 70-80 billion km3.2 Both rivers have high seasonal and multi-annual variances in their flow, yet the danger from flooding is far more pronounced in the Tigris basin; Iraq controls the infamous Tigris floods by diverting water to the Euphrates basin.

The River system is also referred to as the cradle of Mesopotamian civilization. Historically, infrastructure development occurred downstream. Today, infrastructure development occurs largely upstream, the corner stone being the Southeastern Anatolia Project (GAP) of Turkey. The

water resources of the system are primarily used for agriculture and hydropower development in Turkey, Syria and Iraq.

Turkey is the only country of the three that is considered self-sufficient in terms of food production, Elver (2002)[285]. Iran has abundant water resources outside the basin, which pose less of a technical challenge to develop and utilize, and therefore has no major water development programs under implementation on its tributaries to the Tigris (Diyalah and Lesser Zab) nor on the Kharun.

The Euphrates is navigable only by very light rafts up to the Iraqi city of Hit, further upstream rapids and shoals pose a major challenges to navigation. The Tigris River is navigable by larger vessels to Baghdad and by light rafts all the way upstream to Mosul.

The legal framework for trans-boundary water management in the Euphrates-Tigris system remains weak. There is no multi-lateral or basin-wide agreement, yet a small number of bilateral accords have emerged to resolve occasional questions with respect to water discharge, Elver (2002)[286].

On the occasion of the construction of the Atatürk Dam, the largest dam in Turkey, Turkey and Syria signed a protocol in 1987 in which Turkey agrees to a monthly minimum release of a bit more than half the Euphrate's mean volume at the border between the two countries. According to Article 6 of this protocol, Turkey guarantees a minimum release of **500 m3/second** to Syria and in cases where monthly flow falls below this level, the difference of flow will be made up in the following month. This clause, which allows for a time lag in the release of the agreed minimum amount, has been referred to by Turkey when it claimed that it had fulfilled its obligations under the agreement by making up for the stoppage of the water flow between January 13 and February 12, 1990 during the filling of the reservoir behind the Ataturk dam in subsequent months. Yet due to this arrest of the flow of the Euphrates river, Syria had to temporary halt hydropower production and Iraq lost an estimated 15 percent of agricultural production.

There is no a commitment to the Tigris river waters in the 1987 agreement. In 1990 Syria and Iraq entered into a bilateral agreement according to which the two countries share the waters received from Turkey on a 58% (Iraq) and 42% (Syria) basis. Those who closely follow the politics of cooperation in the basin are skeptical as to whether these occasional agreements have been honored by the countries over time. Kalpakian (2004)[287].

[285] Elver Hilal (2002), Historical Uses of International Rivers – The Euphrates and Tigris River Disputes, Transnational Publishers Inc., Ardsley, New York, p. 354

[286] Elver Hilal, (2002) *Historical Uses of International Rivers The Euphrates and Tigris River Disputes*, Transnational Publishers Inc., Ardsley, New York, p. 375

[287] Kalpakian Jack (2004), *Identity, Conflict and Cooperation in International River Systems*, Ashgate Publishing Ltd, Burlington, Vermont, p. 115

2.1.1. The Euphrates River's Basin

The Euphrates is the longest and one of the most historically important rivers of Western Asia. Together with the Tigris, it is one of the two defining rivers of Mesopotamia. The Euphrates river has its springs in the highlands of Eastern Turkey and its mouth at the Arab Gulf. It is the longest river in Southwestern Asia with 2,700 km, and its actual annual volume is 35.6 billion cubic meters. The Euphrates river is formed in Turkey by two major tributaries; the Murat and the Karasu. These two streams join together and form the Euphrates river and the Keban Dam Lake. Euphrates follows a southeastern route to enter Syria at Karkamýs point.

FACTS:

- 2700 kilometers long
- Begins in Turkey Empties into the Arab Gulf
- 94% of water originates in Turkish highlands
- The Murat Korasuyu and several other Turkish rivers join the Euphrates in central Turkey
- The Khabur joins the Euphrates in eastern Syria
- The Euphrates and Tigris run parallel to each other
- The land between the Euphrates and the Tigris is known as Mesopotamia, which means "between the rivers" in Greek
- The Euphrates and Tigris rivers get to be more that 100 mi. apart and join in southeastern Iraq to form the Shatt al Arab, which empties into the Arab Gulf.

After entering Syria, the Euphrates continues its southeastern course and is joined by two more tributaries, the Khabur and the Balikh. Both of these tributaries have their sources in Turkey and they are the last bodies of water that contribute to the river. After entering Iraq, the river reaches the city of Hit, where it is only 53 m above sea level. From Hit to the delta in the Arab Gulf, for 735 km, the river loses a major portion of its waters to irrigation canals and to Lake Hammar. The remainder joins the Tigris river near the city of Qurna, and the combined rivers are called the Shatt al-Arab.

In its upper course, the Euphrates flows rapidly through deep canyons and narrow gorges. In 1990, the Atatürk Dam, the first in the Southeastern Anatolia project in Turkey, was completed. Plans ultimately call for 22 dams on the Tigris and Euphrates that altogether will provide enough water to irrigate over 3,700,000 acres (1.5 million hectares) of land. A series of hydroelectric power stations will also be built. This huge diversion of water in Turkey may have serious implications for other countries, such as Syria and Iraq, that rely on the river.

The middle Euphrates traverses a wide floodplain in Syria, where it is used extensively for irrigation. Euphrates Dam, 70 m high, constructed with Soviet aid at Tabqa, North Syria, is the main unit of the Tabqa Barrage Scheme. The huge reservoir impounded by the dam provides electrical power but has failed to transform the region into a productive agricultural area. Below the dam the Euphrates receives the Belikh and Khabur rivers, its only major tributaries.

Entering the Syrian Desert and the plains of Iraq, the river loses velocity and becomes a sluggish stream with shifting channels. In N Iraq it is studded with islands, some with remains of old castles. The river's lower course supplies water through a system of dams and canals to allow wheat and barley cultivation. Flooding and overirrigation have resulted in serious problems of soil salinization. Before merging with the Tigris at Basra, Iraq, the Euphrates divided into many channels, forming a marshland and Lake Hammar. The marshes were drained in the early 1990s to increase Iraqi government control over the Shitte Marsh Arabs living there; restoration of the marshes began in 2003.

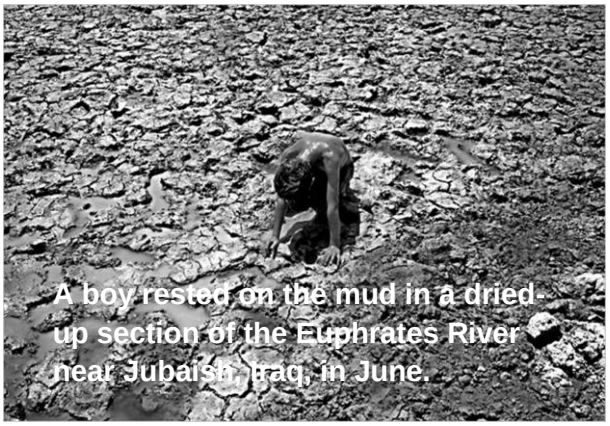
Mesopotamia, birthplace of many great civilizations, depended on the waters of the Euphrates and the Tigris for survival. However, as the maintenance of irrigation and drainage networks was neglected, the siltation of canals and the salinization of fields eventually made the land unsuitable for agriculture.

The construction of dams on the river has greatly reduced fresh water inflow that would dilute pollution – The Southeast Anatolia project involves the construction of 22 dams and 19 power plants by 2005.

- Turkey's 22 dams and 19 hydroelectric power plants will significantly decrease the amount of water to reach Syria and Iraq.
- Iraq must contend with high salt content in the Euphrates as a result of leaching and chemical applications in upstream areas
- The optimum use of water quality is being hindered by Turkey's dams
- Syria is also using too much of the river's water

Is the Euphrates drying up?. That is the threaten question to both Iraq and Syria, For Iraq the water policies of Turkey and Syria is the mean reason for them for the drying up of Euphrates in the Iraq side; a few years of drought; and years of misuse by Iraq and its farmers, the river is significantly shrinking than it was just a few years ago, may be with more drought longer cycles could be half of what it is now. The shrinking of the Euphrates, and its drying up has decimated farms along its banks, has left fishermen impoverished and has depleted riverside towns as farmers flee to the cities looking for work. The poor suffer more acutely, but all strata of society are feeling the effects. Along the river, rice and wheat fields have turned to baked dirt. Canals have dwindled to shallow streams, and fishing boats sit on dry land. Pumps meant to feed water treatment plants dangle pointlessly over brown puddles.





Moises Saman for The New York Times

The drought is widespread in Iraq. The area sown with wheat and barley in the rainfed north is down roughly 95% from the usual, and the date palm and citrus orchards of the east are parched, agriculture is going to die. Iraq is importing now more and more grain.

Droughts have been more frequent in recent years. But drought is only part of what is choking the Euphrates and its larger, healthier twin, the Tigris. Iraq is a downstream country, and beside the frequent drought there there are at least seven dams on the Euphrates in Turkey and Syria, with no treaties or agreements, the situation that leave Iraq in the situation of begging its neighbors for water.

In the southeast, where the Euphrates nears the end of its 2700 kilometers journey and mingles with the less salty waters of the Tigris before emptying into the Arab Gulf, the situation is grave. The marshes there that were intentionally re-flooded in 2003, are drying up again. Sheep graze on land in the middle of the river.

2.1.2.The Tigris River's Basin

The Tigris river also has its springs in the highlands of Eastern Turkey, but the main contribution to the river comes from the tributaries in Iraq. The Tigris river follows a southeastern route in Turkey to the city of Cizre, where it forms the border between Turkey and Syria for 32 km before entering Iraq. It joins the Euphrates in Qurna and continues its journey as the Shatt al-Arab to the Arab Gulf. The Tigris is the second longest river in Southwest Asia, 1,840 km long. The city of Baghdad is located on the conjunction of the Tigris and Diyala rivers and navigation is possible from Baghdad downstream. Because of the irregularities of the tributaries' flows, the Tigris is widely known for its infamous floods. In the southern part of Iraq, immense areas are regularly inundated, levees often collapse, and villages and roads must be built on high embankments.
The Tharthar reservoir was planned in the 1950s to protect Baghdad from the ravages of the periodic flooding of the Tigris by storing extra water discharge upstream of the Samarra barrage. A derivation canal that links the Tigris to the Euphrates through the Tharthar Valley has already been realized and operative since 1988. Thus both rivers are connected with each other far before Shatt-el-Arab.

2.1.2. Decreased water quality and quantity in Syria and Iraq due to the GAP

Since the 1980s, the Turkish State has endeavored to implement the Southeastern Anatolia Project (Güneydogu Anadolu Projesi-GAP),[288] (Figure 2.2). The Project (GAP) is a multi-sector and integrated regional development effort approached in the context of sustainable development. Its basic objectives include the improvement of living standards and income levels of people so as to eliminate regional development disparities and contributing to such national goals as social stability and economic growth by enhancing productivity and employment opportunities in the rural sector. The project area covers 9 administrative provinces (**Adiyaman, Batman, Diyarbakir, Gaziantep, Kilis, Mardin, Siirt, Sanliurfa and Sirnak)** in the basins of the Euphrates and Tigris and in Upper Mesopotamia.

GAP project area covers 75,000 km2 (29,000 mi2) and 9 provinces in the Euphrates – Tigris basins and Upper Mesopotamia plains (Adiyaman, Batman, Diyarbakir, Gaziantep, Kilis, Mardin, Siirt, Sanliurfa and Sirnak).

[288] Wikipedia Southeastern Anatolia Project



Figure 2.2 . Map showing sites of various dams as part of Turkey's GAP Project.

As the GAP region has a share of about 10 % in both the total population and geographical area of Turkey, around 20 % of total irrigable land in the country is in this region and the region represents 28 % of Turkey's total hydraulic potential. The original initiative consisted of irrigation and hydroelectric energy production projects on the Euphrates (Firat) and the Tigris (Dicle) rivers. Accordingly, the project includes the construction of 22 dams along the Euphrates and Tigris rivers and 19 power plants and irrigation schemes on an area extending over 1.7 million hectares, with a total cost of the project close to about 32 billion US$.

The reason for the sheer number of dams in the project, is maintenance. Dams need to be cleaned from the debris carried with the water flow. After a while the dam becomes obsolete as water flow slows down to inadequate levels. The dams will be shut down every 5 to 10 years for *fall maintenance* (also called fall cleanup). Water levels are normally lowest in fall. The extra dams are placed in service during this maintenance period. In cases of natural disasters such as floods, the maintenance may be performed earlier. The plan is to have one or two dams spare in case an emergency shutdown of any dam is necessary. While shutting down a dam also shuts down irrigation channels linked to it, it can nevertheless continue providing power.

GAP main purposes are energy production (an installed capacity of 7500 Megawatts is planned) and regional development through irrigated (1.82 Mio. Ha land) agro-industrial production for export. However, the socio-economic and political implications of the GAP are rather controversial both domestically and internationally, (Ayboga 2009).[289] But since the 80s, the project was transformed into a multi-sectoral regional development program of a socio-economic

[289] Ercan Ayboga 2009. Turkey's GAP and its Impact in the Region, Kurdish Herald Vol. 1 Issue 5

character. This program covers such sectors as irrigation, hydraulic energy production, agriculture, urban and rural infrastructure, forestry, education and health, (Figure 2.3).

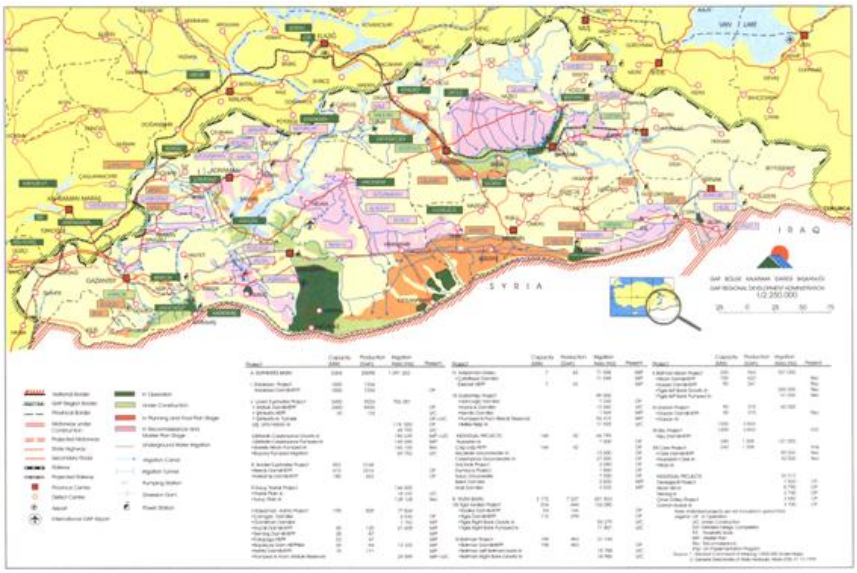


Figure 2.3. GAP PROJECT – Water Resources

The center-piece of the GAP is the 3,000-million-cubic-feet (84.4-million-cubic-meter) rock and earth-fill Ataturk Dam, the third largest of its type in the world. Various dams are in different stages of construction or planning in the southeast area. In 1997, irrigation of Harran fields started and farmers for many years are harvesting their crops, especially superb quality Turkish cotton, which is considered as the second best in the world, after the Egyptian cotton. When the projects are completed, 1.7 million hectares of land will be effectively irrigated, (Figure 2.4).

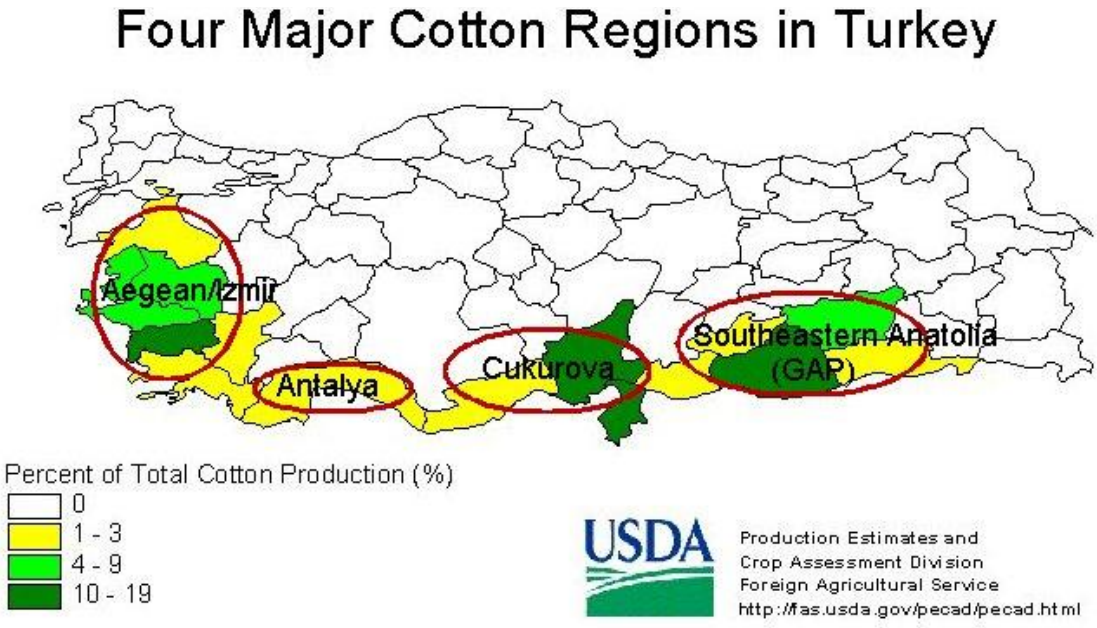


Figure 2.4. Four major cotton regions in Turkey

The Euphrates and Tigris rivers in southeast Turkey have been the primary sources of irrigation and drinking water for Syria and Iraq for thousands of years. If the GAP is ever fully realized,

- Up to 50% of the river water will be used within the Turkish borders.
- Quality of water is expected to deteriorate due to water waste from larger cities, which are located in upstream of the planned reservoir, and from developing agro-industrial irrigation in Turkey.

Concerns among people in Syria and Iraq with regards to the implementation of the GAP are not farfetched. But also if the Ilisu dam (138-meter high and 45 km around the Syrian-Iraqi border, which would be the largest in the Tigris River Basin, Figure (2.5), and other planned irrigation works in the Tigris Basin will drastically affect millions people along the Tigris in Iraq, including approximately four to five million people in the marshlands in southern Iraq that depend almost entirely on the rivers for their water supply.

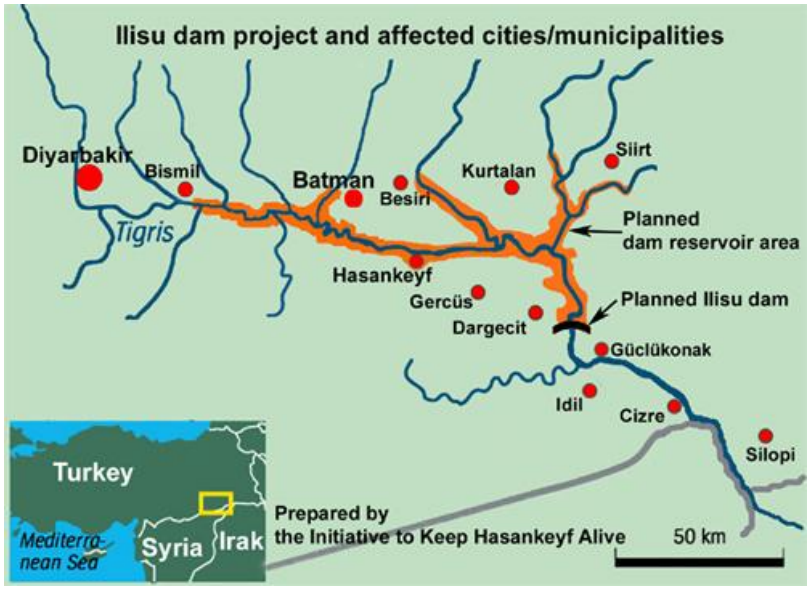


Figure 2.5. The Ilisu Dam Project

The Euphrates River has already shown a substantial change due to a partial completion of the GAP. All planned dams on the Euphrates have completely been built and while complete irrigation has not been implemented, this already has negative effects on Iraq and Syria concerning water quantity. Between 2000 and 2001, and since 2008, there have been a series of severe droughts in the region, dramatically reducing water flow to Iraq and Syria. Since April 2009, the Iraqi government has communicated official statements to Turkey to release more water from the Euphrates.

The storage capacity of the constructed five dams on the Euphrates within Turkey is about 90 cubic kilometers while the annual mean flow of the Euphrates River is approximately 32 cubic kilometers. The planned capacity of the dams in the Tigris River Basin is 20.5 cubic kilometer, and the annual mean flow of the Tigris is approximately 17 cubic kilometer at the Turkish-Iraqi border. In other words, the water storage capacity of the existing and planned dams of the both rivers is more than enough to cease water flow for a long period of time.

The most relevant international agreement that Turkey has long refused to sign for the GAP is the UN Convention on Non-Navigational Use of Trans-boundary Watercourses (1997). Nevertheless, the cut of water is still a breach of international customary law regardless of whether there are formal legal agreements between Turkey and the other two countries. These factors are of great concern but the international community has not paid enough attention despite the historical precedent of detrimental relationship between the states in the politically-fragile Middle East.

3.1.The Orontes River Basin

The Orontes is one of the most famous rivers of Antiquity. Its source is in the valley between the Lebanon and the Anti-Lebanon. The Orontes rises in the great springs of Labweh on the east side of the Beqaa Valley, very near the fountains of the southward-flowing Litani, and it runs due north, parallel with the coast, falling 2000 feet (600 m) through a rocky gorge. Leaving this it expands into the Lake of Homs., having been dammed back in antiquity, (Figure 2.6). Among the cities along the river are Laodicea near the Lebanon, Homs; Hama and Apamea, which is at about two thirds of the rivers' entire course. The valley widens out into the rich district of Hamah. This central Orontes valley ends at the rocky barrier of Jisr al-Hadid, where the river is diverted to the west, and the plain of Antioch opens. Two large tributaries from the north, the Afrin and Karasu, here reach it through the former Lake of Antioch, which is now drained through an artificial channel (Nahr al-Kowsit).



Figure 2.6. Location Map of the Orontes River Basin.

Passing north of the modern Antakya the Orontes plunges southwest into a gorge, and falls 150 feet (50 m) in 10 miles (16 km) to the sea just south of the little port of Samandağı.The Orontes is about 500 km long and has a drainage area of 24,000 Km2 The river flows through Lebanon for 65 km, Syria for 366 km, and Turkey for 88 km. Snowfall in Lebanon contributes to the stream flow, as well as groundwater flow from large karstic springs. The Orontes and its tributaries Afrin and Karasu discharge about 2,400 million cubic meters (MCM) of water per year. The Karasu River flows through Turkey and forms the border between Turkey and Syria, the Afrin crosses Syrian territory before re-entering into Lake Amik in Turkey (Kobaroglu et al, 2011)[290].

Currently Syria uses about 90 % of the water of the Orontes. Syrian water developments include five dams with a total storage of 736 MCM/year. 82 % of the waters are used for agriculture. From the total 1.2 BCM/year annual flow, Syria only leaves 120 MCM/year for the downstream country Turkey, (Table 2.1). Only unilateral actions have been taken and there is no basin-wide agreement on water allocations.

[290] Kibaroglu, Aysgül, Waltina Scheumann, and Annika Kramer 2011. Turkey's Water Policy: National Frameworks and International Cooperation. Berlin: Springer

Table 2.1. Calculated catchment area per riparian

Countries	**Catchment area in**	
	km2	**%**
Lebanon	1915.65	8
Syria	16404.60	69
Turkey	5402.84	23
Total	**23723.09**	**100**

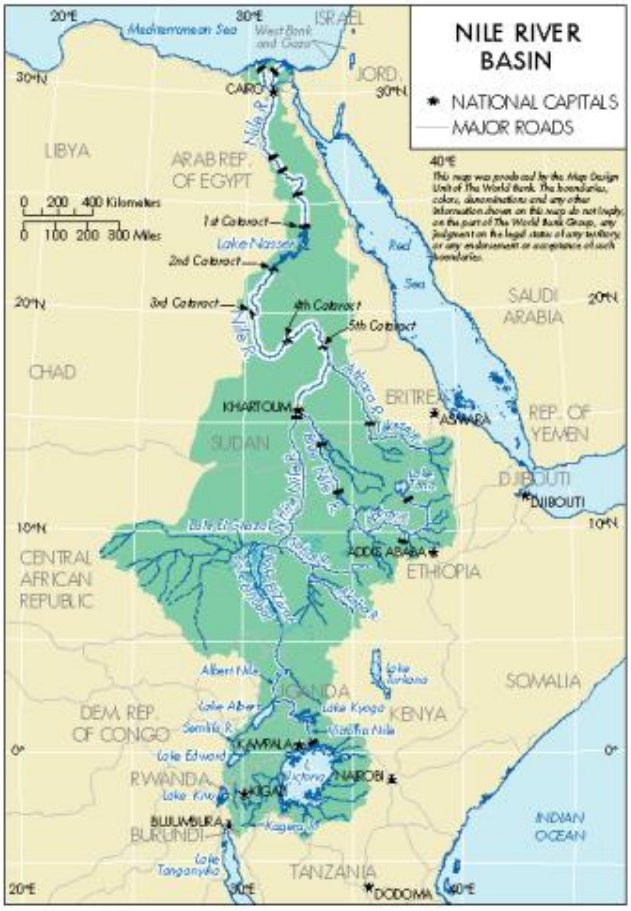
Since the Lebanon and Syria Agreement of 1994 concerning the division of the water river that defined the share of water allocated to Lebanon to be fixed at (80 MCM/year if the river flow exceeds 400 MCM and 20% of the annual flow if the discharge volume is less than 400 MCM/year. In 1999, the Lebanese – Syrian High Council of Coordination considered resuming the negotiations based on the UN Convention on non-navigational international watercourses sharing of 1997 ratified by both the Syrian and Lebanese parliaments

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2.4. The Nile River's Basin

2.4.1. Main Characteristics of Nile River's Basin Countries

The Nile River, with an estimated length of over 6800 km, is the longest river flowing from south to north over 35 degrees of latitude. It is fed by two main river systems: the White Nile, with its sources on the Equatorial Lake Plateau (Burundi, Rwanda, Tanzania, Kenya, Congo and Uganda), and the Blue Nile, with its sources in the Ethiopian highlands. The sources are located in humid regions, with an average rainfall of over 1000 mm per year. The arid region starts in Sudan, the largest country of Africa, which can be divided into three rainfall zones: the extreme south of the country where rainfall ranges from 1200 to 1500 mm per year; the fertile clay-plains where 400 to 800 mm of rain falls annually; and the desert northern third of the country where rainfall averages only 20 mm per year. Further north, in Egypt, precipitation falls to less than 20 mm per year. The total area of the Nile basin represents 10.3% of the area of the continent and spreads over eleven countries (Figure 2.7), and (Table 2.2).



BOX.1 Nile Basin Challenges

- NB estimated population - 160 million
- 4 NB countries amongst 10 poorest countries
- ≤10% of NB residents access electricity
- Poor water quality & extensive sanitation challenges
- Diseases
- Socio- economic & political instability
- Famine & food insecurity
- Floods & droughts
- Minimal interdependency - virtual water "trade" within NB is minimal.

BOX 2.
One Nile – One Family
Nile River Basin Countries:
BURUNDI . DR CONGO . EGYPT . ERITREA . ETHIOPIA . KENYA . RWANDA . SUDAN . SOUTH SUDAN. TANZANIA . UGANDA]

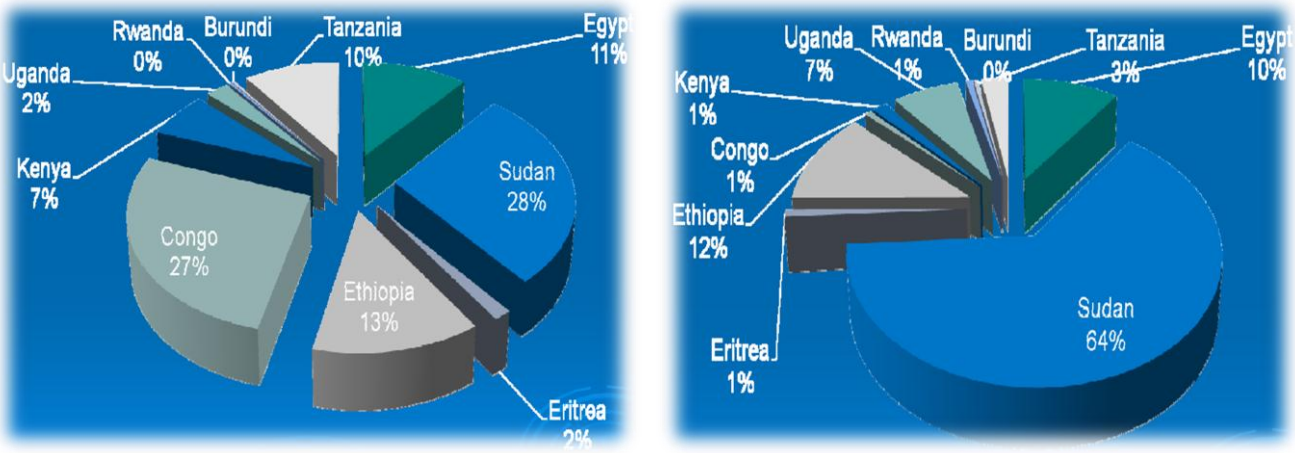
Figure 2.7 Nile River Basin

For some countries, like Congo, the Nile basin forms only a very small part of their territory. Other countries, like Burundi, Rwanda, Uganda, Sudan and Egypt, are almost completely integrated into the Nile basin.' However, all the waters in Burundi and Rwanda and more than

half the waters in Uganda are produced internally, while most of the water resources of Sudan and Egypt originate outside their borders: 77% of Sudan's and more than 97% of Egypt's water resources as shown in Table 5. Moreover, these latter two countries already use nearly all of the water currently allocated to them, as shown in (figure 2.8 and 2.9). The main characteristics of Nile river's basin countries are described in (Table 2.3).

Table 2.2. Nile Basin: Areas and Rainfall by Country

Country	Total area		As % of		Average annual rainfall in the basin area (mm)		
	of the country	within the basin	total area of basin	total area of country			
	(km^2)	(km^2)	(%)	(%)	min.	max.	mean
Burundi	**27834**	**13260**	**0.4**	**47.6**	**895**	**1 570**	**1 110**
Rwanda	**26340**	**19876**	**0.6**	**75.5**	**840**	**1 935**	**1 105**
Tanzania	**945090**	**84200**	**2.7**	**8.9**	**625**	**1 630**	**1 015**
Kenya	**580370**	**46229**	**1.5**	**8**	**505**	**1 790**	**1 260**
DRCongo	**2344860**	**22143**	**0.7**	**0.9**	**875**	**1 915**	**1 245**
Uganda	**235880**	**231366**	**7.4**	**98.1**	**395**	**2 060**	**1 140**
Ethiopia	**1100010**	**365117**	**11.7**	**33.2**	**205**	**2 010**	**1 125**
Eritrea	**121890**	**24921**	**0.8**	**20.4**	**240**	**665**	**520**
Sudan	**2505810**	**1978506**	**63.6**	**79**	**0**	**1 610**	**500**
Egypt	**1001450**	**326751**	**10.5**	**32.6**	**0**	**120**	**15**
Nile basin	**8889534**	**3112369**	**100**	**35.01**	**0**	**2 060**	**615**



a. Nile Countries Area (8.9 million km2) **b. Nile Basin Area (3.0 Million km2)**

Figure 2.8 Relative Area of total Nile basin Countries and its share within Nile basin Countries

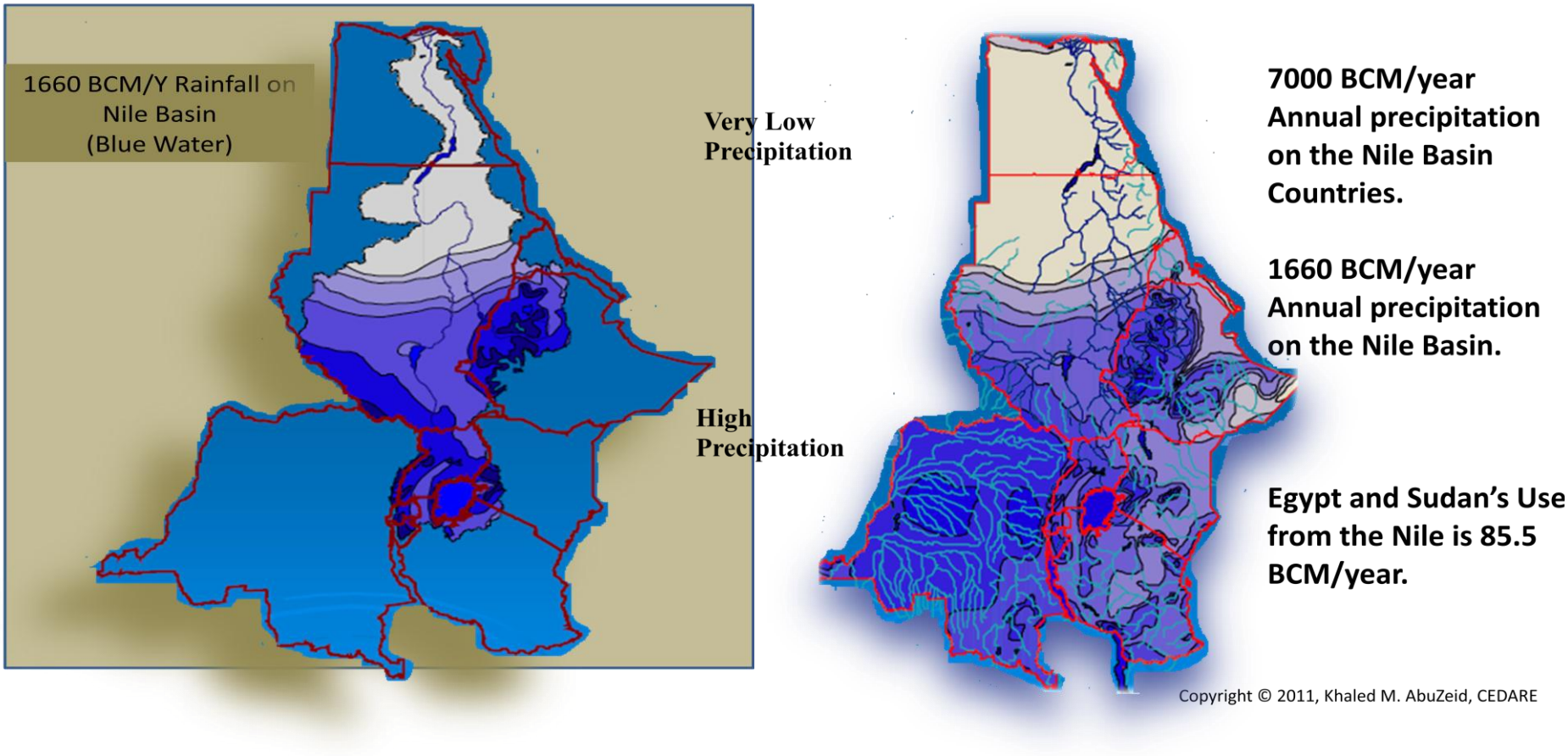


Figure 2.9 Rainfall distribution over basin countries and within Nile River's Basin areas

Table 2.3. Main Characteristics of Nile River's Basin Countries

Item	Egypt	Ethiopia	DR Congo	Tanzania	Sudan and S. Sudan	Kenya	Uganda	Rwanda	Burundi	Eritrea
Area in Million Km2	1	1.1	2.3	0.9	2.5	0.39	0.23	0.03	0.03	0.12
Population Annual gross %	1.8	3.21	3.2	2.1	2.6	2.6	2.7	2.4	3.3	2.4
Ranking in Population development report	116	152	175	153	146	144	157	166	172	165
Poverty %	16.7	44.2	71.3	35.7	40	52	37.7	60.3	68	53
Water / capita	86.8	110	1,283	91	154	30.2	66	5.2	3.6	6.3
Average Age	71	49	46	50	49	55	51	48	51	59
Low nutrition %	5	44	75	35	20	30	15	40	63	66
literacy %	66.4	35.9	67.2	72.3	60.9	73.6	73.6	64.9	59.3	64.2
Nile Countries Rainfall % of (Green Water) 7000 BCM/Y	0	13	55	9	14	5	3	0	1	0
Nile Basin Rainfall (Green Water) 1660 BCM/Y	0	25	2	4	50	3	13	1	1	1

2.4.2. Rivers and discharges

The most distant source from the sea is the Luvinzora River in Burundi, a tributary of the Kagera River. The Kagera River forms the border between Rwanda and Tanzania, then between Uganda and Tanzania and then flows into Lake Victora, the second-largest freshwater lake in the world with an area of about 67000 km^2. Total flow into the lake is about 20 km^3/year, of which 7.5 km^3 from the Kagera River, 8.4 km^3/year from the forest slopes in the north-east (Kenya), 3.2 km^3/year from the drier Serengeti Plains in the south-east (Tanzania) and from 1 to 2 km^3/year from the swamps in the north-west (Uganda). The level of Lake Victoria is extremely sensitive to moderate changes in rainfall over the lake and its tributaries. Average lake rainfall and evaporation are the main factors affecting the lake balance and are more or less equal. As evaporation varies little from year to year, high rainfall gives rise to a disproportionate surplus and also greatly increases the tributary flows which are themselves relatively more variable than the rainfall. The rise in lake level during 1961-64 of about 2 metres seems to be the result of a higher rainfall during that period over the lake and its basin. This surplus then influences the outflow which declines only gradually over a longer period of years.

The only outlet of Lake Victoria is at Ripon Falls (Owen Falls Dam) in Uganda. From there begins Victoria Nile which flows through Lake Kyoga into Lake Albert, also called Lake Mobutu Sesse Seko. This lake also receives water from the Semliki River, which originates in the Mufumbiru mountains in Congo and flows through Lake Edward to Lake Albert. The combined waters of the Semliki and the Victoria Nile leave Lake Albert at the northern end and become the Albert Nile, which then flows into Sudan.

Uganda is a humid country with numerous lakes and wet lands and with internal renewable water resources globally estimated at 39 km^3/year. However, the total annual flow into the country (at Ripon Falls and from Congo) is about equal to the total annual outflow to Sudan, which means that a lot of water disappears within the country through evaporation and evapotranspiration from the lakes and wetland.

Entering Sudan, the Albert Nile becomes the Bahr el Jebel. It flows into the Sudd region, the great wetlands which are a maze of channels, lakes and swamps in southern Sudan, and which also receive water from the Bahr el Gazal River, originating in south-west Sudan.

The most remarkable topographic feature of the Sudd area is its flatness: for 400 km, from south to north, the slope is a mere 0.01 % and much of it is even flatter. The soils of the whole area are generally clayish and poor in nutrients. Rain falls in a single season, lasting from April to November and varying in the Sudd area from about 900 mm in the south to 800 mm in the north. As the rainy season coincides with, though is slightly shorter than, the flood seasons of the rivers, there is land of water and mud for half of the year and, away from the rivers, land of desert-like dryness for the other half. The main natural channels flow through a swamp area waterlogged throughout the year, and are then flanked by grasslands flooded at high river and exposed when the river level drops. Because of the important rainfall in the Equatorial Lake Plateau during the 1960s and 1970s the permanent swamp area increased from 2700 km^2 in 1952 to 16200 km in 1980.

Less than half of the water entering the Sudd region flows out of it into the White Nile. The rest disappears through evaporation and evapotranspiration. The quantity entering the Sudd region varies greatly over the years, mainly depending on the rainfall in the upper catchment area, and

hydrological measurements have shown that the greater the flow of water into the Sudd, the greater the percentage of water 'lost' in evaporation (Table 2.4).

Table 2.4: Average annual discharges at different locations in the Sudd region

Period	Discharge at Mongalla	Discharge at tail of swamps	Quantity disappeared	% disappeared
	(km3/year)			
1905-1960	26.8	14.2	12.6	47
1961-1980	50.3	21.4	28.9	57.5
1905-1980	33	16.1	16.9	51.2

In order to bypass the Sudd region and to direct downstream a proportion of the water considered lost each year by spill from the river and evaporation in the swamps, the construction of the Jonglei Canal had been planned. This water could then have become available for irrigation and other uses downstream in Sudan and Egypt. Construction of the canal began in 1978 for a planned total length of 360 km, but work stopped in November 1983 after 240 km because of the civil war. By that time it had also become clear that these 'losses' create resources in pasture and fisheries and that the canal causes enormous human and environmental problems in the area. The issue is now how much water can be drained from the Sudd through the construction of the Jonglei Canal without serious and irreparable damage to the local environment and economy and its potential expansion. The Sobat River, that flows into the White Nile just upstream of Malakal, is fed by the Baro and Akobo Rivers and others with catchment areas situated mainly in the southern Ethiopian foothills.

The Blue Nile and its main tributaries, the Dinder and the Rahad, rise in the Ethiopian mountains and around Lake Tana. The confluence of the White Nile and the Blue Nile is at Khartoum. Further downstream is the Atbara tributary, the last important tributary of the Nile system, again deriving from the Ethiopian plateau north-east of Lake Tana and forming the border between Ethiopia and Eritrea before entering Sudan. There are no important tributaries further downstream in Egypt.

The contribution of the rivers of the Ethiopian catchment area (Blue Nile system) to the Nile is about twice the contribution of the rivers of the Equatorial Lake Plateau catchment area (White Nile system), figure (28), but it is characterized by the extreme range in discharges between the peak and low periods, while the flow from the Equatorial Lake Plateau is more uniform. At its peak the former provides nearly 90% of all water reaching Egypt, the latter only 5%. During the months with low flow the contributions are nearer 30% and 70% respectively.

As already mentioned, variations in rainfall over the years can cause quite considerable variations in discharges and lake levels. This seems to be more explicitly the case for the White Nile River system. For this reason, average discharge figures might vary greatly depending on the period under consideration, as shown in (Figure 2.10).

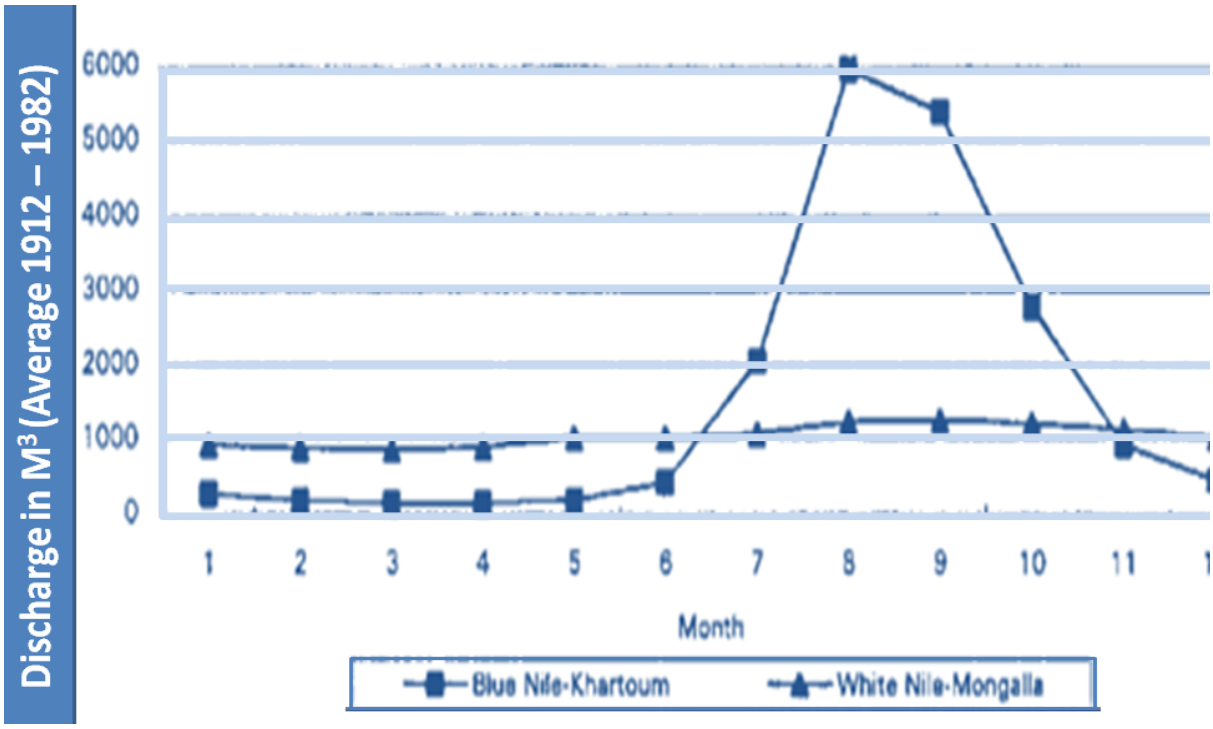


Figure 2.10. Average discharges of the Blue Nile and the White Nile

As already mentioned, variations in rainfall over the years can cause quite considerable variations in discharges and lake levels. This seems to be more explicitly the case for the White Nile River system. For this reason, average discharge figures might vary greatly depending on the period under consideration, as shown in (Table 2.5). In addition to variations due to rainfall, the discharges might vary also due to water abstractions, mainly for irrigation purposes.

Table 2.5: Variations in discharges at different locations on the Nile

Location	Average annual discharges in km^3		
	Period 1961-1970	period 1948-1970	period 1912-1982
Lake Victoria exit	41.6	29.4	27.2
Lake Kyoga exit	44.1	30.1	26.4
Lake Albert exit	48.8	33.7	31.4
Mongalla (White Nile)	52.6	36.8	33.1
Malakal (White Nile)	37.8	31.6	29.6
Khartoum (Blue Nile)	45.9	49.8	50.1
Mouth of the Atbara	10.9	12.1	10.6
Dongola (Nile)	86.2	86.2	82.7

2.4.2. Irrigation potential and water requirements

Irrigation Potential Areas within the Nile Basin Countries (in Ha) could be illustrated as in (figure 2.11). The potential areas vary from country to another as follows:

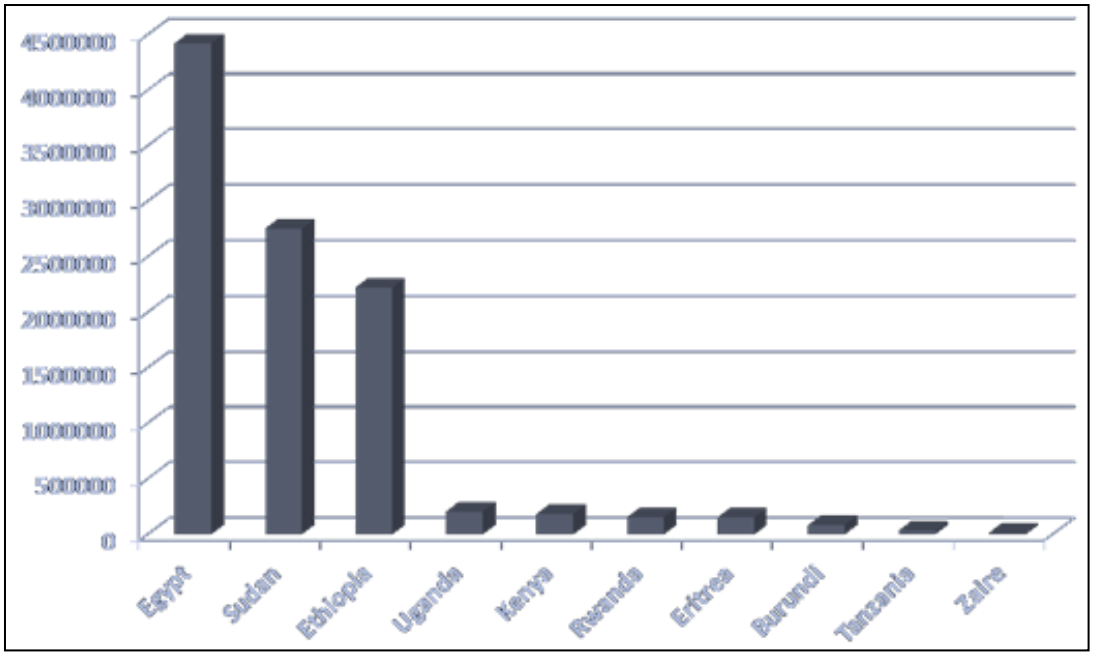


Figure 2.11 . Irrigation Potential Areas Within the Nile Basin Countries (in Ha)

Both **Burundi** and **Rwanda** are characterized by a rolling topography with a continuous pattern of hills and valleys, with lakes and marshy lowlands at the bottom of the valleys. Improving the drainage network in part of the swamp areas, combined where possible with an irrigation network, would allow year-round cultivation, which is important for these small, but very densely populated countries. The total area of these valley bottoms in the Nile basin is estimated at 105000 ha for Burundi and 150000 ha for Rwanda.

For **Tanzania** the irrigation potential has been estimated at 30000 ha, but this would require the construction of considerable water conveyance works [199]. In addition to this, at the beginning of the century settlers from Germany, the then colonial power in the country, proposed a plan to transfer water from Lake Victoria to the Vembere Plateau in the Manonga River basin in central Tanzania to irrigate between 88000 and 230000 ha of cotton. Though this project is still on the table, it would be very expensive. The transfer would be affected by gravity as the plateau lies below the water level of the lake.

The Lake Victoria basin in **Kenya** covers only 8.5% of the total area of the country but it contains over 50 % of the national freshwater resources. The national water master plan identified an irrigation potential of 180000 ha based on 80% dependable flow. As part of the plan, dams and water transfers to other (sub) basins are proposed. At present only about 6000 ha are irrigated. Moreover, in Kenya there has been lengthy debate as to whether, given adequate technology, Lake Victoria basin water should be transferred to arid areas of the country for irrigation. It is considered that perhaps the most appropriate location for such an experiment would be the Kerio Valley (located in the Rift Valley, see section The Rift Valley), for which a

special development authority has been established by the Kenyan Parliament. The feasibility of such a project is a question of engineering and several observers consider it possible. Such an undertaking would use significant quantities of water. Projects of this kind are analogous to the irrigation of the Vembere steppe proposed in Tanzania.

The Nile basin in **Congo** covers less than 1 % of the area of the country. The area is hilly and does not really lend itself to irrigation. This area is rather densely populated with most people engaged in cattle rearing and fishery activities around Lake Albert. It is considered that about 10000 ha could be developed for irrigation.

Uganda has large swamp areas covering about 700000 ha. The irrigation potential is estimated at 202000 ha, requiring, however, major works such as storage, river regulation and large-scale drainage. At present only 5550 ha are irrigated.

The irrigation potential in the Nile basin in **Ethiopia** has been estimated at more than 2.2 million hectares. The irrigated area was about 23000 ha in 1989. The irrigation potential in the Nile basin in **Ethiopia** has been estimated at more than 2.2 million hectares. The irrigated area was about 23000 ha in 1989, (table 2.6).

Table 2.6 Water resources, irrigation potential and areas under irrigation in the different Nile sub-basins in Ethiopia

Nile sub-basin	Annual surface runoff (km^3)	Irrigation potential (ha)	Irrigated area in 1989 (ha)
Baro-Akobo	13.4	905500	350
Blue Nile (Abbey)	54.7	1001500	21010
Setit-Tekeze/Atbara	12	312700	1800
Total Nile basin	80.1	2219700	23160

The seasonality of the flows in Ethiopia is very high. This means that very considerable regulation would be necessary for their full utilization. The risk of rapid siltation of the reservoirs because of the steep slopes is a real problem. Construction of dams would augment the quantity of water available, because of a loss of only 3 % by evaporation as against a loss of almost 16% in the Aswan reservoir. Egypt, however, would no longer be the beneficiary of additional water in years of high flood, which would then be stored and regulated in the Blue Nile reservoirs instead of Aswan.

The irrigation potential in the Nile basin in **Eritrea** has been estimated at between 60000 and almost 300000 ha, though these figures are based on very limited studies. Most of it would be in the Tekeze-Setit basin, which Eritrea shares with Ethiopia. The Mereb-Gash basin has mainly spate flows and its water reaches the Atbara River in Sudan only during extremely high floods. In this review the average irrigation potential has been estimated at 150000 ha.

Irrigation potential in **Sudan** has been estimated at over 4.8 million hectares, but this figure does not take into consideration the available water resources. The irrigated area was about 1.6 million hectares in 1979 and 1.9 million hectares in 1990. There are plans to increase irrigation to about 2.8 million hectares by the year 2000, almost all to be irrigated by Nile water.

The figures in table (2.7) for irrigated area in 1979 and 1990 correspond to the area equipped for irrigation. The actual irrigated area in 1990 was about 1.2 million hectares, or about 63 % of the total equipped area of 1.9 million hectares. About 16.8 km^3 of water was used, corresponding to 14000 m^3/ha. Despite this relatively high value, water management is a problem, for example water supply on the old established cotton schemes of Gezira-Managil was and is about 12% below crop requirements at crucial points in the growth cycle. At the same time, as much as 30% of the water delivered is not used by crops. In large state-run irrigation projects, like Gezira-Managil and Khashm al Girba, average water deliveries to the command area are between 9700 and 12600 m^3 per cultivated hectare per year. Sugar cane, a very water-consuming crop, uses between 28000 and 40000 m^3 per ha per year.

Table 2.7. Irrigated land use in Sudan.

Nile system: **in ha**	**Available fertile land**	**Irrigation in 1979**	**Irrigation in 1990**	**Irrigation From 2000**
White Nile upstream of Malakal	n.a.	16800	16800	121800
White Nile betw. Malakal & Khart.	752220	209580	196140	380100
Blue Nile upstream of Khartoum	2633820	1132740	1270080	1525860
Main Nile betw. Khart. & Egypt	226800	130620	147000	249060
Atbara	571200	168420	168000	407820
Mereb-Gash	285600	n.a.	25200	> 25200
Other non-Nilotic streams	372960	n.a.	29400	> 29400
Groundwater	n.a.	n.a.	55430	> 55430
Total	4842600	1658160	1908050	>2794670

Considering an availability of 25 km^3 of water for irrigation in 2015, (table 2.8) and a water requirement of 14000 m^3/ha, only about 1.8 million hectares could be irrigated as opposed to the proposed 2.8 million hectares. The water balance of Sudan at present, and as proposed over the next 20 years can be summarized as follows.

Table 2.8. Estimated water balance of Sudan in 1995 and 2015.

(in km^3/year)	1995	2015
Water Inputs:		
Sudan share of Nile water (1)	20.55	20.55
Other regional surface runoff	1.45	1.45
Internal runoff	0.70	2.50
Jonglei Canal + swamp reclamation (2)	0.00	4.00
Groundwater	0.70	1.10
Total Water Input	**23.40**	**26.60**
Water Demands:	**based on 2%**	**growth/year**
Irrigation	16.80	25.00
Domestic	0.80	1.10
Industrial	0.20	0.30
Other (incl reservoir evaporation)	0.20	0.20
Total Water Demand	**18.00**	**26.60**
Net surplus	5.40	0.00

(1) Under the Nile Water Agreement between Sudan and Egypt, the quantity of water allocated to Sudan is 18.5 km^3/year at Aswan, which corresponds to 20.55 km^3 further upstream.

(2) The total amount of water becoming available through the construction of the Jonglei Canal is estimated at 8 km^3 in 2015, of which 50% for Sudan and 50% for Egypt under the agreement between the two countries. Egypt considers 2 km^3 to be available by the year 2000 as shown in its water balance in Table 27. Work on the canal is currently stopped as explained at the beginning of this section.

In **Egypt** the agricultural land use in 1990, almost all irrigated, was as shown in (table 2.9).

Table 2.9: Agricultural land use in Egypt

Agriculture land	**(in 1000 ha)**
Rainfed + supplementary irrigation	168
Irrigated old lands	2394
Reclaimed land (pre 1980):	
. cropped	252
. not cultivated	126
Reclaimed (1980- 1987):	
. cropped	126
. not cultivated	84
Reclamation (1987-1992)	294
To be reclaimed by 2000	546
Total cropped in 1990	2940
Total area including reclamation	**3990**

It should be noted that each time new land is reclaimed it is of a lower quality than the already cultivated land. The best soils in Egypt cover an area of only about 1 pillion ha, while the best plus suitable soils cover an area of about 3.6 million ha. Adding the still more marginal land, the maximum area for agriculture could be 4.8 million ha. The remaining soils are unsuitable for agriculture.Taking into consideration water saving and possibilities of re-use, the water balance of the Nile basin in Egypt in 1993 and 2000 is presented in (Table 2.10). Taking an average water requirement of 13000 m^3/ha per year in the Nile Valley and Delta in this study, about 4420000 ha could be irrigated using the 57.4 km^3/year of Nile water.

As can be seen from Table 28, the sum of the irrigation potential of the countries leads to a water deficit of over 26 km^3/year, (column 7) without considering possibilities of reusing water as indicated by Egypt and Sudan in their water balance, but after deducting the water 'losses' in the Sudd region.

Table 2.10. Estimated water balance of Egypt in 1993 and 2000

(in km^3 /year)	**1993**	**2000**
Water Inputs:		
Surface water resources (1)	56.0	58.0
Groundwater in Nile Valley and Delta	2.3	4.8
Agricultural drainage water	4.0	6.5
Treated sewage water	0.2	1.2
Improved water management	0.0	1.0
Total Water Input	62.5	71.5
Water Demands:		
Irrigation	47.4	57.4
Municipal	3.1	3.1
Industrial	4.6	6.1
Navigation, etc.	1.8	0.3
Total Water Demand	56.9	66.9
Net Surplus	5.6	4.6

(3) It is expected that the first phase of the construction of the Jonglei Canal will be terminated by 2000, giving 2 km^3 per year of water both to Sudan and to Egypt.

This deficit corresponds to an area of almost 2.2 million hectares, considering an average water requirement in the region of 12000 m^3/ha per year. This leads to an irrigation potential for the basin as a whole of 8 million hectares instead of the nearly 10.2 million hectares, (table 2.11). However, even these 8 million hectares are still a very optimistic estimate and should be considered as a maximum value, requiring very important storage works and optimum water use.

Table 2.11: Nile basin: irrigation potential. Water requirements, water availability and areas under irrigation

Country area within the Nile basin	Irrigation potential	Gross irrigation water requirement		Actual flows		Flows after deduction for irrigation and losses		Area already under irrigation
		per ha	total	inflow	outflow	inflow	outflow	
	(ha)	(m^3/ha.year)	(km^3/yr)	(km^3/yr)	(km^3/yr)	(km^3/yr)	(km^3/yr)	(ha)
Burundi	80 000	13 000	1.04	0.00	1.50	0.00	0.46	0
Rwanda	150 000	12 500	1.88	1.50	7.00	0.46	4.09	2 000
Tanzania	30 000	11 000	0.33	7.00	10.70	4.09	7.46	10 000
Kenya	180 000	8 500	1.53	0.00	8.40	0.00	6.87	6 000
Congo	10 000	10 000	0.10	0.00	1.50	0.00	1.40	0
Uganda	202 000	8 000	1.62	28.70	37.00	23.83	30.51	9 120
Ethiopia	2 220 000	9 000	19.98	0.00	80.10	0.00	60.12	23 160
Eritrea	150 000	11 000	1.65	0.00	2.20	0.00	0 55	15 124
Sudan	2 750000	14000	38.50	117.10	55.50	90.63	31.13	1 935 200
Egypt	4 420 000	13 000	57.46	55.50	rest to se	31.13	minus 26.33	3 078 000
Sum of countries	10 192 000		124.08					5 078 604
Total for Nile basin	< 8 000 000							

2.5. The Senegal River basin

2.5.1. Location and Major Physical Characteristics

The Senegal River basin is located in West Africa. It is drained by the 1,800 km-long Senegal river, the second longest river of West Africa, and its main tributaries, the Bafing, Bakoye and Faleme Rivers, all three of which have their source in the Fouta Djallon mountains (Guinea). Most of the Senegal River basin has a sub-Saharan desert climate, which has been aggravated by more or less long periods of drought during the 1970s. Access to sufficient quantities of good-quality water is therefore a particularly sensitive issue and absolutely crucial for the health of the population and the economy.

As shown in the table, the Senegal River basin is shared by the following four countries: Guinea, Mali, Mauritania, and Senegal. The basin has three distinct parts: the upper basin, which is mountainous, the valley, and the delta, which is a source of biological diversity and wetlands. Topographical, hydrographic and climatic conditions are very different in these three regions and seasonal temperature variations are extensive. The Senegal River basin, located in West Africa, covers 1.6% of the continent and spreads over four countries Figure 2.12 and Table 2.12).



Figure 2.12Senegal River Basin,
Source: Prepared for the World Water Assessment Programme (WWAP) by AFDEC, 2002.

TABLE 2.12 Senegal River Basin: Areas and Rainfall by Country

Country	Total area		As % of		Average annual rainfall in the basin area (mm)		
	of the country	within the basin	total area of basin	total area of country			
	(km^2)	(km^2)	(%)	(%)	min.	max.	mean
Guinea	245857	29475	6.1	12.0	1120	2100	1475
Mali	1240190	139098	28.8	11.2	455	1410	855
Mauritania	1025520	242742	50.2	23.7	55	600	270
Senegal	196720	71866_	14.9	36.5	270	1340	520
For Senegal basin	2708287	483181	100	17.84	55	2100	550

2.5.2. Rivers and Discharges

The sources of the Senegal River are located in Guinea and in the wetter south-western part of Mali. Total annual discharge leaving Guinea is estimated at about 8 km^3, but during the dry season the rivers frequently run dry. The Falémé River forms the border between Senegal and Mali over most of its distance. By the time they reach the border point between Mali, Mauritania and Senegal, the different tributaries have become one river, the Senegal River, which then continues to form the border between Senegal and Mauritania. The Karakoro River, flowing into the Senegal River at more or less the same point, originates in Mauritania. The annual discharge of the Senegal River at Bakel is 20 km . The Gorgol River, originating in Mauritania, joins it about 200 km downstream. Further downstream there are no other important tributaries.

2.5.3. Irrigation Potential and Water Requirements

The Senegal river basin irrigation potential, water requirements and areas under irrigation, are shown in (table 2.13). Irrigation potential in Guinea is rather limited by the topography. It has been estimated at 5000 ha. The irrigation potential in **Mali** is also limited by the topography.

Once the Manantali dam (on the Bafing tributary in Mali) is operational, it is estimated that about 10000 ha can be irrigated. The Senegal River valley in **Mauritania** is rather narrow, with the exception of two depressions in the downstream part. It is expected that with the Manantali dam about 125000 ha can be irrigated. In the present transitional period, with the dam not yet fully operational, an artificial flood is created through the dam in order to practice flood recession cropping on an area of 50000 ha at maximum. In the Gorgol and Karakoro tributary areas the irrigation potential is estimated at a maximum of 40000 ha, mainly through flood recession cropping with the construction of small earth dams. This brings the total to 165000 ha. In addition there are some 2000 ha of oases in the Senegal basin area. For Senegal, the prospects for irrigation development in the Falémé basin are very limited: a few hundred hectares. However, with the Manantali dam and the Diama dam (near the mouth of the Senegal River), it is expected that 240000 ha in the Senegal River valley will be irrigated. During the transitional period the flood created through the Manantali dam allows flood recession cropping on 50000 ha, as is the case in Mauritania. The Diama dam, essentially designed to prevent intrusion of salt water, was completed in 1985.

Table 2.13: Senegal River Basin: Irrigation Potential, Water Requirements and Areas under Irrigation

Country	Irrigation potential (ha)	Gross potential irrigation water requirement		Area under irrigation (ha)
		per ha (m^3/ha per year)	total (km^3/year)	
Guinea	5000	23000	0.115	0
Mali	10000	19000	0.190	300
Mauritania	165000	14000-37000	5.185	46450
Senegal	240000	22000-37000	8.880	71400
Sum of countries	420000		14.370	118150
Total for Senegal basin	<=420000		14.370	

If double rice cropping is practiced in the Senegal River valley, the water requirements are estimated at 37000 m^3/ha per year in this study. In the delta, gross water requirements of 18000 m/ha have been measured for rice in the rainy period and well over 20000 m/ha in the dry period. Some literature even gives estimates up to 50000 m^3/ha per year for double rice cropping.
In Guinea and Mali the annual river discharges largely exceed the water requirements for irrigation. However, if double rice cropping is to be considered on the whole potential area in the Senegal River valley and delta in Mauritania and Senegal, the total quantity of water in the basin might not be sufficient to meet the demand for irrigation. Therefore, the figure of 420000 ha for the basin should be considered as an upper limit.

2.5.4. Socio-economic characteristics

– Population

The Senegal River basin has a total population of around 3,500,000 inhabitants, 85 percent of whom live near the river.A large ethnic diversity characterizes the basin's population, with, among others, Peuls, Toucouleurs, Soninkes, Malinkes, Bambaras, Wolofs and Moors. However, there is massive emigration of the youngest generations towards the major cities and to Europe.

- Agriculture: the main activity of the basin[291]

The first major attempts to control the Senegal River discharge were made in the 1940s in order to grow rice in the delta (at Richard-Toll in Senegal). But it was not until 1973 that the State Company for Agricultural Development (SAED, Société d'Aménagement et d'Exploitation des Terres du Delta du Fleuve Sénégal) decided to increase this activity by building dikes around 10,000 hectares of flood land and created, in 1975, an irrigated area of 650 hectares. Irrigated agriculture rapidly expanded immediately after the new dams were filled (between 1986 and 1988). Today, irrigation is the motor of development in the basin, notably in the valley and in the delta, due not only to improved technology, but also to the wider variety of produce grown (rice, onions, tomatoes, potatoes, sweet potatoes). About 100,000 hectares of land are now cultivated in the basin: 60,000 hectares during the rainy season (June-September) and 20,000 during the dry

[291] The Organization for then Development of the Senegal River (OMVS, Organisation pour la mise envaleur du fleuve Sénégal) Senegal River Basin, Guinea, Mali, Mauritania, Sengal pilot case studies: a focus on real – World examples

season (March-June). Livestock raising has also always been a major economic activity in the basin. Due to the existence of rather high-potential pasture land, combined with the carrying capacity of the grasslands and the flood plains, the riparian populations, and even those living elsewhere, practice transhumance and extensive cattle, sheep and goat raising.

Fishing, in terms of the income of the work force that it employs, is undoubtedly the largest economic activity in the basin after agriculture, notably for populations living near the river in the valley and the delta. Today, however, the future of this sector is in question because for several years now there has been a steady drop in the tonnage caught throughout the OMVS region (i.e. the basin area shared by Mali, Mauritania and Senegal). Some observers link this to the river development projects (dams, dikes) and to their impact on the environment (significant decrease in salinity, proliferation of floating water weeds, eutrophication, etc.).

– Other economic activities

Operational since September 2001, the hydroelectric power plant in Manantali had the following initial objectives: producing 200 megawatts (Mw), to furnish an average of 800 giga watt per hour per year (Gwh/year) to electricity companies in the three OMVS member states. These figures were based on hydrological data from 1950 to 1994, but new simulations done with data from between 1974 and 1994 predict an energy production of only 547 Gwh. As a result of this decrease, the expected savings in OMVS member states expenditures for energy would unfortunately drop from 22 to 17 percent.

Navigation on the Senegal River is today very limited. The OMVS is aware of the strategic importance of its development over the short term, and a navigation project is under study. Like the exploitation of mineral resources, the ability to transport heavy goods at a lower cost and, especially, access to the Atlantic Ocean for Mali could give a new impetus to the region's economy. Industrial sector is slightly developed.

3. MAJOR RESULTS

The Major results for the impact of ADH on the stability in different major trans-boundary river's basins in Arab region could be discussed under each Basin; Figure (3.1) shows the major trans-boundary river's basins discussed in Arab region.

3.1. Euphrates River basin

3.1.1. Creating and Studying Agriculture drought Hazard

Creation of Agriculture drought hazard from ADI, ADV, ADF , ADC the results will include both the geographical distribution of the classes of each product and the table with areas in Ha, and percentage of each class by countries sharing the basin. Creating the Agriculture Drought Hazard ADH, from the analysis of the monthly band seasonally VHI.

- **The ADI map of Euphrates river basin is shown in figure (3.1), and (Table 3.1). The results shows that drought intensity is extend in 60% of the basin most of it belong to the class of low ADI and is distributed as follows 37% of in Syria, 18% in Turkey and 4.8% in Lebanon.**
- **The ADV map of Euphrates river basin is shown in figure (3.2), and (Table 3.2). The results shows that drought variability is extend in 94% of the basin most of it belong to the class 1, that correspond to low variability ADI and is distributed as follows 60% of in Syria, 25.5% in Turkey and 6% in Lebanon.**
- **The ADF map of Euphrates river basin is shown in figure (3.3), and (Table 3.3). The results shows that drought frequency is extend in most parts of the basin, almost, 36% are in classes 1 and 2 and 53% are in classes of 3, 4, 5 and 6 and less than 2% are in classes 7 to 10. The majority of the ADF are distributed as follows: 33% of in Syria, 18% in Turkey and 3% in Lebanon.**
- **The A ADC map of Euphrates river basin is shown in figure (3.4), and (Table 3.4). The results show that drought consecutive is very low in most parts of the basin.**
- **Finally, the ADH map of Orontes River basin as shown in figure (3.5), and (Table 3.5) illustrate that almost 52% of the basin is under low level of ADH, and 8% is in moderate ADH while only 0.2% is in Sever ADH.**

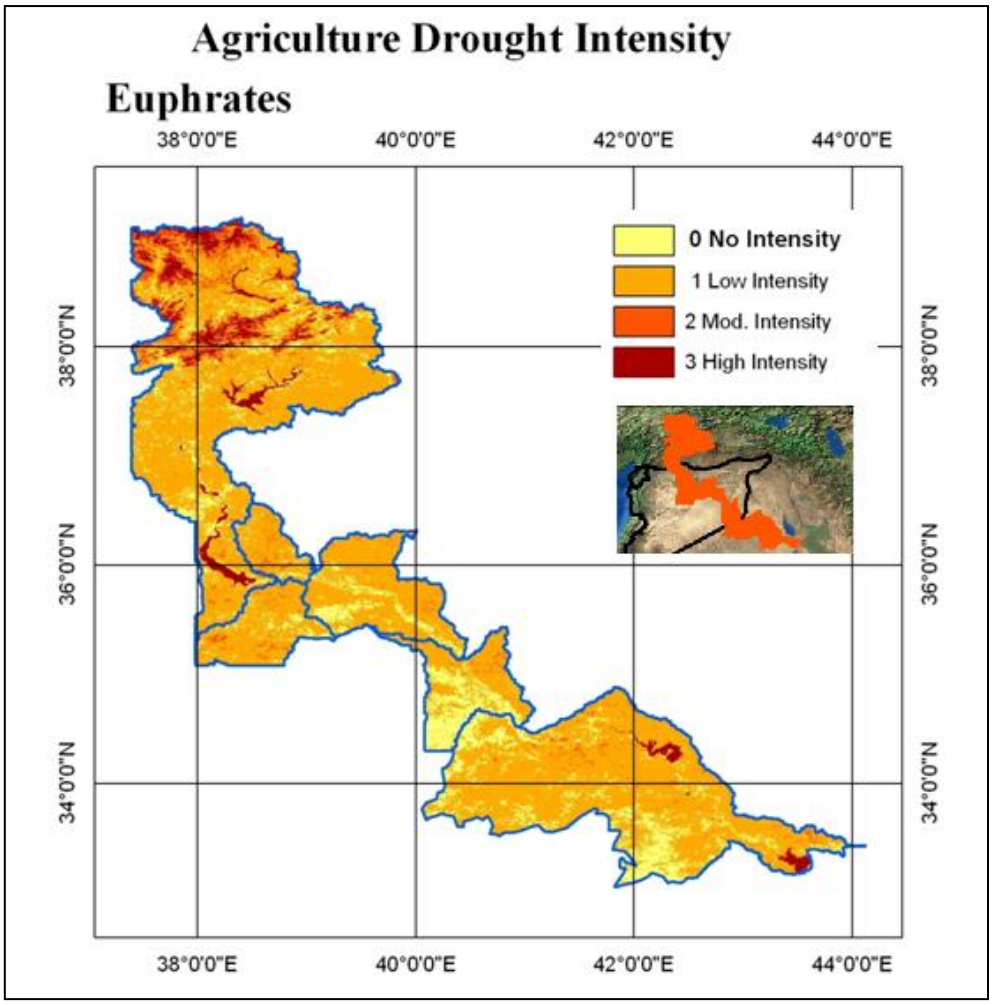


Figure 3.1 Agriculture Drought Intensity Map in Euphrates River's Basin

Table 3.1 Agriculture Drought intensity Areas in Euphrates River's Basin

ADI classes	Country	Areas in Ha	Areas in %
No drought	Iraq	542424.3	5.34
	Syria	759470.8	7.47
	Turkey	368438.8	3.63
Low	Iraq	2419435.9	23.81
	Syria	2595100.6	25.54
	Turkey	2382394.6	23.45
Moderate	Iraq	57915.2	0.57
	Syria	83912.6	0.83
	Turkey	448168.4	4.41
High	Iraq	61819.3	0.61
	Syria	62420	0.61
	Turkey	378959.1	3.73

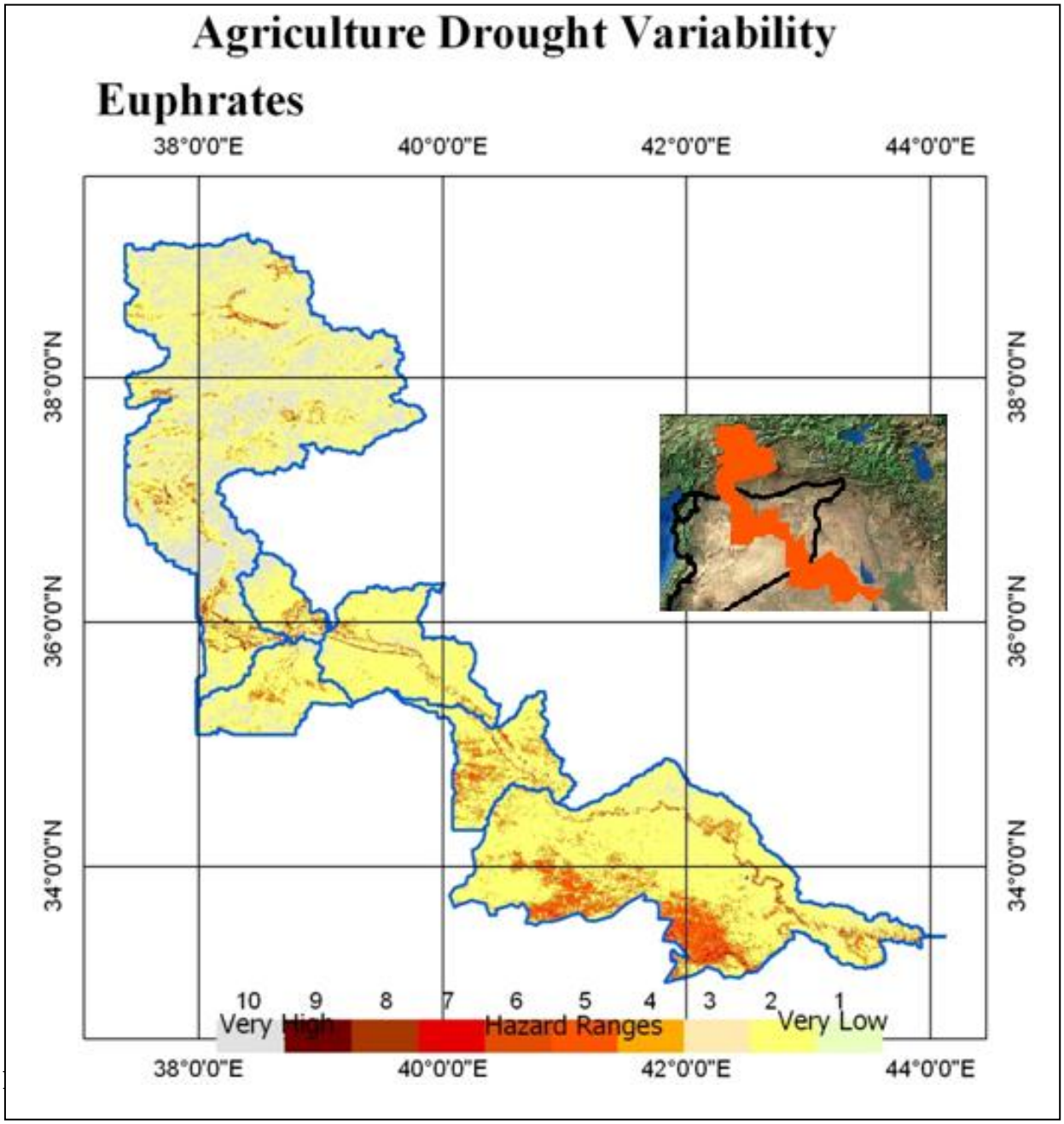

Agriculture Drought Variability
Euphrates
38°0'0"E
40°0'0"E
42°0'0"E
44°0'0"E
38°0'0"N
36°0'0"N
34°0'0"N
10 9 8 7 6 5 4 3 2 1
Very High
Hazard Ranges
Very Low

Table 3.2 Agriculture Drought Variability Areas in Euphrates River's Basin

Country	AD Variability classes	Area in ha	%
Iraq	No ADV	111.10	0.00
Syria		654.45	0.01
Turkey		1480.35	0.01
Iraq	Very low	2718951.90	26.76
Syria		3342909.16	32.90
Turkey		3484442.76	34.29
Iraq	Moderate	340584.77	3.35
Syria		129179.40	1.27
Turkey		78669.11	0.77
Iraq	Very high	21946.99	0.22
Syria		28161.03	0.28
Turkey		13368.83	0.13

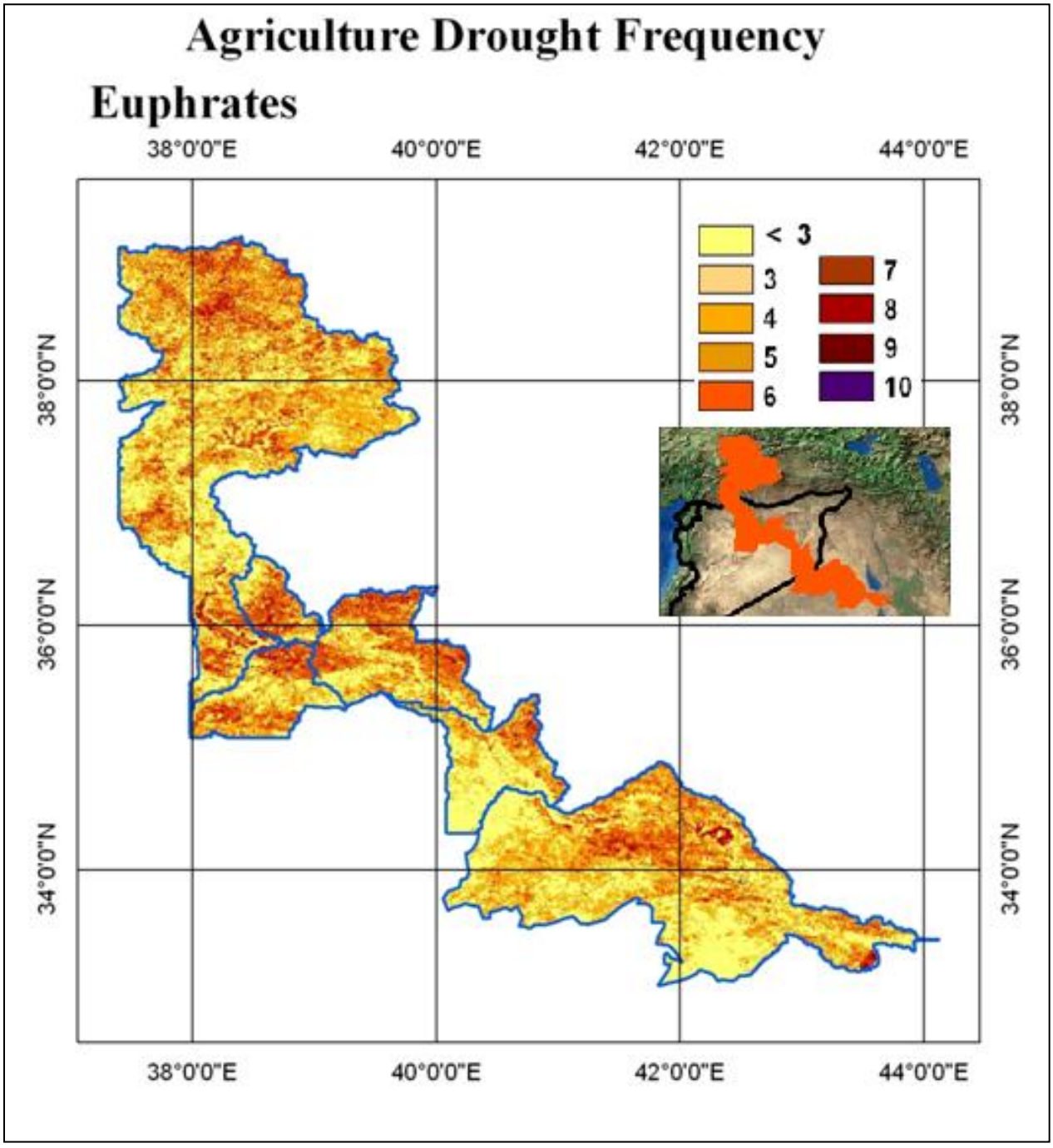


Figure 3.3. Agriculture Drought Frequency Map in Euphrates River's Basin

Table 3.3 Agriculture Drought Frequency Areas in Euphrates River's Basin

Year	Country	Area in Ha	Area in %
0	Iraq	24305.92	0.24%
0	Syria	42548.55	0.42%
0	Turkey	26682.03	0.26%
1	Iraq	205471.84	2.02%
1	Syria	237828.38	2.34%
1	Turkey	184303.54	1.81%
2	Iraq	430367.86	4.24%
2	Syria	498434.75	4.91%
2	Turkey	431243.00	4.24%
3	Iraq	649620.76	6.39%
3	Syria	683918.58	6.73%
3	Turkey	650707.69	6.40%
4	Iraq	670333.29	6.60%
4	Syria	586060.06	5.77%
4	Turkey	773732.24	7.62%
5	Iraq	528217.22	5.20%
5	Syria	501008.65	4.93%
5	Turkey	649561.94	6.39%
6	Iraq	329230.44	3.24%
6	Syria	445102.10	4.38%
6	Turkey	449197.79	4.42%
7	Iraq	170023.62	1.67%
7	Syria	323204.41	3.18%
7	Turkey	266575.55	2.62%

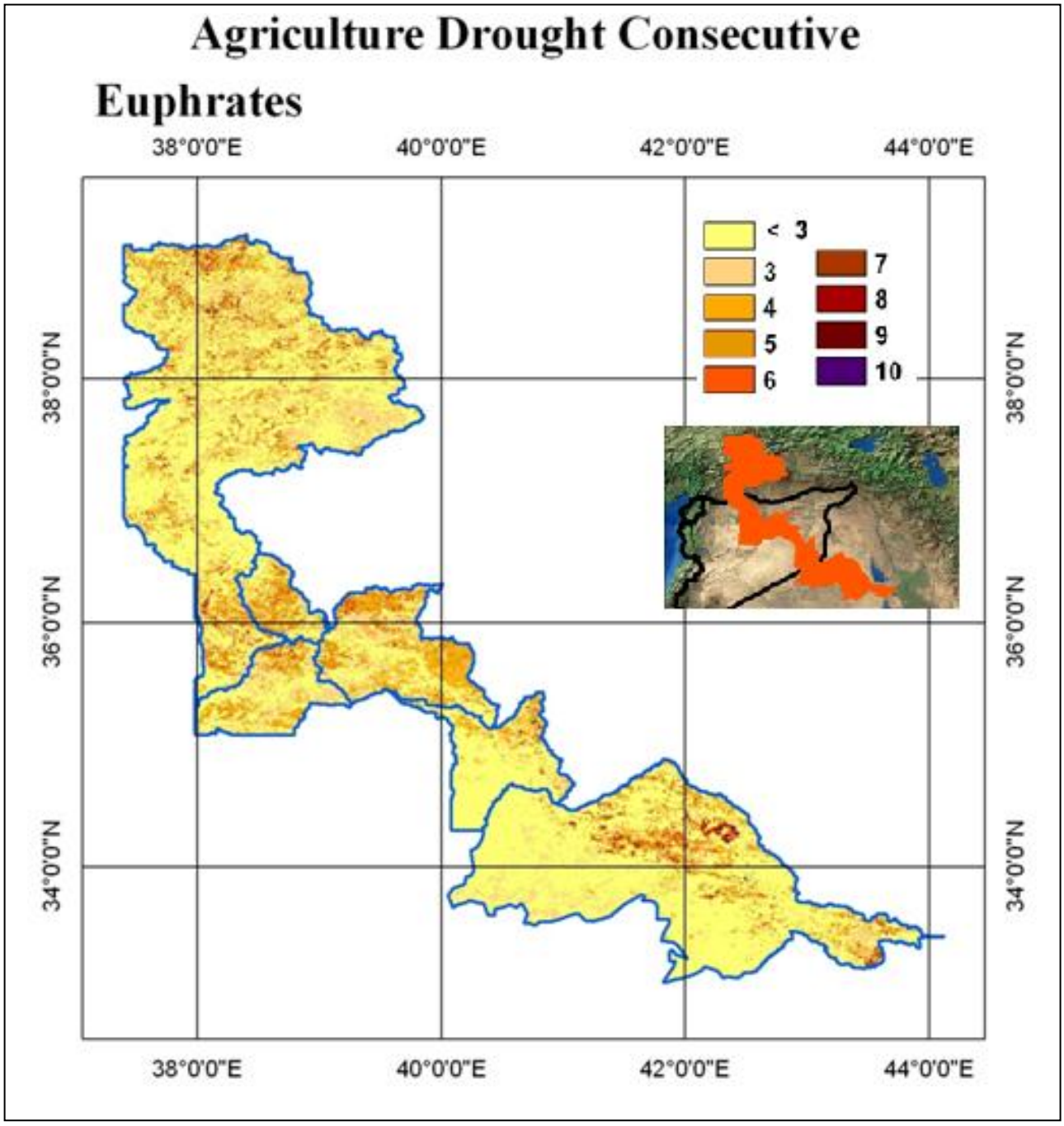


Figure 3.4. Agriculture Drought Consecutive Map in Euphrates River's Basin

Table3.4. Agriculture Drought Consecutive Areas in Euphrates River's Basin

Number of year	Country	Area in Ha	%
0	Iraq	24863.37	0.24
1	Iraq	727095.31	7.16
2	Iraq	1362231.38	13.41
3	Iraq	509919.59	5.02
4	Iraq	163812.20	1.61
5	Iraq	159771.63	1.57
6	Iraq	61508.39	0.61
7	Iraq	16437.88	0.16
8	Iraq	45332.94	0.45
9	Iraq	5114.28	0.05
10	Iraq	5507.42	0.05
0	Syria	43454.69	0.43
1	Syria	666478.00	6.56
2	Syria	1085108.61	10.68
3	Syria	794131.42	7.82
4	Syria	417540.86	4.11
5	Syria	373927.20	3.68
6	Syria	100420.72	0.99
7	Syria	6546.07	0.06
8	Syria	6311.73	0.06
9	Syria	4977.85	0.05
10	Syria	2006.48	0.02
0	Turkey	26795.67	0.26
1	Turkey	795131.95	7.83
2	Turkey	1144010.76	11.26
3	Turkey	932218.94	9.17
4	Turkey	333675.73	3.28
5	Turkey	198889.38	1.96
6	Turkey	49717.69	0.49
7	Turkey	32167.97	0.32
8	Turkey	38570.04	0.38
9	Turkey	25494.89	0.25
10	Turkey	1287.99	0.01

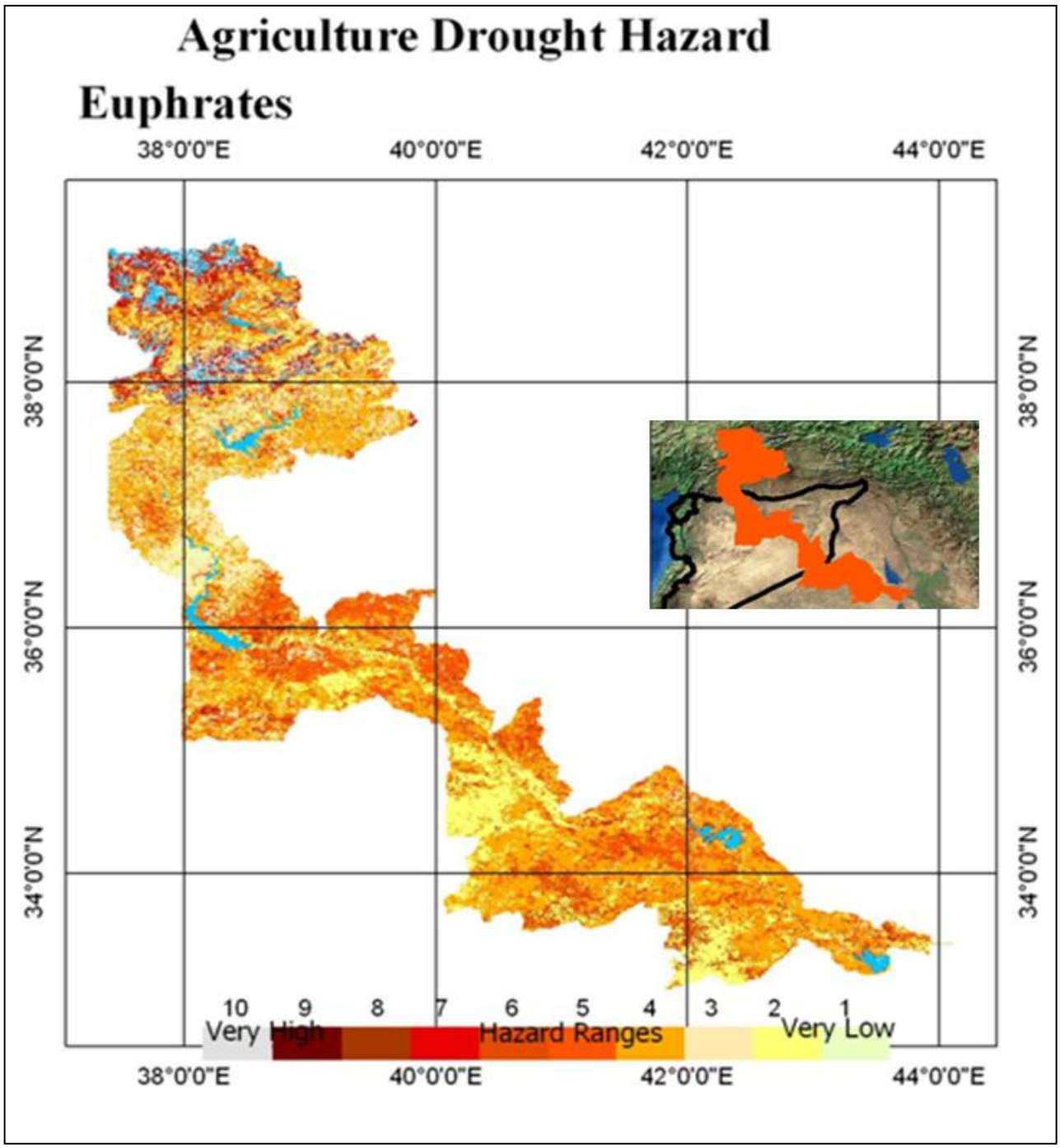


Figure 3.5. Agriculture Drought Hazard Map in Euphrates River's Basin

Table 3.5. Agriculture Drought Hazard Areas in Euphrates River's Basin

AD HAZARD Classes ADH	Area in Ha	%
1	326167.73	2.11
2	2149051.76	13.89
3	2062734.96	13.33
4	5714836.02	36.93
5	2497874.28	16.14
6	981703.62	6.34
7	610905.57	3.95
8	323254.14	2.09
9	4022.18	0.03
10	264452.30	1.71

3.1.2. Agriculture drought Hazard with Land Degradation

– **Land degradation map is shown in figure (3.6), and (Table 3.6 and3.7). The results shows that**

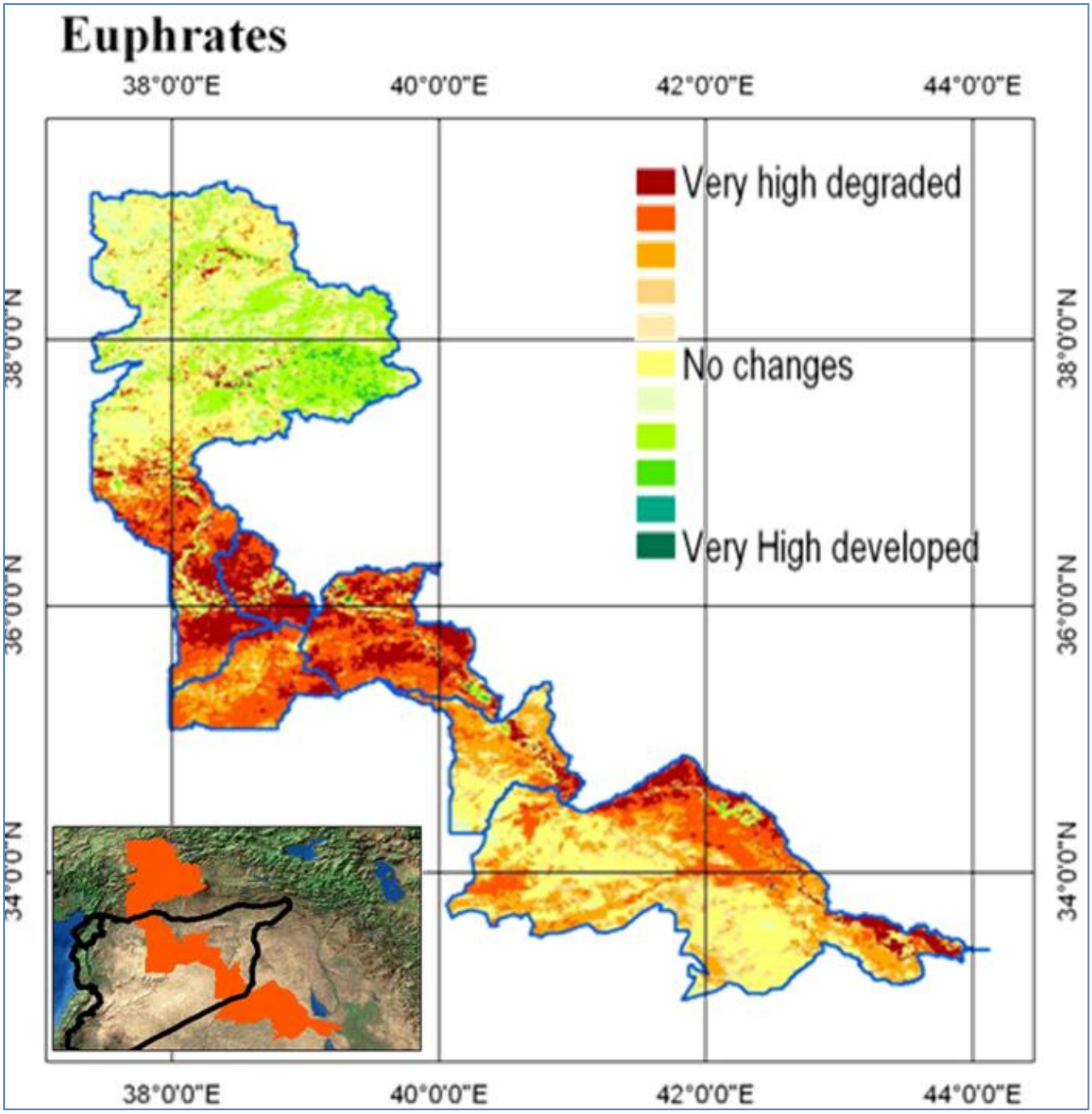


Figure 3.6. Aland Degradation Map in Euphrates River's Basin

Table 3.6. Land Degradation Areas in Euphrates River's Basin

Country	Area in	vh_deg	h_deg	m_deg	l_deg	vl_deg	L. Deg Total
Turkey	Ha	63689.39	121024.01	156829.75	92642.18	42128.38	476313.71
	%	0.63	1.19	1.54	0.91	0.41	4.68
Syria	Ha	927200.01	1249017.65	634992.63	167688.04	46201.83	3025100.16
	%	9.13	12.29	6.25	1.65	0.45	29.77
Iraq	Ha	239532.62	565116.22	759911.58	396848.96	123761.11	2085170.49
	%	2.36	5.56	7.48	3.91	1.22	20.53
TOTAL	Ha	1230422.02	1935157.88	1551733.96	657179.18	212091.32	5586584.36
	%	12.12	19.04	15.27	6.47	2.08	54.98

Table3.7. Land Developed Areas in Euphrates River's Basin

Country	Area in	vh_dev	h_dev	m_dev	l_dev	vl_dev	L. Dev Total
Turkey	Ha	4977.62	22009.64	79274.24	989846.02	872696.83	1968804.35
	%	0.05	0.22	0.78	9.74	8.59	19.38
Syria	Ha	1846.71	4529.76	6187.37	51892.27	75679.04	140135.15
	%	0.02	0.04	0.06	0.51	0.74	1.37
Iraq	Ha	0	553.55	3009.71	17385.93	39669.54	60618.73
	%	0	0.01	0.03	0.17	0.39	0.6
TOTAL	Ha	6824.33	27092.95	88471.32	1059124.22	988045.41	2169558.23
	%	0.07	0.27	0.87	10.42	9.72	21.35

3.1.3. Agriculture drought Hazard with Land Cover/Use

– **Land Cover map is shown in figure (3.7), and the LC map legend is shown in Table (3.8), the impact of Agriculture drought Hazard in Land Cover/Use is shown in figure (3.8) and (Table 3.9).**

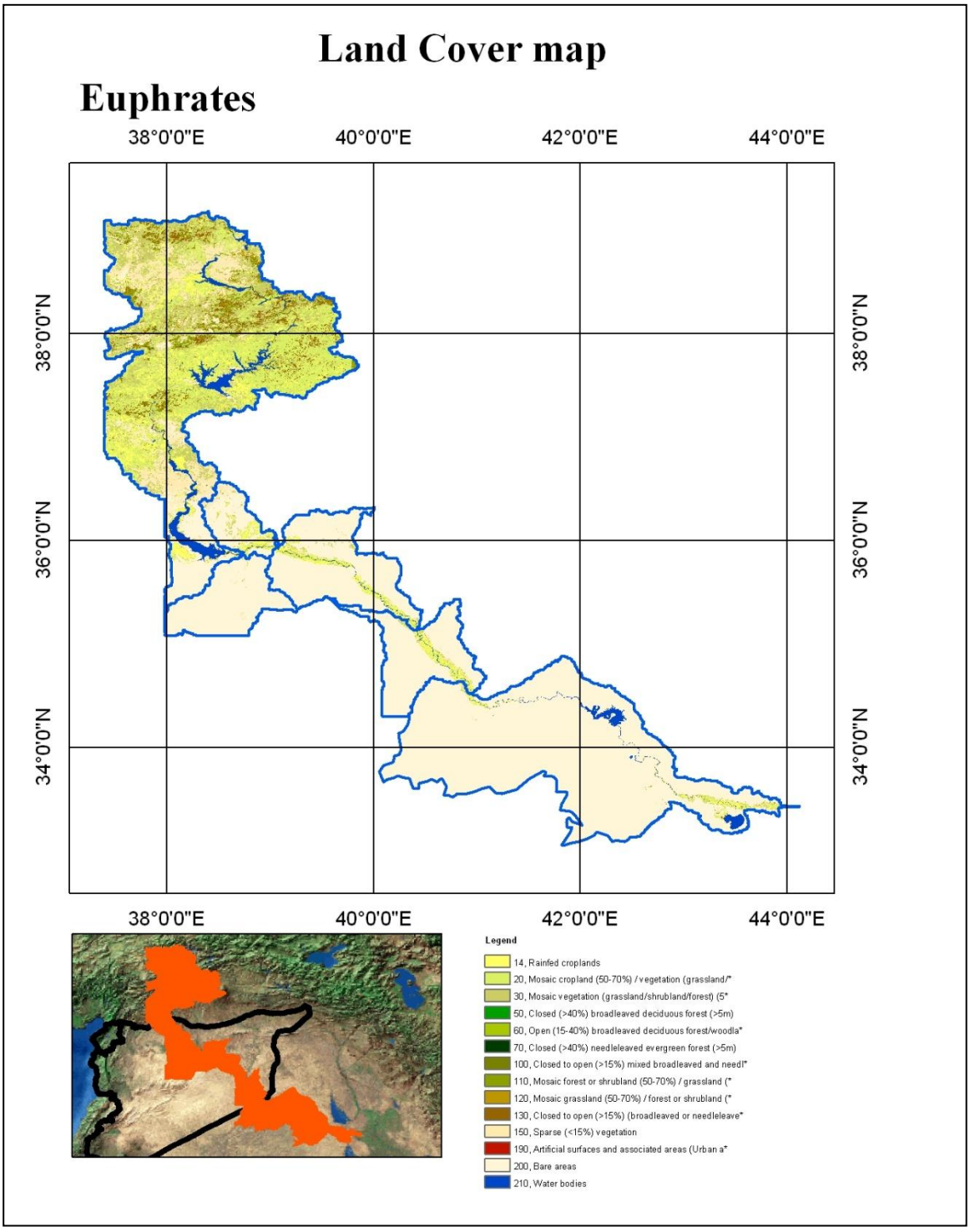


Figure 3.7. Cover Map in Euphrates River's Basin

Table.3.8. Land Cover Legend.

Land Cover Description in Euphrates River Basin	Area in		Country	Area in	
	Ha	%		Ha	%
Rainfed croplands	751653.02	4.86%	Iraq	28330.68	0.18%
			Syria	238827.69	1.54%
			Turkey	484494.66	3.13%
Mosaic Croplands/Vegetation	2121239.95	13.71%	Iraq	31036.99	0.20%
			Syria	215024.55	1.39%
			Turkey	1875178.41	12.12%
Mosaic Vegetation/Croplands	1882089.78	12.16%	Iraq	23426.76	0.15%
			Syria	194108.70	1.25%
			Turkey	1664554.31	10.76%
Closed broadleaved deciduous forest	860.39	0.01%	Turkey	860.39	0.01%
Closed needleleaved evergreen forest	2822.93	0.02%	Syria	333.41	0.00%
			Turkey	2489.52	0.02%
Closed to open mixed broadleaved and needleleaved forest	190.45	0.00%	Syria	94.41	0.00%
			Turkey	96.04	0.00%
Mosaic Forest-Shrubland/Grassland	311160.85	2.01%	Iraq	4929.33	0.03%
			Syria	18120.45	0.12%
			Turkey	288111.06	1.86%
Mosaic Grassland/Forest-Shrubland	97819.75	0.63%	Iraq	57.24	0.00%
			Syria	1952.00	0.01%
			Turkey	95810.51	0.62%
Closed to open shrubland	308427.38	1.99%	Iraq	886.37	0.01%
			Syria	2075.68	0.01%
			Turkey	305465.33	1.97%
Sparse vegetation	1209753.38	7.82%	Iraq	38376.40	0.25%
			Syria	419885.38	2.71%
			Turkey	751491.59	4.86%
Closed to open vegetation regularly flooded	63.14	0.00%	Iraq	63.14	0.00%
Bare areas	8381217.09	54.17%	Iraq	4232263.91	27.35%
			Syria	4043863.56	26.13%
			Turkey	105089.62	0.68%
Water bodies	405744.20	2.62%	Iraq	92982.39	0.60%
			Syria	141477.09	0.91%
			Turkey	171284.72	1.11%

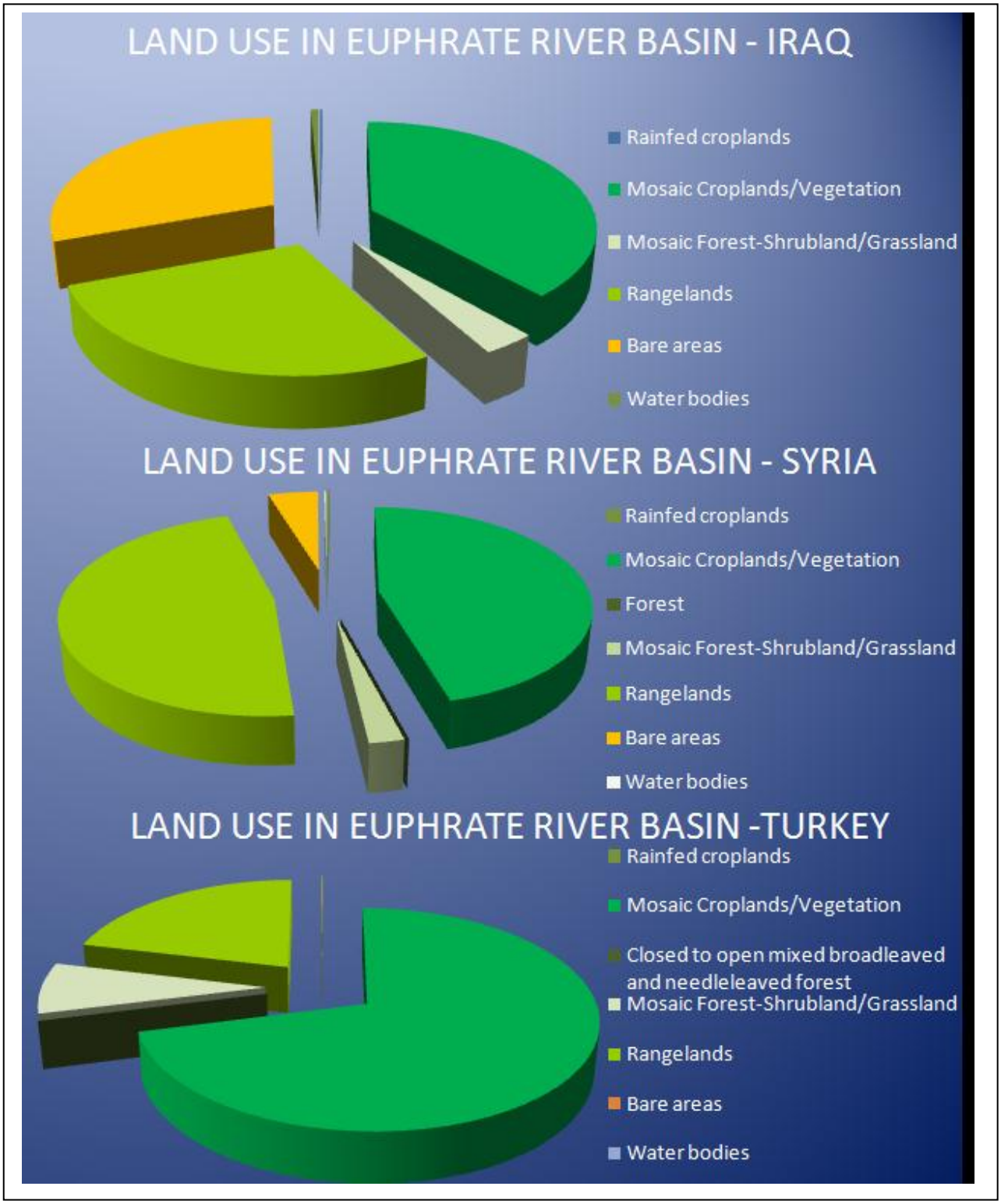


Figure 3.8. Distribution of Land Cover among Euphrates Basin Countries

Table 3.9.Agriculture Drought Hazard Areas in Euphrates River's Basin

Land Cover	Level of Hazard	Area in Ha	%
Rainfed croplands	Non	144578.94	0.93
	Slight	435585.57	2.82
	Moderate	151012.13	0.98
	Severe	12466.21	0.08
Mosaic Croplands/Vegetation	Non	480390.99	3.10
	Slight	2285100.40	14.77
	Moderate	801695.97	5.18
	Severe	253914.94	1.64
Forest	Non	1185.46	0.01
	Slight	1830.97	0.01
	Moderate	780.59	0.01
	Severe	59.34	0.00
Mosaic Forest-Shrubland/Grassland	Non	51912.27	0.34
	Slight	170054.00	1.10
	Moderate	109694.13	0.71
	Severe	43378.62	0.28
Rangelands	Non	212340.83	1.37
	Slight	737023.70	4.76
	Moderate	362344.36	2.34
	Severe	124332.37	0.80

– **The results shows that**

3.2. Blikh River basin

3.2.1. Creating and Studying Agriculture drought Hazard

Creation of Agriculture drought hazard from ADI, ADV, ADF , ADC the results will include both the geographical distribution of the classes of each product and the table with areas in Ha, and percentage of each class by countries sharing the basin. Creating the Agriculture Drought Hazard ADH, from the analysis of the monthly band seasonally VHI.

- **The ADI map of Blikh River basin is shown in figure (3.9), and (Table 3.10). The results shows that drought intensity is extend in 60% of the basin most of it belong to the class of low ADI and is distributed as follows 37% of in Syria, 18% in Turkey and 4.8% in Lebanon.**
- **The ADV map of Blikh River basin is shown in figure (3.10), and (Table 3.11). The results shows that drought variability is extend in 94% of the basin most of it belong to the class 1, that correspond to low variability ADI and is distributed as follows 60% of in Syria, 25.5% in Turkey and 6% in Lebanon.**
- **The ADF map of Blikh River basin is shown in figure (3.11), and (Table 3.12). The results shows that drought frequency is extend in most parts of the basin, almost, 36% are in classes 1 and 2 and 53% are in classes of 3, 4, 5 and 6 and less than 2% are in classes 7 to 10. The majority of the ADF are distributed as follows: 33% of in Syria, 18% in Turkey and 3% in Lebanon.**
- **The A ADC map of Blikh River basin is shown in figure (3.12), and (Table 3.13). The results show that drought consecutive is very low in most parts of the basin.**
- **Finally, the ADH map of Blikh river basin as shown in figure (3.13), and (Table 3.14) illustrate that almost 52% of the basin is under low level of ADH, and 8% is in moderate ADH while only 0.2% is in Sever ADH.**

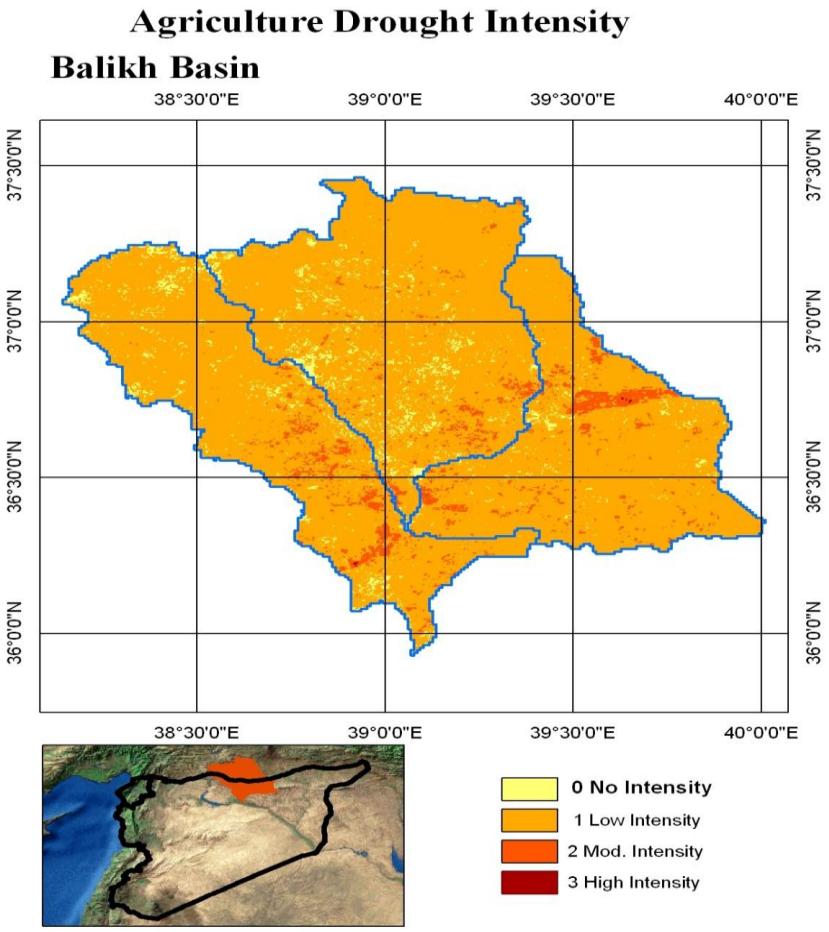


Figure 3.9 Agriculture Drought Intensity Map in Blikh River's Basin

Table 3.10Agriculture Drought intensity Areas in Blikh River's Basin

Country	class	Area_Ha	%
Syria	No drought	23116.07	1.64%
	Low	625821.43	44.39%
	Moderate	51550.53	3.66%
	High	263.41	0.02%
Turkey	No drought	36216.76	2.57%
	Low	657572.76	46.64%
	Moderate	15337.29	1.09%

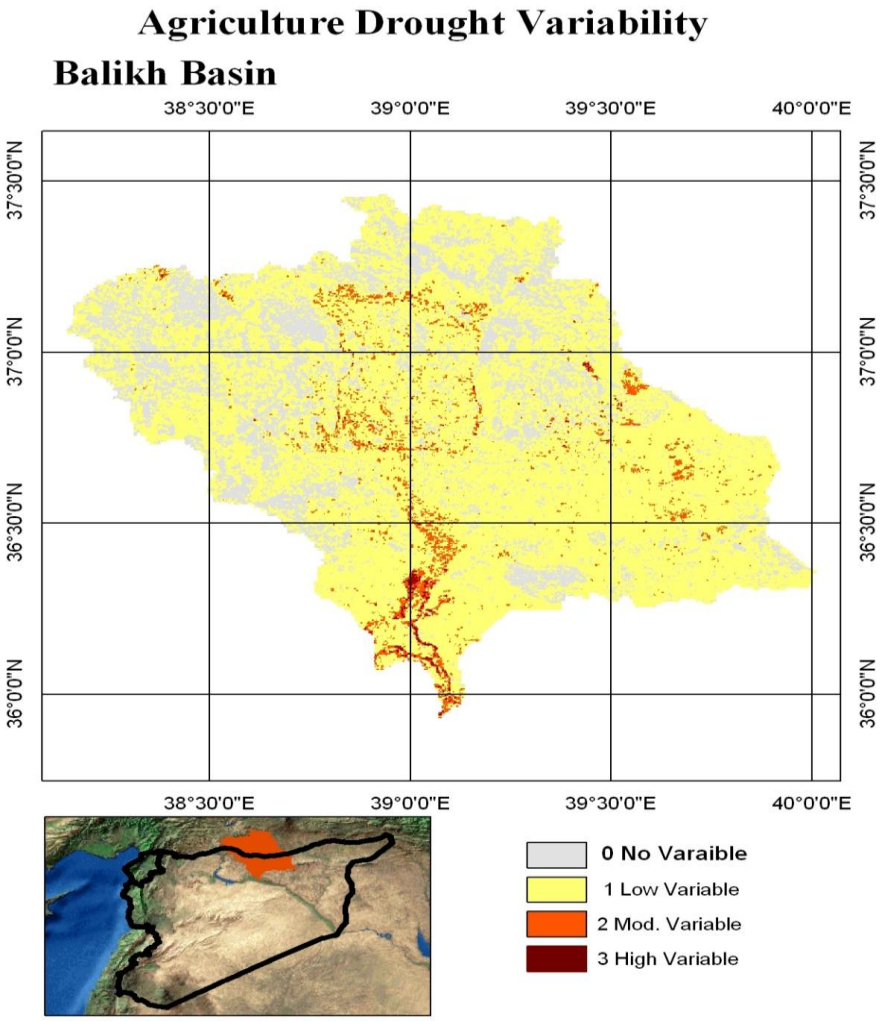


Figure 3.10 Agriculture Drought Variability Map in Blikh River's Basin

Table 3.11Agriculture Drought Variability Areas in Blikh River's Basin

Country	Variability class	Area in Ha	%
Syria	0	6.19	0.00
Syria	1	679398.35	48.21
Syria	2	17797.94	1.26
Syria	3	3264.45	0.23
Turkey	0	77.99	0.01
Turkey	1	695712.99	49.37
Turkey	2	11825.04	0.84
Turkey	3	1125.22	0.08
TOTAL		1409208.16	100.00

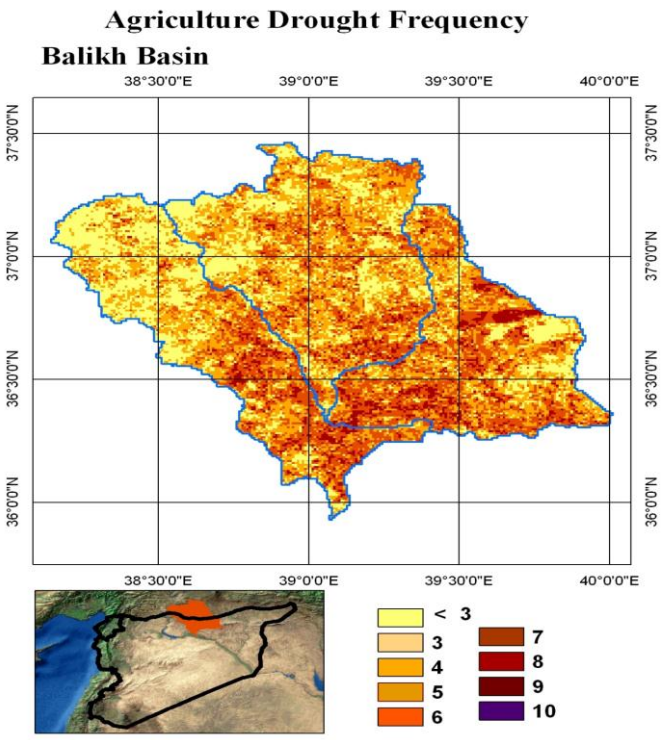


Figure 3.11.Agriculture Drought Frequency Map in Blikh River's Basin

Table 3.12 Agriculture Drought Frequency Areas in Blikh River's Basin

Frequency Classes Year	Country	Area in Ha	%
0	Syria	710.14	0.05
1	Syria	9884.85	0.70
2	Syria	46525.89	3.30
3	Syria	75165.37	5.33
4	Syria	111265.89	7.89
5	Syria	134607.80	9.55
6	Syria	137698.07	9.77
7	Syria	109001.07	7.73
8	Syria	58946.29	4.18
9	Syria	16430.79	1.17
10	Syria	515.34	0.04
0	Turkey	126.54	0.01
1	Turkey	26382.35	1.87
2	Turkey	86656.87	6.15
3	Turkey	134032.24	9.51
4	Turkey	153647.48	10.90
5	Turkey	140159.93	9.94
6	Turkey	99285.23	7.04
7	Turkey	51563.37	3.66
8	Turkey	15451.53	1.10
9	Turkey	1757.22	0.12
10	Turkey	63.99	0.00

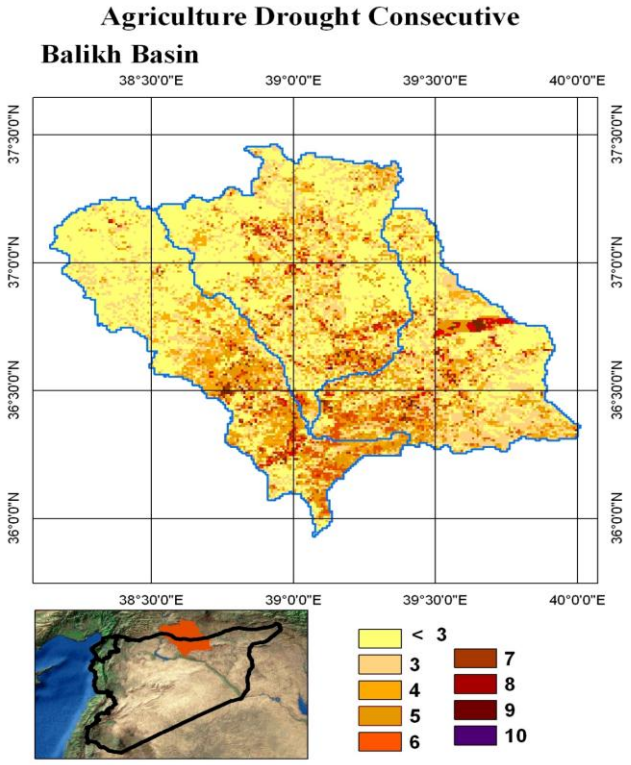


Figure 3.12 Agriculture Drought Consecutive Map in Euphrates River's Basin

Table 3.13. Agriculture Drought Consecutive Areas in Blikh River's Basin

Consecutive Classes	Country	Area in Ha	%
0	Syria	708.35	0.05
1	Syria	45614.13	3.24
2	Syria	163787.68	11.62
3	Syria	172112.60	12.21
4	Syria	92735.08	6.58
5	Syria	104060.26	7.38
6	Syria	48991.78	3.47
7	Syria	13297.62	0.94
8	Syria	9183.57	0.65
9	Syria	6342.91	0.45
10	Syria	515.34	0.04
0	Turkey	128.33	0.01
1	Turkey	207628.18	14.73
2	Turkey	232380.49	16.48
3	Turkey	153655.07	10.90
4	Turkey	83131.87	5.90
5	Turkey	37477.18	2.66
6	Turkey	14024.62	0.99
7	Turkey	12702.38	0.90
8	Turkey	7915.96	0.56
9	Turkey	3420.85	0.24
10	Turkey	63.99	0.00

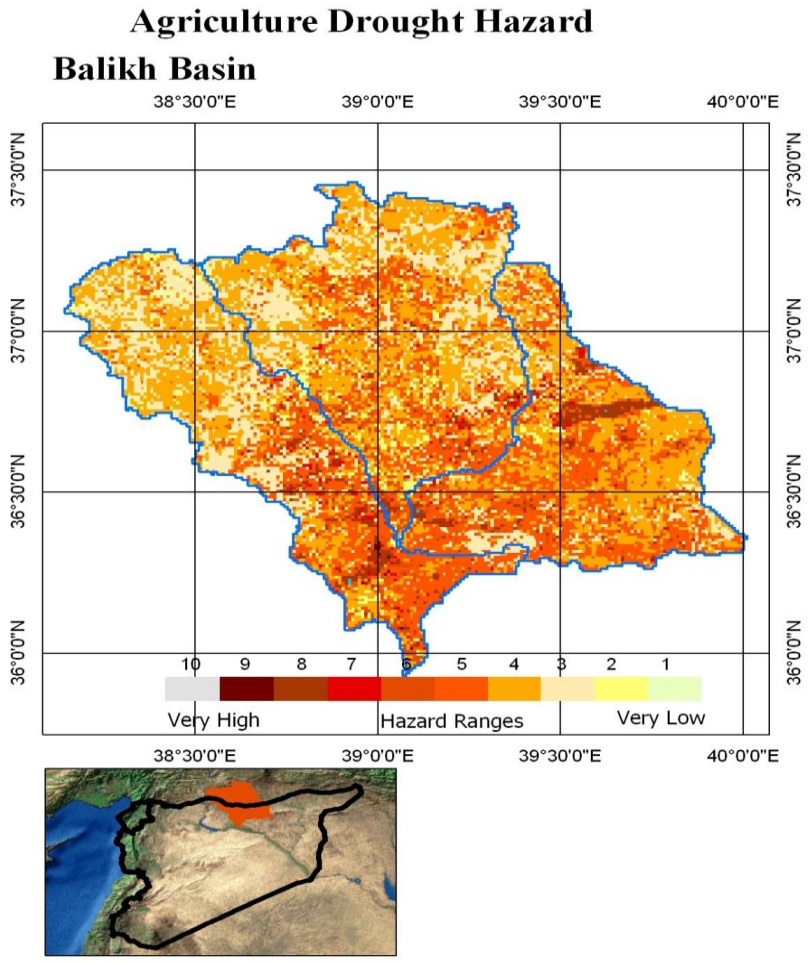


Figure 3.13 Agriculture Drought Hazard Map in Blikh River's Basin

Table 3.14. Agriculture Drought Hazard Areas in Blikh River's Basin

HAZARD Classes ADH	Area_ha	%
1	20784.23	0.95
2	69592.22	3.17
3	467680.36	21.33
4	846569.74	38.61
5	589310.25	26.88
6	91628.66	4.18
7	25276.44	1.15
8	79802.06	3.64
9	1569.71	0.07

3.2.2. Agriculture drought Hazard with Land Degradation

– **Land degradation map is shown in figure (3.14), and (Table 3.15 and 3.16). The results shows that**

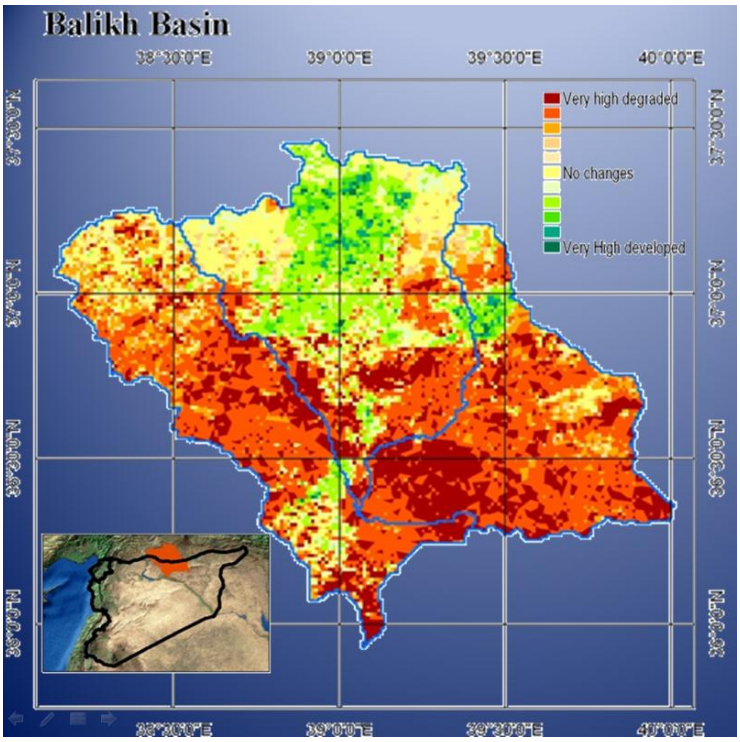


Figure 3.14. Aland Degradation Map in Blikh River's Basin

Table 3.15. Land Degradation Areas in Blikh River's Basin

Country	Area in	vh_deg	h_deg	m_deg	l_deg	vl_deg	L. Deg Total
Turkey	Ha	60390.3	123207.4	83358.8	40993	13923.9	321873.4
	%	4.28	8.74	5.91	2.91	0.99	22.83
Syria	Ha	225348.7	339747.3	60596.8	11807.4	3446.4	640946.6
	%	15.98	24.1	4.3	0.84	0.24	45.46
TOTAL	Ha	285739	462954.7	143955.6	52800.4	17370.3	962820
	%	20.26	32.84	10.21	3.75	1.23	68.29

Table 3.16. Land Developed Areas in Blikh River's Basin

Country	Area in	vh_dev	h_dev	m_dev	l_dev	vl_dev	L. Dev Total
Turkey	Ha	49775.3	132431.3	33300.6	14149.3	4239.2	233895.7
	%	3.53	9.39	2.36	1	0.3	16.58
Syria	Ha	12222.3	16666.8	1962.9	431	215.9	31498.9
	%	0.87	1.18	0.14	0.03	0.02	2.24
TOTAL	Ha	61997.6	149098.1	35263.5	14580.3	4455.1	265394.6
	%	4.4	10.57	2.5	1.03	0.32	18.82

3.2.3. Agriculture drought Hazard with Land Cover/Use

– **Land Cover map is shown in figure (3.15), and the LC map legend is shown in table (3.17), the impact of Agriculture drought Hazard in Land Cover/Use is shown in figure (3.16) and (table 3.18).**

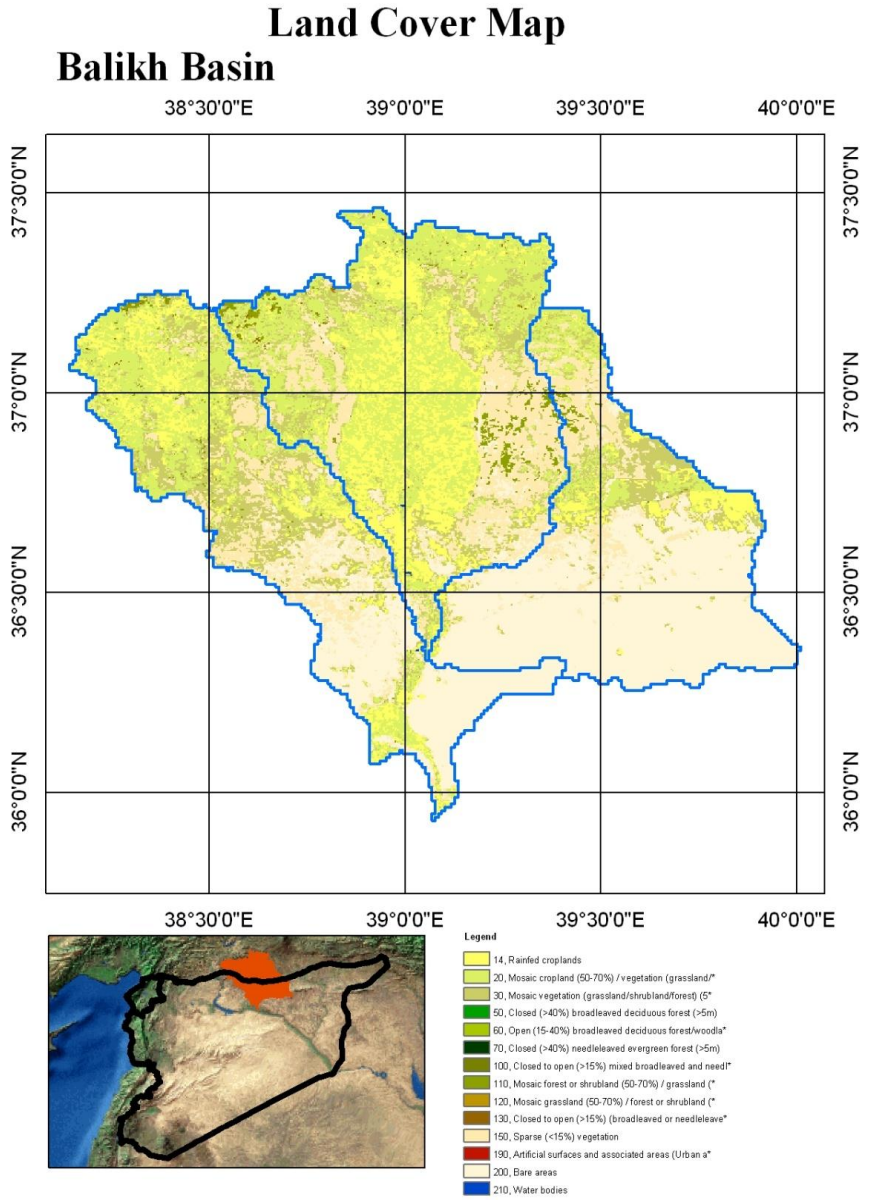


Figure 3.15. Cover Map in Blikh River's Basin

Table 3.17. Land Cover Legend.

Land Cover Description in Blikh River Basin	Area in		Country	Area in	
	Ha	%		Ha	%
Rainfed croplands	306290.49	13.97%	Syria	102006.43	4.65%
			Turkey	204284.06	9.32%
Mosaic Croplands/Vegetation	552235.79	25.19%	Syria	88843.85	4.05%
			Turkey	463391.95	21.13%
Mosaic Vegetation/Croplands	310003.20	14.14%	Syria	140023.07	6.39%
			Turkey	169980.13	7.75%
Closed broadleaved deciduous forest	7.65	0.00%	Turkey	7.65	0.00%
Mosaic Forest-Shrubland /Grassland	27272.34	1.24%	Syria	1966.26	0.09%
			Turkey	25306.08	1.15%
Mosaic Grassland/Forest-Shrubland	738.76	0.03%	Syria	23.70	0.00%
			Turkey	715.06	0.03%
Closed to open shrub land			Turkey	1907.53	0.09%
Sparse vegetation	369671.61	16.86%	Syria	145833.71	6.65%
			Turkey	223837.90	10.21%
Bare areas	624277.41	28.47%	Syria	605918.32	27.63%
			Turkey	18359.09	0.84%
Water bodies			Syria	248.89	0.01%

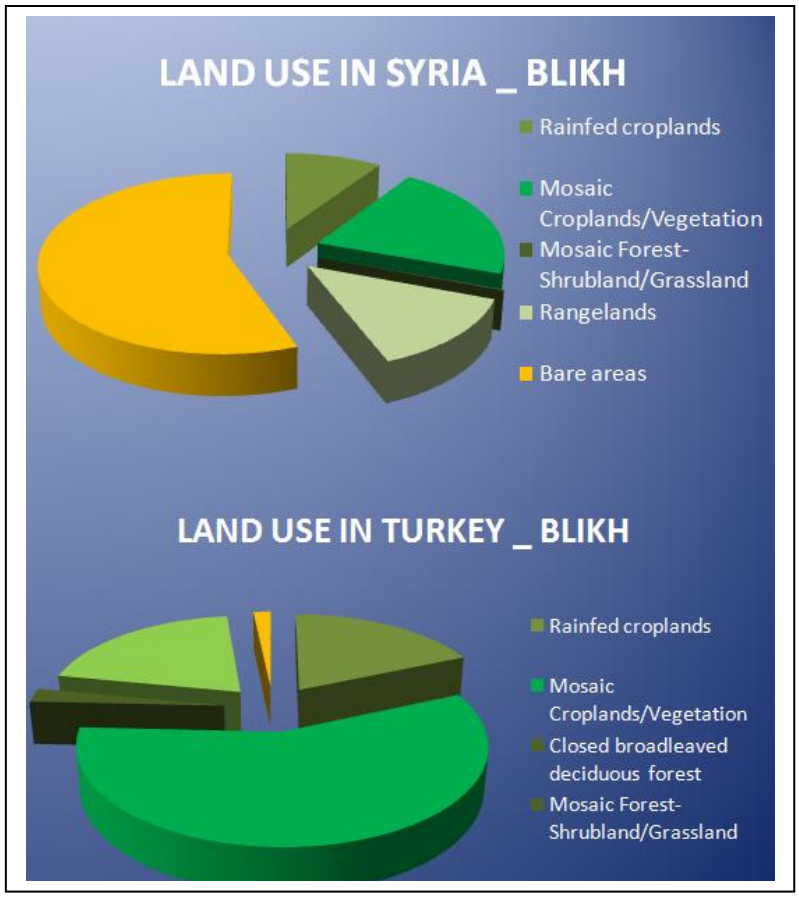


Figure 3.16. Distribution of Land Cover among Blikh Basin Countries

Table 3.18. Agriculture Drought Hazard Areas in Blikh River's Basin

Land Cover	Level of Hazard	Area in Ha	%
Rainfed croplands	Non	23610.01	1.08
	Slight	194496.66	8.87
	Moderate	83443.69	3.81
	Severe	4740.12	0.22
Mosaic Croplands/Vegetation	Non	42589.13	1.94
	Slight	593321.56	27.06
	Moderate	189860.96	8.66
	Severe	31401.70	1.43
Mosaic Forest-Shrubland/Grassland	Non	2174.17	0.10
	Slight	21731.66	0.99
	Moderate	3978.82	0.18
	Severe	126.44	0.01
Rangelands	Non	13875.21	0.63
	Slight	239704.65	10.93
	Moderate	104106.65	4.75
	Severe	13729.92	0.63

- **The results shows the following:**

3.3. Khabour River basin

3.3.1. Creating and Studying Agriculture drought Hazard

Creation of Agriculture drought hazard from ADI, ADV, ADF , ADC the results will include both the geographical distribution of the classes of each product and the table with areas in Ha, and percentage of each class by countries sharing the basin. Creating the Agriculture Drought Hazard ADH, from the analysis of the monthly band seasonally VHI.

- The ADI map of Khabour River basin is shown in figure (3.17), and (Table 3.19). The results shows that drought intensity is extend in 60% of the basin most of it belong to the class of low ADI and is distributed as follows 37% of in Syria, 18% in Turkey and 4.8% in Lebanon.
- The ADV map of Khabour River basin is shown in figure (3.18), and (Table 3.20). The results shows that drought variability is extend in 94% of the basin most of it belong to the class 1, that correspond to low variability ADI and is distributed as follows 60% of in Syria, 25.5% in Turkey and 6% in Lebanon.
- The ADF map of Khabour River basin is shown in figure (3.19), and (Table 3.21). The results shows that drought frequency is extend in most parts of the basin, almost, 36% are in classes 1 and 2 and 53% are in classes of 3, 4, 5 and 6 and less than 2% are in classes 7 to 10. The majority of the ADF are distributed as follows: 33% of in Syria, 18% in Turkey and 3% in Lebanon.
- The A ADC map of Khabour River basin is shown in figure (3.20), and (Table3.22). The results show that drought consecutive is very low in most parts of the basin.
- Finally, the ADH map of Khabour h river basin as shown in figure (3.21), and (Table3.23) illustrate that almost 52% of the basin is under low level of ADH, and 8% is in moderate ADH while only 0.2% is in Sever ADH.

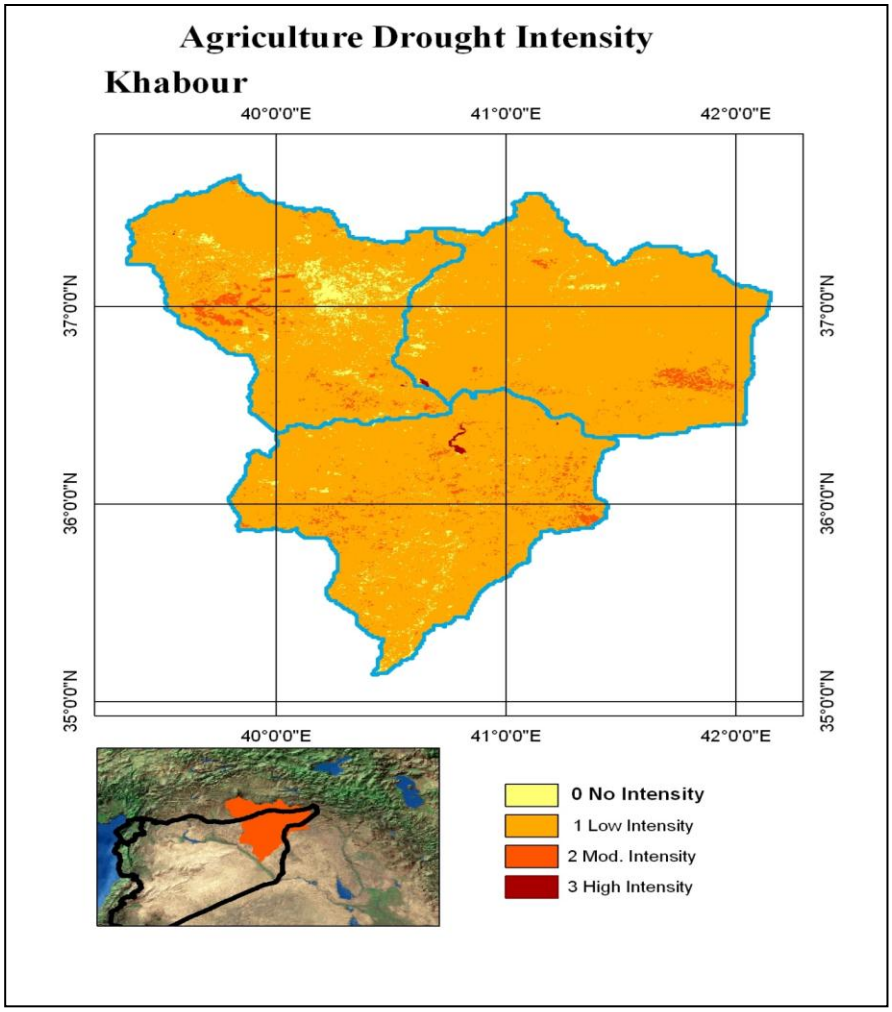


Figure 3.17 Agriculture Drought Intensity Map in Khabour River's Basin

Table 3.19. Agriculture Drought intensity Areas in Khabour River's Basin

Country	class	Area_Ha	%
Turkey	No drought	70033.21	1.93%
	Low	859699.47	23.63%
	Moderate	33211.49	0.91%
	High	108.60	0.00%
Syria	No drought	54196.87	1.49%
	Low	2336266.83	64.23%
	Moderate	67291.23	1.85%
	High	4019.16	0.11%
Iraq	No drought	593.97	0.02%
	Low	199491.78	5.48%
	Moderate	12656.85	0.35%

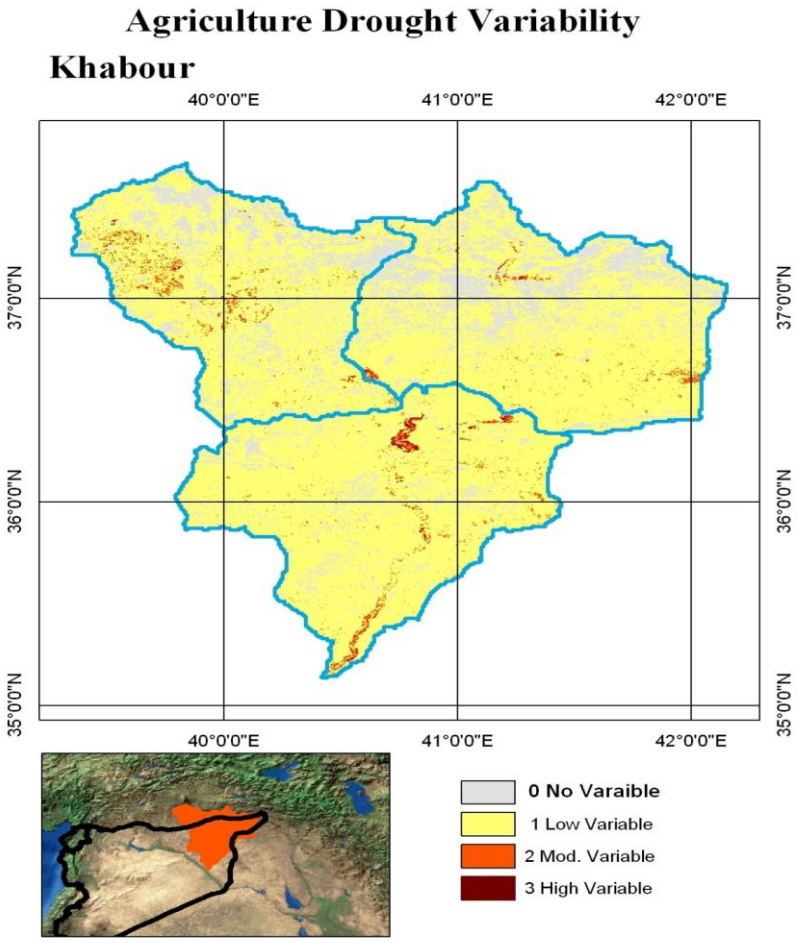


Figure 3.18 Agriculture Drought Variability Map in Khabour River's Basin

Table 3.20. Agriculture Drought Variability Areas in Khabour River's Basin

Country	Variability class	Area in Ha	%
Syria	**0**	68.58	0.00
	1	2432730.26	66.88
	2	23216.69	0.64
	3	5758.62	0.16
Turkey	**0**	354.52	0.01
	1	946132.73	26.01
	2	15767.74	0.43
	3	797.78	0.02
Iraq	**1**	211262.12	5.81
	2	1474.05	0.04
	3	6.47	0.00

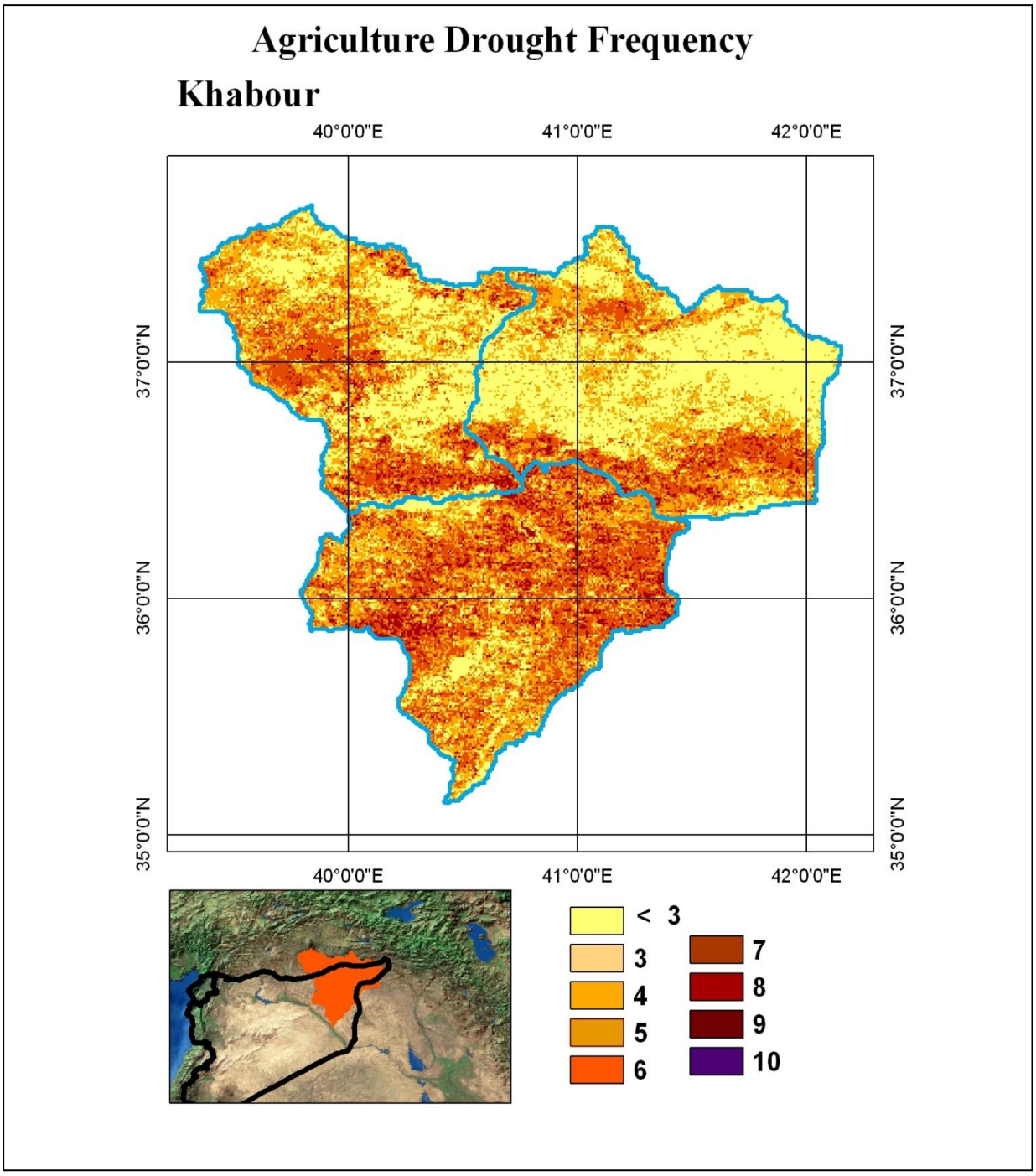


Figure 3.19. Agriculture Drought Frequency Map in Khabour River's Basin

Table 3.21. Agriculture Drought Frequency Areas in Khabour River's Basin

Country	Frequency in Classes	Area in Ha	%
Iraq	1	2270.89	0.06
	2	12366.79	0.34
	3	19839.06	0.55
	4	32513.63	0.89
	5	44941.75	1.24
	6	47443.11	1.30
	7	34218.00	0.94
	8	16791.48	0.46
	9	2357.95	0.06
Syria	0	710.10	0.02
	1	107843.86	2.96
	2	314232.84	8.64
	3	396215.84	10.89
	4	383253.21	10.54
	5	384424.40	10.57
	6	388091.10	10.67
	7	303919.74	8.36
	8	147872.05	4.07
	9	34242.06	0.94
	10	968.84	0.03
Turkey	0	1405.79	0.04
	1	39319.29	1.08
	2	121869.91	3.35
	3	186977.37	5.14
	4	208156.17	5.72
	5	179314.39	4.93
	6	133792.05	3.68
	7	71881.65	1.98
	8	18421.75	0.51
	9	1914.39	0.05

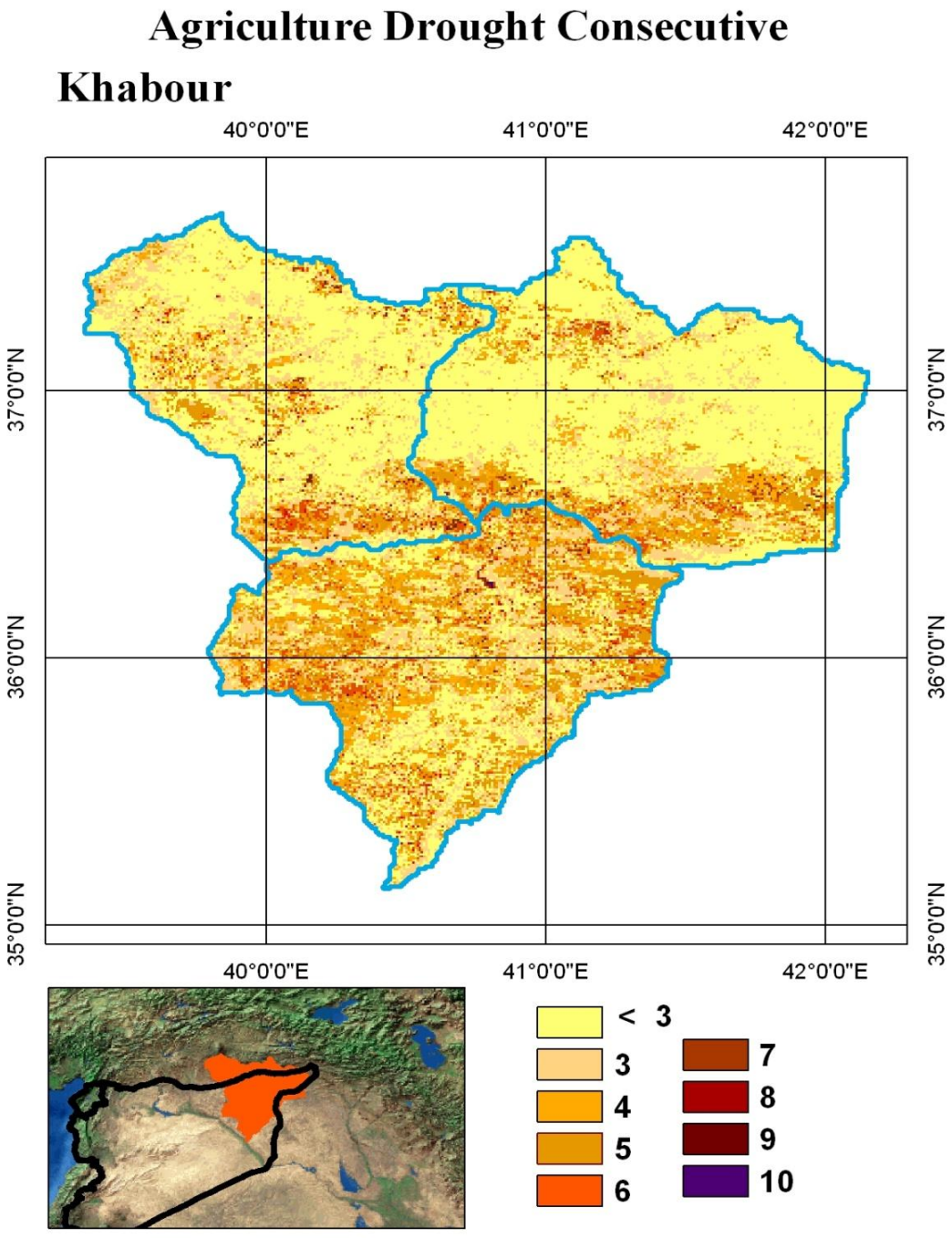


Figure 3.20 Agriculture Drought Consecutive Map in Khabour River's Basin

Table 3.22. Agriculture Drought Consecutive Areas in Khabour River's Basin

Country	Consecutive Classes	Area in Ha	%
Iraq	1	5266.02	0.14
	2	67020.79	1.84
	3	45069.27	1.24
	4	22726.89	0.62
	5	56883.82	1.56
	6	14665.61	0.40
	7	322.81	0.01
	8	142.82	0.00
	9	644.52	0.02
Syria	0	710.10	0.02
	1	265231.90	7.29
	2	848662.16	23.33
	3	547695.03	15.06
	4	320574.92	8.81
	5	333960.80	9.18
	6	114726.24	3.15
	7	7029.09	0.19
	8	14174.25	0.39
	9	8040.77	0.22
	10	968.84	0.03
Turkey	0	1405.79	0.04
	1	269949.65	7.42
	2	354076.19	9.73
	3	180256.83	4.96
	4	76911.27	2.11
	5	52984.84	1.46
	6	17021.53	0.47
	7	2362.09	0.06
	8	6490.33	0.18
	9	1594.26	0.04

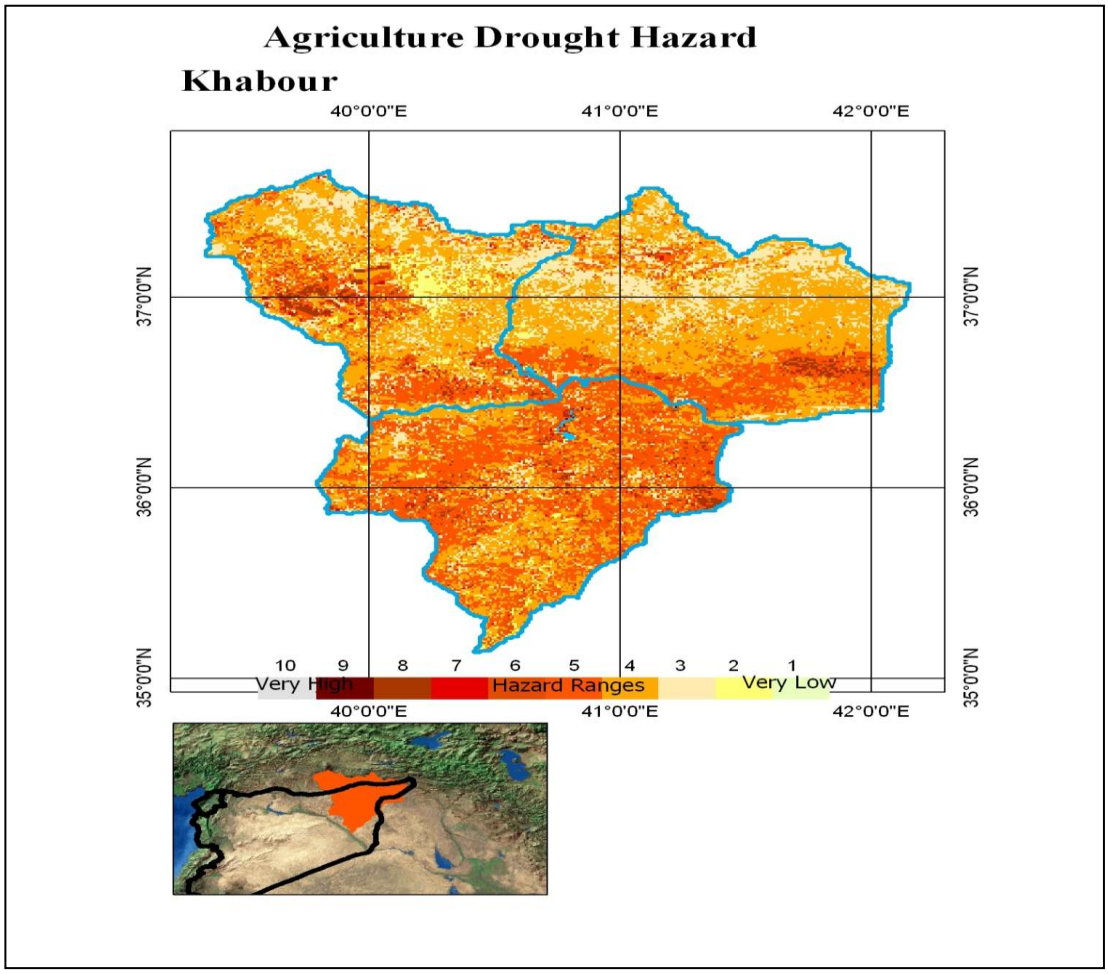


Figure 3.21. Agriculture Drought Hazard Map in Khabour River's Basin

Table 3.23.Agriculture Drought Hazard Areas in Khabour River's Basin

HAZARD Classes ADH	Area_ha	%
1	40763.84	0.72
2	150207.54	2.67
3	947922.07	16.83
4	2433853.71	43.21
5	1734061.93	30.78
6	146338.04	2.60
7	40255.17	0.71
8	132187.20	2.35
9	846.48	0.02
10	122.48	0.00

3.3.2. Agriculture drought Hazard with Land Degradation

– **Land degradation map is shown in figure (3.22), and (Table 3.24and 3.25). The results shows that**

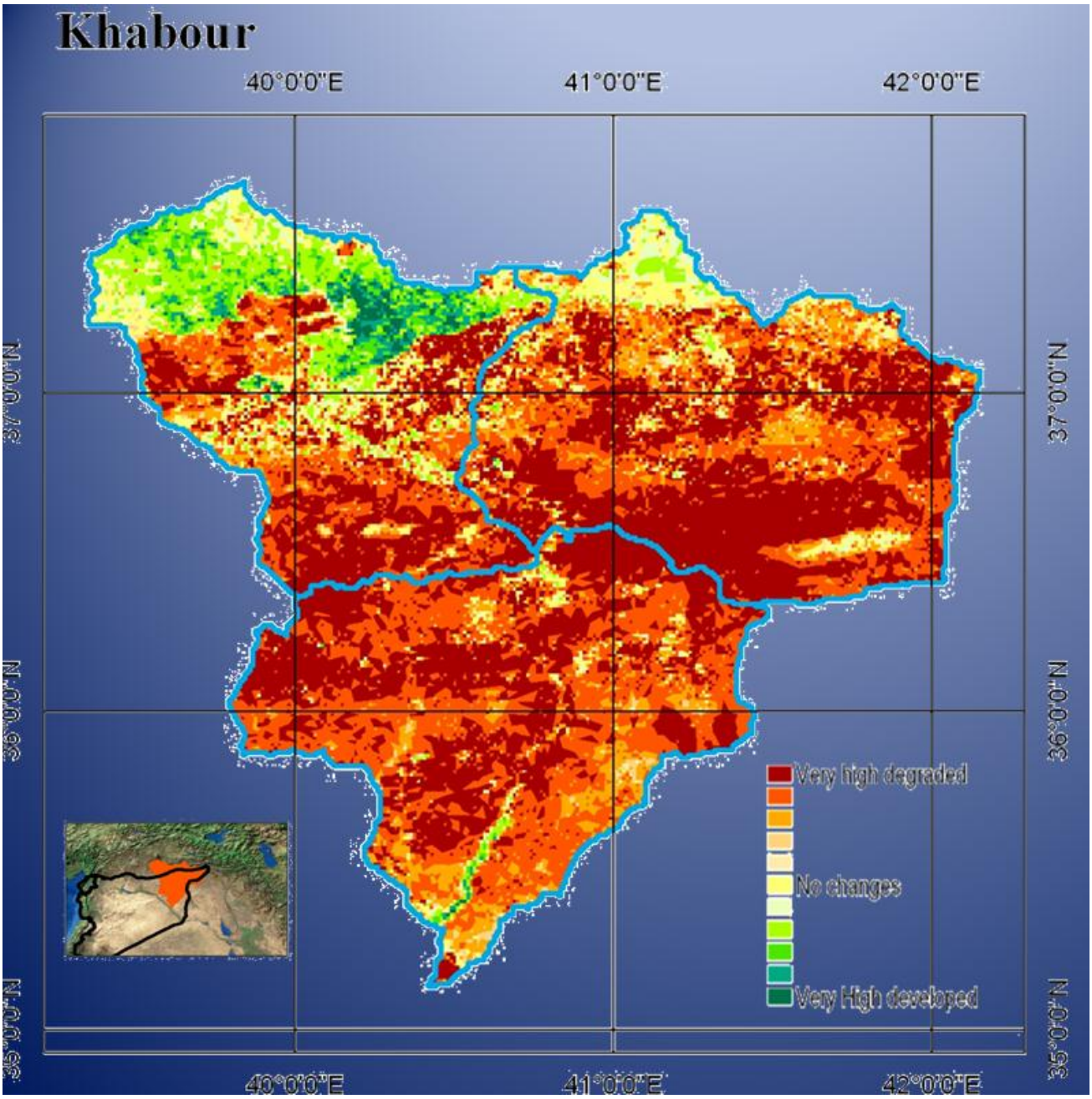


Figure 3.22. Aland Degradation Map in Khabour River's Basin

Table 3.24. Land Degradation Areas in Khabour River's Basin

Country	Area in	vh_deg	h_deg	m_deg	l_deg	vl_deg	L. Deg Total
Turkey	Ha	131117.5	142060.4	100513.3	35766.8	10934.10	420392.1
	%	3.6	3.91	2.76	0.98	0.30	11.55
Syria	Ha	1128172.3	887411.5	257675.4	52516.5	9987	2335762.7
	%	31.01	24.4	7.08	1.44	0.27	64.2
Iraq	Ha	102171.4	85642.9	11978.5	3050.9	755.3	203599
	%	2.81	2.35	0.33	0.08	0.02	5.59
TOTAL	Ha	1361461.2	1115114.8	370167.2	91334.2	21676.4	2959753.8
	%	37.42	30.66	10.17	2.5	0.59	81.34

Table 3.25.Land Developed Areas in Khabour River's Basin

Country	Area in	vh_dev	h_dev	m_dev	l_dev	vl_dev	L. Dev Total
Turkey	Ha	26873.9	45683.9	64011.9	176185	80929.8	393684.5
	%	0.74	1.26	1.76	4.84	2.22	10.82
Syria	Ha	656	1744.2	3023.7	20980.4	19754.9	46159.2
	%	0.02	0.05	0.08	0.58	0.54	1.27
Iraq	Ha	0	0	0	215.8	2265.8	2481.6
	%	0	0	0	0.01	0.06	0.07
TOTAL	Ha	27529.9	47428.1	67035.6	197381.2	102950.5	442325.3
	%	0.76	1.31	1.84	5.43	2.82	12.16

3.3.3. Agriculture drought Hazard with Land Cover/Use

– **Land Cover map is shown in figure (3.23), and the LC map legend is shown in Table (2.26), the impact of Agriculture drought Hazard in Land Cover/Use is shown in figure (3.24) and (Table 3.27).**

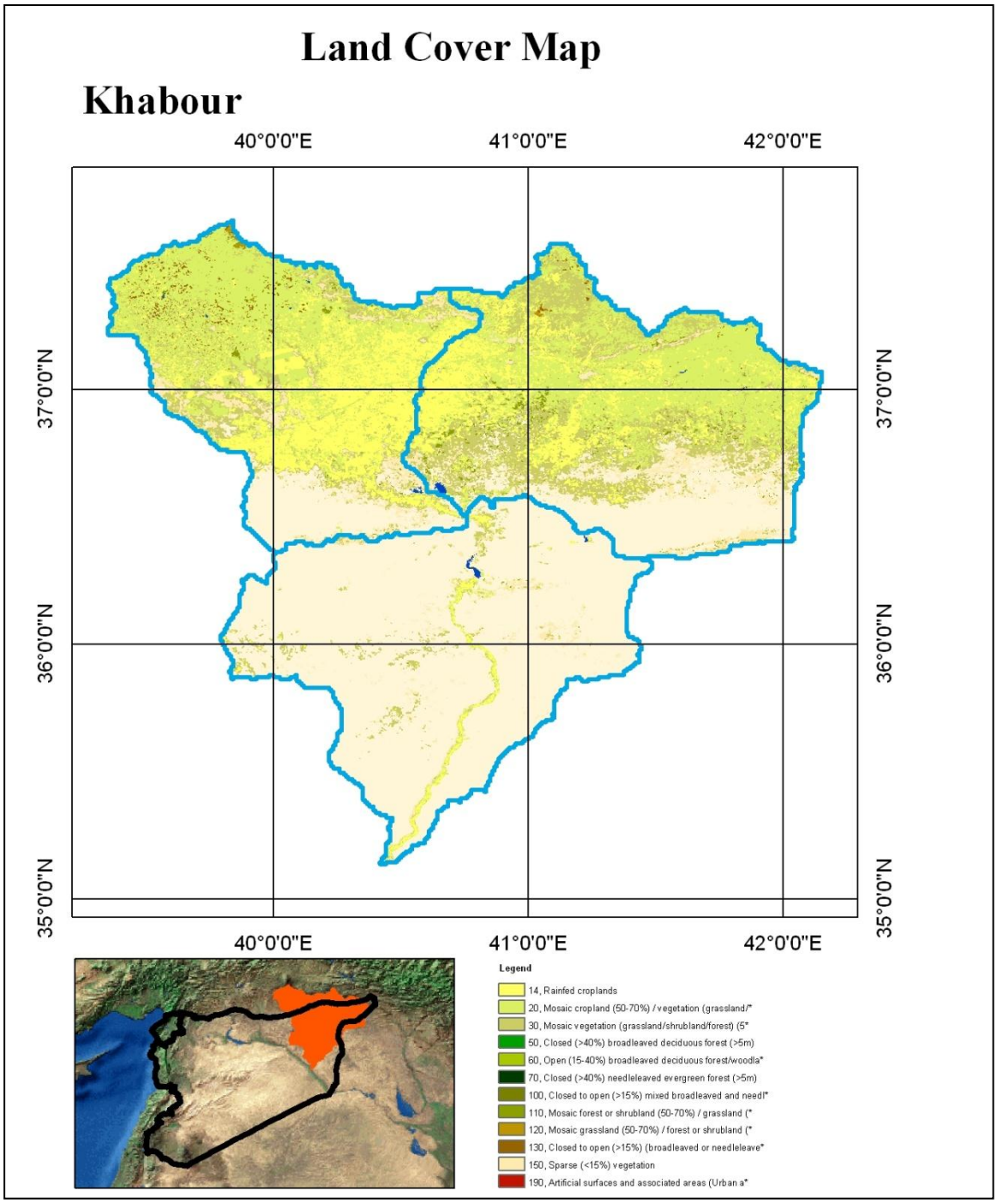


Figure 3.23. Land Cover Map in Khabour River's Basin

Table 3.26. Land Cover Legend.

Land Cover Description in Khabour River Basin	Area in		Country	Area in	
	ha	%		ha	%
Rainfed croplands			Iraq	989.29	0.00
	778954.43	13.81	Syria	480174.37	8.52
			Turkey	297790.77	5.29
Mosaic Croplands/Vegetation			Iraq	3392.67	0.06
	1313807.60	23.32	Syria	508706.00	9.03
			Turkey	801708.93	14.23
Mosaic Vegetation/Croplands			Iraq	14995.93	0.27
	742493.92	13.18	Syria	421486.81	7.48
			Turkey	306011.18	5.43
Closed broadleaved deciduous forest	59.84	0.00	Turkey	59.84	0.00
Closed needleleaved evergreen forest	23.95	0.00	Turkey	23.95	0.00
Mosaic Forest-Shrubland/Grassland			Iraq	2355.13	0.04
	40544.03	0.72	Syria	28847.02	0.51
			Turkey	9341.88	0.17
Mosaic Grassland/Forest-Shrubland			Syria	83.90	0.00
	7132.03	0.13	Turkey	7048.13	0.13
Closed to open shrubland			Syria	271.48	0.00
	17300.95	0.31	Turkey	17029.47	0.30
Sparse vegetation			Iraq	32475.38	0.58
	311147.53	5.52	Syria	207975.31	3.69
			Turkey	70696.84	1.26
Bare areas			Iraq	273151.81	4.85
	2415649.44	42.88	Syria	2136833.82	37.93
			Turkey	5663.81	0.10
Water bodies			Syria	5594.13	0.10
	6056.58	0.11	Turkey	462.45	0.01

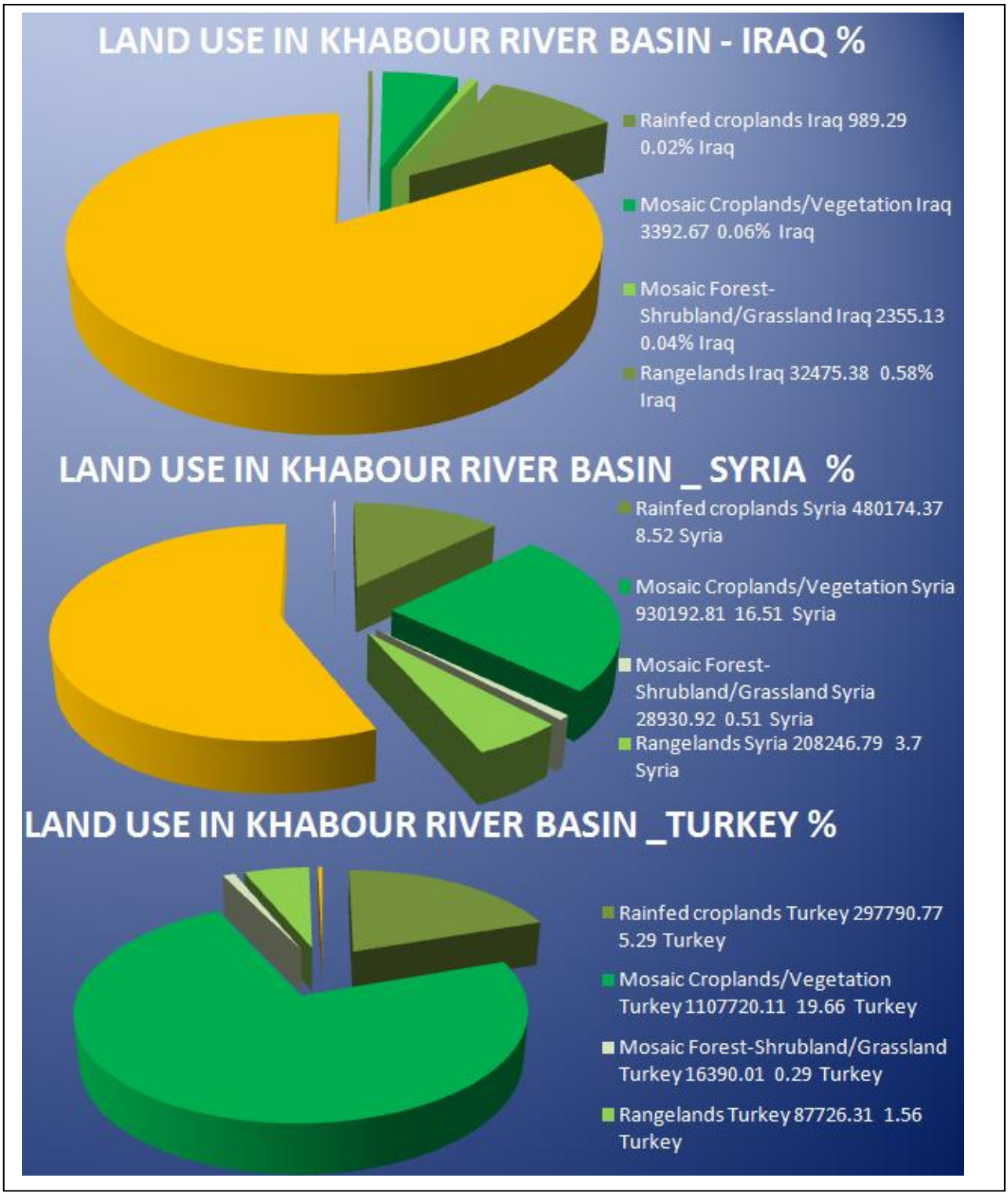


Figure 3.24. Distribution of Land Cover among Khabour Basin Countries

Table 2.27. Agriculture Drought Hazard Areas in Khabour River's Basin

Land Cover	Level of Hazard	Area in Ha	%
Rainfed croplands	Non	**81414.42**	**1.45**
	Slight	**587976.12**	**10.44**
	Moderate	**98953.15**	**1.76**
	Severe	**10571.59**	**0.19**
Mosaic Croplands/Vegetation	Non	**68432.55**	**1.21**
	Slight	**1610576.75**	**28.59**
	Moderate	**347588.84**	**6.17**
	Severe	**28916.19**	**0.51**
Forest	Non	**0**	**0**
	Slight	**36.23**	**0.00**
	Moderate	**47.56**	**0.00**
	Severe	**0**	**0**
Mosaic Forest-Shrubland/Grassland	Non	**1353.66**	**0.02**
	Slight	**38112.70**	**0.68**
	Moderate	**7748.31**	**0.14**
	Severe	**419.36**	**0.01**
Rangelands	Non	**5704.13**	**0.10**
	Slight	**195095.44**	**3.46**
	Moderate	**116238.95**	**2.06**
	Severe	**267.87**	**0.00**

– **The results shows that**

3.4. Tigris River basin

3.4.1. Creating and Studying Agriculture drought Hazard

Creation of Agriculture drought hazard from ADI, ADV, ADF , ADC the results will include both the geographical distribution of the classes of each product and the table with areas in Ha, and percentage of each class by countries sharing the basin. Creating the Agriculture Drought Hazard ADH, from the analysis of the monthly band seasonally VHI.

- The ADI map of Tigris River basin is shown in figure (3.25), and (Table 3.28). The results shows that drought intensity is extend in 60% of the basin most of it belong to the class of low ADI and is distributed as follows 37% of in Syria, 18% in Turkey and 4.8% in Lebanon.
- The ADV map of Tigris River basin is shown in figure (3.26), and (Table 3.29). The results shows that drought variability is extend in 94% of the basin most of it belong to the class 1, that correspond to low variability ADI and is distributed as follows 60% of in Syria, 25.5% in Turkey and 6% in Lebanon.
- The ADF map of Tigris River basin is shown in figure (3.27), and (Table 3.30). The results shows that drought frequency is extend in most parts of the basin, almost, 36% are in classes 1 and 2 and 53% are in classes of 3, 4, 5 and 6 and less than 2% are in classes 7 to 10. The majority of the ADF are distributed as follows: 33% of in Syria, 18% in Turkey and 3% in Lebanon.
- The A ADC map of Tigris River basin is shown in figure (3.28), and (Table 3.31). The results show that drought consecutive is very low in most parts of the basin.
- Finally, the ADH map of Tigris river basin as shown in figure (3.29), and (Table 3.32) illustrate that almost 52% of the basin is under low level of ADH, and 8% is in moderate ADH while only 0.2% is in Sever ADH.

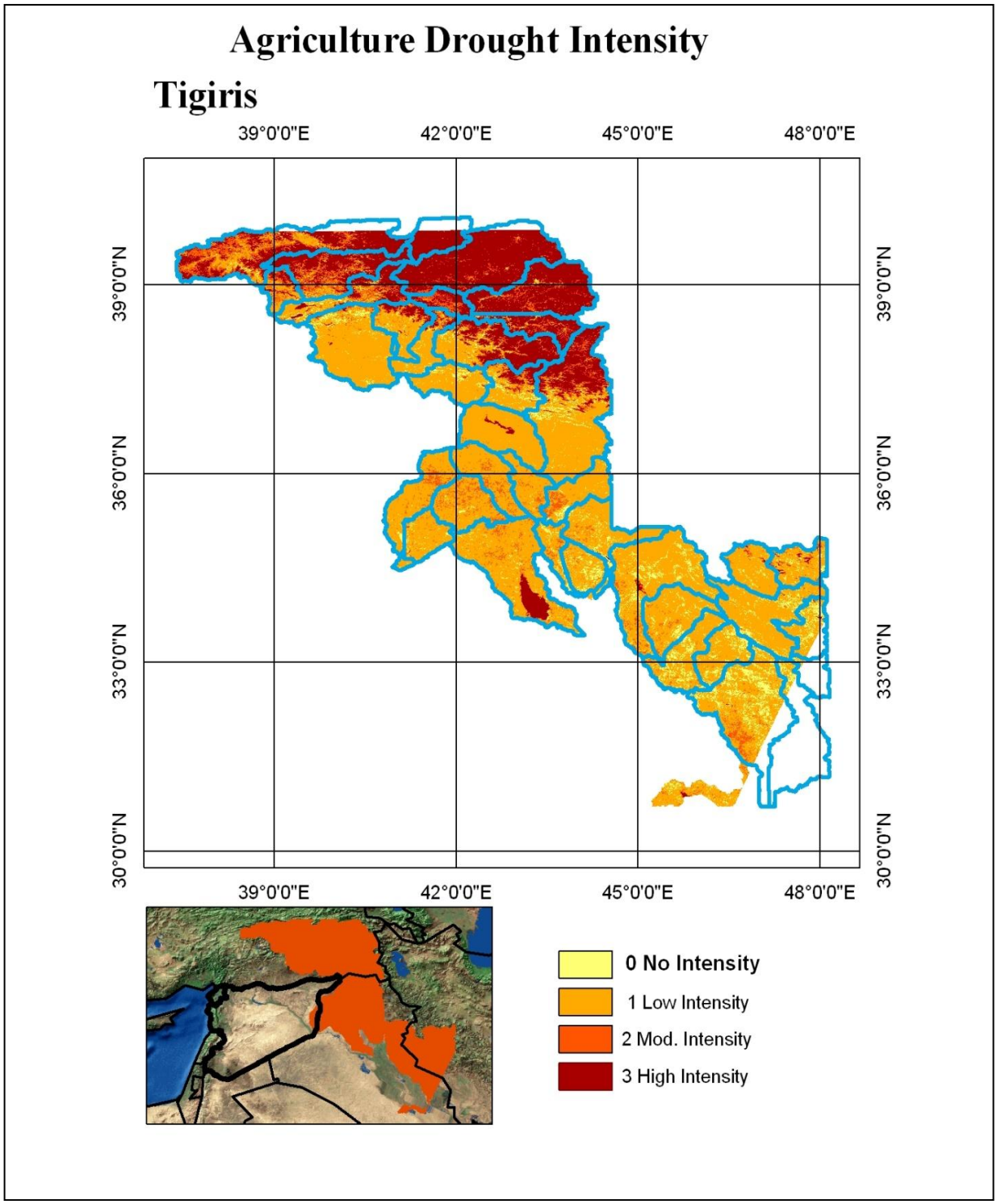


Figure 3.25 Agriculture Drought Intensity Map in Tigris River's Basin

Table 3.28. Agriculture Drought intensity Areas in Tigris River's Basin

Country	class	Area Ha	%
Turkey	No drought	368438.82	3.63%
	Low	2382394.62	23.45%
	Moderate	448168.44	4.41%
	High	378959.15	3.73%
Syria	No drought	759470.77	7.47%
	Low	2595100.63	25.54%
	Moderate	83912.62	0.83%
	High	62419.99	0.61%
Iraq	No drought	368438.82	3.63%
	Low	2382394.62	23.45%
	Moderate	448168.44	4.41%
	High	378959.15	3.73%

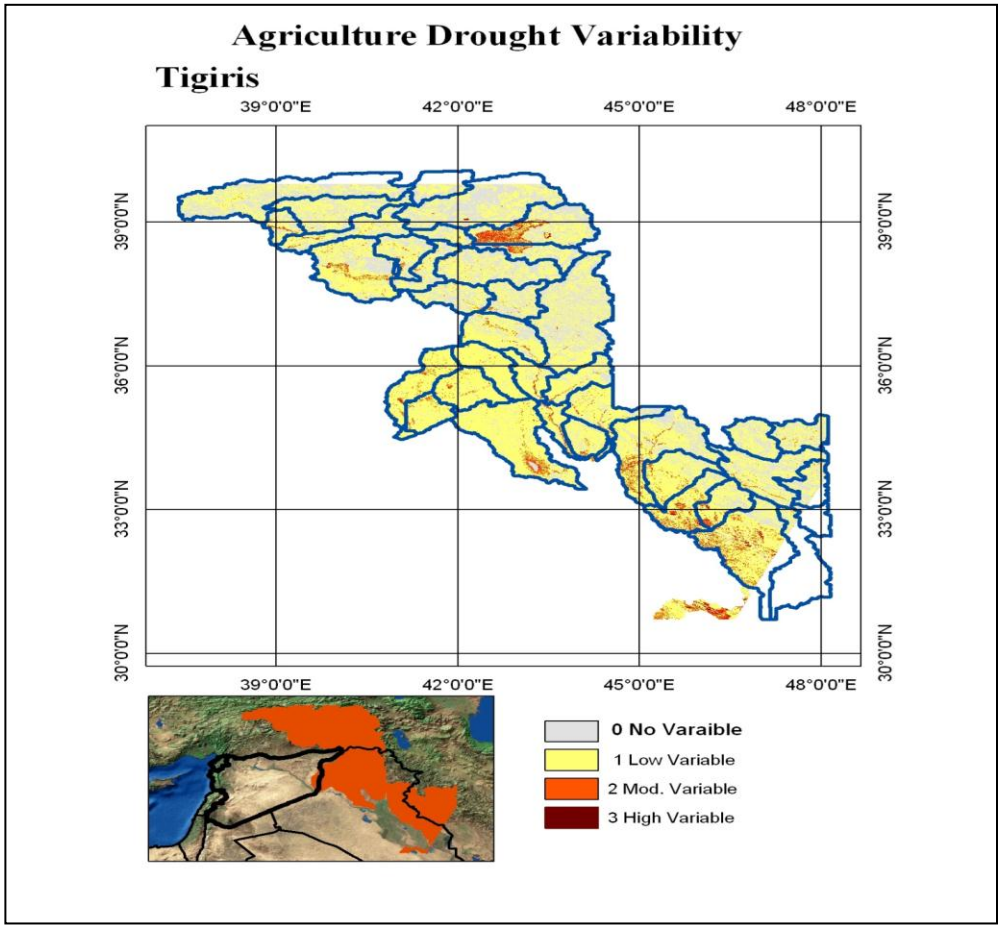


Figure 3.26. Agriculture Drought Variability Map in Tigris River's Basin

Table 3.29. Agriculture Drought Variability Areas in Tigris River's Basin

Country	Variability Classes	Area in Ha	%
Iran	0	3043.91	0.01
Iran	1	4671950.89	14.87
Iran	2	52105.61	0.17
Iran	3	2684.33	0.01
Iraq	0	3764.45	0.01
Iraq	1	12485075.70	39.74
Iraq	2	545578.91	1.74
Iraq	3	111027.21	0.35
Syria	0	35.53	0.00
Syria	1	524950.63	1.67
Syria	2	18991.02	0.06
Syria	3	2645.19	0.01
Turkey	0	140158.65	0.45
Turkey	1	12508102.20	39.81
Turkey	2	298051.85	0.95
Turkey	3	47538.88	0.15

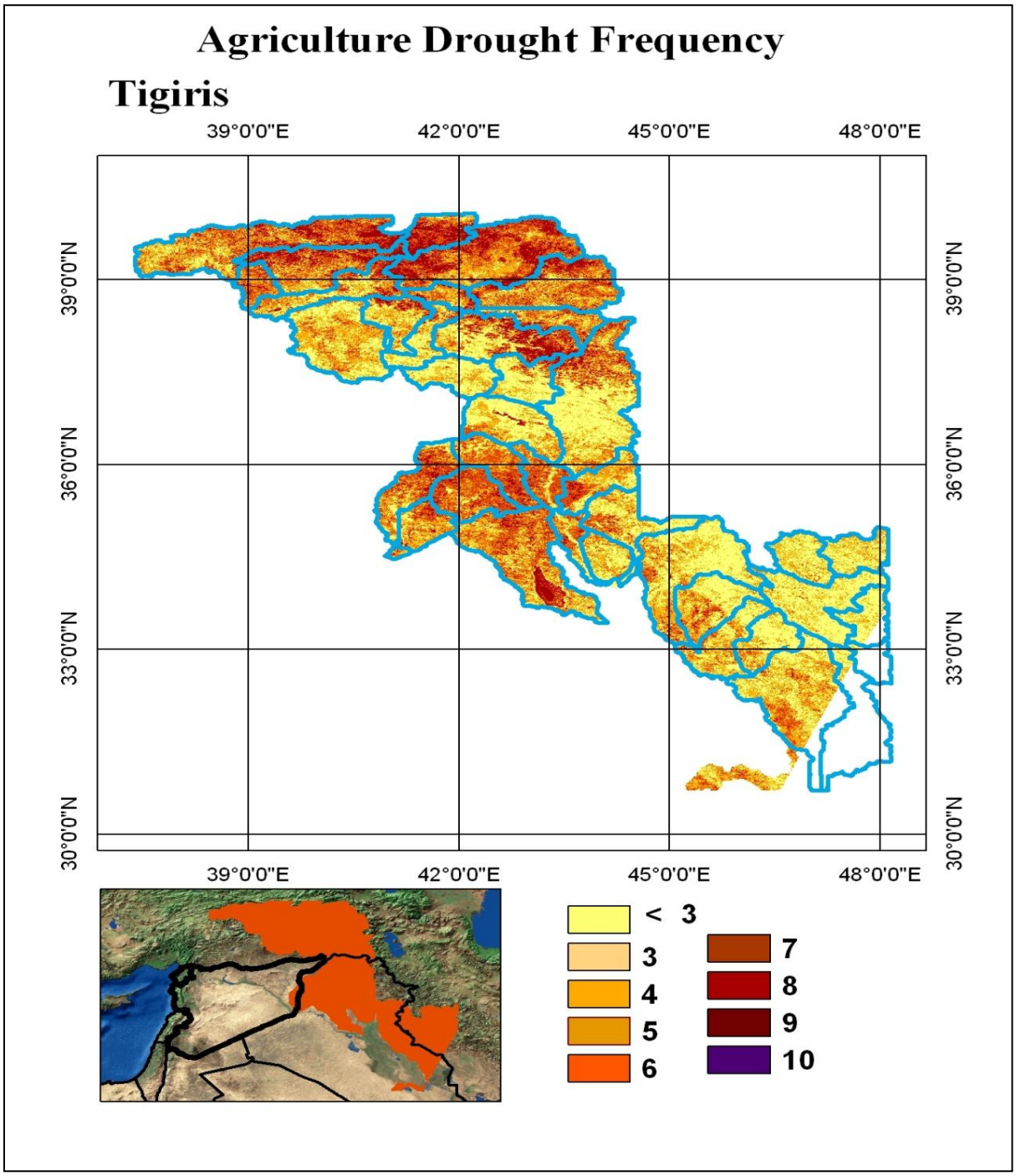


Figure 3.27. Agriculture Drought Frequency Map in Tigris River's Basin

Table 3.30. Agriculture Drought Frequency Areas in Tigris River's Basin

Country	Frequency Classes	Area in Ha	%
Iran	0	25957.66	0.08
	1	902655.52	2.64
	2	1441414.05	4.21
	3	1315551.41	3.84
	4	813245.70	2.37
	5	355394.63	1.04
	6	127558.12	0.37
	7	35484.38	0.10
	8	7805.73	0.02
	9	1221.92	0.00
	10	77.38	0.00
Iraq	0	55959.62	0.16
	1	722833.32	2.11
	2	1889893.13	5.52
	3	2468518.51	7.21
	4	2553022.61	7.45
	5	2374749.06	6.93
	6	2024897.18	5.91
	7	1448135.13	4.23
	8	650596.76	1.90
	9	114457.42	0.33
	10	47746.93	0.14
Syria	0	4318.98	0.01
	1	22680.55	0.07
	2	73946.23	0.22
	3	99547.93	0.29
	4	99857.29	0.29
	5	102942.81	0.30
	6	92101.91	0.27
	7	60889.37	0.18
	8	22424.32	0.07
	9	2117.08	0.01
Turkey	0	45746.90	0.13
	1	440046.42	1.28
	2	1131664.22	3.30
	3	1661377.24	4.85
	4	2015012.04	5.88
	5	2119208.49	6.19
	6	2091309.54	6.11
	7	1863392.69	5.44
	8	1523066.13	4.45
	9	1012512.04	2.96
	10	393225.13	1.15

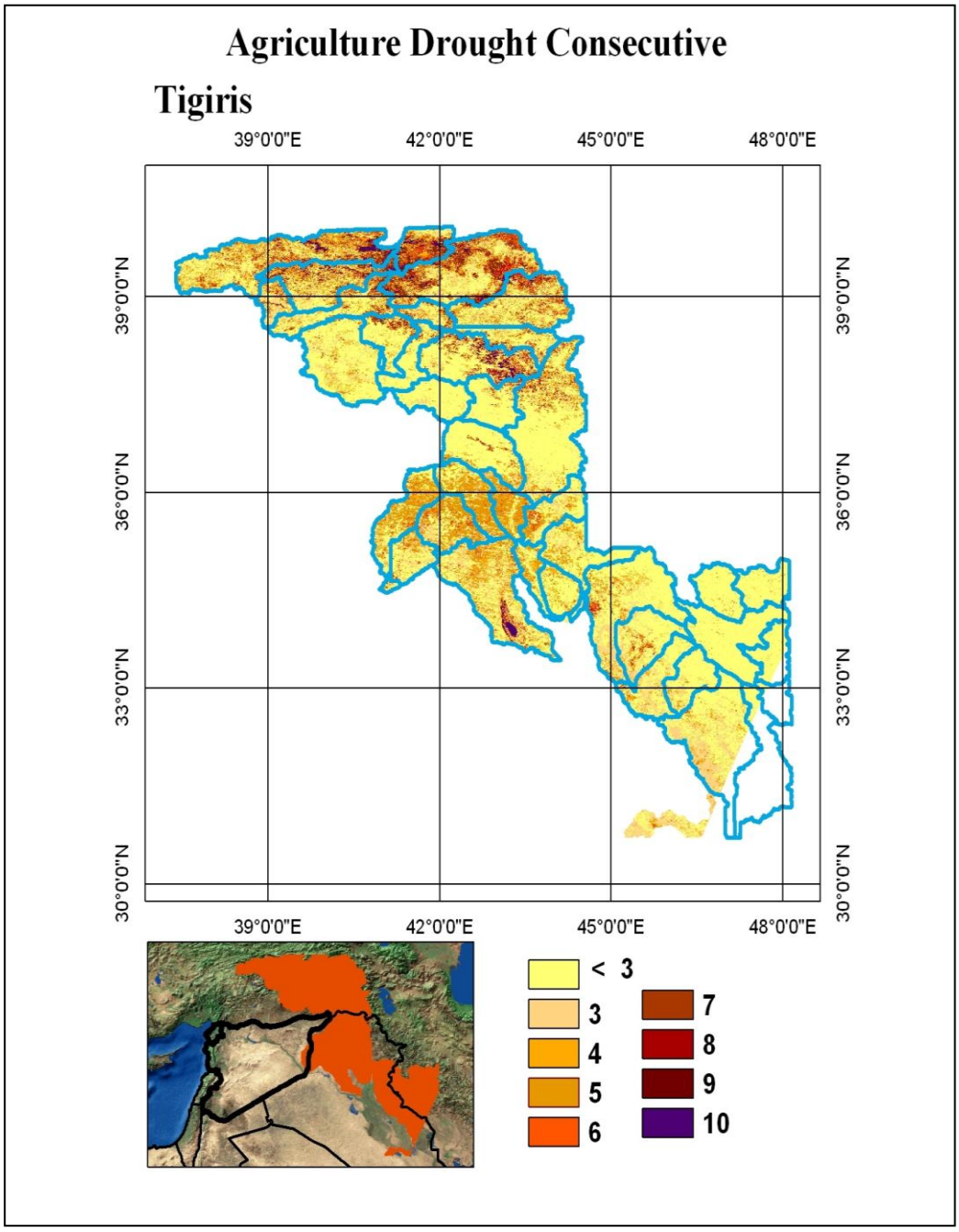


Figure 3.28. Agriculture Drought Consecutive Map in Tigris River's Basin

Table 3.31. Agriculture Drought Consecutive Areas in Tigris River's Basin

Country	Consecutive Classes	Area in Ha	
Iran	0	26022.36	0.08
	1	3195460.12	9.33
	2	1382093.49	4.03
	3	268195.16	0.78
	4	54920.69	0.16
	5	13836.64	0.04
	6	16003.58	0.05
	7	892.64	0.00
	8	412.92	0.00
	9	1543.93	0.00
Iraq	0	57539.28	0.17
	1	2756194.08	8.05
	2	4589750.37	13.40
	3	3310377.13	9.66
	4	1293224.65	3.78
	5	1884371.58	5.50
	6	401152.96	1.17
	7	58517.73	0.17
	8	39215.61	0.11
	9	18045.92	0.05
	10	47877.36	0.14
Syria	0	3723.94	0.01
	1	54325.02	0.16
	2	205791.20	0.60
	3	104882.22	0.31
	4	57579.29	0.17
	5	103207.93	0.30
	6	7415.43	0.02
	7	1951.83	0.01
	8	2375.95	0.01
	9	1401.57	0.00
Turkey	0	46022.81	0.13
	1	2753414.11	8.04
	2	3221047.32	9.40
	3	2504359.40	7.31
	4	1603231.77	4.68
	5	1070362.01	3.12
	6	1061074.14	3.10
	7	384957.76	1.12
	8	533721.41	1.56
	9	722798.79	2.11
	10	395271.37	1.15

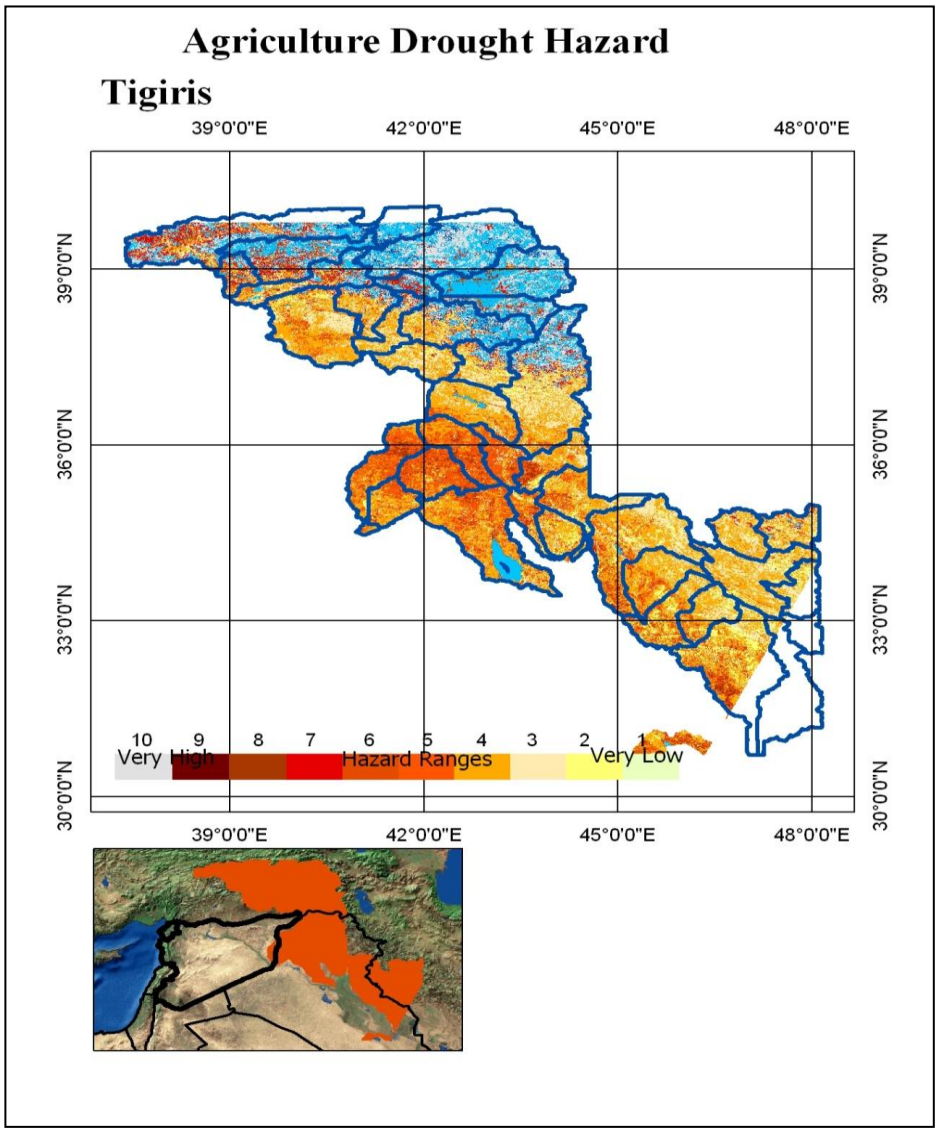


Figure 3.29. Agriculture Drought Hazard Map in Tigris River's Basin

Table 3.32. Agriculture Drought Hazard Areas in Tigris River's Basin

HAZARD Classes ADH	Area_ha	%
1	818522.53	1.72
2	2272928.98	4.78
3	7168652.99	15.0
4	14244827.65	29.94
5	5798889.18	12.19
6	1453121.96	3.05
7	2365038.42	4.97
8	1438508.90	3.02
9	22288.54	0.05
10	4598858.45	9.67

3.4.2. Agriculture drought Hazard with Land Degradation

– **Land degradation map is shown in figure (3.30), and (Table3.33 and 3.34). The results shows that**

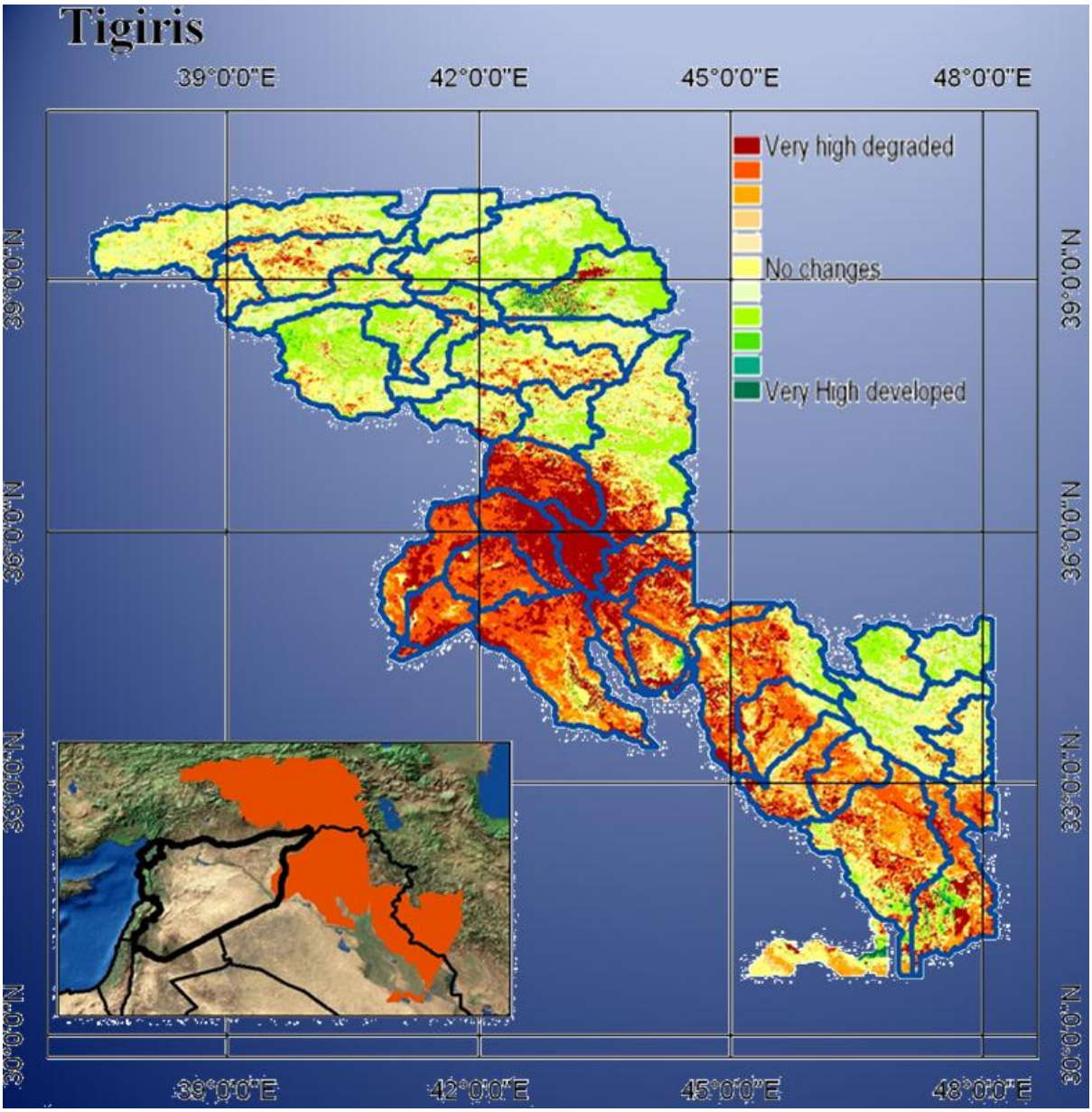


Figure 3.30. Aland Degradation Map in Tigris River's Basin

Table 3.33. Land Degradation Areas in Tigris River's Basin

Country	Area in	vh_deg	h_deg	m_deg	l_deg	vl_deg	L. Deg Total
Turkey	Ha	263833.3	477604.1	605922.2	379287.7	163912.6	1890559.9
	%	0.77	1.39	1.77	1.11	0.48	5.52
Syria	Ha	161379.3	206246.6	95495.6	23710.6	6047.4	492879.5
	%	0.47	0.6	0.28	0.07	0.02	1.44
Iraq	Ha	3985434.9	4318857.8	2292241.7	696027	193708.4	11486269.8
	%	11.63	12.61	6.69	2.03	0.57	33.53
Iran	Ha	215183.6	939662.2	784428.5	256581.6	81805.8	2277661.7
	%	0.63	2.74	2.29	0.75	0.24	6.65
TOTAL	Ha	4625831.1	5942370.7	3778088	1355606.9	445474.2	16147370.9
	%	13.5	17.34	11.03	3.96	1.31	47.14

Table 3.34 Land Developed Areas in Tigris River's Basin

Country	Area in	vh_dev	h_dev	m_dev	l_dev	vl_dev	L. Dev Total
Turkey	Ha	42113.2	35995.7	103684.7	3439660	3635964.5	7257418.1
	%	0.12	0.11	0.3	10.04	10.61	21.18
Syria	Ha	0	0	0	2410.5	5720.7	8131.2
	%	0	0	0	0.01	0.02	0.03
Iraq	Ha	53045.6	32899	57605.3	840922.7	578962.8	1563435.4
	%	0.15	0.1	0.17	2.45	1.69	4.56
Iran	Ha	1250.2	2166.6	13722	941553.7	1037652.6	1996345.1
	%	0	0.01	0.04	2.75	3.03	5.83
TOTAL	Ha	96409	71061.3	175012	5224546.9	5258300.6	10825329.8
	%	0.27	0.22	0.51	15.25	15.35	31.6

3.4.3. Agriculture drought Hazard with Land Cover/Use

– **Land Cover map is shown in figure (3.31), and the LC map legend is shown in Table (3.35), the impact of Agriculture drought Hazard in Land Cover/Use is shown in figure (3.32) and (Table 3.36).**

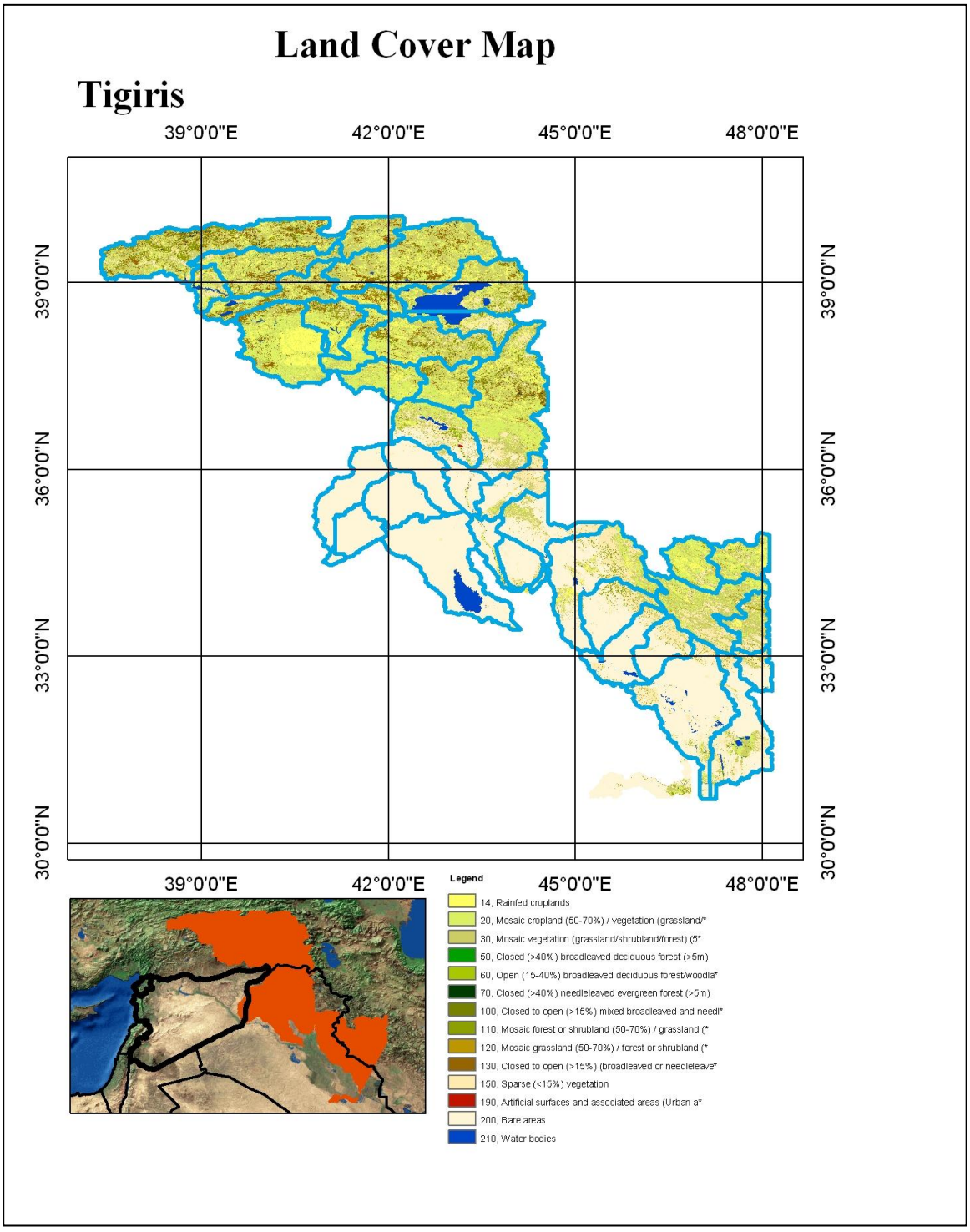


Figure 3.31 Land Cover Map in Tigris River's Basin

Table. 3.35 Land Cover Legend.

Land Cover Description I Tigris River Basin	Area in		Country	Area in	
	ha	%		ha	%
Rainfed croplands	3423213.70	6.6	Iran	382172.50	0.73
			Iraq	346698.08	0.66
			Syria	15814.06	0.03
			Turkey	2678529.07	5.13
Mosaic Croplands/Vegetation	8136863.90	15.6	Iran	1368616.21	2.62
			Iraq	1473406.76	2.82
			Syria	93289.03	0.18
			Turkey	5201551.89	9.96
Mosaic Vegetation/Croplands	13027065.36	24.9	Iran	2098438.75	4.02
			Iraq	1844301.65	3.53
			Syria	10051.11	0.02
			Turkey	9074273.85	17.37
Closed broadleaved deciduous forest	22835.25	0.0	Iran	11.19	0.00
			Iraq	140.52	0.00
			Turkey	22683.54	0.04
Open broadleaved deciduous forest	11.49	0.00	Iraq	11.49	0.00
Closed needleleaved evergreen forest	51592.53	0.1	Iran	16.55	0.00
			Iraq	2554.04	0.00
			Turkey	49021.94	0.09
Closed to open mixed broadleaved and needleleaved forest	5456.25	0.0	Turkey	5456.25	0.01
Mosaic Forest-Shrubland/Grassland	1778547.32	3.4	Iran	299039.45	0.57
			Iraq	275743.87	0.53
			Syria	804.51	0.00
			Turkey	1202959.49	2.30
Mosaic Grassland/Forest-Shrubland	341526.13	0.7	Iran	29949.44	0.06
			Iraq	40148.57	0.08
			Syria	60.66	0.00
			Turkey	271367.46	0.52
Closed to open shrubland	1845667.47	3.5	Iran	7723.78	0.01
			Iraq	57560.61	0.11
			Syria	592.91	0.00
			Turkey	1779790.17	3.41
Closed to open grassland	396.05	0.00	Turkey	396.05	0.00
Sparse vegetation	5039018.71	9.6	Iran	1868877.47	3.58
			Iraq	2315065.83	4.43
			Syria	3089.73	0.01
			Turkey	851985.68	1.63
Closed to open vegetation regularly flooded	40.03	0.0	Iraq	40.03	0.00
Artificial areas	3274.79	0.0	Iraq	3274.79	0.01
Bare areas	17447648.73	33.4	Iran	1946513.41	3.73
			Iraq	14602136.80	27.95
			Syria	698412.33	1.34
			Turkey	200586.19	0.38
Water bodies	1126323.34	2.2	Iran	685.52	0.00
			Iraq	407303.46	0.78
			Syria	665.95	0.00
			Turkey	717668.42	1.37

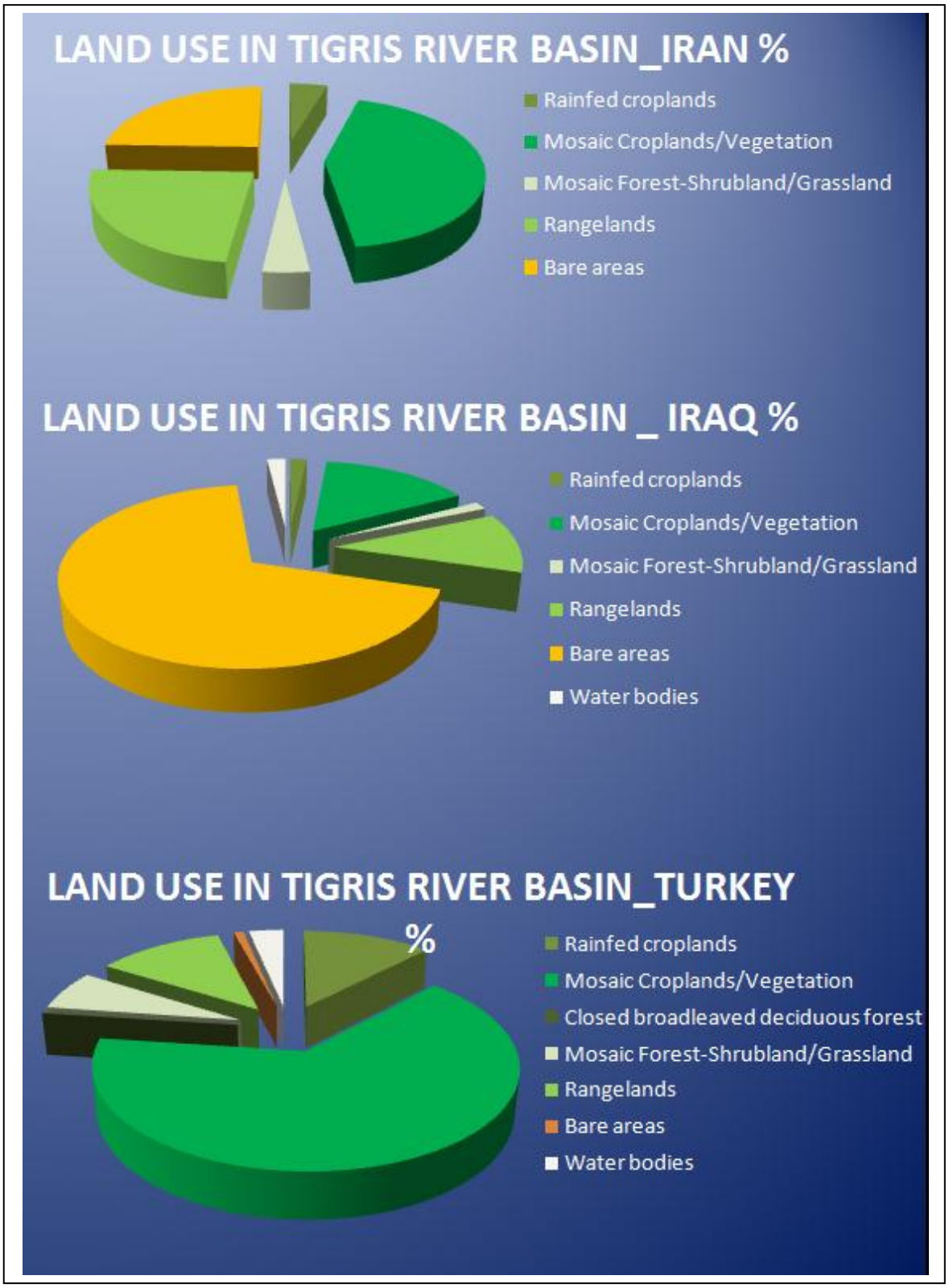


Figure 3.32 Distribution of Land Cover among Tigris Basin Countries

Table 3.36. Agriculture Drought Hazard Areas in Tigris River's Basin

Land Cover	Level of Hazard	Area in Ha	%
Rainfed croplands	Non	160174.86	0.34
	Slight	1465174.26	3.08
	Moderate	396181.88	0.83
	Severe	562063.83	1.18
Mosaic Croplands/Vegetation	Non	1069843.68	2.25
	Slight	8575030.75	18.02
	Moderate	2157650.44	4.54
	Severe	1778049.32	3.74
Forest	Non	2051.12	0.00
	Slight	10527.97	0.02
	Moderate	11357.12	0.02
	Severe	18971.71	0.04
Mosaic Forest-Shrubland/Grassland	Non	127958.43	0.27
	Slight	748372.17	1.57
	Moderate	296787.23	0.62
	Severe	356166.10	0.75
Rangelands	Non	490561.13	1.03
	Slight	3284250.88	6.90
	Moderate	809017.40	1.70
	Severe	695446.38	1.46

– **The results shows the following:**

3.5. Joint Area between Tigris & Euphrates River's basins

3.5.1. Creating and Studying Agriculture drought Hazard

Creation of Agriculture drought hazard from ADI, ADV, ADF , ADC the results will include both the geographical distribution of the classes of each product and the table with areas in Ha, and percentage of each class by countries sharing the basin. Creating the Agriculture Drought Hazard ADH, from the analysis of the monthly band seasonally VHI.

The ADI map of Joint Area between Tigris & Euphrates

- River basin is shown in figure (3.33), and (Table 3.37). The results shows that drought intensity is extend in 60% of the basin most of it belong to the class of low ADI and is distributed as follows 37% of in Syria, 18% in Turkey and 4.8% in Lebanon.

The ADV map of Joint Area between Tigris & Euphrates

- River basin is shown in figure (3.34), and (Table 3.38). The results shows that drought variability is extend in 94% of the basin most of it belong to the class 1, that correspond to low variability ADI and is distributed as follows 60% of in Syria, 25.5% in Turkey and 6% in Lebanon.

The ADF map of Joint Area between Tigris & Euphrates

- River basin is shown in figure (3.35), and (Table 3.39). The results shows that drought frequency is extend in most parts of the basin, almost, 36% are in classes 1 and 2 and 53% are in classes of 3, 4, 5 and 6 and less than 2% are in classes 7 to 10. The majority of the ADF are distributed as follows: 33% of in Syria, 18% in Turkey and 3% in Lebanon.

The A ADC map of Joint Area between Tigris & Euphrates

- River basin is shown in figure (3.36), and (Table3.40). The results show that drought consecutive is very low in most parts of the basin.

Finally, the ADH map of Joint Area between Tigris & Euphrates

- river basin as shown in figure (3.37), and (Table 3.41) illustrate that almost 52% of the basin is under low level of ADH, and 8% is in moderate ADH while only 0.2% is in Sever ADH.

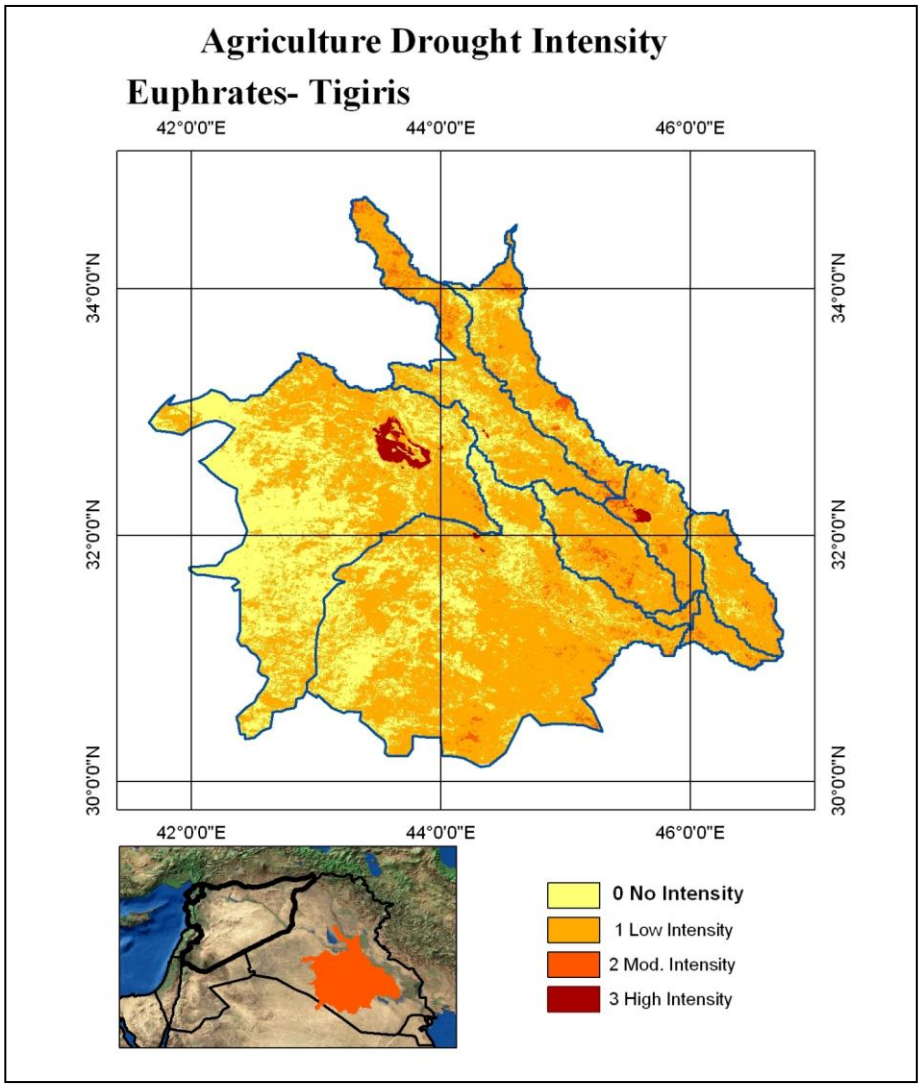


Figure 3.33 Agriculture Drought Intensity Map in Joint Area between Tigris & Euphrates River's basins

Table 3.37.Agriculture Drought intensity Areas in Joint Area between Tigris & Euphrates River's basins

Country	class	Area Ha	%
Iraq	No drought	3566880.70	31.24%
	Low	7511119.42	65.78%
	Moderate	239781.04	2.10%
	High	101131.94	0.89%

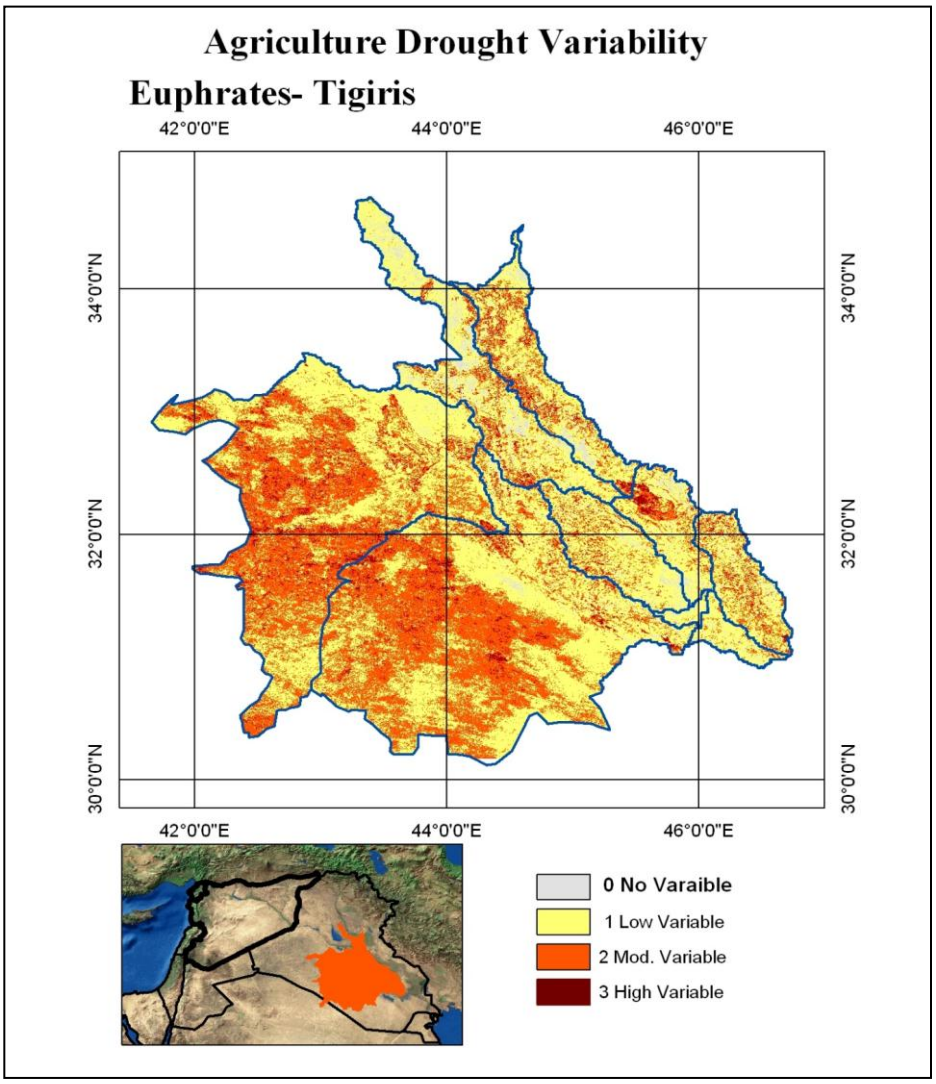


Figure 3.34. Agriculture Drought Variability Map in Joint Area between Tigris & Euphrates River's basins

Table 3.38. Agriculture Drought Variability Areas in Joint Area between Tigris & Euphrates River's basins

Country	Variability Classes	Area in Ha	%
Iraq	0	**3370.14**	**0.04%**
Iraq	1	**6609594.17**	**69.16%**
Iraq	2	**2650492.13**	**27.73%**
Iraq	3	**293054.86**	**3.07%**

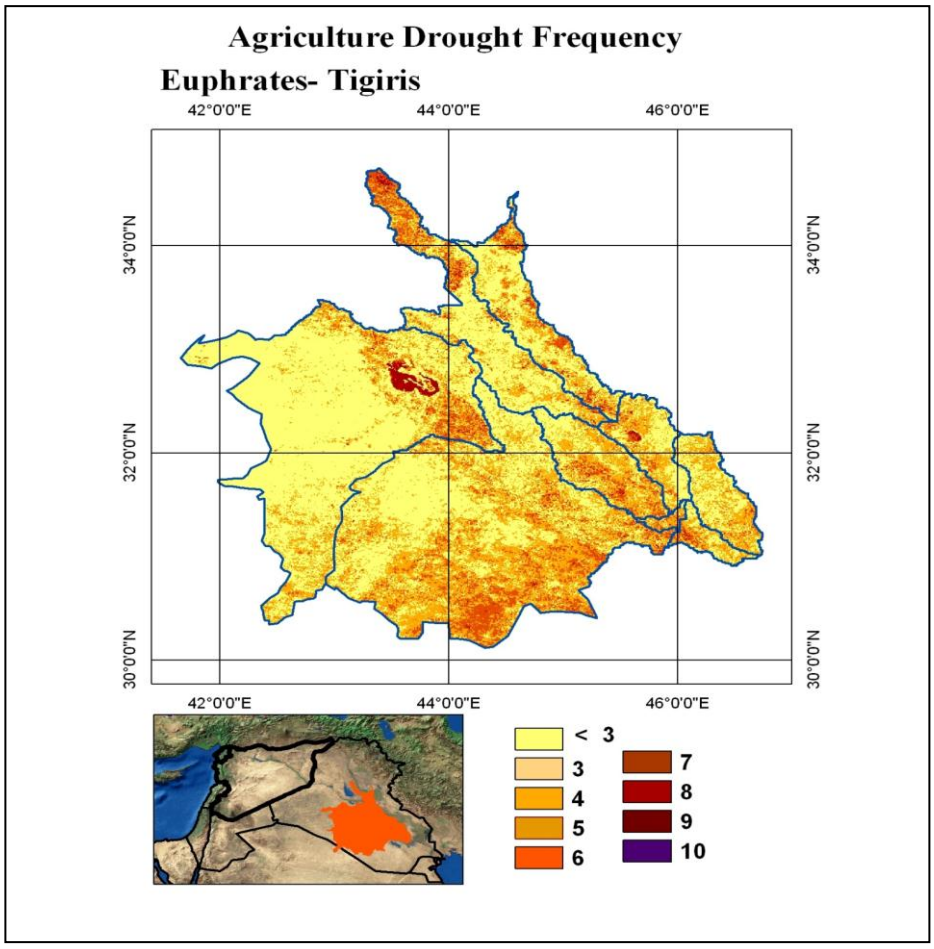


Figure 3.35 Agriculture Drought Frequency Map in Joint Area between Tigris & Euphrates River's basins

Table 3.39Agriculture Drought Frequency Areas in Joint Area between Tigris & Euphrates River's basins

Country	Frequency Classes	Area in Ha	%
Iraq	0	271582.82	2.38%
	1	1477242.36	12.94%
	2	2334628.99	20.45%
	3	2454156.96	21.49%
	4	2082205.03	18.23%
	5	1525455.67	13.36%
	6	828752.70	7.26%
	7	313654.01	2.75%
	8	75499.00	0.66%
	9	28229.02	0.25%
	10	27581.99	0.24%

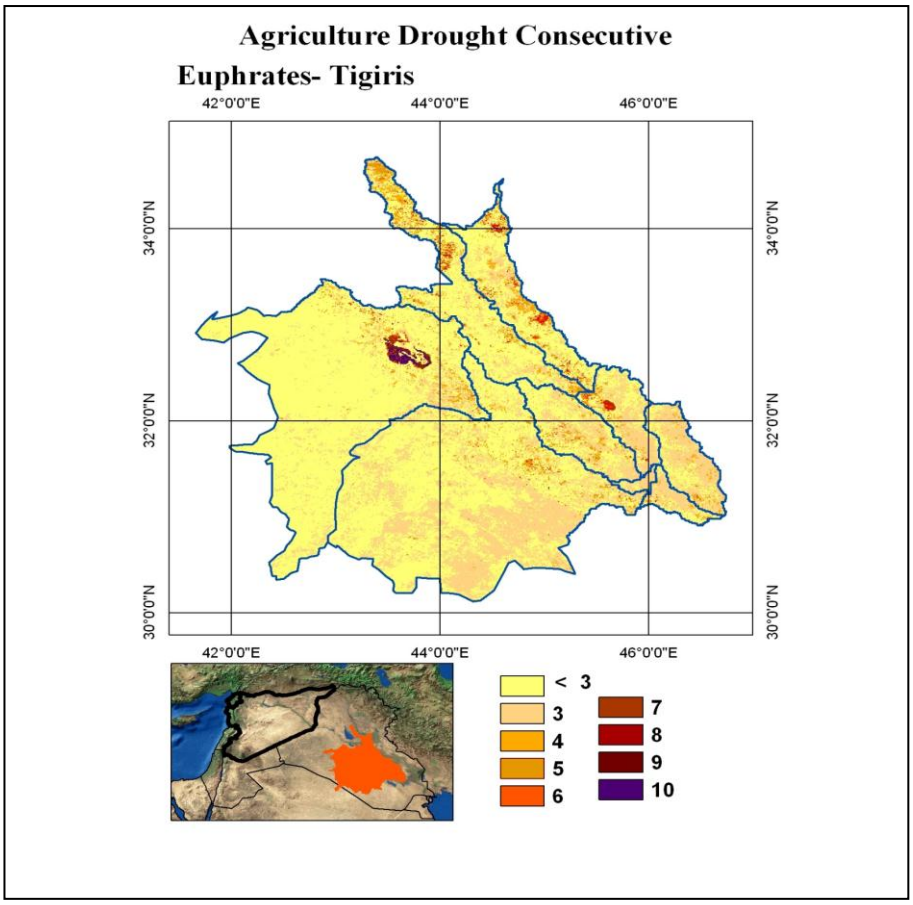


Figure 3.36 Agriculture Drought Consecutive Map in Joint Area between Tigris & Euphrates River's basins

Table 3.40 Agriculture Drought Consecutive Areas in Joint Area between Tigris & Euphrates River's basins

Country	Consecutive Classes	Area in Ha	%
Iraq	0	275577.16	2.41%
	1	4048539.30	35.45%
	2	2952931.18	25.86%
	3	3425484.86	30.00%
	4	377437.07	3.31%
	5	167513.55	1.47%
	6	55658.13	0.49%
	7	39829.04	0.35%
	8	30626.49	0.27%
	9	17632.87	0.15%
	10	27758.88	0.24%

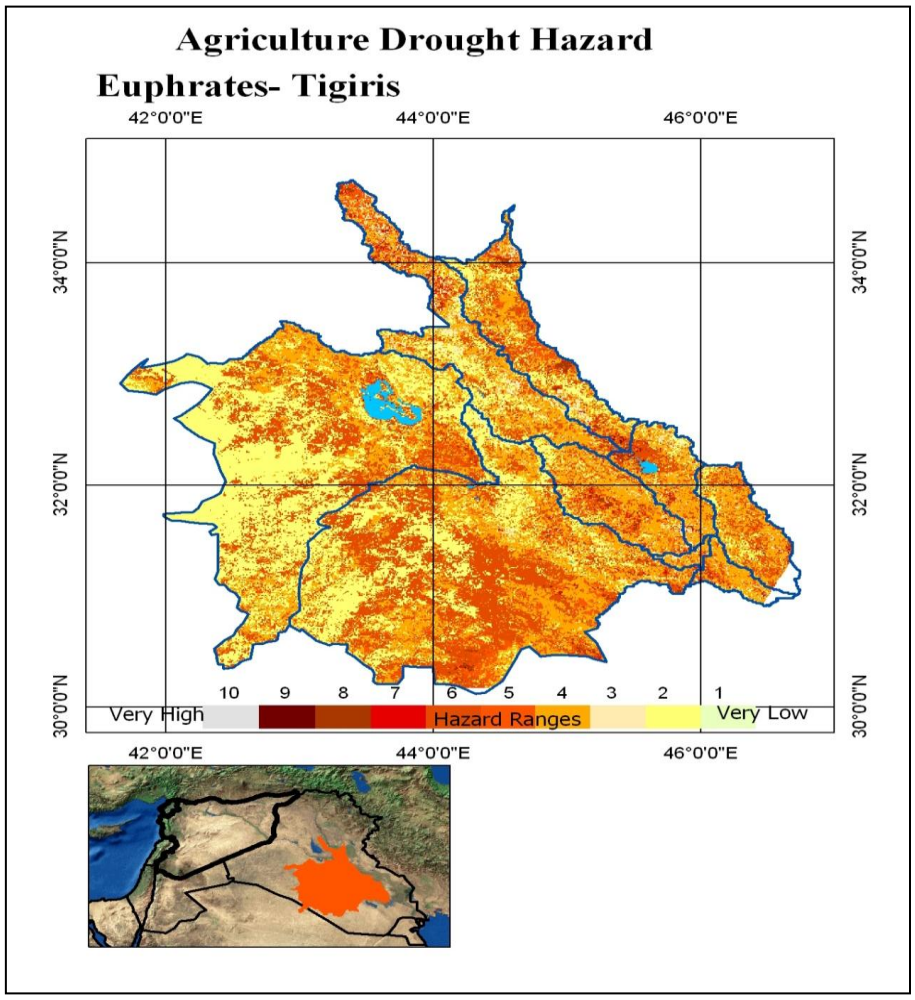


Figure 3.37 Agriculture Drought Hazard Map in Joint Area between Tigris & Euphrates River's basins

Table 3.41Agriculture Drought Hazard Areas in Tigris River's Basin

HAZARD Classes ADH	Area_ha	%
1	120194.46	0.77
2	4790599.15	30.56
3	464996.58	2.97
4	4936231.60	31.49
5	1040818.70	6.64
6	3852177.40	24.57
7	124170.39	0.79
8	196349.35	1.25
9	9308.29	0.06
10	460.50	0.00

3.5.2. Agriculture drought Hazard with Land Degradation

– **Land degradation map is shown in figure (3.38), and (Table 3.42 and 3.43). The results shows that**

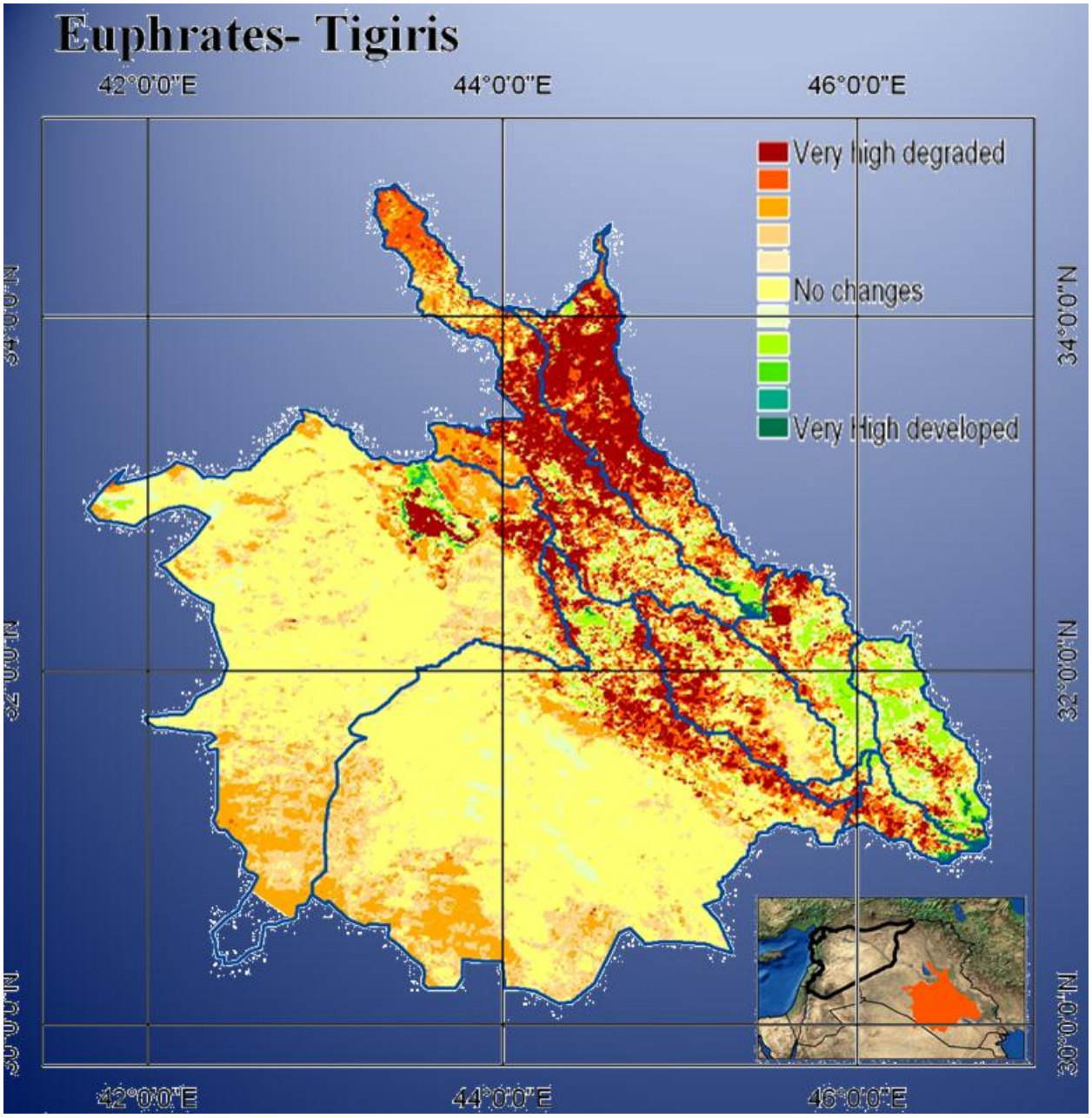


Figure 3.38. Aland Degradation Map in Joint Area between Tigris & Euphrates River's basins

Table 3.42 Land Degradation Areas in Joint Area between Tigris & Euphrates River's basins

Country	Area in	vh_deg	h_deg	m_deg	l_deg	vl_deg	L. Deg Total
Iraq	Ha	1242360.70	911735.30	1419344.20	1389235.50	471419.8	5434095.50
	%	10.9	8	12.4	12.2	4.1	47.60

Table 3.43. Land Developed Areas in Tigris River's Basin

Country	Area in	vh_dev	h_dev	m_dev	l_dev	vl_dev	L. Dev Total
Iraq	Ha	521908.5	409269.2	27755.1	20238.9	37172.8	5984805.5
	%	4.6	3.6	0.2	0.2	0.3	52.4

4.5.3. Agriculture drought Hazard with Land Cover/Use

– **Land Cover map is shown in figure (3.39), and the LC map legend is shown in Table (3.44), the impact of Agriculture drought Hazard in Land Cover/Use is shown in figure (3.40) and (Table 3.45).**

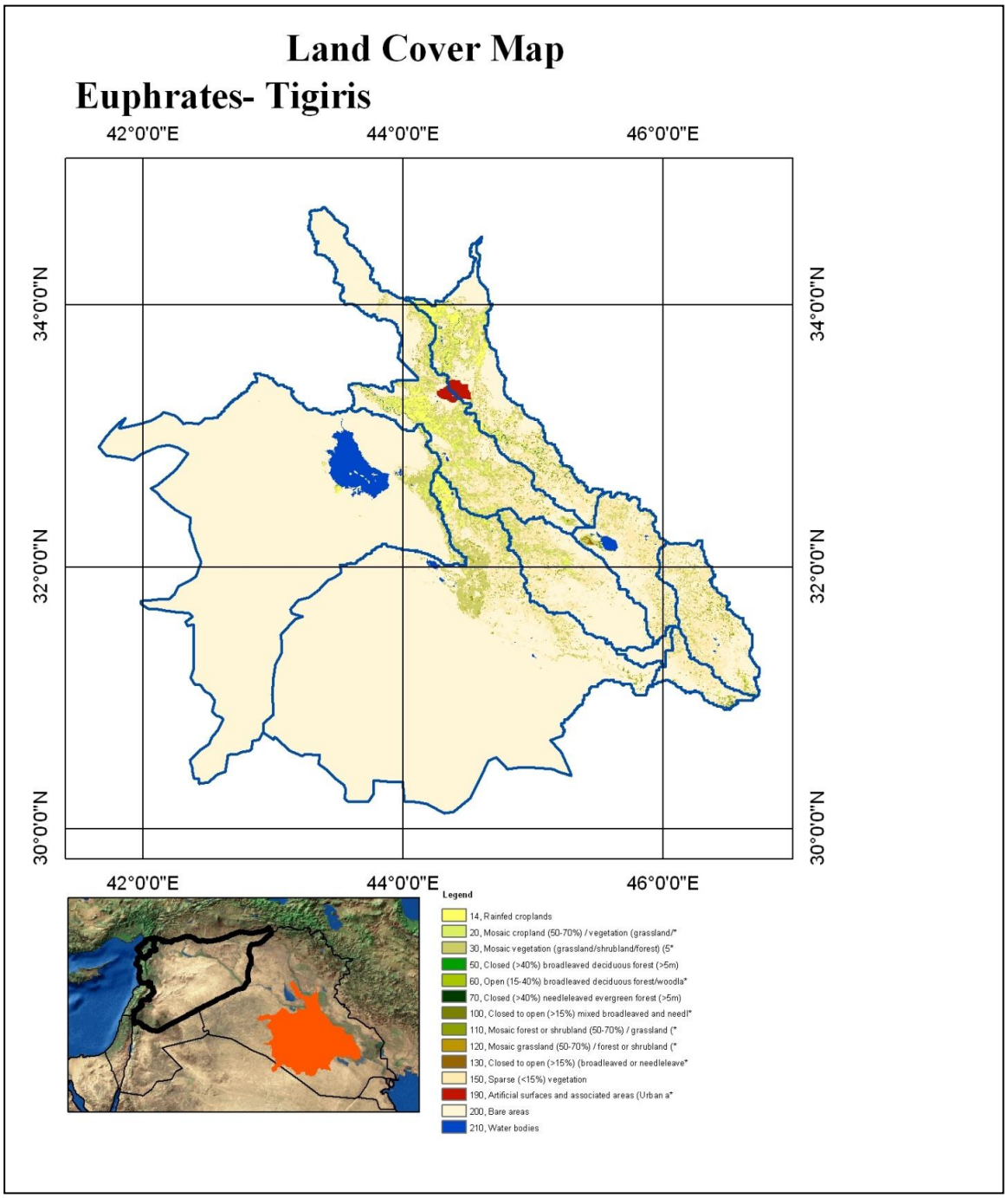


Figure 3.39. Land Cover Map in Joint Area between Tigris & Euphrates River's basins

Table. 3.44. .Land Cover Legend.

Land Cover (Euphrates & Tigris Joint Area)	Area_ha	Area in %
Rainfed croplands	252899.33	1.60%
Mosaic Croplands/Vegetation	262454.49	1.67%
Mosaic Forest-Shrubland/Grassland	149603.81	0.95%
Mosaic Grassland/Forest-Shrubland	4437.25	0.03%
Closed to open shrubland	2780.54	0.02%
Sparse vegetation	1910917.27	12.13%
Artificial areas	42996.83	0.27%
Bare areas	12080376.86	76.66%
Water bodies	243389.56	1.54%
TOTAL	15757701.25	

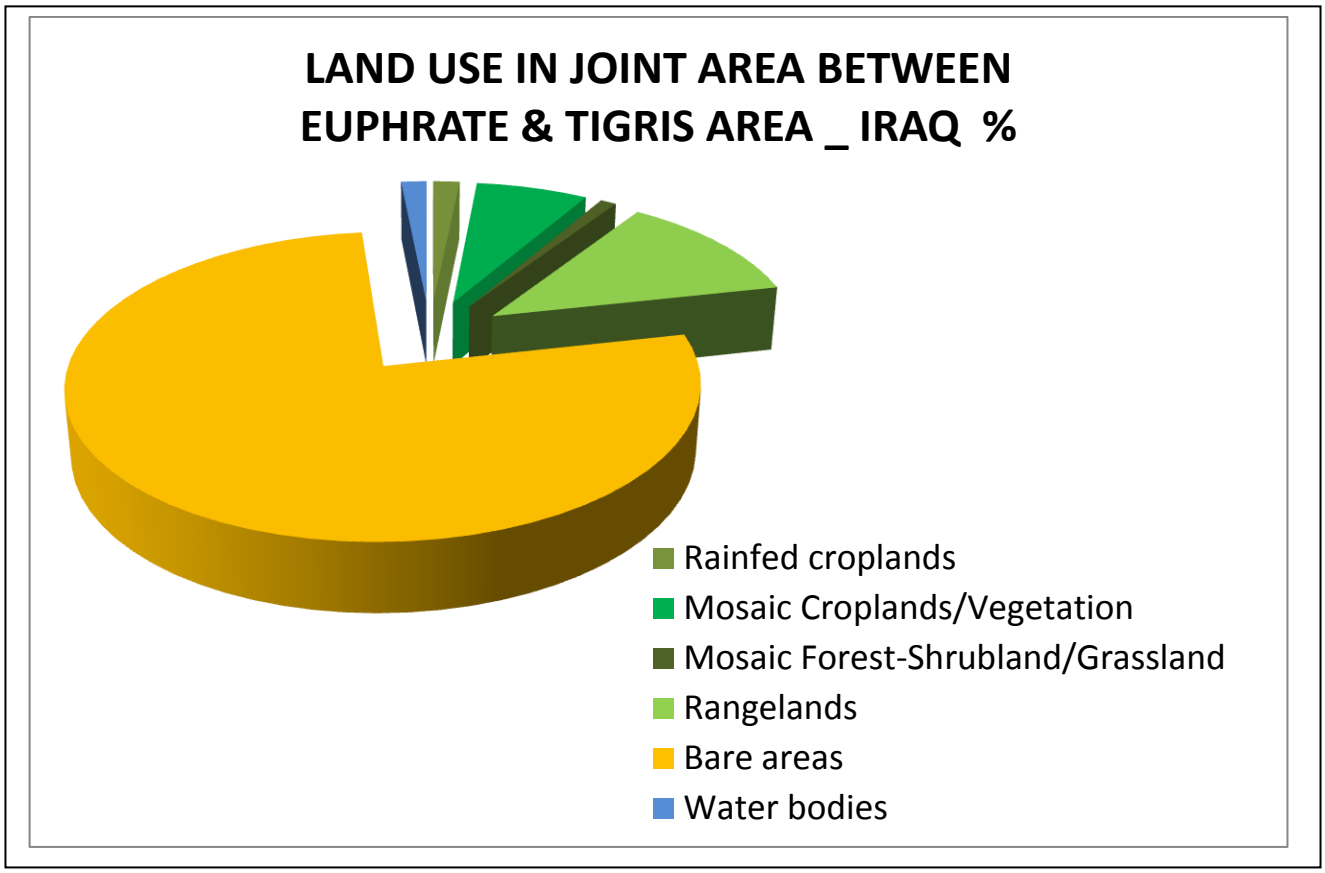


Figure 3.40. Distribution of Land Cover among Joint Area between Tigris & Euphrates River's basins

Table 3.45. Agriculture Drought Hazard Areas in Joint Area between Tigris & Euphrates River's basins

Land Cover	Level of Hazard	Area in Ha	%
Rainfed croplands	Non	127999.37	0.82
	Slight	78788.70	0.50
	Moderate	45860.39	0.29
	Severe	110.84	0.00
Mosaic Croplands/Vegetation	Non	405684.13	2.59
	Slight	429364.74	2.74
	Moderate	216420.82	1.38
	Severe	7169.51	0.05
Forest	Non	5.33	0.00
	Slight	10.14	0.00
	Moderate		
	Severe		
Mosaic Forest-Shrubland/Grassland	Non	27694.80	0.18
	Slight	77606.70	0.50
	Moderate	41554.02	0.27
	Severe	2830.74	0.02
Rangelands	Non	381453.88	2.43
	Slight	1005804.24	6.42
	Moderate	487541.49	3.11
	Severe	23759.50	0.15

– **The results shows that**

3.6. Orontes River basin

3.6.1. Creating and Studying Agriculture drought Hazard

Creation of Agriculture drought hazard from ADI, ADV, ADF , ADC the results will include both the geographical distribution of the classes of each product and the table with areas in Ha, and percentage of each class by countries sharing the basin. Creating the Agriculture Drought Hazard ADH, from the analysis of the monthly band seasonally VHI.

- The ADI map of Orontes River basin is shown in figure (3.41), and (Table 3.46). The results shows that drought intensity is extend in 60% of the basin most of it belong to the class of low ADI and is distributed as follows 37% of in Syria, 18% in Turkey and 4.8% in Lebanon.
- The ADV map of Orontes River basin is shown in figure (3.42), and (Table 3.47). The results shows that drought variability is extend in 94% of the basin most of it belong to the class 1, that correspond to low variability ADI and is distributed as follows 60% of in Syria, 25.5% in Turkey and 6% in Lebanon.
- The ADF map of Orontes River basin is shown in figure (3.43), and (Table 3.48). The results shows that drought frequency is extend in most parts of the basin, almost, 36% are in classes 1 and 2 and 53% are in classes of 3, 4, 5 and 6 and less than 2% are in classes 7 to 10. The majority of the ADF are distributed as follows: 33% of in Syria, 18% in Turkey and 3% in Lebanon.
- The A ADC map of Orontes River basin is shown in figure (3.44), and (Table 3.49). The results show that drought consecutive is very low in most parts of the basin.
- Finally, the ADH map of Orontes River basin as shown in figure (3.45), and (Table 3.50) illustrate that almost 52% of the basin is under low level of ADH, and 8% is in moderate ADH while only 0.2% is in Sever ADH.

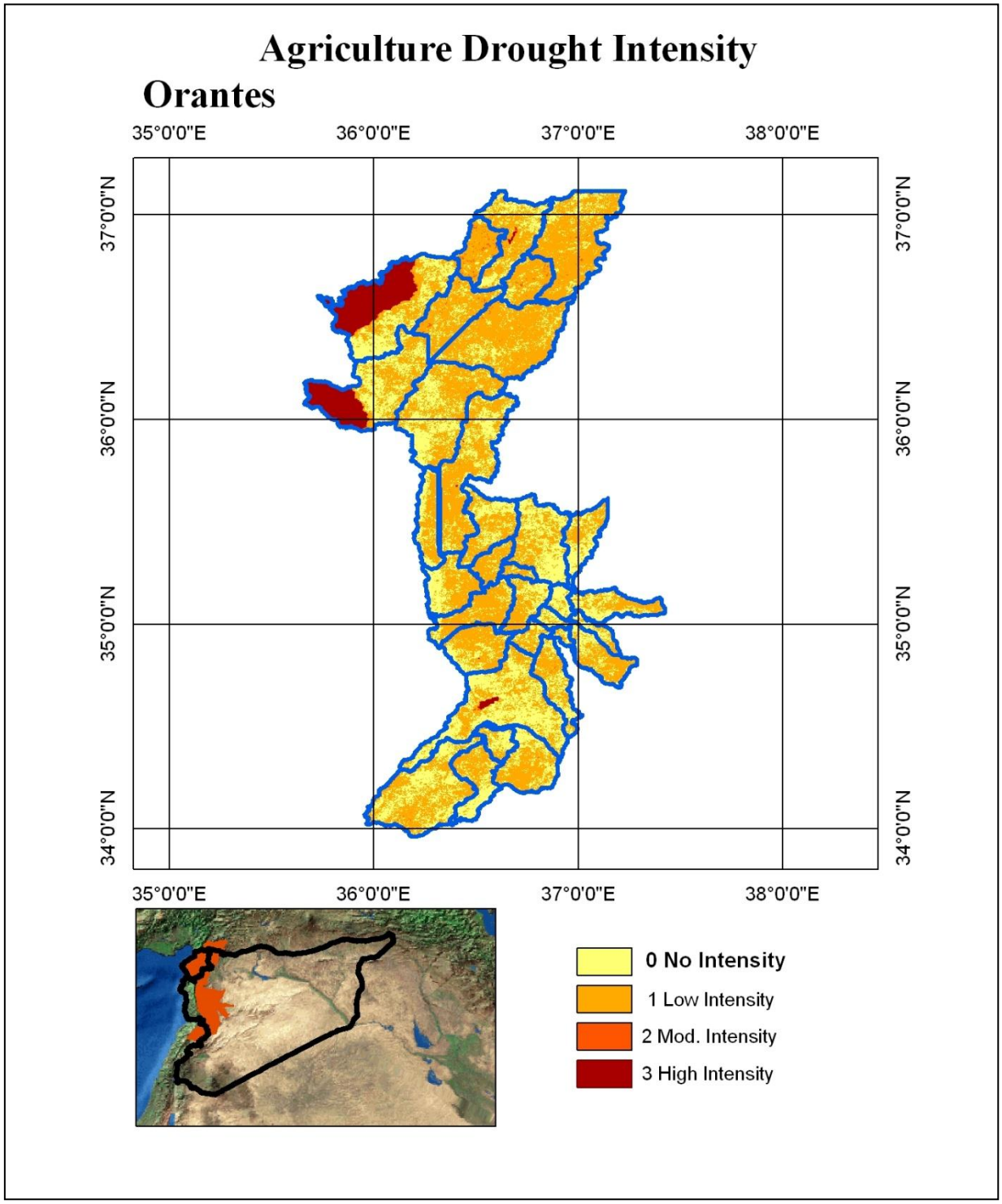


Figure 3.41 Agriculture Drought Intensity Map in Orontes River's Basin

Table 3.46 Agriculture Drought intensity Areas in Orontes River's Basin

Country	class	Area Ha	%
Turkey	No drought	222621.96	9.93%
	Low	404772.47	18.06%
	Moderate	5533.19	0.25%
	High	4751.01	0.21%
Syria	No drought	553093.66	24.68%
	Low	832025.76	37.12%
	Moderate	2231.21	0.10%
	High	2857.61	0.13%
Lebanon	No drought	104450.46	4.66%
	Low	108002.98	4.82%
	Moderate	848.91	0.04%
	High	55.48	0.00%

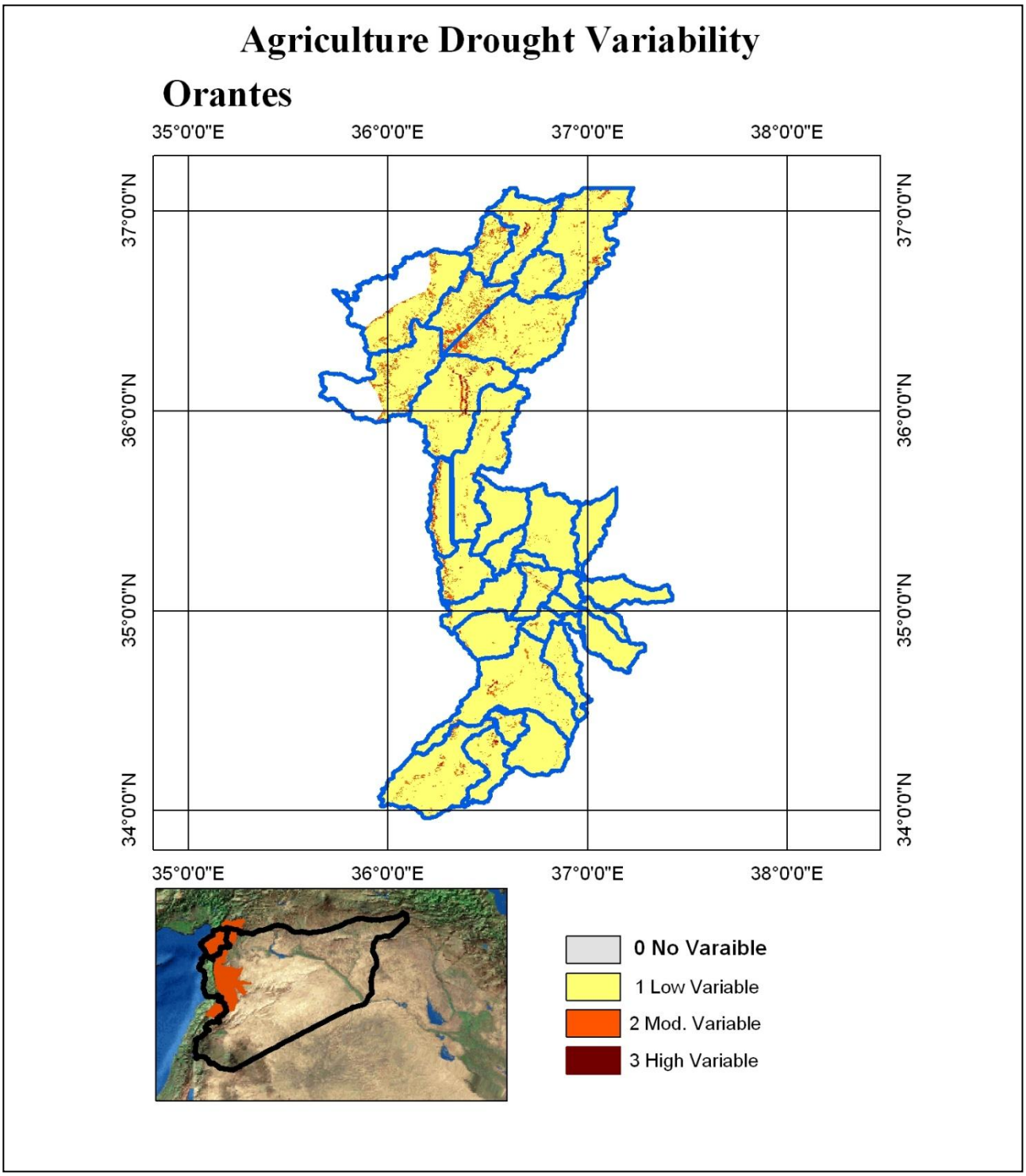


Figure 3.42. Agriculture Drought Variability Map in Orontes River's Basin

Table 3.47. Agriculture Drought Variability Areas in Orontes River's Basin

Country	Variability Classes	Area in Ha	%
Lebanon	0	212.89	0.01%
	1	205310.02	9.16%
	2	6921.94	0.31%
	3	912.98	0.04%
Syria	0	1384.94	0.06%
	1	1350223.40	60.25%
	2	32995.08	1.47%
	3	5604.82	0.25%
Turkey	0	869.52	0.04%
	1	570658.25	25.46%
	2	58319.17	2.60%
	3	7662.86	0.34%

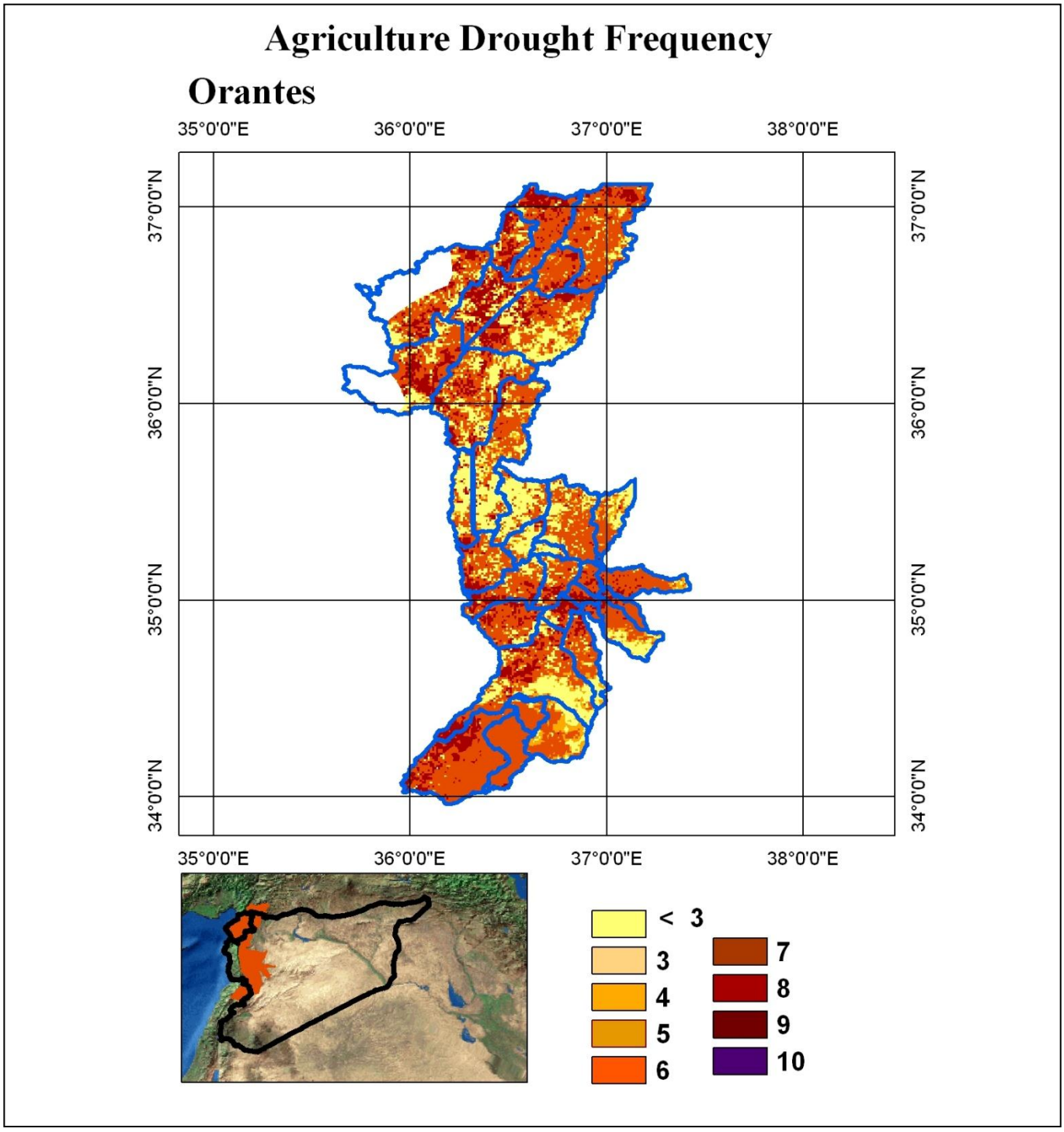


Figure 3.43.Agriculture Drought Frequency Map in Orontes River's Basin

Table 3.48. Agriculture Drought Frequency Areas in Orontes River's Basin

Country	Frequency Classes	Area in Ha	%
Lebanon	0	15066.54	0.67%
	1	58928.14	2.63%
	2	63262.34	2.82%
	3	49087.38	2.19%
	4	19649.93	0.88%
	5	6389.61	0.29%
	6	841.44	0.04%
	7	132.43	0.01%
Syria	0	37945.67	1.69%
	1	210480.44	9.39%
	2	398777.39	17.79%
	3	373915.14	16.68%
	4	214464.46	9.57%
	5	98181.91	4.38%
	6	41307.49	1.84%
	7	11785.44	0.53%
	8	3046.89	0.14%
	9	237.50	0.01%
	10	65.97	0.00%
Turkey	0	26947.60	1.20%
	1	76907.17	3.43%
	2	121847.96	5.44%
	3	145548.09	6.49%
	4	122051.87	5.45%
	5	81692.32	3.64%
	6	41282.40	1.84%
	7	16678.61	0.74%
	8	3035.08	0.14%
	9	226.42	0.01%
	10	1461.05	0.07%

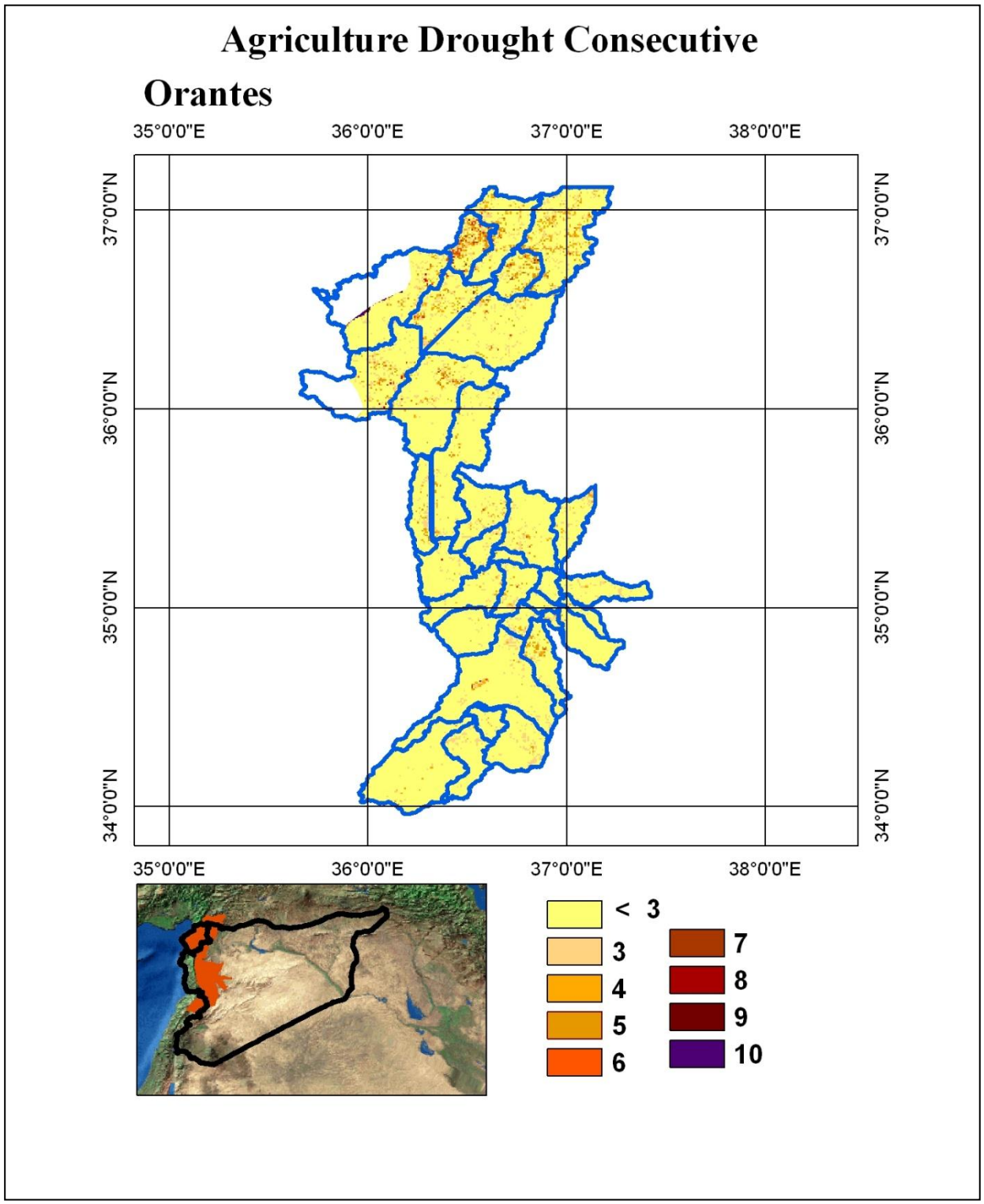


Figure 3.44. Agriculture Drought Consecutive Map in Orontes River's Basin

Table 3.49 Agriculture Drought Consecutive Areas in Orontes River's Basin

Country	Consecutive Classes	Area in Ha	%
Lebanon	0	15239.74	0.68%
Lebanon	1	130824.87	5.84%
Lebanon	2	45452.75	2.03%
Lebanon	3	3993.32	0.18%
Lebanon	4	698.76	0.03%
Lebanon	5	178.01	0.01%
Syria	0	60890.46	2.72%
Syria	1	1001432.01	44.68%
Syria	2	577006.75	25.74%
Syria	3	126065.66	5.62%
Syria	4	32240.85	1.44%
Syria	5	29472.86	1.32%
Syria	6	5340.62	0.24%
Syria	7	1291.97	0.06%
Syria	8	2509.51	0.11%
Syria	9	150.87	0.01%
Syria	10	1513.17	0.07%
Turkey	0	5301.35	0.24%
Turkey	1	80680.52	3.60%
Turkey	2	59910.79	2.67%
Turkey	3	26986.91	1.20%
Turkey	4	17145.74	0.77%
Turkey	5	12266.37	0.55%
Turkey	6	3579.10	0.16%
Turkey	7	320.58	0.01%
Turkey	8	750.68	0.03%
Turkey	10	0.49	0.00%

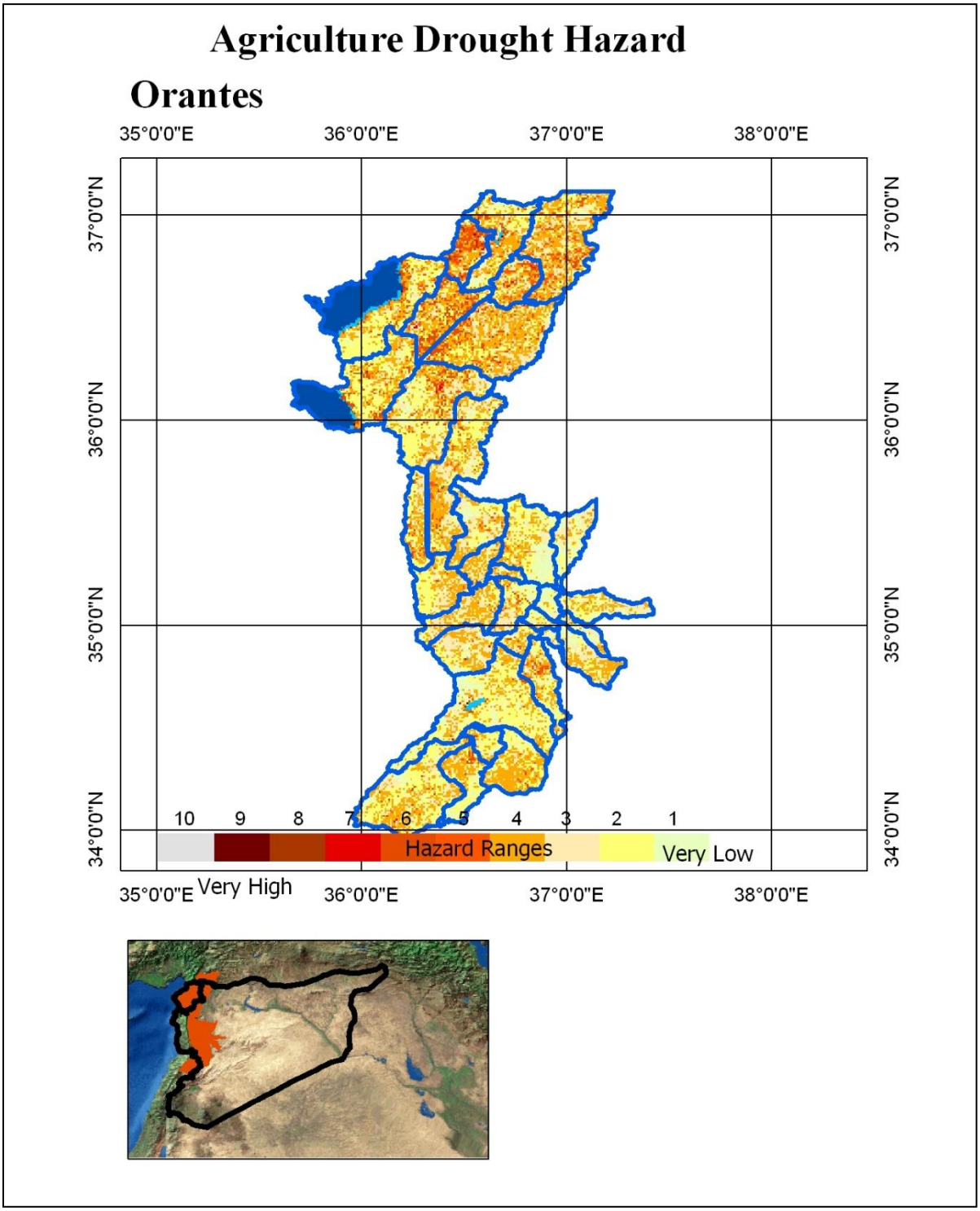


Figure 3.45. Agriculture Drought Hazard Map in Orontes River's Basin

Table 3.50. Agriculture Drought Hazard Areas in Orontes River's Basin

HAZARD Classes ADH	Area_ha	%
1	432200.23	12.64
2	897576.49	26.26
3	623047.06	18.23
4	1136847.17	33.26
5	119196.34	3.49
6	146667.92	4.29
7	7415.36	0.22
8	5978.17	0.17
9	724.80	0.02
10	359.52	0.01

3.6.2. Agriculture drought Hazard with Land Degradation

Land degradation map is shown in figure (3.46), and (Table 3.51 and 3.52). The results shows that land degradation plays a major role in reducing land capability and production, it is recognized that the over all land improvement in Lebanon (5%) is 5 times the land degradation (0.3%) and in turkey (13%) is almost double of the land degradation (6,9%), oboist to that the situation in Syria were land degradation is more than land improvement and casing series problems specially in the areas bordered by Hams and Hama cities.

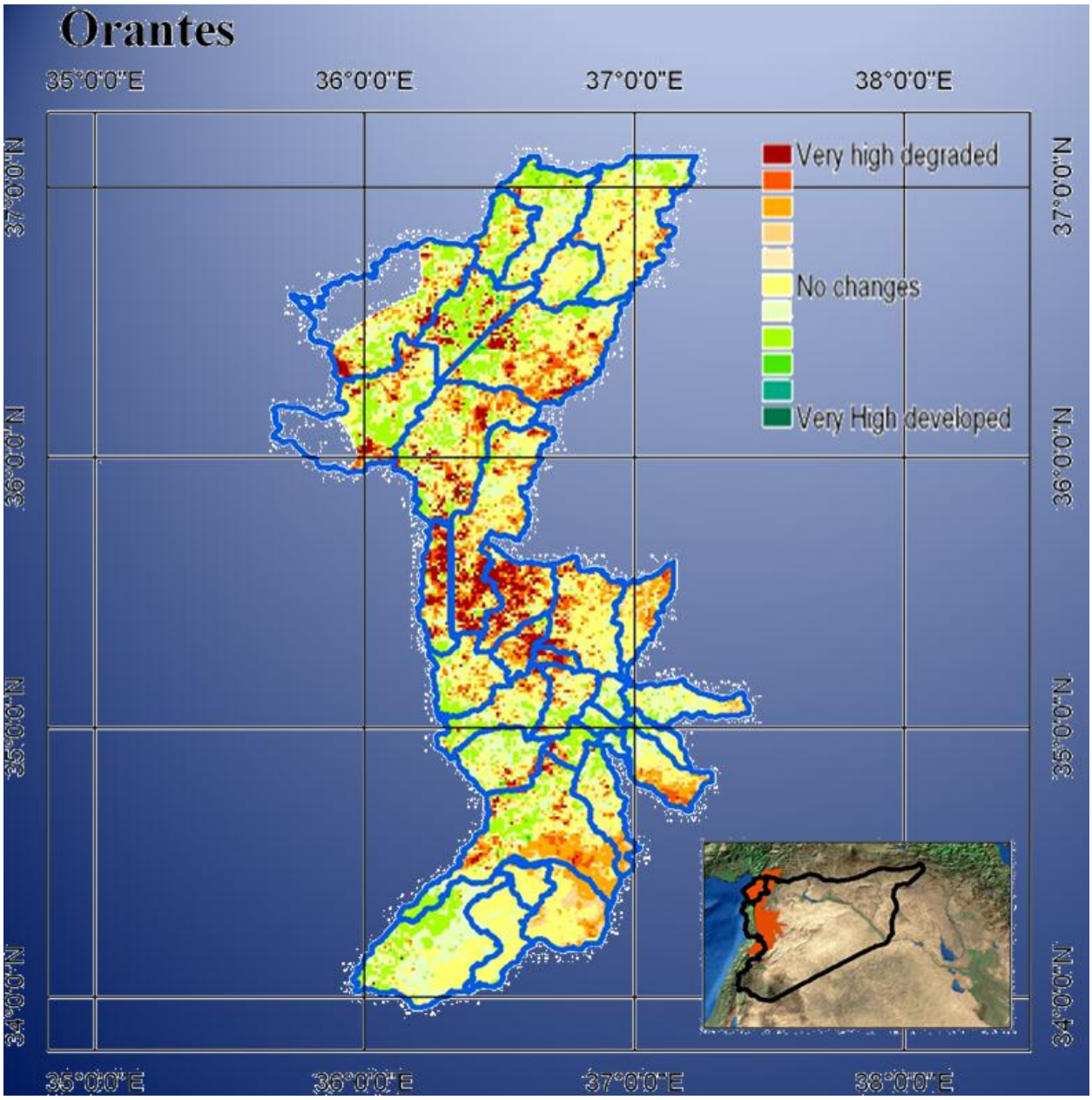


Figure 3.46 Aland Degradation Map in Orontes River's Basin

Table 3.51Land Degradation Areas in Orontes River's Basin

Country	Area in	vh_deg	h_deg	m_deg	l_deg	vl_deg	L. Deg Total
Turkey	Ha	35710.29	40479.59	45020.25	22879.65	10108.95	154198.73
	%	1.59	1.81	2.01	1.02	0.45	6.88
Syria	Ha	90522.21	122239.19	182858.96	97214.55	32740.35	525575.26
	%	4.04	5.45	8.16	4.34	1.46	23.45
Lebanon	Ha	300.38	1243.93	2329.49	1591.57	817.99	6283.36
	%	0.01	0.06	0.1	0.07	0.04	0.28
TOTAL	Ha	126532.88	163962.71	230208.7	121685.77	43667.29	686057.35
	%	5.64	7.32	10.27	5.43	1.95	30.61

Table 3.52 Land Developed Areas in Orontes River's Basin

Country	Area in	vh_dev	h_dev	m_dev	l_dev	vl_dev	L. Dev Total
Turkey	Ha	108.06	1078.48	5556.37	154749.10	135924.91	297416.92
	%	0.01	0.05%	0.25%	6.90%	6.06%	13.27
Syria	Ha	327.78	220.65	2761.73	155986.37	227751.94	387048.47
	%	0	0.01%	0.12%	6.96%	10.16%	17.27
Lebanon	Ha	111.09	0	111.06	42764.08	70789.02	113775.25
	%	0	0	0.00%	1.91%	3.16%	5.08
TOTAL	Ha	546.93	1299.13	8429.16	353499.6	434465.9	798240.64
	%	0.02	0.06	0.38	15.77	19.39	35.62

3.6.3. Agriculture drought Hazard with Land Cover/Use

– **Land Cover map is shown in figure (3.47), and the LC map legend is shown in Table (3.53), the impact of Agriculture drought Hazard in Land Cover/Use is shown in figure (3.48) and (Table 3.54).**

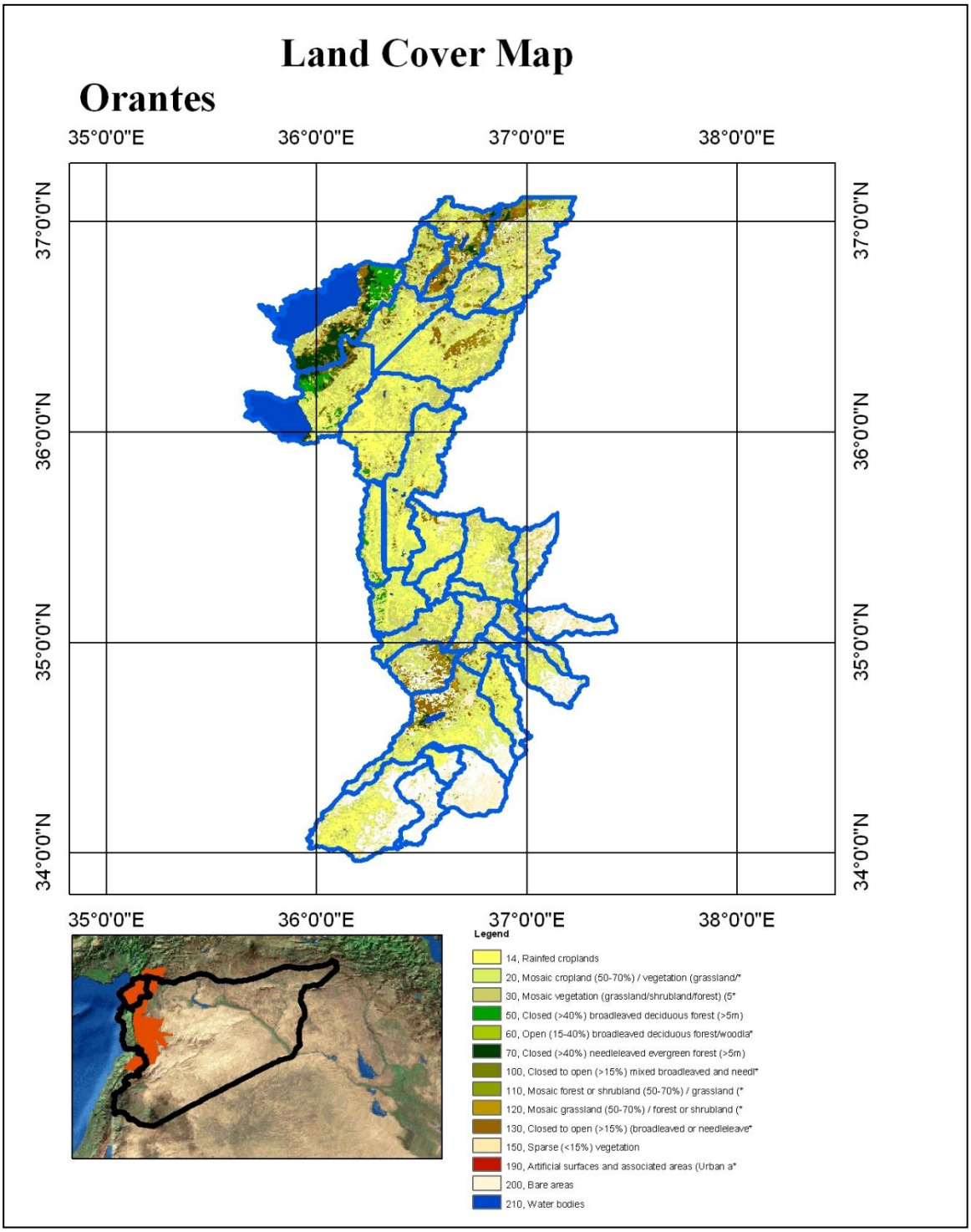


Figure 3.47. Land Cover Map in Orontes River's Basin

Table. 3.53. Land Cover Legend.

Land Cover Description Orontes	Area_ ha	%	Country	Area_ha	%
Rainfed croplands	**641663.73**	**18.77%**	Lebanon	46299.68	1.35%
			Syria	582081.15	17.03%
			Turkey	13282.91	0.39%
Mosaic Croplands/Vegetation	**1250839.40**	**36.59%**	Lebanon	76261.86	2.23%
			Syria	1066740.00	31.20%
			Turkey	107837.54	3.15%
Mosaic Vegetation/Croplands	**500969.03**	**14.65%**	Lebanon	22241.21	0.65%
			Syria	400296.65	11.71%
			Turkey	78431.18	2.29%
Closed broadleaved deciduous forest	**29789.75**	**0.87%**	Syria	23976.88	0.70%
			Turkey	5812.86	0.17%
Closed needle leaved evergreen forest	**137799.59**	**4.03%**	Syria	115324.57	3.37%
			Turkey	22475.02	0.66%
Closed to open mixed broadleaved and needle leaved forest	**18562.55**	**0.54%**	Syria	16591.60	0.49%
			Turkey	1970.94	0.06%
Mosaic Forest-Shrub land/Grassland	**57179.31**	**1.67%**	Lebanon	1648.09	0.05%
			Syria	36969.54	1.08%
			Turkey	18561.68	0.54%
Mosaic Grassland/Forest-Shrub land	**78042.42**	**2.28%**	Lebanon	240.59	0.01%
			Syria	59756.23	1.75%
			Turkey	18045.60	0.53%
Closed to open shrub land	**164106.22**	**4.80%**	Lebanon	506.58	0.01%
			Syria	121012.36	3.54%
			Turkey	42587.28	1.25%
Sparse vegetation	**326557.43**	**9.55%**	Lebanon	109672.26	3.21%
			Syria	206395.33	6.04%
			Turkey	10489.84	0.31%
Bare areas	**160033.83**	**4.68%**	Lebanon	28547.30	0.84%
			Syria	131016.24	3.83%
			Turkey	470.29	0.01%
Water bodies	**53022.05**	**1.55%**	Syria	46217.82	1.35%
			Turkey	6804.23	0.20%

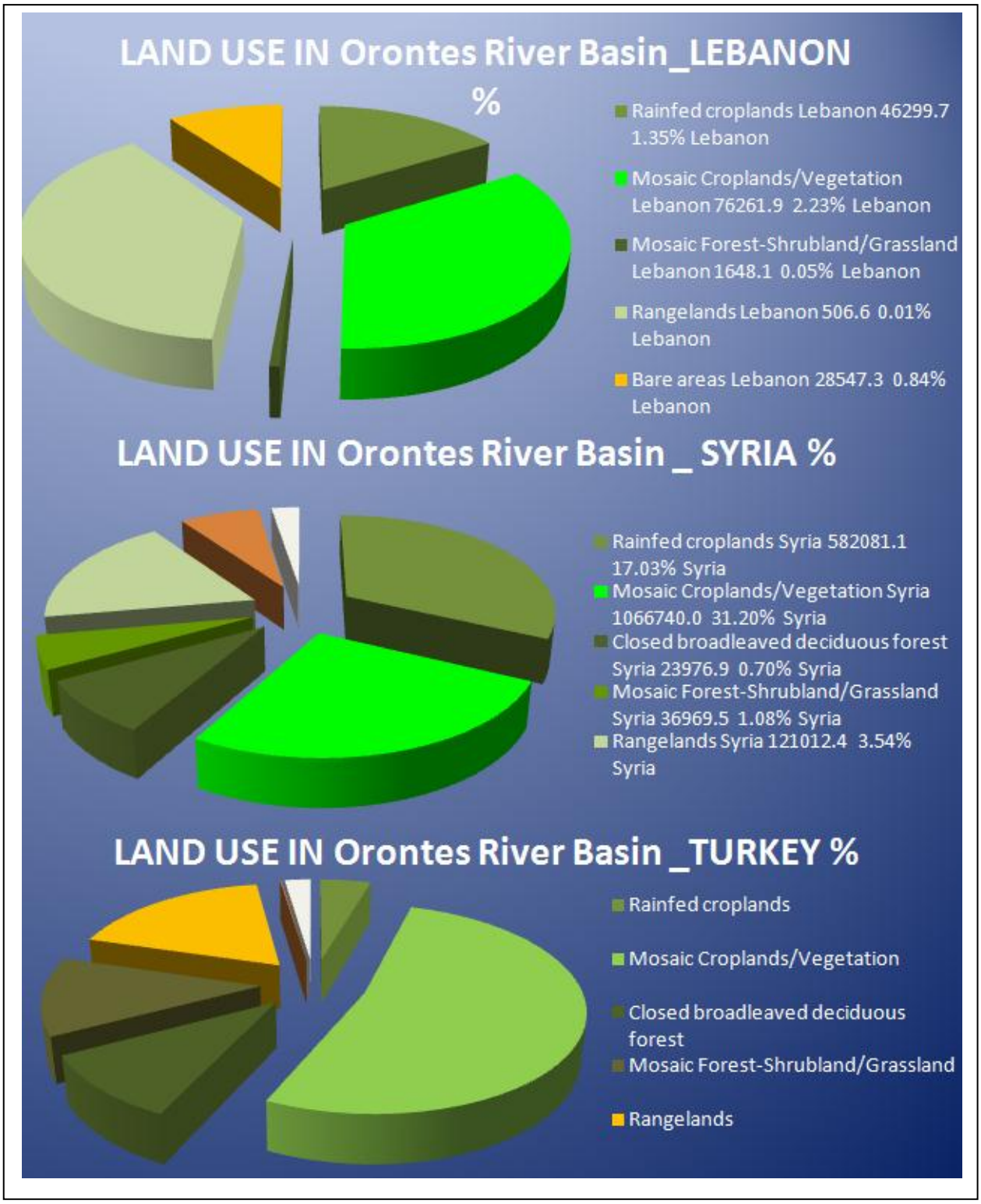


Figure 3.48. Distribution of Land Cover among Orontes Basin Countries

Table 3.54. Agriculture Drought Hazard Areas in Orontes River's Basin

Land Cover	Level of Hazard	Area in Ha	%
Rainfed croplands	Non	257143.18	7.52
	Slight	334036.98	9.77
	Moderate	49678.28	1.45
	Severe	630.26	0.02
Mosaic Croplands/Vegetation	Non	654319.62	19.14
	Slight	938465.41	27.45
	Moderate	149672.46	4.38
	Severe	3641.46	0.11
Forest	Non	105599.24	3.09
	Slight	59108.85	1.73
	Moderate	19859.75	0.58
	Severe	744.95	0.02
Mosaic Forest-Shrubland/Grassland	Non	47360.34	1.39
	Slight	71983.04	2.11
	Moderate	14840.93	0.43
	Severe	436.18	0.01
Rangelands	Non	197791.01	5.79
	Slight	260179.32	7.61
	Moderate	29889.82	0.87
	Severe	671.97	0.02

- **The results shows that**

3.7. Nile River basin

3.7.1. Creating and Studying Agriculture drought Hazard

Creation of Agriculture drought hazard from ADI, ADV, ADF , ADC the results will include both the geographical distribution of the classes of each product and the table with areas in Ha, and percentage of each class by countries sharing the basin. Creating the Agriculture Drought Hazard ADH, from the analysis of the monthly band seasonally VHI.

- The ADI map of Nile River basin is shown in figure (3.49), and (Table 3.55). The results shows that drought intensity is extend in 60% of the basin most of it belong to the class of low ADI and is distributed as follows 37% of in Syria, 18% in Turkey and 4.8% in Lebanon.
- The ADV map of Nile River basin is shown in figure (3.50), and (Table 3.56). The results shows that drought variability is extend in 94% of the basin most of it belong to the class 1, that correspond to low variability ADI and is distributed as follows 60% of in Syria, 25.5% in Turkey and 6% in Lebanon.
- The ADF map of Nile River basin is shown in figure (3.51), and (Table 3.57). The results shows that drought frequency is extend in most parts of the basin, almost, 36% are in classes 1 and 2 and 53% are in classes of 3, 4, 5 and 6 and less than 2% are in classes 7 to 10. The majority of the ADF are distributed as follows: 33% of in Syria, 18% in Turkey and 3% in Lebanon.
- The A ADC map of Nile River basin is shown in figure (3.52), and (Table 3.58). The results show that drought consecutive is very low in most parts of the basin.
- Finally, the ADH map of Nile River basin as shown in figure (3.53), and (Table 3.59) illustrate that almost 52% of the basin is under low level of ADH, and 8% is in moderate ADH while only 0.2% is in Sever ADH.

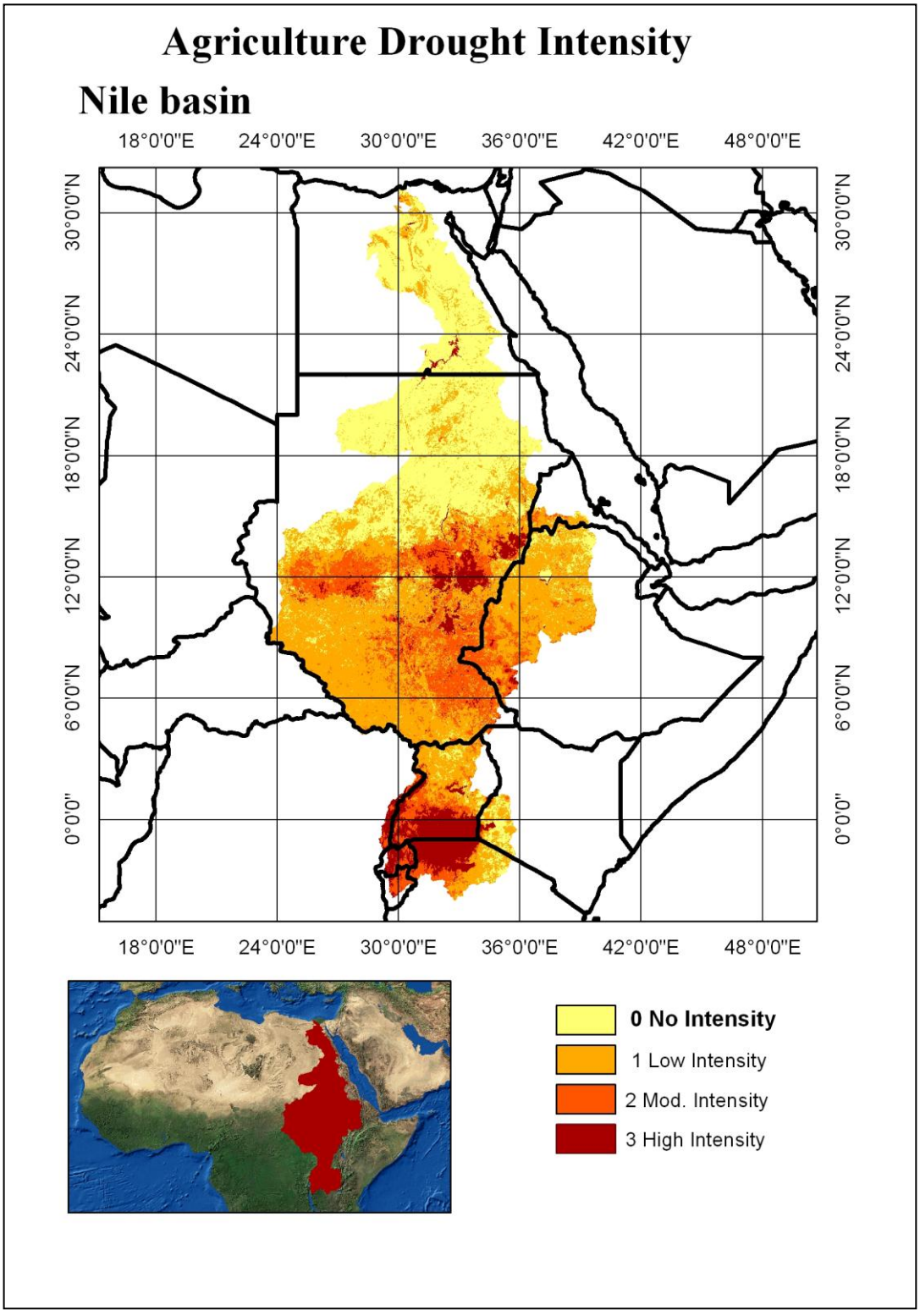


Figure 3.49 Agriculture Drought Intensity Map in Nile River's Basin

Table 3.55. Agriculture Drought intensity Areas in Nile River's Basin

CNTRY	Intensity CLASS	%	area ha
Burundi	2	0.35	1060695.2
Burundi	3	0.10	307811.5
Egypt	0	8.49	25931909.9
Egypt	1	1.19	3644521.9
Egypt	2	0.05	162844.1
Egypt	3	0.13	396553.9
Eritrea	0	0.14	418973.9
Eritrea	1	0.54	1638569.3
Eritrea	2	0.15	449243.5
Ethiopia	0	1.48	4528779.2
Ethiopia	1	8.12	24789335.3
Ethiopia	2	2.19	6674821.8
Ethiopia	3	0.16	503934.6
Kenya	0	0.72	2211700.9
Kenya	1	0.76	2335418.0
Kenya	2	0.09	280879.5
Kenya	3	0.13	408914.6
Rwanda	2	0.25	764529.5
Rwanda	3	0.42	1294379.1
Sudan	0	21.88	66838788.0
Sudan	1	26.32	80408767.8
Sudan	2	11.77	35940916.5
Sudan	3	2.96	9029631.8
Tanzania	0	0.38	1163287.8
Tanzania	1	1.15	3511265.0
Tanzania	2	0.67	2039530.5
Tanzania	3	1.74	5329242.5
Uganda	0	0.50	1528329.2
Uganda	1	2.59	7926337.0
Uganda	2	1.36	4147663.7
Uganda	3	2.51	7662721.2
DR Congo	1	0.04	128570.6
DR Congo	2	0.19	567954.3
DR Congo	3	0.45	1372857.0

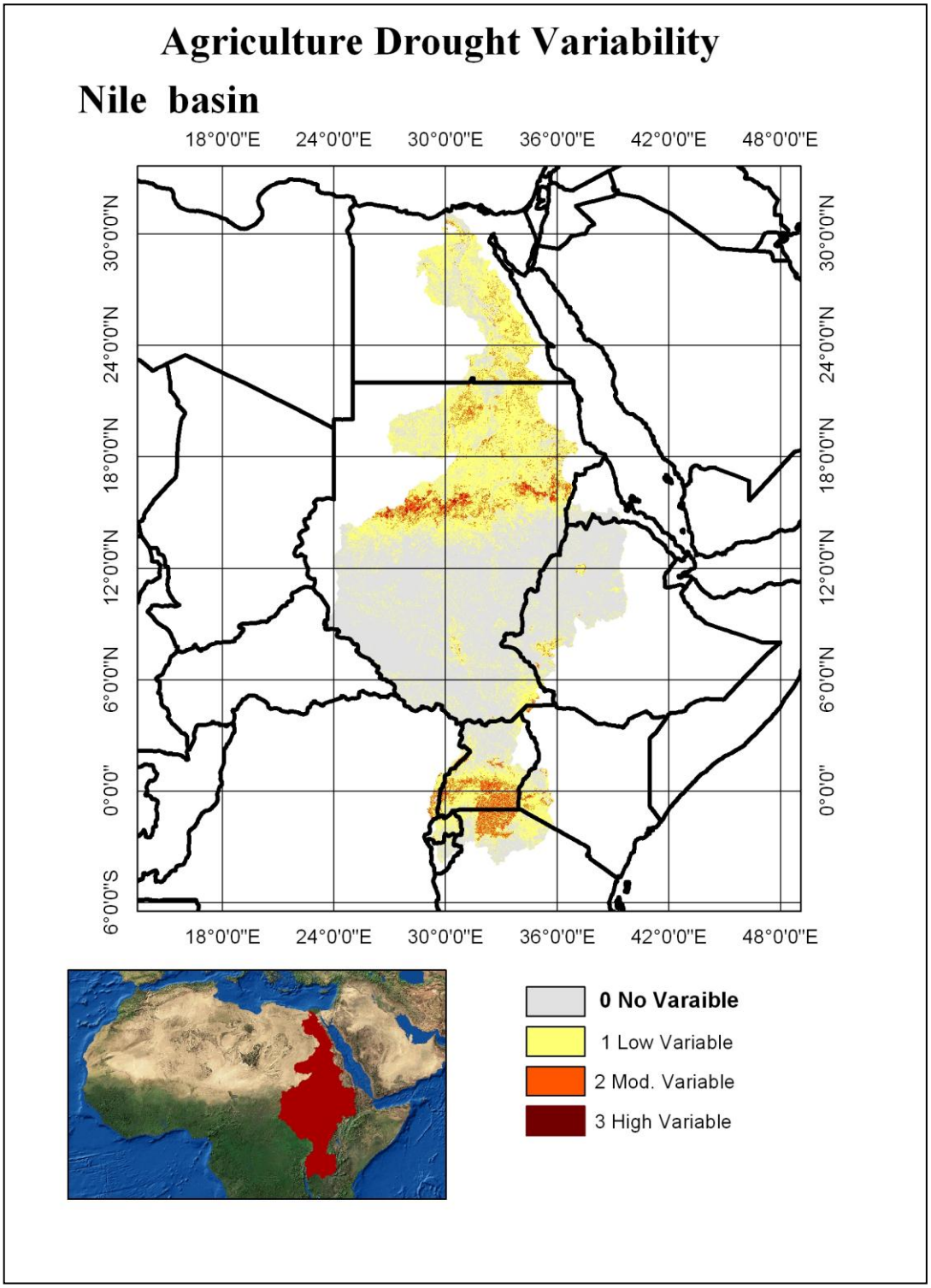


Figure 3.50. Agriculture Drought Variability Map in Nile River's Basin

Table 3.56. Agriculture Drought Variability Areas in Nile River's Basin

CNTRY_NAME	Variability Classes	area ha	%
Burundi	0	1041250.081	0.34
Burundi	1	328962.0695	0.11
Burundi	2	2613.139774	0.00
Burundi	3	90.23630361	0.00
Egypt	0	8995197.592	2.95
Egypt	1	19588380.21	6.41
Egypt	2	1442623.283	0.47
Egypt	3	93363.95589	0.03
Eritrea	0	2178313.135	0.71
Eritrea	1	330942.4914	0.11
Eritrea	2	353.5893513	0.00
Ethiopia	0	32110458.31	10.51
Ethiopia	1	4143807.529	1.36
Ethiopia	2	225656.7339	0.07
Ethiopia	3	15238.51672	0.00
Kenya	0	1443118.205	0.47
Kenya	1	3299669.479	1.08
Kenya	2	464779.2836	0.15
Kenya	3	29340.16472	0.01
Rwanda	0	771968.9096	0.25
Rwanda	1	1234013.989	0.40
Rwanda	2	54785.7161	0.02
Rwanda	3	2968.131333	0.00
Sudan	0	118423736.5	38.78
Sudan	1	65527003.78	21.46
Sudan	2	7174263.767	2.35
Sudan	3	1090068.733	0.36
Tanzania	0	5233377.26	1.71
Tanzania	1	4745763.788	1.55
Tanzania	2	1882431.506	0.62
Tanzania	3	181345.0339	0.06
Uganda	0	7820583.347	2.56
Uganda	1	9574860.066	3.14
Uganda	2	3562982.686	1.17
Uganda	3	304231.0726	0.10
DR Congo	0	399458.3644	0.13
DR Congo	1	1086904.322	0.36
DR Congo	2	533537.9562	0.17
DR Congo	3	49091.6145	0.02

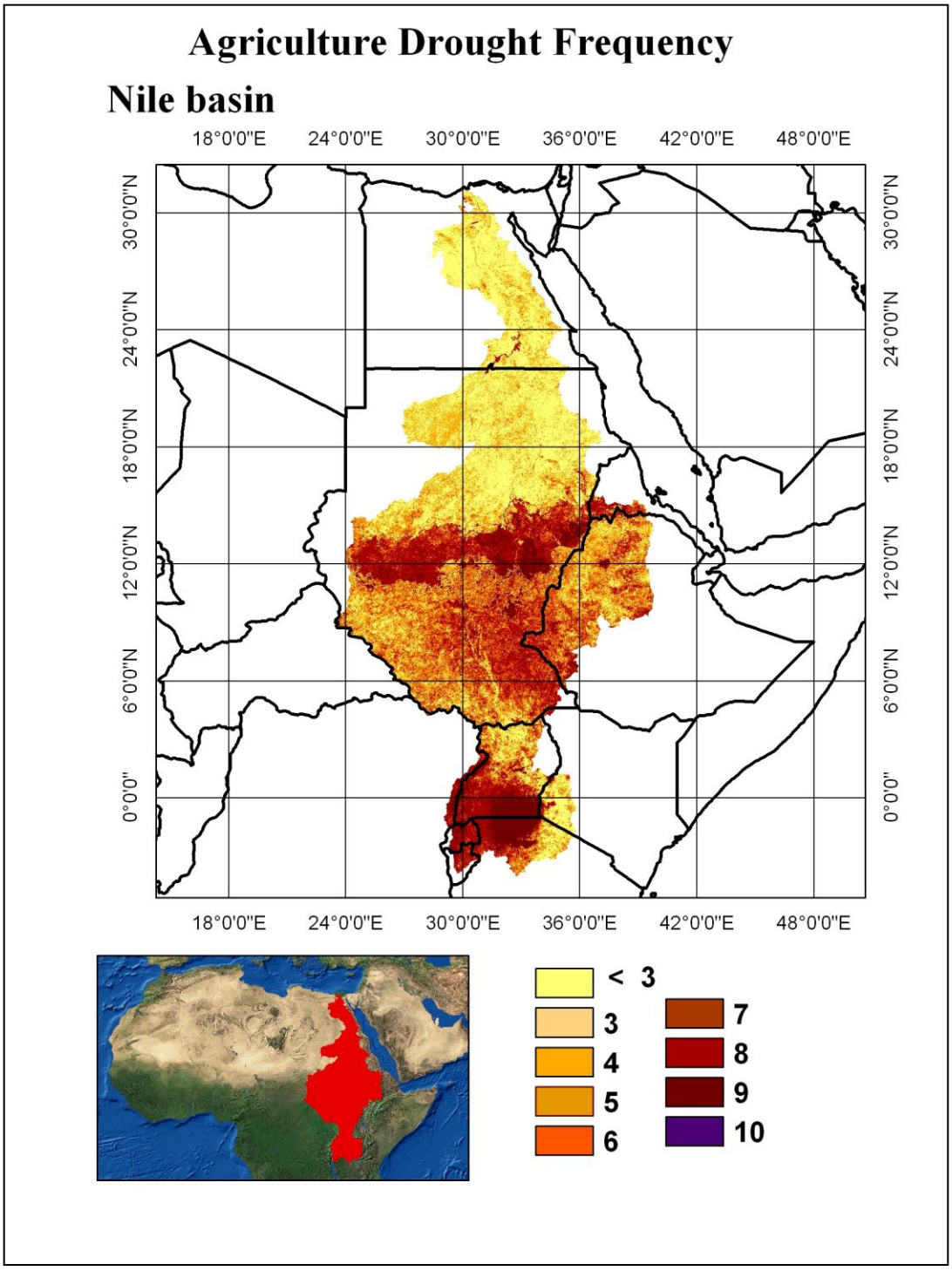


Figure 3.51. Agriculture Drought Frequency Map in Nile River's Basin

Table 3.57. Agriculture Drought Frequency Areas in Nile River's Basin

Country	Frequency Classes	area ha	%
	3	2627.143925	0.001
Burundi	4	8561.143963	0.003
Burundi	5	26907.45175	0.009
Burundi	6	79142.67749	0.026
Burundi	7	172965.8634	0.057
Burundi	8	311940.9629	0.102
Burundi	9	370859.2005	0.121
Burundi	10	278725.3568	0.091
Burundi	11	120907.3257	0.040
Egypt	0	310897.6843	0.102
Egypt	1	3579416.015	1.172
Egypt	2	9595465.403	3.141
Egypt	3	9324931.405	3.053
Egypt	4	4691043.494	1.536
Egypt	5	1622679.9	0.531
Egypt	6	490188.267	0.160
Egypt	7	139507.477	0.046
Egypt	8	59249.9278	0.019
Egypt	9	51751.77981	0.017
Egypt	10	270809.7218	0.089
Eritrea	0	82313.21905	0.027
Eritrea	2	34009.57261	0.011
Eritrea	3	83821.54008	0.027
Eritrea	4	132478.546	0.043
Eritrea	5	188946.5111	0.062
Eritrea	6	262801.8409	0.086
Eritrea	7	373998.8778	0.122
Eritrea	8	509430.5017	0.167
Eritrea	9	496539.2913	0.163
Eritrea	10	268639.964	0.088
Eritrea	11	77415.49293	0.025

Country	Frequency Classes	area ha	%
Ethiopia	0	390740.1728	0.128
Ethiopia	1	278681.0619	0.091
Ethiopia	2	1490906.745	0.488
Ethiopia	3	3915628.289	1.282
Ethiopia	4	6098115.171	1.996
Ethiopia	5	6578969.847	2.154
Ethiopia	6	5841202.232	1.912
Ethiopia	7	4553429.437	1.491
Ethiopia	8	3311512.046	1.084
Ethiopia	9	2086762.012	0.683
Ethiopia	10	1228871.501	0.402
Ethiopia	11	725962.4886	0.238
Kenya	0	127822.9543	0.042
Kenya	1	647332.9	0.212
Kenya	2	1198118.185	0.392
Kenya	3	1034794.453	0.339
Kenya	4	664148.5625	0.217
Kenya	5	417785.6447	0.137
Kenya	6	289411.8982	0.095
Kenya	7	190086.9165	0.062
Kenya	8	147174.1645	0.048
Kenya	9	144901.5856	0.047
Kenya	10	220235.7309	0.072
Kenya	11	155094.4689	0.051
Rwanda	5	14146.82512	0.005
Rwanda	6	39960.48937	0.013
Rwanda	7	102770.2941	0.034
Rwanda	8	234354.1568	0.077
Rwanda	9	430295.9953	0.141
Rwanda	10	698129.9682	0.229
Rwanda	11	539985.8614	0.177
Sudan	1	7922611.021	2.594
Sudan	2	20434017.65	6.690
Sudan	3	28319800.19	9.271
Sudan	4	26372264.51	8.634
Sudan	5	21043995.26	6.889
Sudan	6	18403709.66	6.025
Sudan	7	16782475.26	5.494
Sudan	8	14920427.41	4.885
Sudan	9	13444526.67	4.401
Sudan	10	11479820.64	3.758
Sudan	11	10134701.99	3.318

Country	Frequency Classes	area ha	%
Tanzania	0	33761.66841	0.011
Tanzania	1	352317.0528	0.115
Tanzania	2	775597.2578	0.254
Tanzania	3	889767.8719	0.291
Tanzania	4	877612.0576	0.287
Tanzania	5	849637.9898	0.278
Tanzania	6	801328.5889	0.262
Tanzania	7	760062.7882	0.249
Tanzania	8	766817.7952	0.251
Tanzania	9	816053.8174	0.267
Tanzania	10	1011846.876	0.331
Tanzania	11	4108533.305	1.345
Uganda	0	93942.58848	0.031
Uganda	1	547701.841	0.179
Uganda	2	1253660.243	0.410
Uganda	3	1700940.859	0.557
Uganda	4	1793320.931	0.587
Uganda	5	1724418.213	0.565
Uganda	6	1592388.817	0.521
Uganda	7	1545678.191	0.506
Uganda	8	1651091.585	0.541
Uganda	9	2082770.268	0.682
Uganda	10	2547359.089	0.834
Uganda	11	4731773.373	1.549
DR Congo	2	3446.23765	0.001
DR Congo	3	8695.347956	0.003
DR Congo	4	20705.63156	0.007
DR Congo	5	33139.20671	0.011
DR Congo	6	56885.36021	0.019
DR Congo	7	98142.47036	0.032
DR Congo	8	170705.6058	0.056
DR Congo	9	299195.6655	0.098
DR Congo	10	531709.3235	0.174
DR Congo	11	845853.5254	0.277

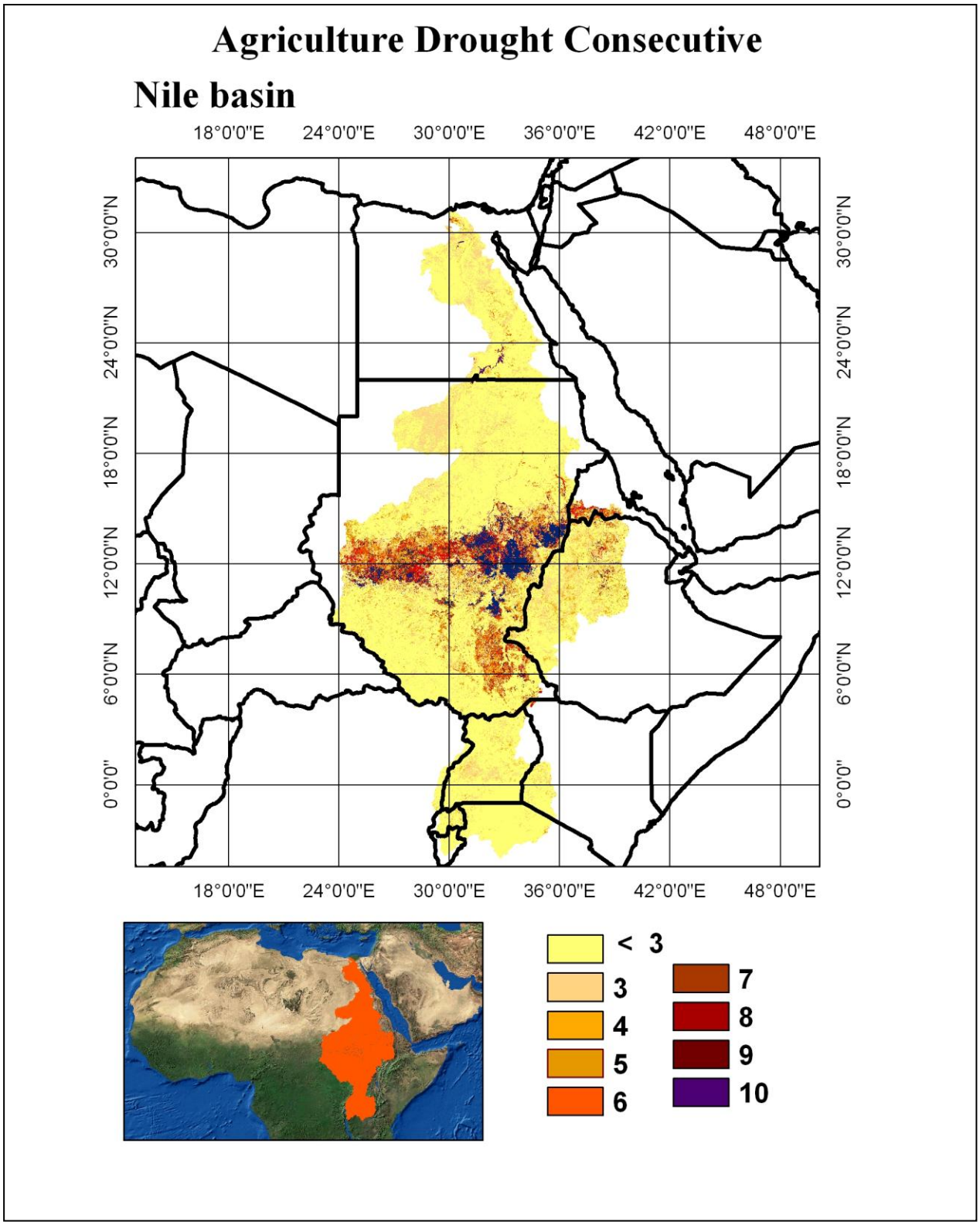


Figure 3.52. Agriculture Drought Consecutive Map in Nile River's Basin

Table 3.58. Agriculture Drought Consecutive Areas in Nile River's Basin

C0untry	Frequency Classes	area ha	%
Burundi	3	2627.143925	0.001
Burundi	4	8561.143963	0.003
Burundi	5	26907.45175	0.009
Burundi	6	79142.67749	0.026
Burundi	7	172965.8634	0.057
Burundi	8	311940.9629	0.102
Burundi	9	370859.2005	0.121
Burundi	10	278725.3568	0.091
Burundi	11	120907.3257	0.040
Egypt	0	310897.6843	0.102
Egypt	1	3579416.015	1.172
Egypt	2	9595465.403	3.141
Egypt	3	9324931.405	3.053
Egypt	4	4691043.494	1.536
Egypt	5	1622679.9	0.531
Egypt	6	490188.267	0.160
Egypt	7	139507.477	0.046
Egypt	8	59249.9278	0.019
Egypt	9	51751.77981	0.017
Egypt	10	270809.7218	0.089
Eritrea	0	82313.21905	0.027
Eritrea	2	34009.57261	0.011
Eritrea	3	83821.54008	0.027
Eritrea	4	132478.546	0.043
Eritrea	5	188946.5111	0.062
Eritrea	6	262801.8409	0.086
Eritrea	7	373998.8778	0.122
Eritrea	8	509430.5017	0.167
Eritrea	9	496539.2913	0.163
Eritrea	10	268639.964	0.088
Eritrea	11	77415.49293	0.025

Table 3.58. Cont'd

C0untry	Frequency Classes	area ha	%
Ethiopia	0	390740.1728	0.128
Ethiopia	1	278681.0619	0.091
Ethiopia	2	1490906.745	0.488
Ethiopia	3	3915628.289	1.282
Ethiopia	4	6098115.171	1.996
Ethiopia	5	6578969.847	2.154
Ethiopia	6	5841202.232	1.912
Ethiopia	7	4553429.437	1.491
Ethiopia	8	3311512.046	1.084
Ethiopia	9	2086762.012	0.683
Ethiopia	10	1228871.501	0.402
Ethiopia	11	725962.4886	0.238
Kenya	0	127822.9543	0.042
Kenya	1	647332.9	0.212
Kenya	2	1198118.185	0.392
Kenya	3	1034794.453	0.339
Kenya	4	664148.5625	0.217
Kenya	5	417785.6447	0.137
Kenya	6	289411.8982	0.095
Kenya	7	190086.9165	0.062
Kenya	8	147174.1645	0.048
Kenya	9	144901.5856	0.047
Kenya	10	220235.7309	0.072
Kenya	11	155094.4689	0.051
Rwanda	5	14146.82512	0.005
Rwanda	6	39960.48937	0.013
Rwanda	7	102770.2941	0.034
Rwanda	8	234354.1568	0.077
Rwanda	9	430295.9953	0.141
Rwanda	10	698129.9682	0.229
Rwanda	11	539985.8614	0.177
Sudan	1	7922611.021	2.594
Sudan	2	20434017.65	6.690
Sudan	3	28319800.19	9.271
Sudan	4	26372264.51	8.634
Sudan	5	21043995.26	6.889
Sudan	6	18403709.66	6.025
Sudan	7	16782475.26	5.494
Sudan	8	14920427.41	4.885
Sudan	9	13444526.67	4.401
Sudan	10	11479820.64	3.758
Sudan	11	10134701.99	3.318

Table 3.58. Cont'd

C0untry	Frequency Classes	area ha	%
Tanzania	0	33761.66841	0.011
Tanzania	1	352317.0528	0.115
Tanzania	2	775597.2578	0.254
Tanzania	3	889767.8719	0.291
Tanzania	4	877612.0576	0.287
Tanzania	5	849637.9898	0.278
Tanzania	6	801328.5889	0.262
Tanzania	7	760062.7882	0.249
Tanzania	8	766817.7952	0.251
Tanzania	9	816053.8174	0.267
Tanzania	10	1011846.876	0.331
Tanzania	11	4108533.305	1.345
Uganda	0	93942.58848	0.031
Uganda	1	547701.841	0.179
Uganda	2	1253660.243	0.410
Uganda	3	1700940.859	0.557
Uganda	4	1793320.931	0.587
Uganda	5	1724418.213	0.565
Uganda	6	1592388.817	0.521
Uganda	7	1545678.191	0.506
Uganda	8	1651091.585	0.541
Uganda	9	2082770.268	0.682
Uganda	10	2547359.089	0.834
Uganda	11	4731773.373	1.549
Dr Congo DR Congo	2	3446.23765	0.001
Dr Congo DR Congo	3	8695.347956	0.003
Dr Congo DR Congo	4	20705.63156	0.007
Dr Congo DR Congo	5	33139.20671	0.011
Dr Congo DR Congo	6	56885.36021	0.019
Dr Congo DR Congo	7	98142.47036	0.032
Dr Congo DR Congo	8	170705.6058	0.056
Dr Congo DR Congo	9	299195.6655	0.098
Dr Congo DR Congo	10	531709.3235	0.174
Dr Congo DR Congo	11	845853.5254	0.277

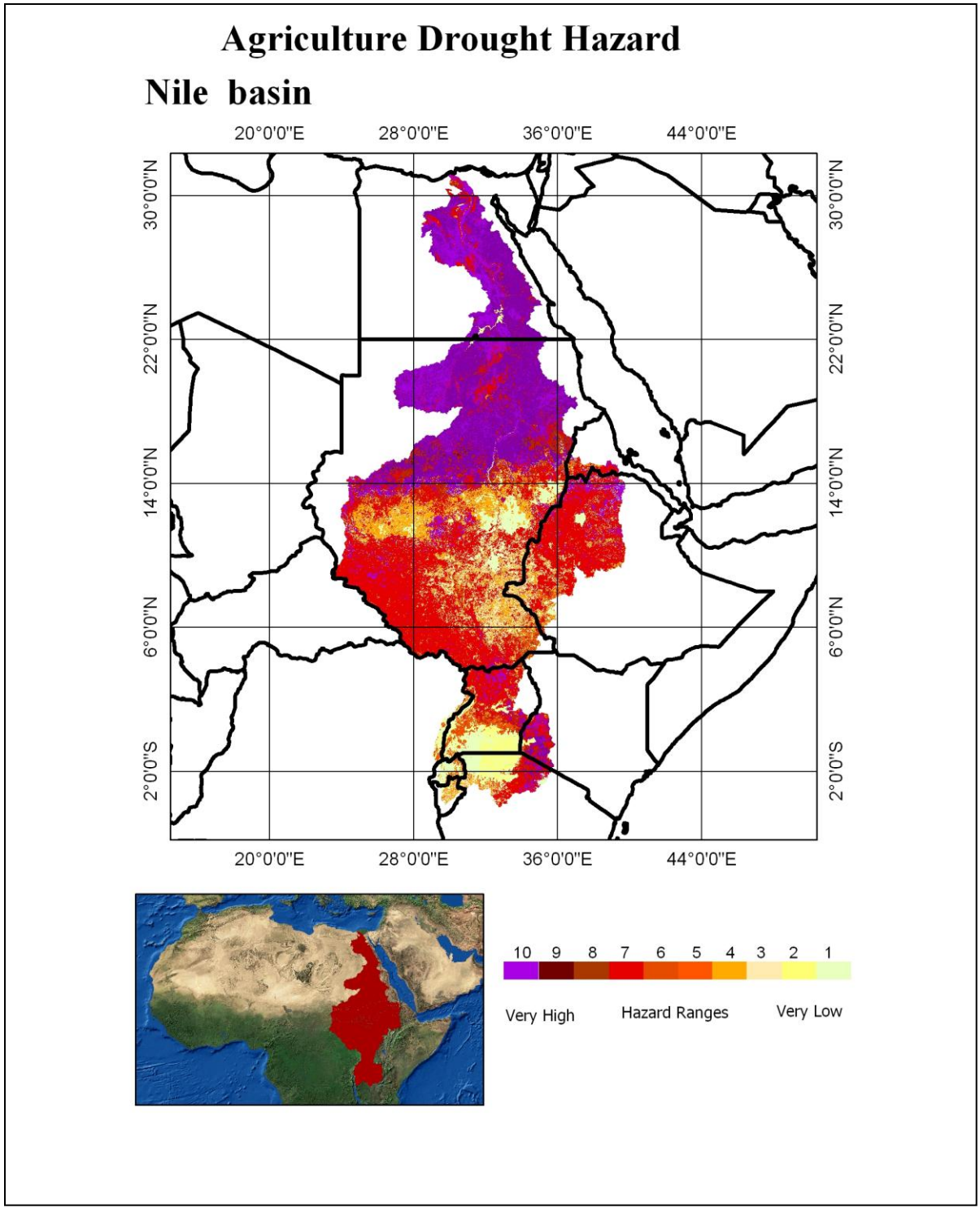


Figure 3.53. Agriculture Drought Hazard Map in Nile River's Basin

Table 3.59. Agriculture Drought Hazard Areas in Nile River's Basin

Hazard classes	Burundi	Egypt	Eritrea	Ethiopia	Kenya	Rwanda	Sudan	Tanzania	DR Congo	Uganda
1	0.1	0.1	0	0.5	0.1	0.4	3.6	1.2	0.3	1.5
2	0	0	0	0	0	0	0	0.7	0.2	1
3	0.1	0	0.1	1.1	0	0	4.3	0.3	0	0.2
4	0.1	0	0	0.7	0	0.1	5.8	0.2	0	0.2
5	0	0	0	0.2	0	0.1	0.7	0.1	0	0.4
6	0	0	0.5	0.2	0.1	0.1	1	0.1	0.1	0.6
7	0	1	0	7.8	0.6	0	23.3	1.1	0	2.3
8	0	0.2	0.1	0.3	0.1	0	2.8	0.1	0	0.3
9		0					0.1	0	0	0
10		2.5					5.2	0.1	0	0.3

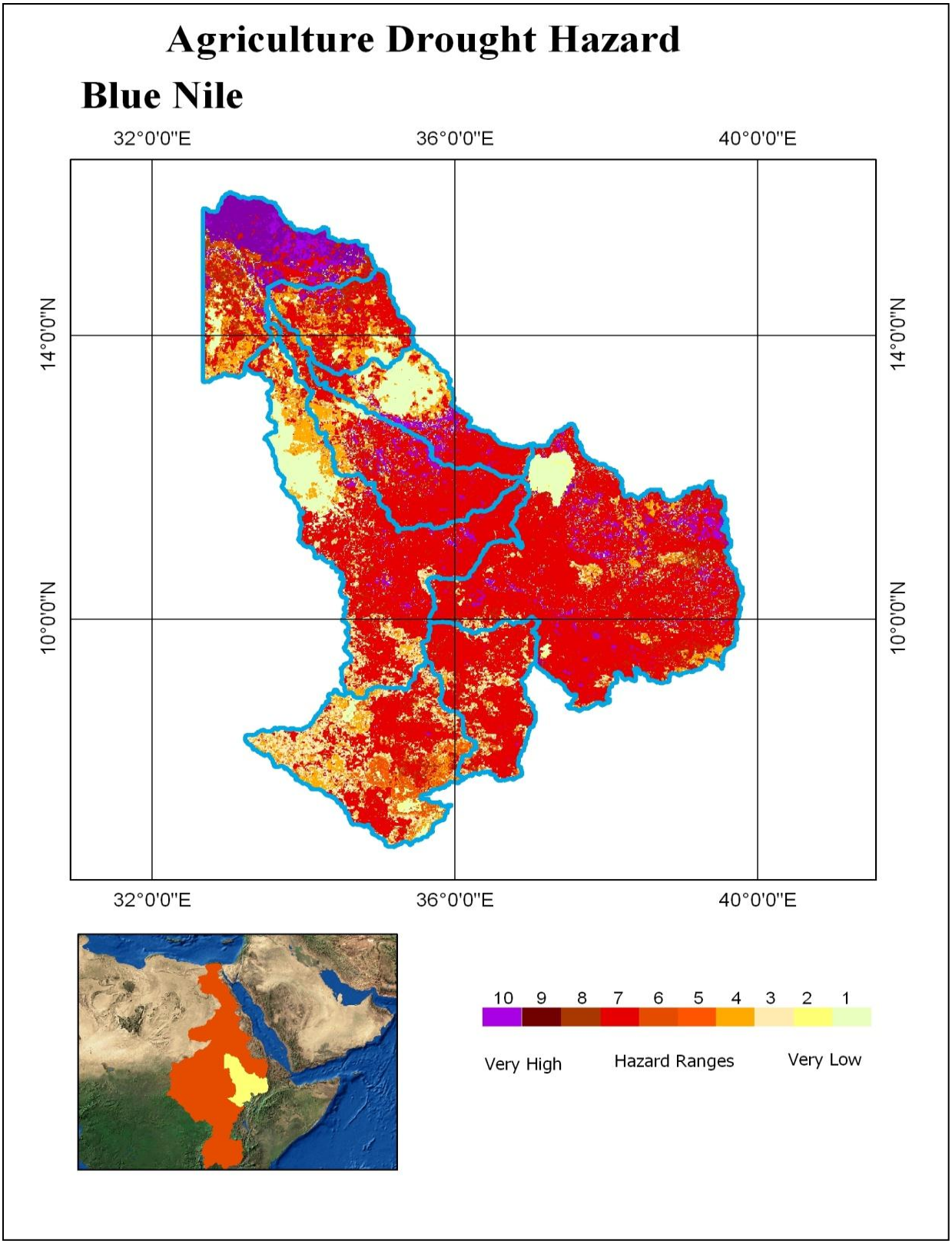


Figure 3.54. Agriculture Drought Hazard of Blue Nile

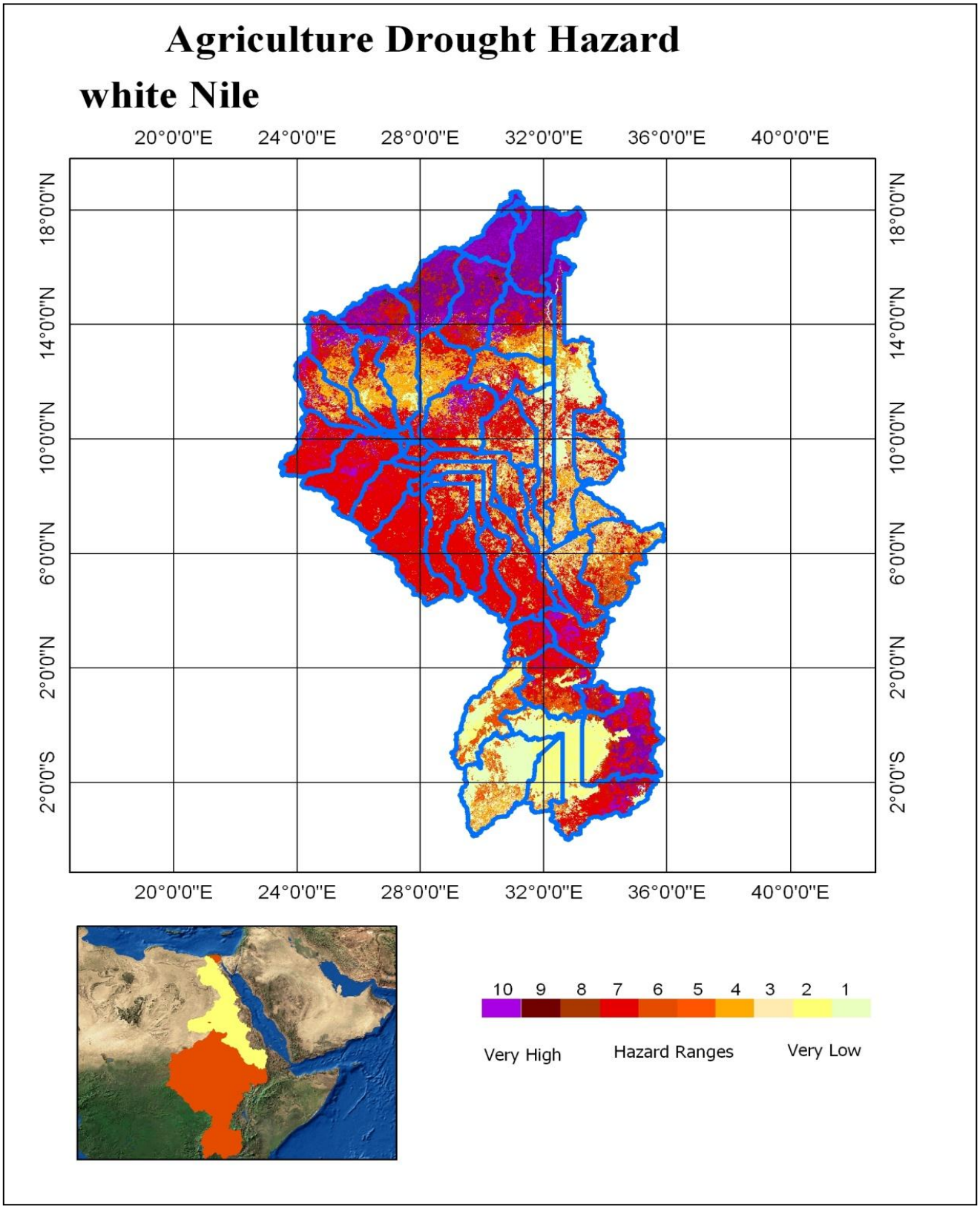


Figure 3.55. Agriculture Drought Hazard of White Nile

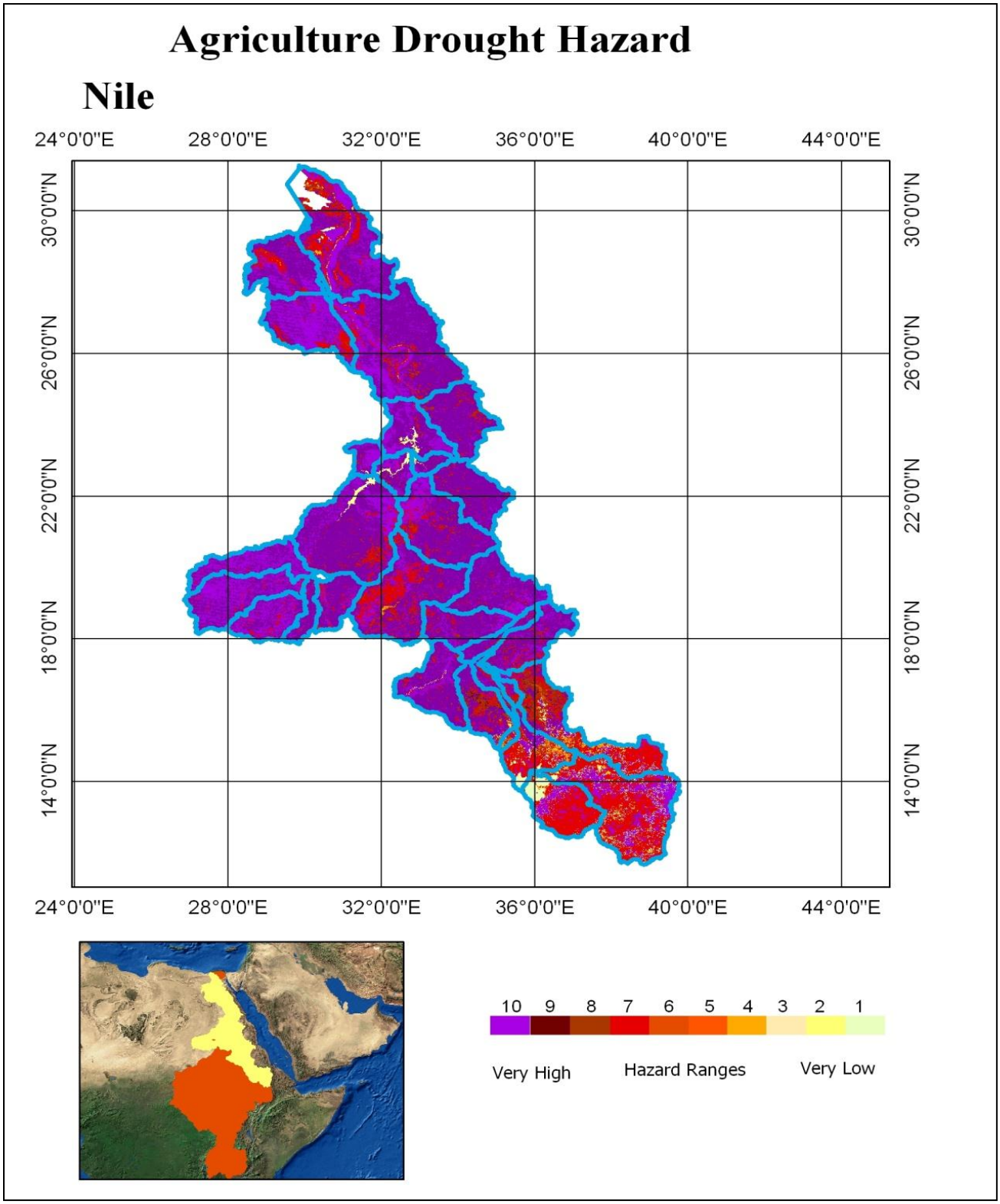


Figure 3.56. Agriculture Drought Hazard of Nile

3.7.2. Agriculture drought Hazard with Land Degradation

– **Land degradation map is shown in figure (3.57), and (Table 3.60 and 3.61). The results shows that**

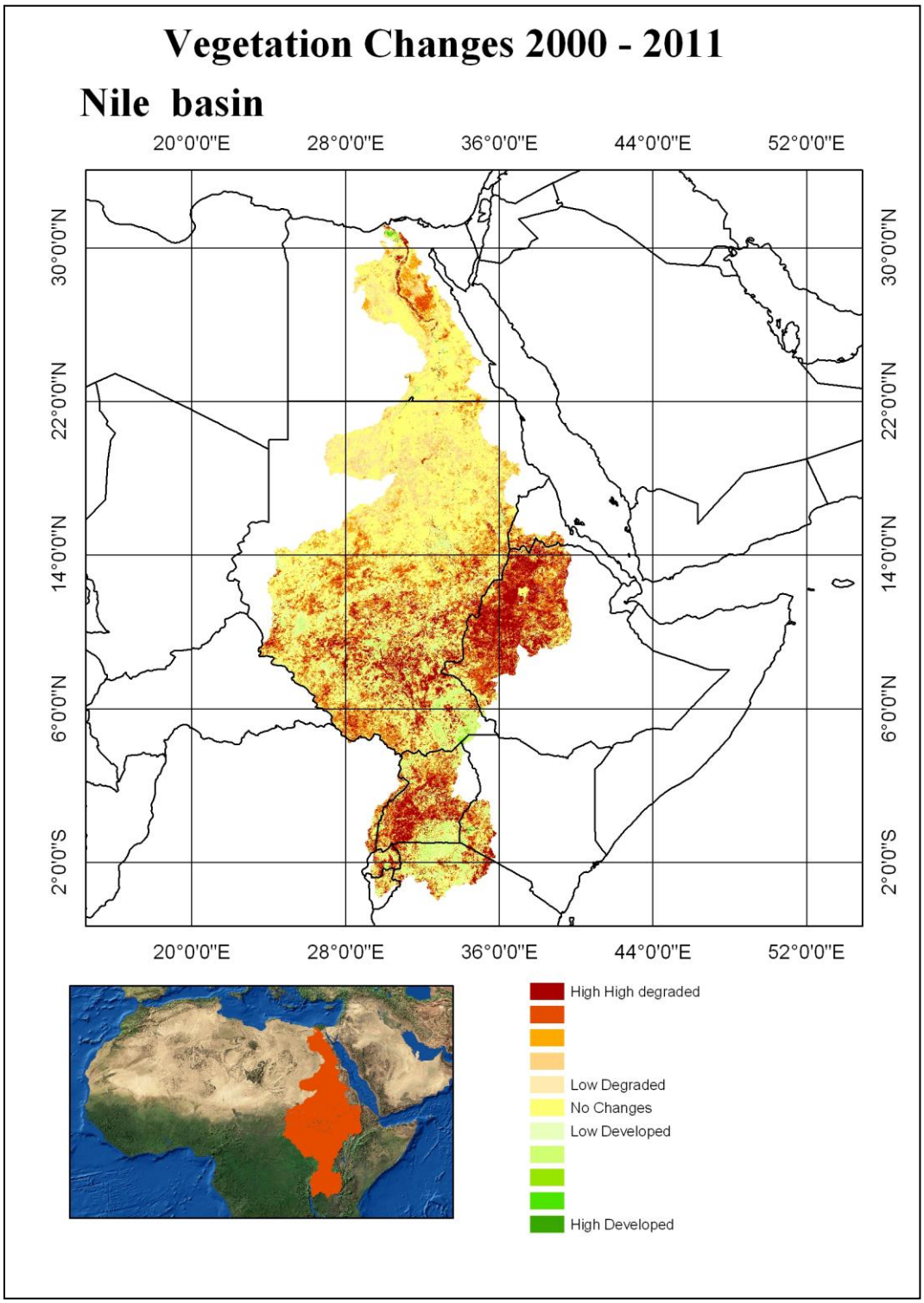


Figure 3.57. land Degradation Map in Nile River's Basin

Table 3.60 Land Degradation Areas in Nile River's Basin

Country	Area in	vh_deg	h_deg	m_deg	l_deg	vl_deg	L. Deg Total
	Ha						
	%						
	Ha						
	%						
	Ha						
	%						
	Ha						
	%						
	Ha						
	%						
	Ha						
	%						
	Ha						
	%						
	Ha						
	%						
	Ha						
	%						
	Ha						
	%						
	Ha						
	%						
	Ha						
	%						

Table 3.61. Land Developed Areas in Nile River's Basin

Country	Area in	vh_dev	h_dev	m_dev	l_dev	vl_dev	L. Dev Total
	Ha						
	%						
	Ha						
	%						
	Ha						
	%						
	Ha						
	%						
	Ha						
	%						
	Ha						
	%						
	Ha						
	%						
	Ha						
	%						
	Ha						
	%						
	Ha						
	%						
	Ha						
	%						
	Ha						
	%						

3.7.3. Agriculture drought Hazard with Land Cover/Use

– **Land Cover map is shown in figure (3.58), and the LC map legend is shown in Table (3.62), the impact of Agriculture drought Hazard in Land Cover/Use is shown in (Table 3.63).**

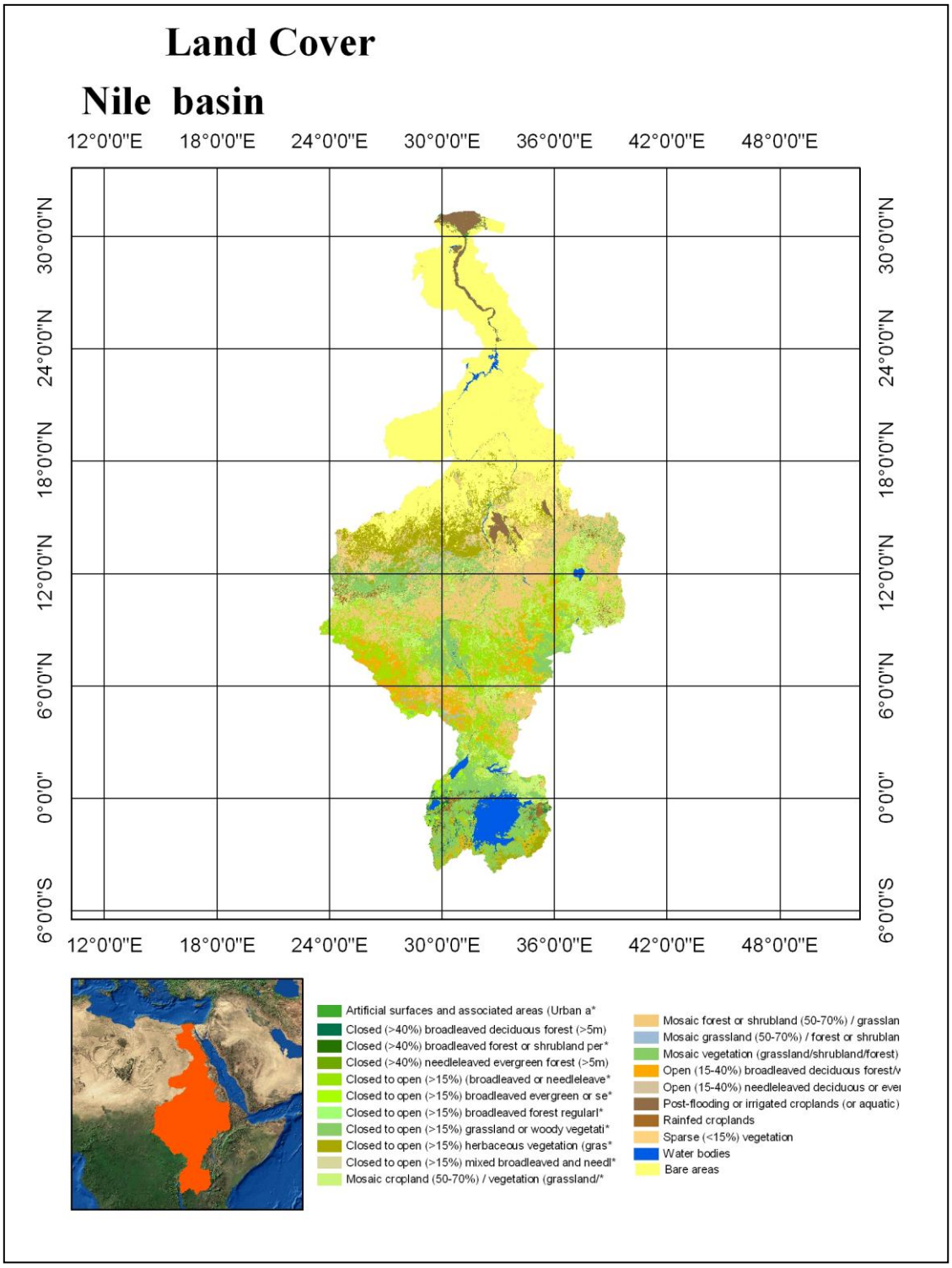


Figure 3.58. Land Cover Map in Nile River's Basin

Table 3.62. Land Cover Legend.

Description	Country	Area_ha	Percentage
Irrigated croplands	Egypt	1520811.18	0.25%
	Kenya	420.04	0.00%
	Sudan	1721275.83	0.28%
	Tanzania	104.79	0.00%
	Uganda	9.49	0.00%
		3242621.34	**0.53%**
Rainfed croplands	Burundi	35158.83	0.01%
	Congo, DRC	111192.88	0.02%
	Egypt	76252.22	0.01%
	Eritrea	148379.20	0.02%
	Ethiopia	1652706.96	0.27%
	Kenya	777164.22	0.13%
	Libya	701.85	0.00%
	Rwanda	89248.58	0.01%
	Sudan	2591179.47	0.43%
	Tanzania	312194.61	0.05%
	Uganda	685573.03	0.11%
		6479751.87	**1.06%**
Mosaic Croplands/Vegetation	Burundi	4766.08	0.00%
	Congo, DRC	231895.13	0.04%
	Egypt	119435.59	0.02%
	Eritrea	215509.67	0.04%
	Ethiopia	15453793.21	2.54%
	Kenya	3098265.35	0.51%
	Libya	472.64	0.00%
	Rwanda	5242.83	0.00%
	Sudan	13504368.94	2.22%
	Tanzania	28500.55	0.00%
	Uganda	3731707.60	0.61%
		36393957.59	**5.98%**

Table 3.62. Cont'd

Description	Country	Area_ha	Percentage
Mosaic Vegetation/Croplands	Burundi	1259271.23	0.21%
	Congo, DRC	12127106.74	1.99%
	Egypt	138537.05	0.02%
	Eritrea	819734.53	0.13%
	Ethiopia	8855400.41	1.46%
	Kenya	5367825.80	0.88%
	Libya	115.53	0.00%
	Rwanda	1362180.16	0.22%
	Sudan	15186568.23	2.50%
	Tanzania	8324284.18	1.37%
	Uganda	7746428.31	1.27%
		61187452.18	**10.05%**
Closed to open broadleaved evergreen or semi-deciduous forest	Burundi	43593.69	0.01%
	Congo, DRC	46137194.31	7.58%
	Ethiopia	962236.59	0.16%
	Kenya	404416.45	0.07%
	Rwanda	87600.83	0.01%
	Sudan	763258.21	0.13%
	Tanzania	159083.78	0.03%
	Uganda	922284.51	0.15%
		49479668.37	**8.13%**
Closed broadleaved deciduous forest	Burundi	319133.67	0.05%
	Congo, DRC	2338111.62	0.38%
	Kenya	721750.74	0.12%
	Rwanda	286323.48	0.05%
	Tanzania	1782225.28	0.29%
	Uganda	476689.61	0.08%
		5924234.40	**0.97%**
Open broadleaved deciduous forest	Burundi	495843.80	0.08%
	Congo, DRC	3134078.55	0.51%
	Eritrea	83.24	0.00%
	Ethiopia	4576701.78	0.75%
	Kenya	949923.58	0.16%
	Rwanda	300714.15	0.05%
	Sudan	10173488.55	1.67%
	Tanzania	4681212.70	0.77%
	Uganda	1301063.90	0.21%
		25613110.26	**4.21%**

Table 3. 62. Cont'd

Description	Country	Area_ha	Percentage
Closed needleleaved evergreen forest	Congo, DRC	221.76	0.00%
	Kenya	432.80	0.00%
	Tanzania	721.69	0.00%
	Uganda	4745.98	0.00%
		6122.24	**0.00%**
Open needleleaved deciduous or evergreen forest	Burundi	7624.91	0.00%
	Congo, DRC	55781.47	0.01%
	Kenya	55282.47	0.01%
	Rwanda	12653.39	0.00%
	Sudan	166.52	0.00%
	Tanzania	58621.43	0.01%
	Uganda	9985.63	0.00%
		200115.83	**0.03%**
Closed to open mixed broadleaved and needleleaved forest	Kenya	3155.99	0.00%
	Rwanda	47.58	0.00%
	Tanzania	31115.52	0.01%
	Uganda	9.51	0.00%
		34328.61	**0.01%**
Mosaic Forest-Shrubland/Grassland	Burundi	4444.20	0.00%
	Congo, DRC	124121.96	0.02%
	Eritrea	1375870.71	0.23%
	Ethiopia	11781675.66	1.94%
	Kenya	6120153.97	1.01%
	Rwanda	1203.62	0.00%
	Sudan	38286320.56	6.29%
	Tanzania	465869.54	0.08%
	Uganda	2634149.89	0.43%
		60793810.11	**9.99%**

Table 3.62. Cont'd

Description	Country	Area_ha	Percentage
Mosaic Grassland/Forest-Shrubland	Burundi	114.32	0.00%
	Congo, DRC	174144.11	0.03%
	Eritrea	10963.06	0.00%
	Ethiopia	157127.32	0.03%
	Kenya	269598.57	0.04%
	Rwanda	151.78	0.00%
	Sudan	2371386.58	0.39%
	Tanzania	135572.38	0.02%
	Uganda	34244.62	0.01%
		3153302.73	**0.52%**
Closed to open shrubland	Burundi	322082.96	0.05%
	Congo, DRC	1218015.15	0.20%
	Egypt	27970.27	0.00%
	Eritrea	14236.64	0.00%
	Ethiopia	9960613.75	1.64%
	Kenya	1632884.42	0.27%
	Rwanda	169597.92	0.03%
	Sudan	24730977.82	4.06%
	Tanzania	2512790.96	0.41%
	Uganda	2483709.37	0.41%
		43072879.27	**7.08%**
Closed to open grassland	Burundi	19152.26	0.00%
	Congo, DRC	39273.06	0.01%
	Eritrea	508156.13	0.08%
	Ethiopia	363903.81	0.06%
	Kenya	11764930.16	1.93%
	Rwanda	43395.37	0.01%
	Sudan	19852927.37	3.26%
	Tanzania	6566593.30	1.08%
	Uganda	96969.01	0.02%
		39255300.47	**6.45%**

Table 3.62. Cont'd

Description	Country	Area_ha	Percentage
Sparse vegetation	Burundi	19.02	0.00%
	Congo, DRC	256.43	0.00%
	Egypt	169969.01	0.03%
	Eritrea	1432543.67	0.24%
	Ethiopia	490708.66	0.08%
	Kenya	2723515.37	0.45%
	Libya	1135.40	0.00%
	Rwanda	19.01	0.00%
	Sudan	8316764.79	1.37%
	Tanzania	419729.28	0.07%
	Uganda	42989.46	0.01%
		13597650.08	**2.23%**
Closed to open broadleaved forest regularly flooded (fresh-brackish water)	Congo, DRC	3947782.76	0.65%
	Ethiopia	4094.76	0.00%
	Kenya	4394.63	0.00%
	Rwanda	485.01	0.00%
	Sudan	491709.25	0.08%
	Tanzania	379290.04	0.06%
	Uganda	195455.51	0.03%
		5023211.96	**0.83%**
Closed broadleaved forest permanently flooded (saline-brackish water)	Congo, DRC	833.12	0.00%
	Kenya	820.80	0.00%
	Uganda	1227.43	0.00%
		2881.34	**0.00%**
Closed to open vegetation regularly flooded	Burundi	4898.23	0.00%
	Congo, DRC	26865.56	0.00%
	Egypt	1852.31	0.00%
	Ethiopia	170447.95	0.03%
	Kenya	24963.24	0.00%
	Libya	8.41	0.00%
	Rwanda	30.12	0.00%
	Sudan	4044010.25	0.66%
	Tanzania	126089.19	0.02%
	Uganda	1252.78	0.00%
		4400418.03	**0.72%**

Table 3.62. Cont'd

Description	Country	Area_ha	Percentage
Artificial areas	Burundi	9563.26	0.00%
	Congo, DRC	211.74	0.00%
	Egypt	114152.62	0.02%
	Eritrea	11199.99	0.00%
	Ethiopia	12598.44	0.00%
	Kenya	47790.81	0.01%
	Rwanda	7685.19	0.00%
	Sudan	240167.75	0.04%
	Tanzania	20641.75	0.00%
	Uganda	21955.68	0.00%
		486058.36	**0.08%**
Bare areas	Congo, DRC	2438.65	0.00%
	Egypt	81054871.69	13.32%
	Eritrea	2140268.87	0.35%
	Ethiopia	904641.79	0.15%
	Kenya	5399623.32	0.89%
	Libya	17840041.65	2.93%
	Sudan	103670743.38	17.04%
	Tanzania	41455.89	0.01%
	Uganda	108460.05	0.02%
		211162545.28	**34.70%**
Water bodies	Burundi	198865.00	0.03%
	Congo, DRC	1198327.61	0.20%
	Egypt	716928.80	0.12%
	Eritrea	138.76	0.00%
	Ethiopia	666244.19	0.11%
	Kenya	1188692.90	0.20%
	Libya	1199.55	0.00%
	Rwanda	152595.14	0.03%
	Sudan	446719.12	0.07%
	Tanzania	3868586.29	0.64%
	Uganda	3704506.27	0.61%
		12142803.62	**2.00%**
Total		**581652223.95**	

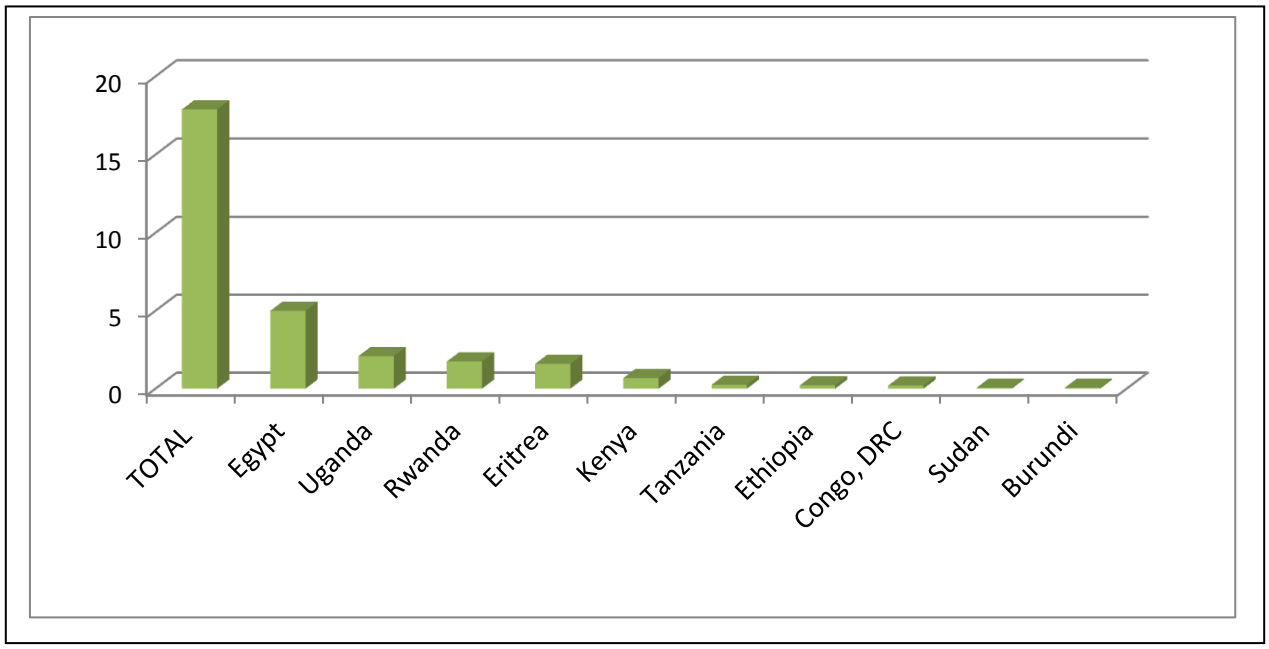


Figure 3.59. Rainfed croplands distribution among Nile Basin countries (17.9% of total Basin Area)

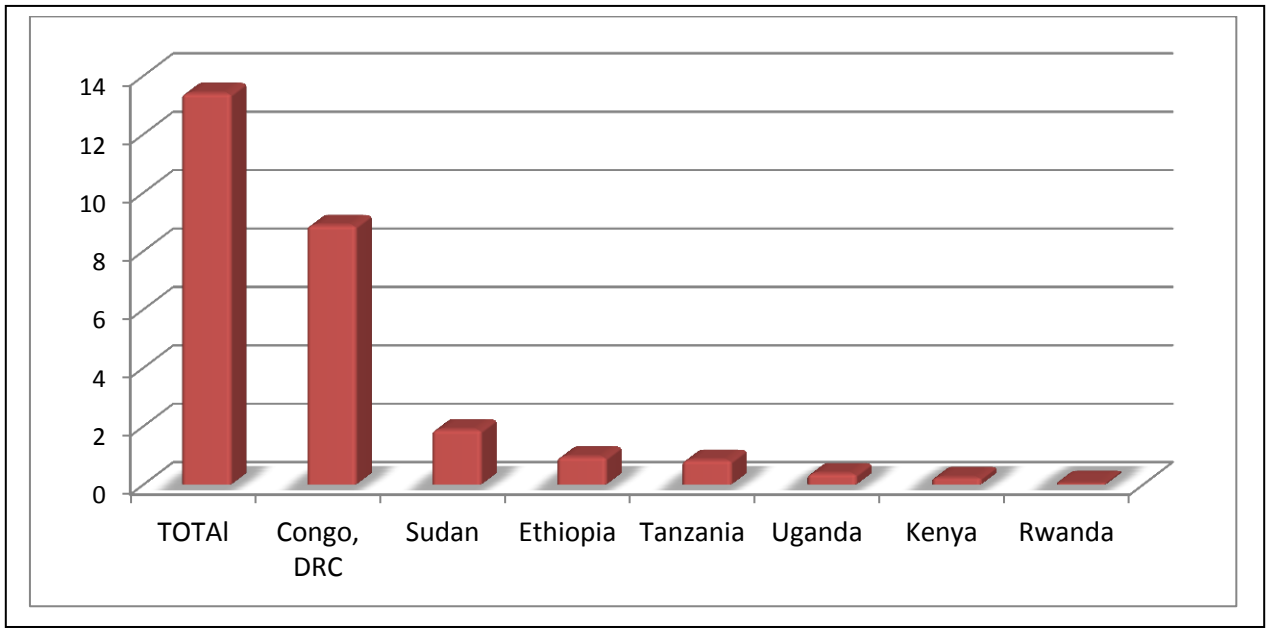


Figure 3.60. Forest distribution among Nile Basin countries (13.4% of total Basin Area)

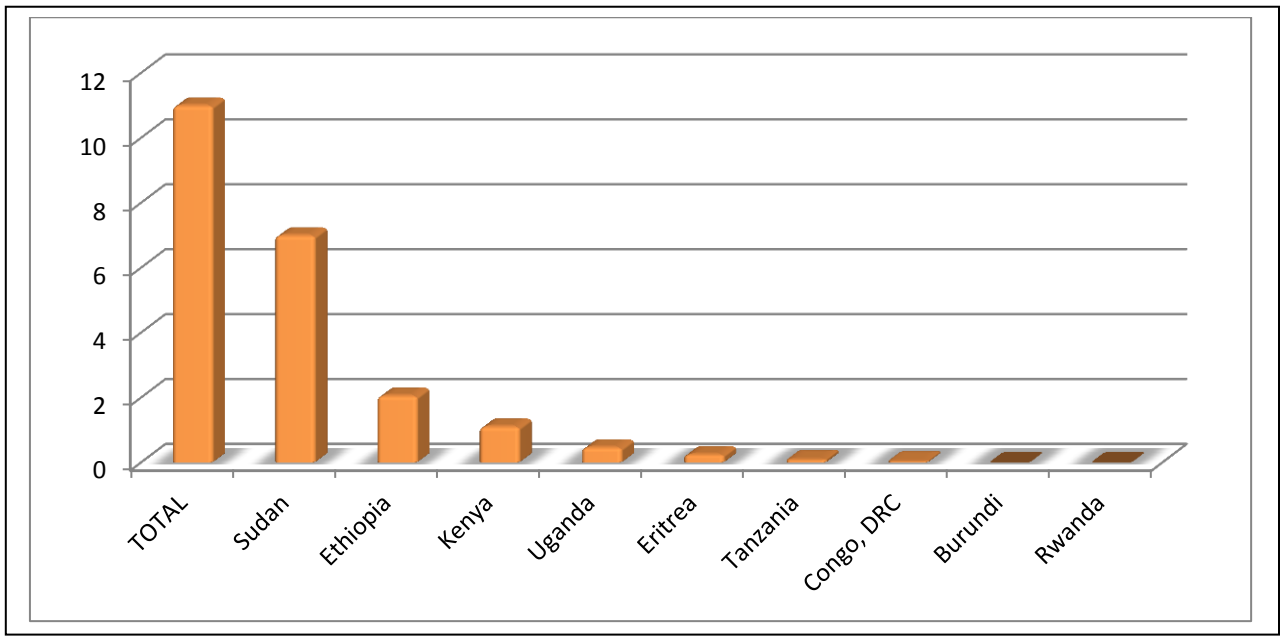


Figure 3.61. Mosaic Forest-Shrubland / Grassland distribution among Nile Basin countries (11.0% of total Basin Area)

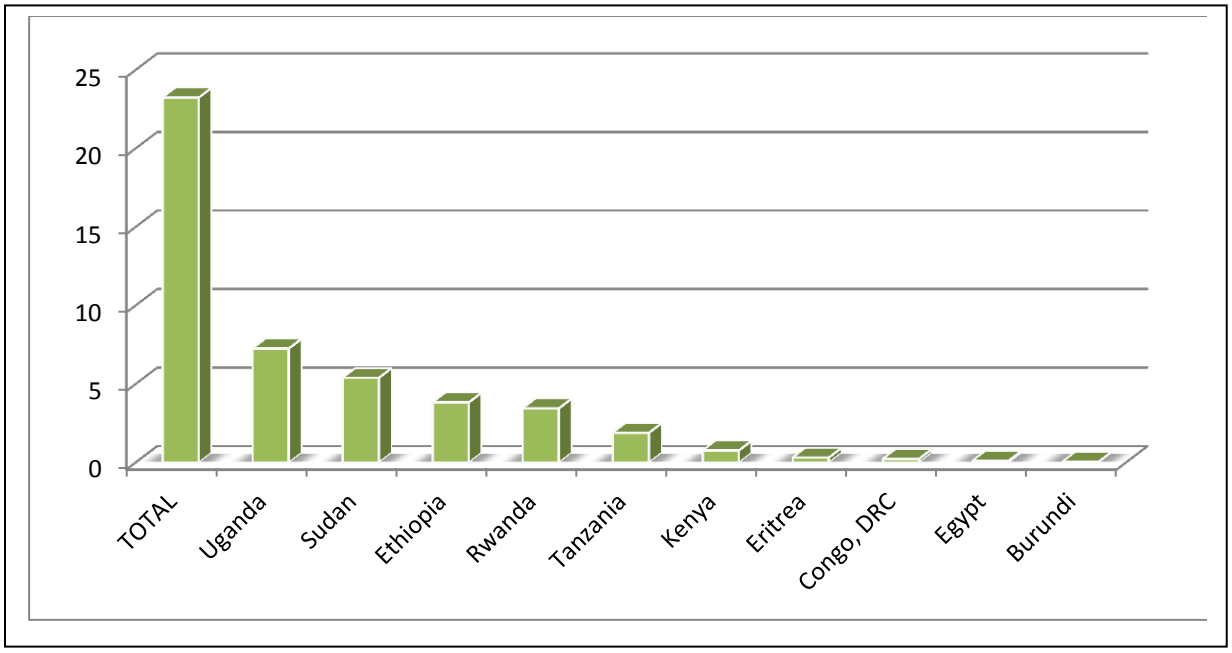


Figure 3.62. Rangelands distribution among Nile Basin countries (23.2% of total Basin Area)

Table 3.63. Agriculture Drought Hazard Areas in Nile River's Basin

Land Cover	Level of Hazard	Area in Ha	%
Rainfed croplands	Non	160174.86	0.34
	Slight	1465174.26	3.08
	Moderate	396181.88	0.83
	Severe	562063.83	1.18
Mosaic Croplands/Vegetation	Non	1069843.68	2.25
	Slight	8575030.75	18.02
	Moderate	2157650.44	4.54
	Severe	1778049.32	3.74
Forest	Non	2051.12	0.00
	Slight	10527.97	0.02
	Moderate	11357.12	0.02
	Severe	18971.71	0.04
Mosaic Forest-Shrubland/Grassland	Non	127958.43	0.27
	Slight	748372.17	1.57
	Moderate	296787.23	0.62
	Severe	356166.10	0.75
Rangelands	Non	490561.13	1.03
	Slight	3284250.88	6.90
	Moderate	809017.40	1.70
	Severe	695446.38	1.46

– **The results shows that**

3.8. Senegal River basin

3.8.1. Creating and Studying Agriculture drought Hazard

Creation of Agriculture drought hazard from ADI, ADV, ADF , ADC the results will include both the geographical distribution of the classes of each product and the table with areas in Ha, and percentage of each class by countries sharing the basin. Creating the Agriculture Drought Hazard ADH, from the analysis of the monthly band seasonally VHI.

- The ADI map of Senegal River basin is shown in figure (3.63), and (Table 3.64). The results shows that drought intensity is extend in 60% of the basin most of it belong to the class of low ADI and is distributed as follows 37% of in Syria, 18% in Turkey and 4.8% in Lebanon.
- The ADV map of Senegal River basin is shown in figure (3.64), and (Table 3.65). The results shows that drought variability is extend in 94% of the basin most of it belong to the class 1, that correspond to low variability ADI and is distributed as follows 60% of in Syria, 25.5% in Turkey and 6% in Lebanon.
- The ADF map of Senegal River basin is shown in figure (3.65), and (Table 3.66). The results shows that drought frequency is extend in most parts of the basin, almost, 36% are in classes 1 and 2 and 53% are in classes of 3, 4, 5 and 6 and less than 2% are in classes 7 to 10. The majority of the ADF are distributed as follows: 33% of in Syria, 18% in Turkey and 3% in Lebanon.
- The A ADC map of Senegal River basin is shown in figure (3.66), and (Table 3.67). The results show that drought consecutive is very low in most parts of the basin.
- Finally, the ADH map of Senegal River basin as shown in figure (3.67), and (Table 3.68) illustrate that almost 52% of the basin is under low level of ADH, and 8% is in moderate ADH while only 0.2% is in Sever ADH.

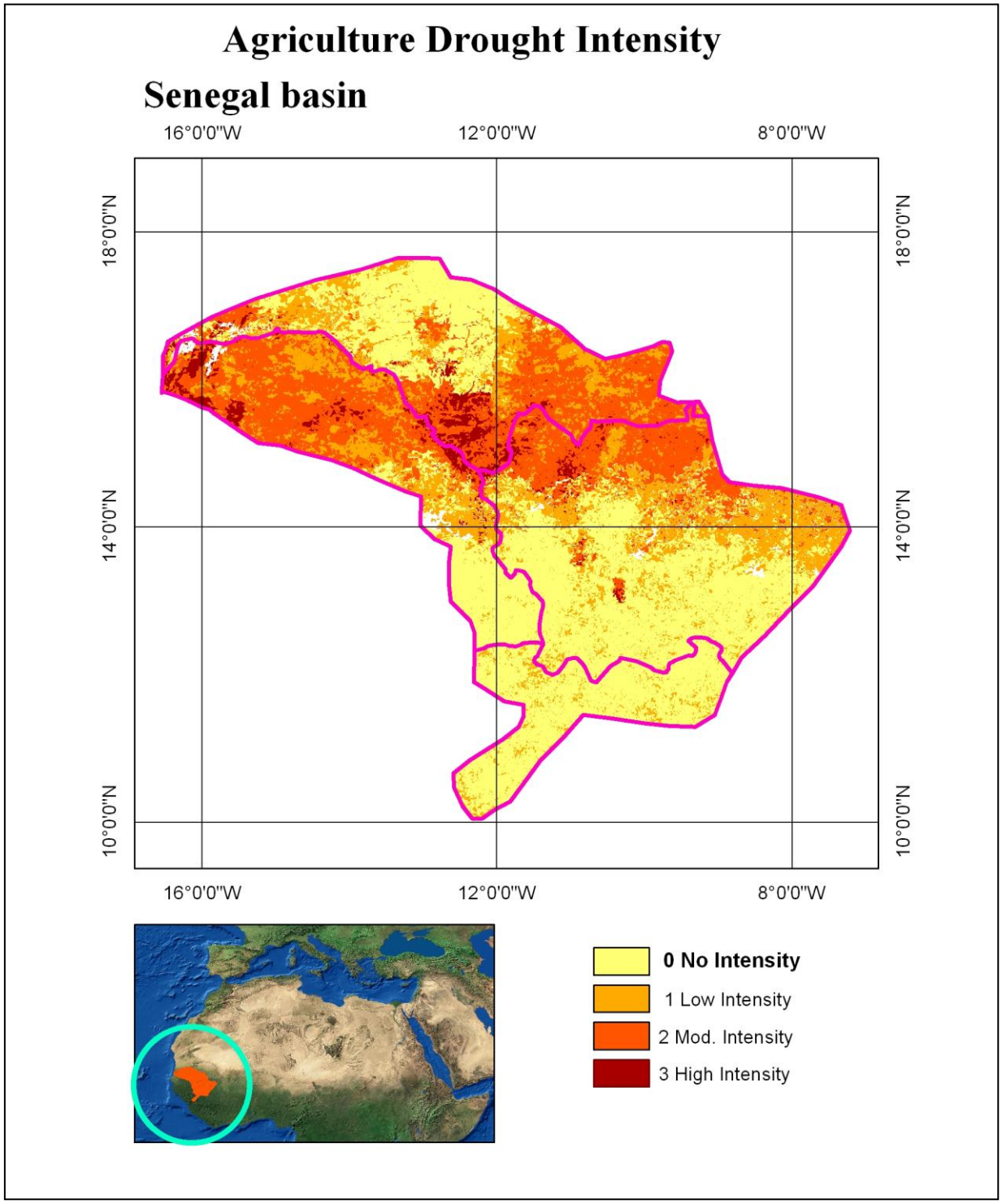


Figure 3.63. Agriculture Drought Intensity Map in Senegal River's Basin

Table 3.64.Agriculture Drought intensity Areas in Senegal River's Basin

Country	class	Area Ha	%
Turkey	No drought	222621.96	9.93%
	Low	404772.47	18.06%
	Moderate	5533.19	0.25%
	High	4751.01	0.21%
Syria	No drought	553093.66	24.68%
	Low	832025.76	37.12%
	Moderate	2231.21	0.10%
	High	2857.61	0.13%
Lebanon	No drought	104450.46	4.66%
	Low	108002.98	4.82%
	Moderate	848.91	0.04%
	High	55.48	0.00%

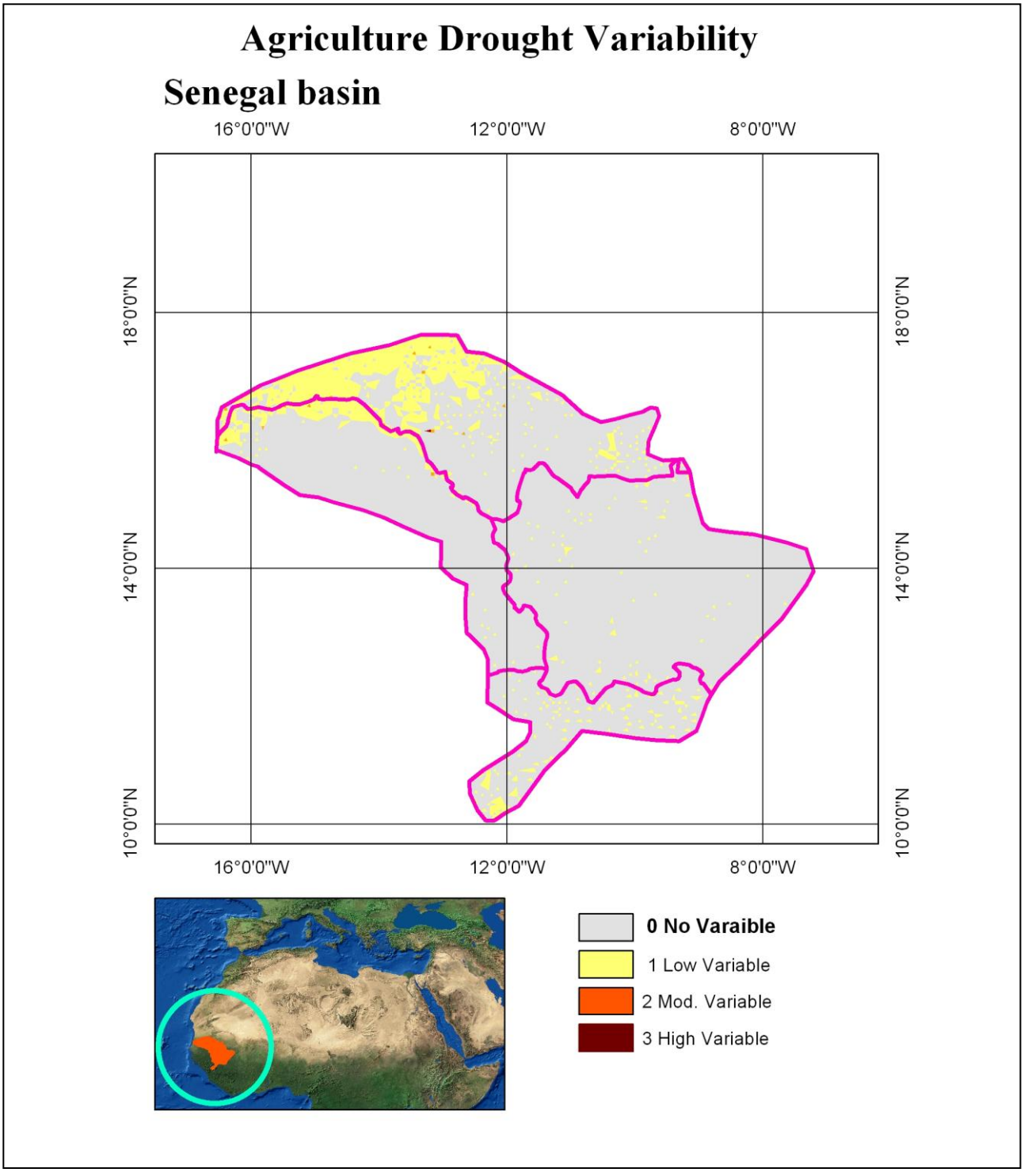


Figure 3.64. Agriculture Drought Variability Map in Senegal River's Basin

Table 3.65. Agriculture Drought Variability Areas in Senegal River's Basin

Country	Variability Classes	Area in Ha	%
Lebanon	0	212.89	0.01%
	1	205310.02	9.16%
	2	6921.94	0.31%
	3	912.98	0.04%
Syria	0	1384.94	0.06%
	1	1350223.40	60.25%
	2	32995.08	1.47%
	3	5604.82	0.25%
Turkey	0	869.52	0.04%
	1	570658.25	25.46%
	2	58319.17	2.60%
	3	7662.86	0.34%

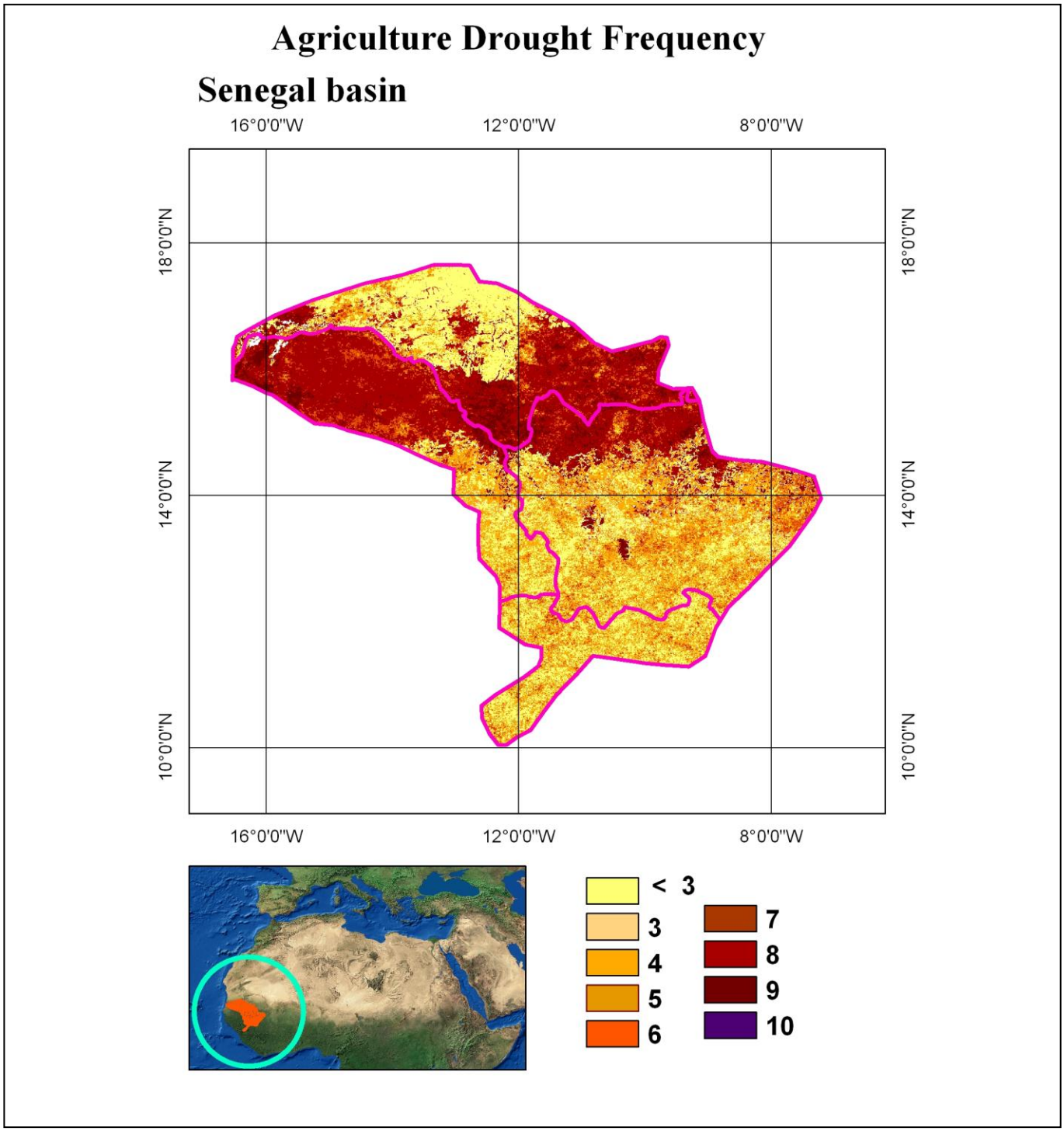


Figure 3.65. Agriculture Drought Frequency Map in Senegal River's Basin

Table 3.66. Agriculture Drought Frequency Areas in Senegal River's Basin

Country	Frequency Classes	Area in Ha	%
Lebanon	0	15066.54	0.67%
	1	58928.14	2.63%
	2	63262.34	2.82%
	3	49087.38	2.19%
	4	19649.93	0.88%
	5	6389.61	0.29%
	6	841.44	0.04%
	7	132.43	0.01%
Syria	0	37945.67	1.69%
	1	210480.44	9.39%
	2	398777.39	17.79%
	3	373915.14	16.68%
	4	214464.46	9.57%
	5	98181.91	4.38%
	6	41307.49	1.84%
	7	11785.44	0.53%
	8	3046.89	0.14%
	9	237.50	0.01%
	10	65.97	0.00%
Turkey	0	26947.60	1.20%
	1	76907.17	3.43%
	2	121847.96	5.44%
	3	145548.09	6.49%
	4	122051.87	5.45%
	5	81692.32	3.64%
	6	41282.40	1.84%
	7	16678.61	0.74%
	8	3035.08	0.14%
	9	226.42	0.01%
	10	1461.05	0.07%

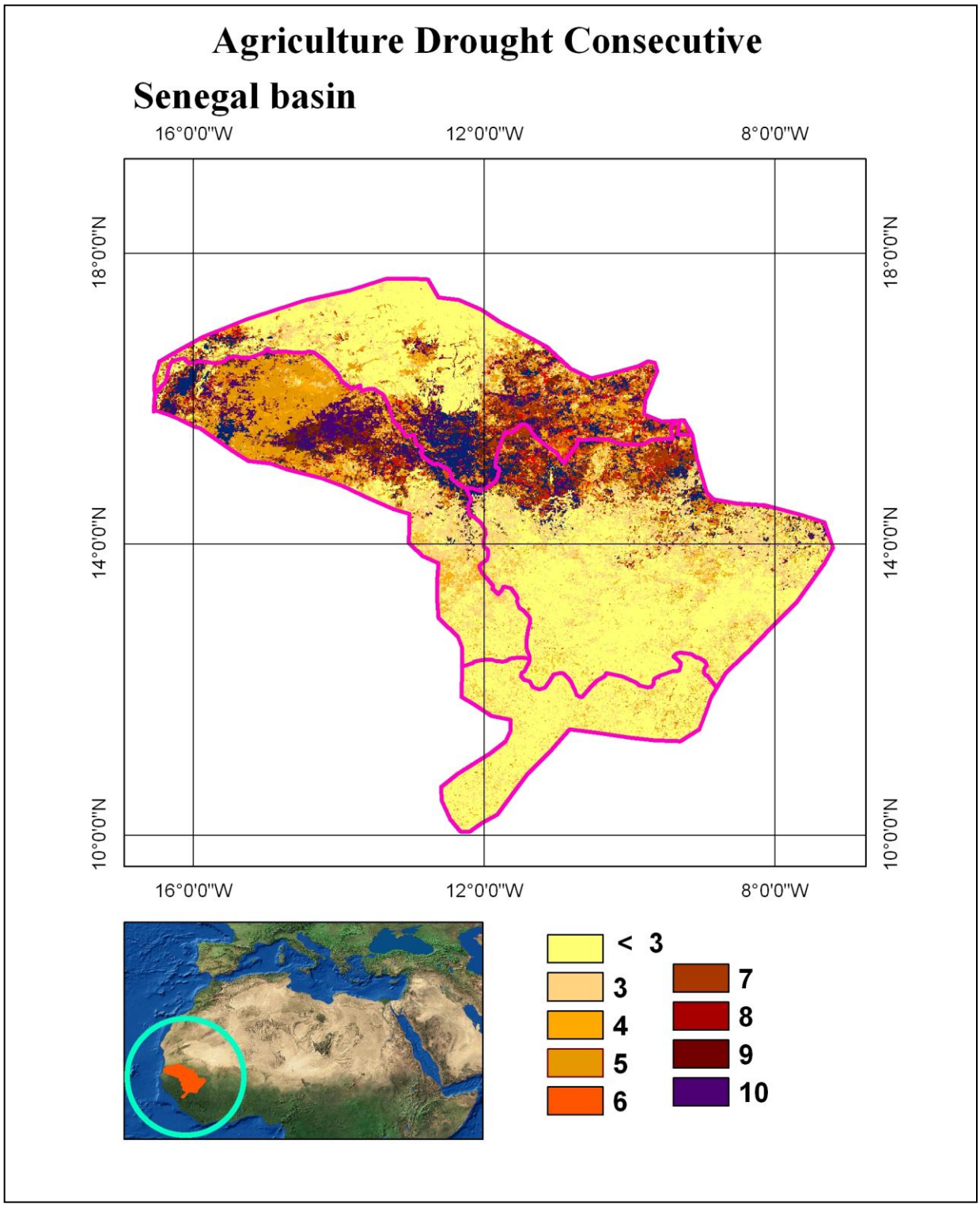


Figure 3.66. Agriculture Drought Consecutive Map in Senegal River's Basin

Table 3.67.Agriculture Drought Consecutive Areas in Senegal River's Basin

Country	Consecutive Classes	Area in Ha	%
Lebanon	0	15239.74	0.68%
Lebanon	1	130824.87	5.84%
Lebanon	2	45452.75	2.03%
Lebanon	3	3993.32	0.18%
Lebanon	4	698.76	0.03%
Lebanon	5	178.01	0.01%
Syria	0	60890.46	2.72%
Syria	1	1001432.01	44.68%
Syria	2	577006.75	25.74%
Syria	3	126065.66	5.62%
Syria	4	32240.85	1.44%
Syria	5	29472.86	1.32%
Syria	6	5340.62	0.24%
Syria	7	1291.97	0.06%
Syria	8	2509.51	0.11%
Syria	9	150.87	0.01%
Syria	10	1513.17	0.07%
Turkey	0	5301.35	0.24%
Turkey	1	80680.52	3.60%
Turkey	2	59910.79	2.67%
Turkey	3	26986.91	1.20%
Turkey	4	17145.74	0.77%
Turkey	5	12266.37	0.55%
Turkey	6	3579.10	0.16%
Turkey	7	320.58	0.01%
Turkey	8	750.68	0.03%
Turkey	10	0.49	0.00%

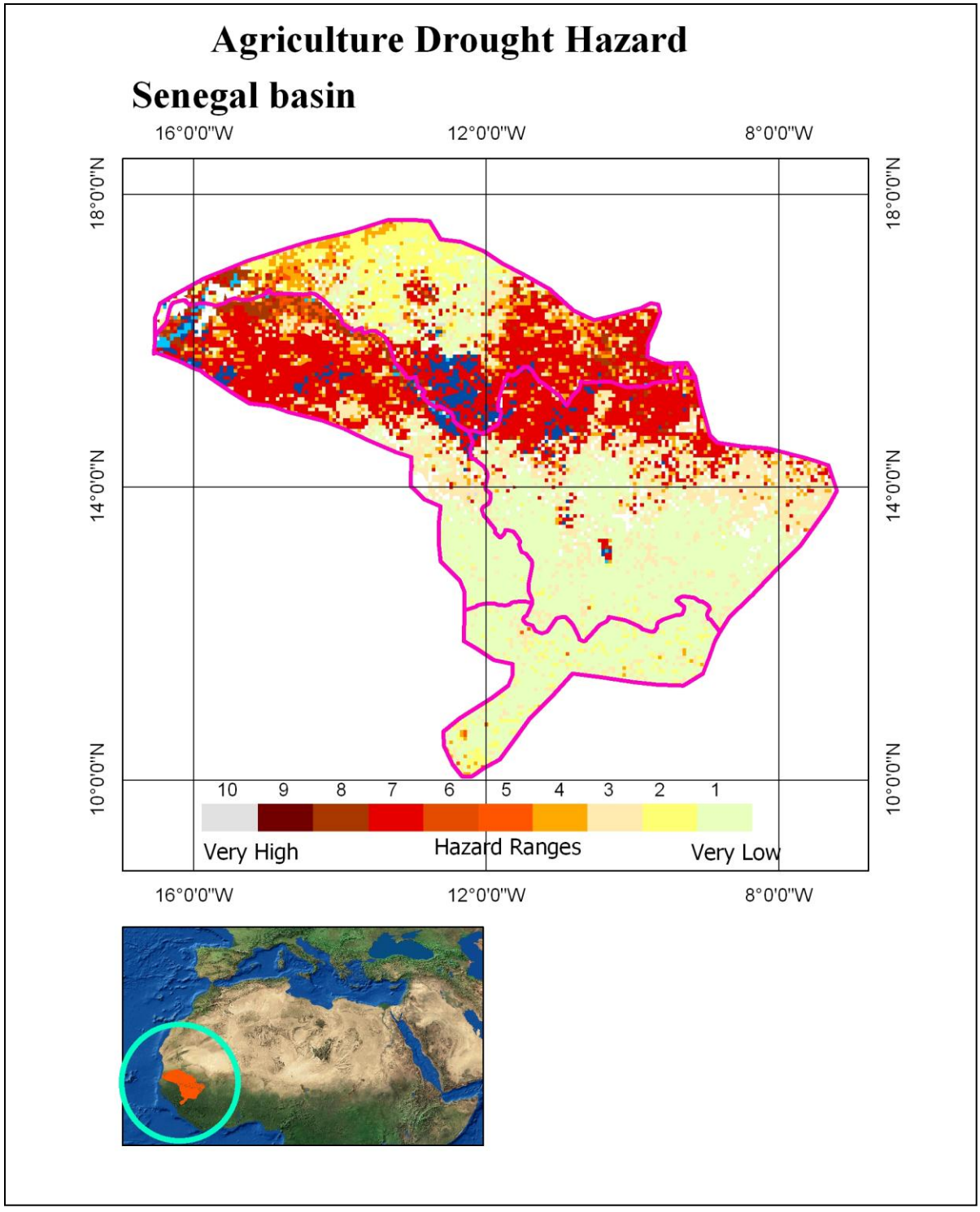


Figure 3.67. Agriculture Drought Hazard Map in Senegal River's Basin

Table 3.68.Agriculture Drought Hazard Areas in Senagal River's Basin

HAZARD Classes ADH	Area_ha	%
1	432200.23	12.64
2	897576.49	26.26
3	623047.06	18.23
4	1136847.17	33.26
5	119196.34	3.49
6	146667.92	4.29
7	7415.36	0.22
8	5978.17	0.17
9	724.80	0.02
10	359.52	0.01

3.8.2. Agriculture drought Hazard with Land Degradation

– **Land degradation map is shown in figure (3.68), and (Table 3.69 and 3.70). The results shows that**

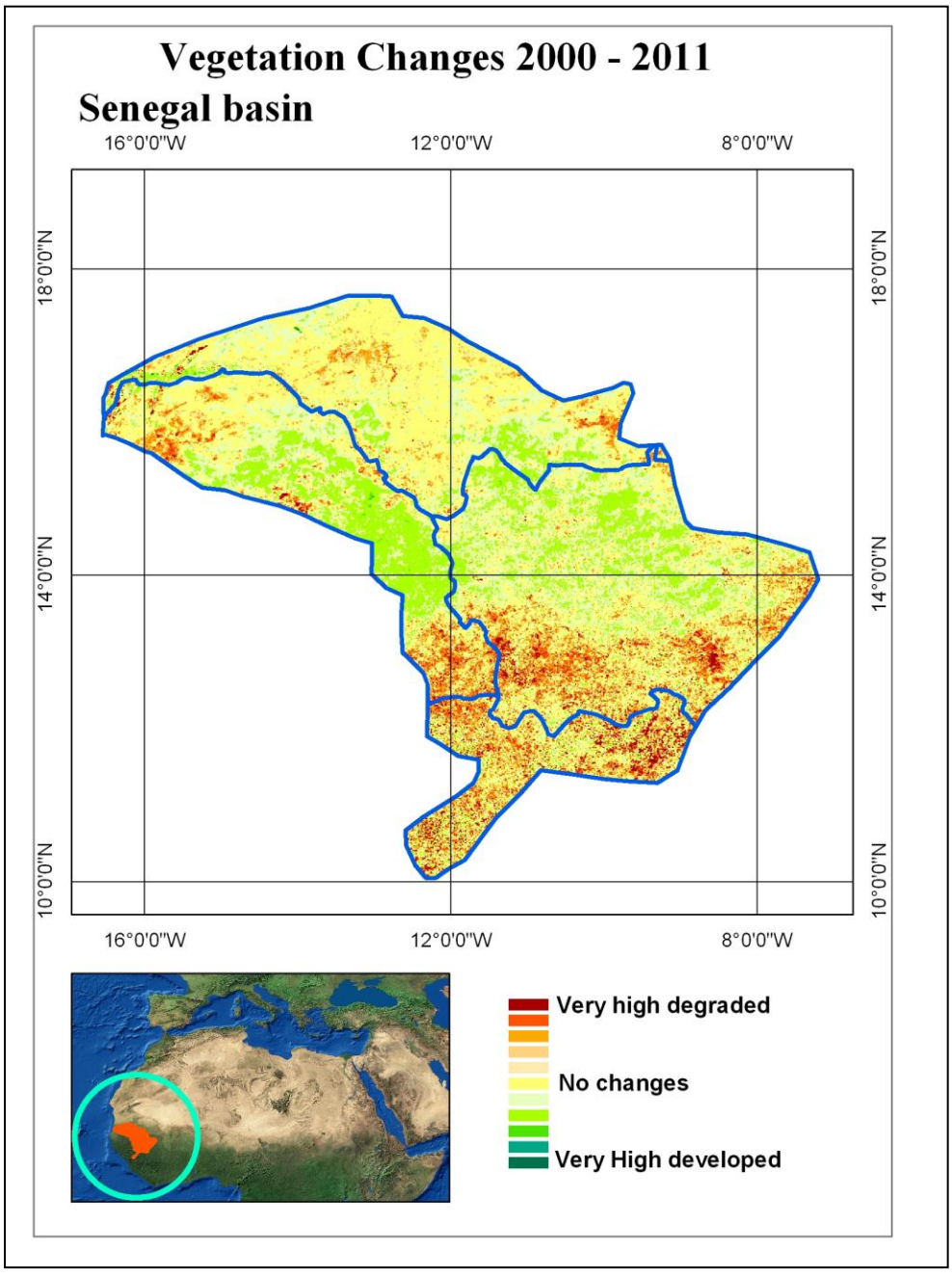


Figure 3.68. A land Degradation Map in Senegal River's Basin

Table 3.69. Land Degradation Areas in Senagal River's Basin

Country	Area in	vh_deg	h_deg	m_deg	l_deg	vl_deg	L. Deg Total
Turkey	Ha	35710.29	40479.59	45020.25	22879.65	10108.95	154198.73
	%	1.59	1.81	2.01	1.02	0.45	6.88
Syria	Ha	90522.21	122239.19	182858.96	97214.55	32740.35	525575.26
	%	4.04	5.45	8.16	4.34	1.46	23.45
Lebanon	Ha	300.38	1243.93	2329.49	1591.57	817.99	6283.36
	%	0.01	0.06	0.1	0.07	0.04	0.28
TOTAL	Ha	126532.88	163962.71	230208.7	121685.77	43667.29	686057.35
	%	5.64	7.32	10.27	5.43	1.95	30.61

Table 3.70.Land Developed Areas in Senagal River's Basin

Country	Area in	vh_dev	h_dev	m_dev	l_dev	vl_dev	L. Dev Total
Turkey	Ha	35710.29	40479.59	45020.25	22879.65	10108.95	154198.73
	%	1.59	1.81	2.01	1.02	0.45	6.88
Syria	Ha	90522.21	122239.19	182858.96	97214.55	32740.35	525575.26
	%	4.04	5.45	8.16	4.34	1.46	23.45
Lebanon	Ha	300.38	1243.93	2329.49	1591.57	817.99	6283.36
	%	0.01	0.06	0.1	0.07	0.04	0.28
TOTAL	Ha	126532.88	163962.71	230208.7	121685.77	43667.29	686057.35
	%	5.64	7.32	10.27	5.43	1.95	30.61

3.8.3. Agriculture drought Hazard with Land Cover/Use

– **Land Cover map is shown in figure (3.69), and the LC map legend is shown in Table (3.71), the impact of Agriculture drought Hazard in Land Cover/Use is shown in (Table 3.72).**

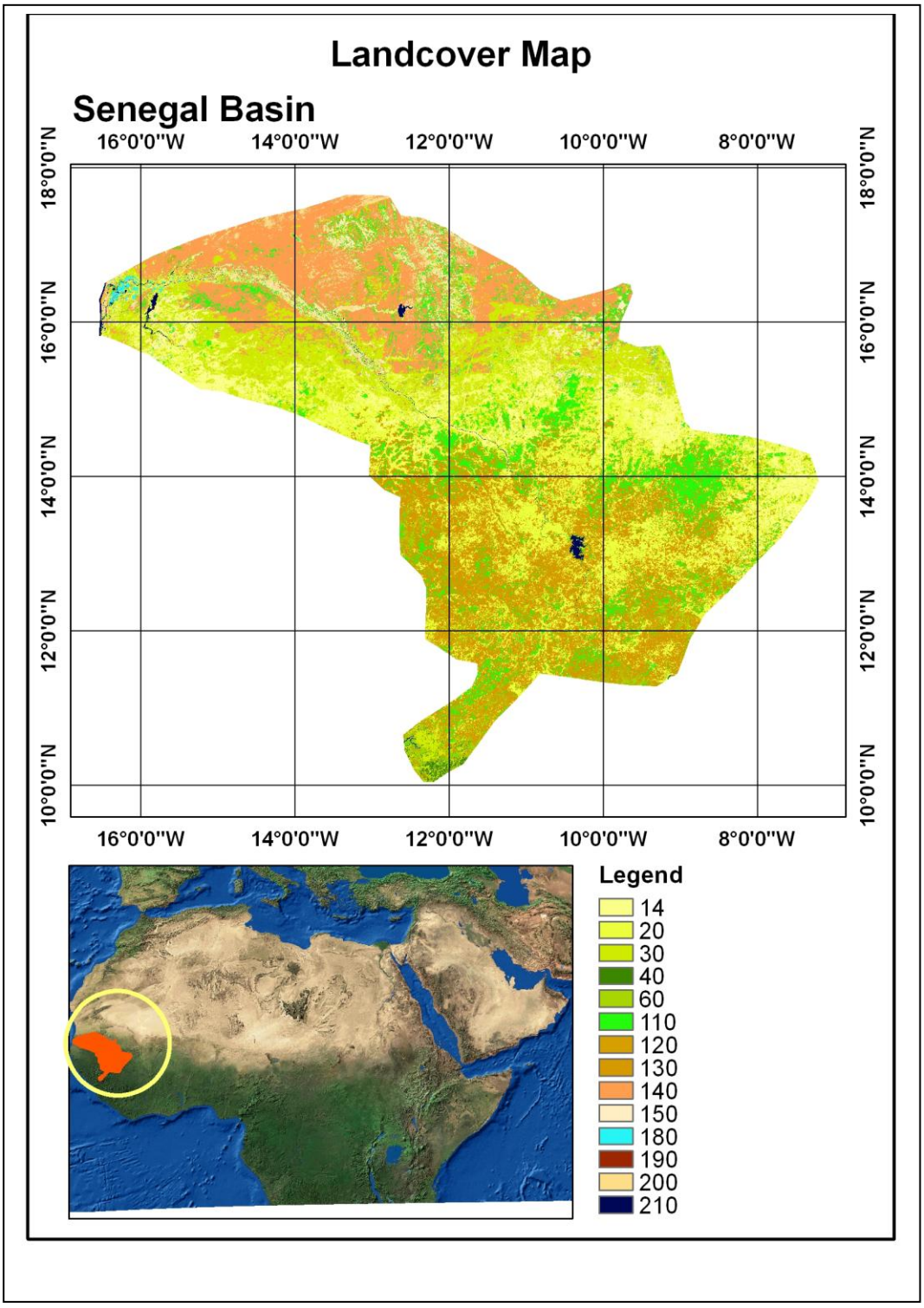


Figure 3.69.Land Cover Map in Senegal River's Basin

Table.3.71. Land Cover Legend.

Land Cover Description Orontes	Area_ ha	%	Country	Area_ha	%
Rainfed croplands	**641663.73**	**18.77%**	Lebanon	46299.68	1.35%
			Syria	582081.15	17.03%
			Turkey	13282.91	0.39%
Mosaic Croplands/Vegetation	**1250839.40**	**36.59%**	Lebanon	76261.86	2.23%
			Syria	1066740.00	31.20%
			Turkey	107837.54	3.15%
Mosaic Vegetation/Croplands	**500969.03**	**14.65%**	Lebanon	22241.21	0.65%
			Syria	400296.65	11.71%
			Turkey	78431.18	2.29%
Closed broadleaved deciduous forest	**29789.75**	**0.87%**	Syria	23976.88	0.70%
			Turkey	5812.86	0.17%
Closed needle leaved evergreen forest	**137799.59**	**4.03%**	Syria	115324.57	3.37%
			Turkey	22475.02	0.66%
Closed to open mixed broadleaved and needle leaved forest	**18562.55**	**0.54%**	Syria	16591.60	0.49%
			Turkey	1970.94	0.06%
Mosaic Forest-Shrub land/Grassland	**57179.31**	**1.67%**	Lebanon	1648.09	0.05%
			Syria	36969.54	1.08%
			Turkey	18561.68	0.54%
Mosaic Grassland/Forest-Shrub land	**78042.42**	**2.28%**	Lebanon	240.59	0.01%
			Syria	59756.23	1.75%
			Turkey	18045.60	0.53%
Closed to open shrub land	**164106.22**	**4.80%**	Lebanon	506.58	0.01%
			Syria	121012.36	3.54%
			Turkey	42587.28	1.25%
Sparse vegetation	**326557.43**	**9.55%**	Lebanon	109672.26	3.21%
			Syria	206395.33	6.04%
			Turkey	10489.84	0.31%
Bare areas	**160033.83**	**4.68%**	Lebanon	28547.30	0.84%
			Syria	131016.24	3.83%
			Turkey	470.29	0.01%
Water bodies	**53022.05**	**1.55%**	Syria	46217.82	1.35%
			Turkey	6804.23	0.20%

Table 3.72. Agriculture Drought Hazard Areas in Senegal River's Basin

Land Cover	Level of Hazard	Area in Ha	%
Rainfed croplands	Non	257143.18	7.52
	Slight	334036.98	9.77
	Moderate	49678.28	1.45
	Severe	630.26	0.02
Mosaic Croplands/Vegetation	Non	654319.62	19.14
	Slight	938465.41	27.45
	Moderate	149672.46	4.38
	Severe	3641.46	0.11
Forest	Non	105599.24	3.09
	Slight	59108.85	1.73
	Moderate	19859.75	0.58
	Severe	744.95	0.02
Mosaic Forest-Shrubland/Grassland	Non	47360.34	1.39
	Slight	71983.04	2.11
	Moderate	14840.93	0.43
	Severe	436.18	0.01
Rangelands	Non	197791.01	5.79
	Slight	260179.32	7.61
	Moderate	29889.82	0.87
	Severe	671.97	0.02

- **The results shows that**

4. LESSON LEARNED AND RECOMMENDATIONS

4.1. INTRODUCTION

T***he participants on ACSAD Trans-boundary river's basins workshops*** agreed with the World Bank - Sustainable Development Department Middle East and North Africa Region, Flagship Report, lunched on 2012 and titled "Adaptation to a Changing Climate in the Arab Countries MNA", World Bank (2012)[292] ,**on the following:**

- Climate has shaped the cultures of Arab countries. The first settlements, farming communities, and cities in the world all began in this region and all were formed partly in response to the variable climate. For thousands of years, people have coped with the challenges of the marked climate variability of the region by adapting their survival strategies to changes in rainfall and temperature.
- Over the next century the climate of Arab countries will experience unprecedented extremes. Temperatures will reach highs never before experienced. In many places, there will be less rainfall, lower precipitation combined with increased temperatures and a growing population will mean that the already water-scarce region may not have enough water to irrigate crops, support industry, or provide drinking water for its people. As climate variability increases so does vulnerability to it, especially for the poor and those heavily dependent on natural resources like the farmers and pastoralists.
- Across the Globe and in Arab countries, climate change is considered a major threat to poverty reduction and economic growth and may unravel many of the development gains made in recent decades.
- Climate variability and change threaten development by restricting the fulfillment of human potential and disempowering people and communities, constraining their ability to protect and enrich their livelihoods.
- Extreme events and impacts of climate change is already being felt in Arab countries, with 2010 tying 2005 as the warmest year since records began in the late 1800s. Of the 19 countries that set new record highs in 2010, five were Arab countries, including Kuwait (52.6 °C), Iraq (52.0 °C), Saudi Arabia (52.0 °C), Qatar (50.4 °C), and Sudan (49.7 °C). Last year the Arabian Sea experienced the second strongest tropical cyclone on record—Cyclone Phet in June 2010 peaked at Category 4 strength with 145 mph winds, killing 44 people and wreaking US$700 million in damage in Oman.[293] Coral reefs took the second worse beating on record because of record or near record summer ocean water temperatures. A snapshot of the impacts of climate change in Arab countries shows:

    - Higher temperatures; frequent and intense heat waves, threatening lives and crops.
    - Loss of winter precipitation storage in snow mass, inducing summer droughts.
    - Increased frequency of prolonged (semi-mega) droughts loss of livelihood, income and reduced well-being.
    - Less but more intense rainfall, causing both more droughts and greater flooding.
    - Higher air temperatures leading to loss of terrestrial biodiversity and increased acidification of oceans, impacting marine ecosystems and fisheries.
    - Sea level rise, threatening river deltas, coastal cities, wetlands, and small island nations such as Comoros and Bahrain with storm surges, salinized water, and flooding.

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[292] World Bank 2012." Adaptation to a Changing Climate in the Arab Countries MNA", Flagship Report, Sustainable Development Department Middle East and North Africa Region, Report N° 64635 – MNA

[293] Only Category 5 Cyclone Gonu of 2007 was a stronger Arabian Sea cyclone killing about 50 people in Oman with damage estimated at roughly US$4.2 billion.

- More intense cyclones.
- Loss of coral reefs.
- New areas exposed to dengue, malaria, and other vector and waterborne diseases.
- Reduced education attainment, especially of girls.
- Increased number of sick days for people due to diseases both to old and new diseases

– Arab countries are located in a hyper-arid to arid region (less than 0.2 on the Aridity Index (AI) with pockets of semi-arid areas (between 0.2 and 0.5 AI). Environmental challenges in the Arab world include water scarcity—with the lowest freshwater resource endowment in the world5—very low and variable precipitation, and excessive exposure to extreme events including drought, and desertification.
– Climate change also affects gender dynamics and people's health.
– Climate change has already affected or will affect most of the 340 million people in the Arab region, but the roughly 100 million poor people have the least resilience to cope with these changes and are the most vulnerable to its negative impacts.[294]
– Climate change adaptations, including innovative technology as well as livelihood and social protection schemes, can reduce these negative impacts on well-being and livelihoods.
– There are indications that the number of droughts has increased in and that droughts may become more frequent in the future. Low rainfall leads to reductions in crop yields or, in extreme cases, to complete loss of the harvest, especially for rainfed agriculture.
– Droughts also affect livestock, particularly animals that rely on pastures for feed. Dry periods may also last longer; prolonged periods of low rainfall tend to exacerbate the impact. In addition to these direct effects on the agricultural sector and farm households, droughts affect other sectors of the economy and nonfarm households indirectly.

The participants on ACSAD Trans-boundary river's basins workshops agreed with the Special Report on Extreme Events (SREX), **<u>on the following:</u>**

– Exposure and vulnerability are key determinants of disaster risk and of impacts when risk is realized. Exposure and vulnerability are dynamic, varying across temporal and spatial scales, and depend on economic, social, geographic, demographic, cultural, institutional, governance, and environmental factors (*high confidence*).
– Individuals and communities are differentially exposed and vulnerable based on inequalities expressed through levels of wealth and education, disability, and health status, as well as gender, age, class, and other social and cultural characteristics.
– The core concepts of how exposure and vulnerability to weather and climate events determine impacts and the likelihood of disasters (disaster risk) as illustrated in figure (4.1), it evaluates the influence of natural climate variability and anthropogenic climate change on climate extremes and other weather and climate events that can contribute to disasters, as well as the exposure and vulnerability of human society and natural ecosystems.
– It also considers the role of development in trends in exposure and vulnerability, implications for disaster risk, and interactions between disasters and development, (IPCC 2012)[295].

[294] IPCC (2007) points out that there are "sharp differences across regions and those in the weakest economic position are often the most vulnerable to climate change and are frequently the most susceptible to climate-related damages, especially when they face multiple stresses. There is increasing evidence of greater vulnerability of specific groups…" IPCC (2007) makes specific mention of traditional peoples and ways of living only in the cases of Polar Regions and small island states.

- Disaster risk management and adaptation to climate change can reduce exposure and vulnerability to weather and climate events and thus reduces disaster risk, as well as increase resilience to the risks that cannot be eliminated, figure (4.2), after (IPCC 2012).
- The new global approach discussed and reported by IPCC 2012 in the SREX report infancies that both adaptation and disaster risk management approaches for reducing and managing disaster risk in a changing climate.

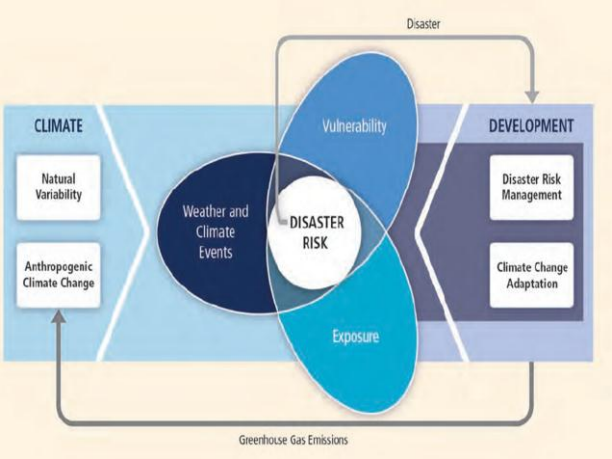


Figure 4.1. Exposure and vulnerability to weather and climate events determine impacts and the likelihood of disasters (disaster risk).

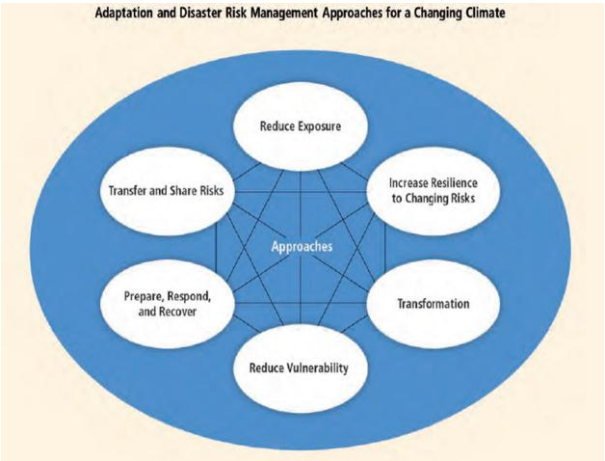


Figure 4.2. Disaster risk management and adaptation to climate change can reduce exposure and vulnerability to weather and climate events and thus reduces disaster risk, as well as increase resilience to the risks that cannot be eliminated

- Settlement patterns, urbanization, and changes in socioeconomic conditions have all influenced observed trends in exposure and vulnerability to climate extremes (*high confidence*). Rapid urbanization and the growth of megacities, have led to the emergence of highly vulnerable urban communities, particularly through informal settlements and inadequate land management (*high agreement, robust evidence*). Vulnerable populations also include refugees, internally displaced people, and those living in marginal areas.
- There is evidence from observations gathered since 1950 of change in some extremes. Confidence in observed changes in extremes depends on the quality and quantity of data and the availability of studies analyzing these data, which vary across regions and for different extremes. Assigning 'low confidence' in observed changes in a specific extreme on regional or global scales neither implies nor excludes the possibility of changes in this extreme. Extreme events are rare, which means there are few data available to make assessments regarding changes in their frequency or intensity. The more rare the event the more difficult it is to identify long-term changes. Global-scale trends in a specific extreme may be either more reliable (e.g., for temperature extremes) or less reliable (e.g., for droughts) than some regional-scale trends, depending on the geographical uniformity of the trends in the specific extreme.

[295] IPCC, 2012: *Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation*. A Special Report of Working Groups I and II of the Intergovernmental Panel on Climate Change [Field, C.B., V. Barros, T.F. Stocker, D. Qin, D.J. Dokken, K.L. Ebi, M.D. Mastrandrea, K.J. Mach, G.-K. Plattner, S.K. Allen, M. Tignor, and P.M. Midgley (eds.)]. Cambridge University Press, Cambridge, UK, and New York, NY, USA, 582 pp.

The participants on ACSAD Trans-boundary river's basins workshops agreed with the Special Report on Extreme Events (SREX), **on the following:**

Drought Definition: The definition was presented in figure (4.3), after (Erian 2011)[296].

"A period of abnormally dry weather long enough to cause a serious hydrological imbalance. Drought is a relative term, therefore any discussion in terms of precipitation deficit must refer to the particular precipitation-related activity that is under discussion. For example, shortage of precipitation during the growing season impinges on crop production or ecosystem function in general (due to soil moisture drought, also termed agricultural drought), and during the runoff and percolation season primarily affects water supplies (hydrological drought). Storage changes in soil moisture and groundwater are also affected by increases in actual evapo-transpiration in addition to reductions in precipitation. A period with an abnormal precipitation deficit is defined as a meteorological drought. A mega-drought is a very lengthy and pervasive drought, lasting much longer than normal, usually a decade or more".

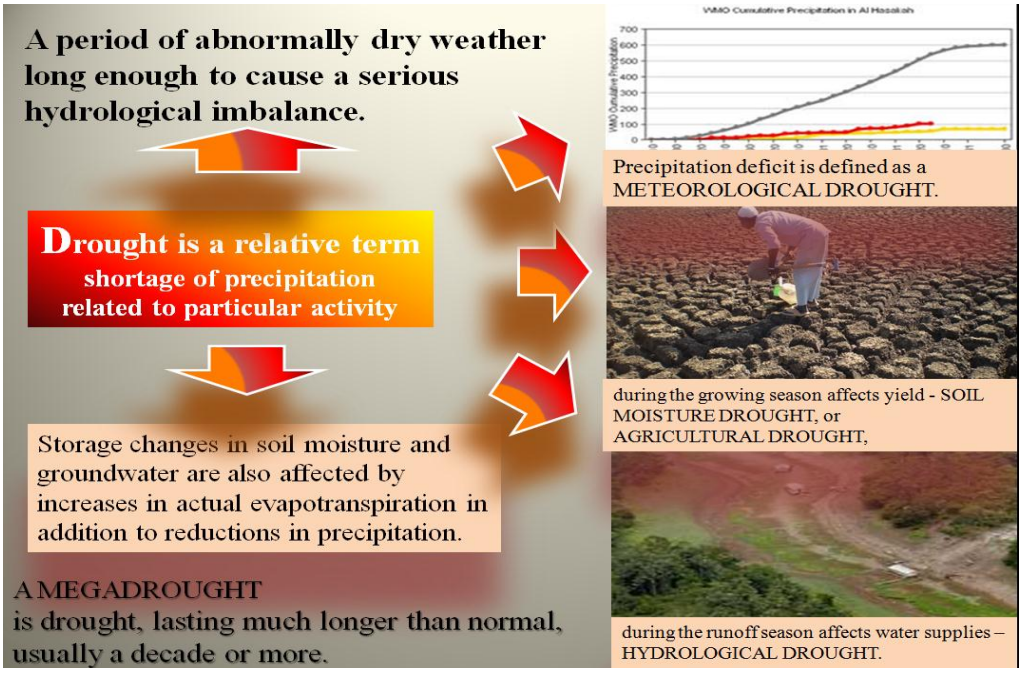


Figure 4.3.representation in Drought Definition, after (Erian 2011).

Major key massage[297]:

– There is medium confidence that some regions of the world have experienced more intense and longer droughts, in particular in southern Europe and West Africa, but in some regions droughts have become less frequent, less intense, or shorter, for example, in central North America and northwestern Australia. There is medium confidence that droughts will intensify in the 21st century in some seasons and areas, due to reduced precipitation and/or increased evapo-transpiration.

[296] Erian 2011. Living with Drought: Challenges and Solutions, Presentation on the Disaster Risk: Integrated Science and Practice Conference, Hosted by the Integrated Research on Disaster Risk Programme IRDR and the China Association for Science and Technology, Oct. 31 – Nov. 2, Beijing, China

[297] There is evidence from observations gathered since 1950 of change in some extremes; confidence in observed changes in extremes depends on the quality and quantity of data and the availability of studies analyzing these data, which vary across regions and for different extremes.

- This applies to regions including southern Europe and the **Mediterranean region**, central Europe, central North America, Central America and Mexico, northeast Brazil, and southern Africa. Elsewhere there is overall low confidence because of inconsistent projections of drought changes (dependent both on model and dryness index). Definitional issues, lack of observational data, and the inability of models to include all the factors that influence droughts preclude stronger confidence than medium in drought projections.

The participants on ACSAD Trans-boundary river's basins workshops **agreed with the following:**

- Insists on sharing -as a major way for partnership- blue and green water (runoff surface water and ground water), as downstream countries are not achieving sustainable development based on missing legal rights and unbalanced sharing water resources roles.
- The upstream countries will benefit the most of the basins and rivers (water, green and blue) through the deployment of systems of water harvesting, which has been observed differently when comparing the situation in the river basin countries and that land degradation and water quality will increase within the basin depending on the competition list.
- The importance of sharing is increasing on the light of the expected increase in drought intensity and frequency and duration (Consecutive) which may affect the water flow of rivers, and recharging ground water. Water resources development in upstream countries has significantly reduced river runoff in downstream Arab countries.
- Arab countries are already experiencing water deficits in terms of internal and external renewable water resources. The rapid population growth, urbanization, and industrialization have contributed to pollution of vital water resources including strategic aquifers.
- As indicated in the World Bank report, (WB 2012), it is expected that by midcentury all Arab countries will face serious water deficits as demand and supply continue to diverge. Total regional renewable water shortage will be about 200 cubic kilometers per year in 2040–2050 based on the average climate change projection.[298] The demand is expected to rise by about 25 percent in 2020–2030 and up to 60 percent in 2040–2050 while renewable supply will drop by more than 10 percent over the same time period in the region. This will result in an unmet demand for the entire MENA region, expressed as percentage of total demand, which will increase from 16 percent currently to 37 percent in 2020–2030 and 51 percent in 2040–2050

The participants on ACSAD Trans-boundary river's basins workshops Stressed on the importance of rehabilitate the degraded rangelands in Arab region as it is depredated each year on a rate of about (1.67%), and will have an impact on the stability of the livelihood on the Bedouin communities and will have negative implications on economic, social and environmental. Participants also highlighted the importance of focusing on forest areas stability and sustainability, as it has been observed that it is depredated annually on a rate of (1%) due to forest fires and changes on biodiversity. It is widely recognized that water resources ideally should be managed at the watershed level. Integrated watershed management facilitates optimal and balanced allocation of water resources among all the watershed inhabitants and ecosystems. The same applies to managing aquifer systems.

[298] Uncertainty in the climate change projections was considered and the 10% and 90% range in water shortage is between 90 and 280 km3 per year in the dry and wet scenarios considered in the World Bank study. The 2000-2009 supply-demand gap is filled by non-renewable water resources including fossil groundwater and desalination as well as through reuse.

However, such an approach faces major obstacles if these natural basins are shared among different countries, or even among different administrative divisions within the same country. First, national socio-economic development objectives could be at odds with those of integrated watershed/aquifer management, as countries seek to utilize natural resources within their national boundaries for the benefit of their citizens.

This may include not only utilizing water resources within the same watershed or aquifer, but also transferring that water to other parts of the country. Second, technological advances have made it possible to develop large water storage and conveyance infrastructure and to utilize deep aquifers that were not accessible in the past. Third, the high variability and uneven distribution of water makes its value, and the potential of conflict over it, vary over time and space.

4.2. LESSON LEARNED

- Drought hazard, especially with respect to competition for water supply between agriculture, power generation, urban areas, and environmental flows (high confidence) and salinization. Increased evaporation and possible decreases in rainfall in many areas would adversely affect water supply, agriculture, and the survival and reproduction of key species in parts of the world that depend on uncertain sources. Water resources are stressed in Arab countries areas but likely to create a conflict situation between countries sharing Trans-boundary River's basins.
- Drought in countries sharing Trans-boundary River's basins needs a cross-cutting approach and therefore requires a wide range of inputs (e.g. cultural, socio-economic, etc.). Accordingly, drought management capacities must be strengthened, including capacities to develop integrated plans, sharing systems.
- Few countries sharing Trans-boundary River's basins vary in terms of exposure to drought as many areas are in recent years characterized by greater inter-annual variability than previous 40 years, with the western Sahel remaining dry and the eastern Sahel returning to wetter conditions.
- Evaluation of drought risk management measures and practices must be undertaken to determine if they are effective
- drought risk in countries experiencing more intense and longer droughts is expanding in all where less advanced agricultural practices, they are vulnerable to increasing variability in seasonal rainfall and drought, at the meantime vulnerability is increased by population growth, degradation of ecosystems, and depletion of natural resources, as well as poor standards for health, education, and governance.
- Political issues play a role within drought risk management. Governments should invest and promote inter-disciplinary dialogue to improve awareness and to define the issue and communication to address drought risk
- Better agreement on triggers for early warning and actions to improve preparedness within particularly vulnerable areas by changing land use and crop patterns, introducing new seed varieties more tolerant for drought, improve community socio-economical preparedness (assets, governance and technology) and create alternative economic opportunities
- The health impact of drought is complex and long standing affecting livelihoods and successive generations. It is important that governments ensure robust surveillance systems are in place to record impact on health and to inform action.
- Weakness of sectorial cooperation to drought and inadequate coordination between the concerned authorities reduce the capability of reducing drought risk and has an impact on

low socio-economic stability particularly in increased migration from rural areas with water scarcities and food shortages.

- Many options that reduce exposure and vulnerability across a range of hazard trends could be implemented and including, rainfall and groundwater harvesting, water management and improved irrigation efficiency measures, conservation agriculture, crop rotation, and livelihood diversification, increasing use of drought-resistant crop varieties, early warning systems integrating seasonal forecasts with drought projections, with improved communication involving extension services and risk pooling at the regional or national level.
- Conflict and cooperation in the Euphrates-Tigris basin is a classic example of upstream-downstream imbalance of power in an international river basin. Turkey is not only the most powerful country in hydrological terms due to its geographic positions as upstream riparian of both rivers; it is also currently the most powerful riparian in terms of economic and political power. This leaves the down-stream riparian countries with little opportunities for cooperative basin-wide management planning, as long as the up-stream country is disinclined to engage.
- From the perspective of managing a river basin as one hydrographic unit with a view to locate water infrastructure on those stretches of the river where they can produce highest returns, the GAP project, in particular its hydropower generation components, have a certain merit. The amount of water lost to evaporation relative to surface area is lower in reservoirs that are located at higher altitudes, where lower temperatures prevail. However, in a basin, where water has already been fully controlled, projects of this kind raise serious political problems.
- Similar to GAP project, Ethiopia has an irrigation potential areas estimated by 2.1 million hectare, and the construction of the Millennium dam (lake volume is approx. 62 billion cubic meter), (figure 4.4).

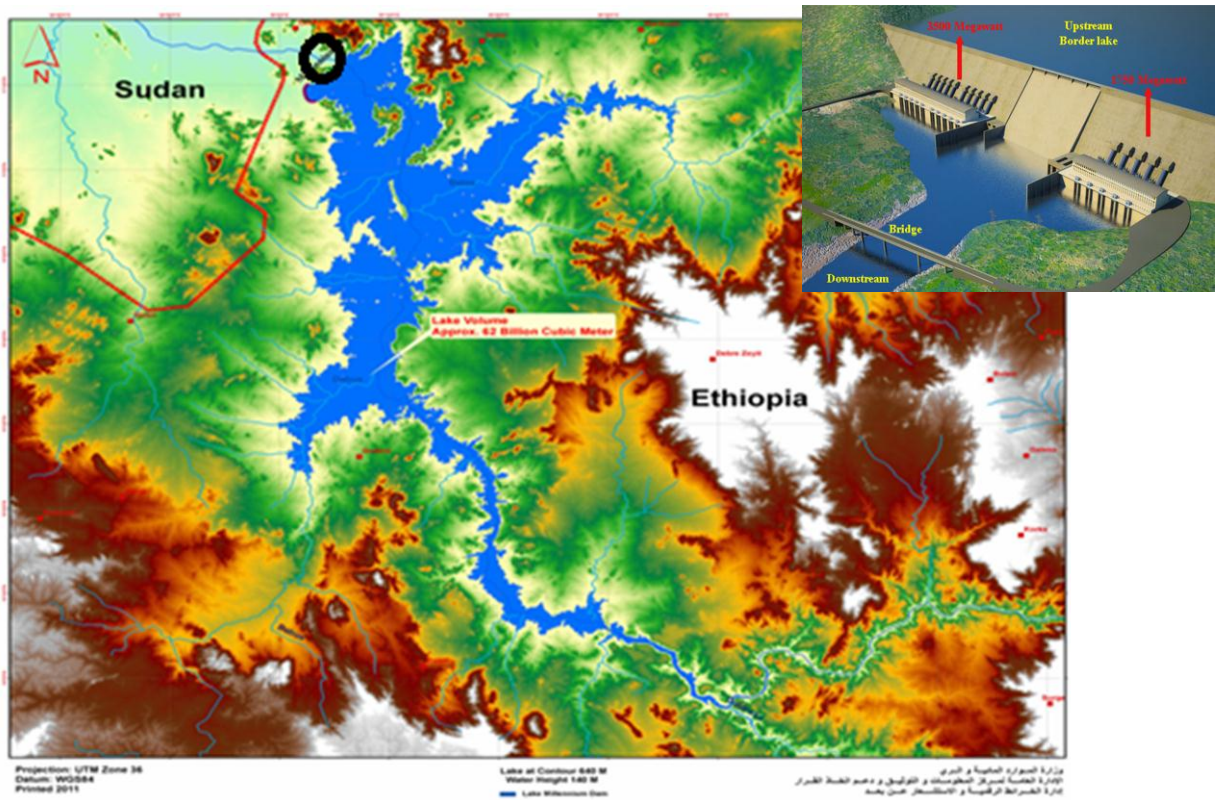


Figure 4.4. Millennium dam in Ethiopia.

4.3. RECOMMENDATIONS

The participants on ACSAD Trans-boundary river's basins workshops agreed with the proposal proposed by several International organizations[299] to urge member of the group of eight leaders, to allocate funds to promote cooperation over trans-boundary waters, International Rivers and Lakes. The proposal stressed the following:

4.3.1. Sustainable trans-boundary water resources management requires*:*

(a) **Sharing water-related benefits** among nations for regional economic integration rather than polarized claims for water;

[299] Quoted from the A Newsletter of several International organizations that including:

- Right to Water (rightwater@iatp.org).
- Global Water Partnership,
- Green Cross International,
- The World Conservation Union (IUCN),
- International Network of Basin Organizations,
- International Secretariat for Water,Programme Solidarit @ Eau,
- World Water Council and
- World Wide Fund for Nature. Posted: 05/28/2003 by svarghese@iatp.org.

The Newsletter prepared jointly by the Department for Economic and Social Affairs, United Nations, New York and the Economic Commission for Latin America and the Caribbean, Santiago, Chile No. 39

(b) **balancing competing uses** of basin and aquifer resources, especially upstream and downstream uses, in a transparent and participative way for local and regional sustainable development;

(c) Focusing on **poverty reduction**, **public participation** and gender balance to ensure **equitable access to water** for livelihoods;

(d) Recognizing the **fundamental need of freshwater** ecosystems for resource protection and **natural risk prevention**;

(e) **Protecting watercourses** during wars and conflicts and post-conflict rehabilitation of water resources;

(f) **Improving our knowledge** about the causes of conflicts and potential policy responses to prevent conflicts triggered by competition for the resource among different uses and users, and environmental concerns such as pollution; and

(g) Developing **capacity building** on integrated water resources management (IWRM).

Unfortunately, international law and development support for cooperation in trans-boundary river, lake and aquifer basins are currently insufficient to meet these challenges.

4.3.2. Integrated trans-boundary water resources and basin management

As a resource that transcends political and administrative boundaries, the world's freshwater resources must be shared amongst individuals, economic sectors, intra-state jurisdictions and sovereign nations, while respecting the need for environmental sustainability. The implementation of IWRM (integrated water resources management) needs political will and long-term financial commitment. This should include:

(a) The development and adoption of new national water laws which introduce or reinforce IWRM and basin management techniques;

(b) The establishment of national and international river basin organizations;

(c) The adoption of international conventions, treaties, and/or declarations concerning the management of freshwater;

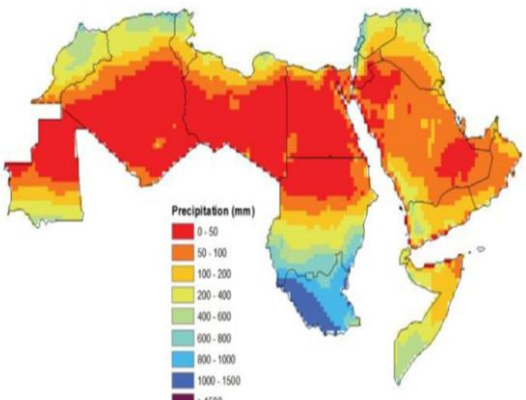
(d) The implementation of coherent systems of monitoring, exchange of appropriate information and the setting up of relevant databases;

(e) The elaboration and adoption of national and regional master plans for water; and

(f) The creation of sound funding systems based on common causes and solidarity within basins.

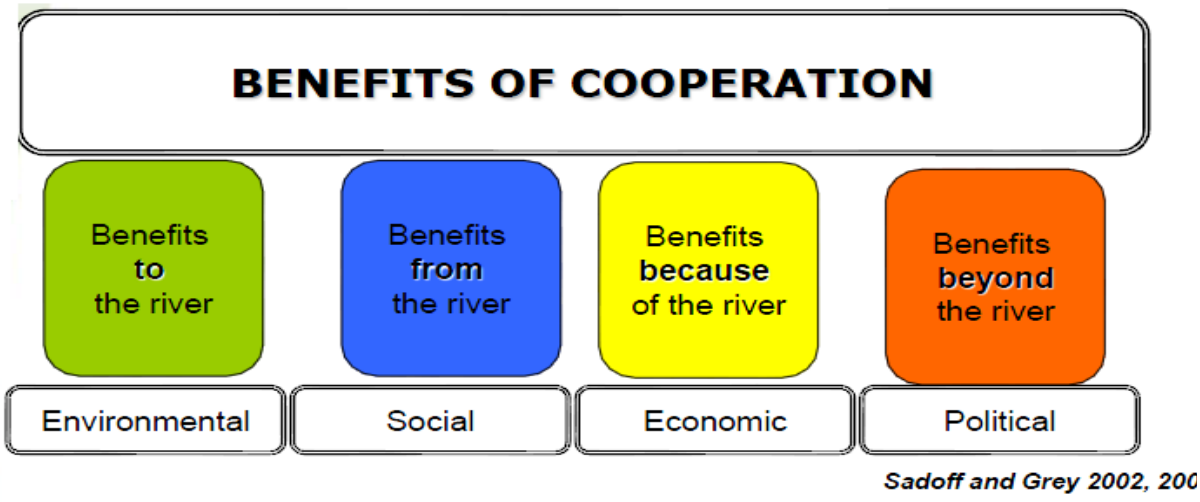
4.3.3. Trans-boundary water law and institutions improved governance

The establishment of trans-boundary basin organizations has been a success in many basins at the international and sub national levels, such as the Rhine, Lake Geneva, the Great Lakes and St Lawrence (US/Canada), the Senegal, but many



trans-boundary basin institutions do not have sufficient authority, capacity or resources.

What is worse, the majority of trans-boundary basins have no interstate water institutions at all. The need for widespread establishment and reinforcement of basin organizations to improve governance and facilitate stakeholder participation is in line with recommendations of the international community to elaborate a common vision for basin management.



Sadoff and Grey 2002, 200

Other recommendations are proposed by participants includes:

Sustainable management of resources of trans-boundary water requires the following:

- sharing the benefits of water among countries to achieve regional economic integration, rather than polarized claims for water;
- achieve a balance between resources uses Balahod and groundwater, especially upstream and downstream uses, and in a transparent and participatory process for sustainable development of local and regional levels;
- Focus on poverty reduction, public participation and gender balance to ensure equal access to water for livelihoods;• recognize the basic need of the ecosystems of fresh water for the protection of natural resources and risk prevention;
- Protection of waterways during the wars, conflicts and post-conflict rehabilitation of the water resources;
- improve our knowledge about the causes of conflicts and potential policy responses to prevent conflicts arising from competition for resources between different uses and users, and environmental concerns such as pollution,

- Develop capacity building in integrated water resources management IWRM the adoption of the Arab Center "ACSAD" All respect to the issues of trans-boundary water basins and rivers, and propose common recommendations and scientific programs and studies to this vital issue of water security concepts and Arab food security.
- urged Arab countries to deepen the concepts of cooperation, partnership and transfer of expertise and joint investment with the countries participating in the river basins.
- confirmed attendees on the importance of highlighting the basins and rivers (water, green and blue) in the studies and offers regional, international and give it a greater importance of the rivers (blue water), especially because the drought will reduce the amount of water that will reach to the downstream countries (surface and underground) and will affect the stability and increase the chances of increasing conflict .
- the importance of knowing the other through the languages and cultures and customs, achieving rapprochement between peoples and to establish a culture of cooperation and mutual gains Win to Win Situation rather than conflict.
- Created systems for environmental monitoring and follow-up and monitoring changes in environmental conditions and uses within the basin in order to achieve building bridges of understanding and dialogue on the basis of clear information and knowledge.
- attendance confirmed the importance of land use to review and follow-up periods and suggest modifications commensurate with the increased drought expected in the future and the growing scarcity of water alone.
- assured the audience that the changes observed in the forest areas where lost some kinds of birds and increased types of insects that destroys the types of trees have significant economic importance of forests.
- organization of web pages to communicate data and information dissemination and deepening aspects of knowledge on the Web to broaden the base of research and study and in-depth details and knowledge.
- call Arab institutions concerned to disseminate scientific arbitrator on the terms of water basins and to participate actively in international scientific forums.
- introduction of the national strategy for drought management plan within the water-General of the Syrian Arab Republic being developed, and integrated into the determinants of the national framework for regional planning
- the formation of a committee of experts and national terms of reference of the relevant institutions involved in drought and desertification and combat effects and advisory bodies of Arab and international components of the formulation of this project is subject to a detailed application. (With linking scientific research with the mechanics of the application)

- to involve all those affected in the corporate sector and the community in decision-making and the formulation and implementation, consisting of items complete an interactive knowledge center for natural resources and the use of its systems and data necessary for the operation and investment of the required forms linked to a database of geographic information system.
- insert Chmal study other indicators
- the importance of exchanging information and experience with neighboring countries and others to benefit from the experiences of these countries in identifying risks and strategies to answer and qualifying
- benefit from the popular tradition on measures of adaptation and development of natural resources relying on renewable energies.
- in the protection of cities from the effects of drought has highlighted the seriousness of the drought on the communities and there is no practical experience in this area.