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Diploma Thesis

Forecast of societal instability due to extreme drought by data-driven methods

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Diplomová práce

Ocenění rizko nestálosti ve společnosti z extrémního sucha metodami řízenými daty

Arman Zhussipbek

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Forecast of societal instability due to extreme drought by data-driven methods

Abstract:

The study presented in this thesis is oriented to determine influence of climate on societal stability through analysis of statistical correlations between quantities related to drought patterns and socio-economic data. Procedure of research is to find such dependencies with usage of mathematical methods. For correlation analysis bivariate methodology was implemented. Research methodology is developed on Syrian republic, from their pre-war statistics (before 2011), as a grey-box model. Expected socio-economical mechanisms are to be founded on dependency of agriculture and varying indicators. It is currently understood that Syria was impacted by drought of 2006-2010 year in both economical and social branches through increase of rural unemployment, migration to urban areas, rise of crime level. However, exact causal chains between long-term effects of drought and political stability inside of community were proposed by scientific articles to limited extent. Goal of current study was to obtain statistical interconnection between climatic change and affect on society, or in other words mathematical model, which is to be reapplied to other states for examination of their vulnerability as a societal structure to droughts. As a result, specific correlations were built in this study and other possible correlations were analyzed.

Keywords: climatic parameters, climate change, precipitation, extreme drought, agriculture, society, economy, interconnections, interpolation

Předpověď nestability společnosti v důsledku extrémního sucha metodami založenými na datech

Konspekt:

Studie prezentovaná v tomto příspěvku je zaměřena na stanovení vlivu klimatu na společenskou stabilitu prostřednictvím analýzy statistických korelací mezi veličinami souvisejícími se vzory sucha a socioekonomickými daty. Postup výzkumu je najít takové závislosti s využitím matematických vzorců. Pro korelační analýzu byla implementována bivariační metodika. Metodika výzkumu je vyvinuta na syrské republice z jejich předválečných statistik (před rokem 2011) jako model šedé krabice. Očekávané socioekonomické mechanismy budou založeny na závislosti zemědělství a různých ukazatelích. V současné době se chápe, že Sýrii zasáhlo sucho v letech 2006–2010 v ekonomických i sociálních odvětvích v důsledku zvýšení nezaměstnanosti na venkově, migrace do městských oblastí a zvýšení úrovně kriminality. Přesné příčinné řetězce mezi dlouhodobými účinky sucha a politickou stabilitou uvnitř komunity se však předpokládaly v omezené míře. Cílem současné studie bylo získat statistické propojení klimatických změn a vlivu na společnost, nebo jinými slovy matematický model, který má být znovu aplikován na jiné státy pro zkoumání jejich zranitelnosti jako společenské struktury vůči suchu. V důsledku toho byly v této studii vytvořeny konkrétní korelace.

Klíčová slova: klimatické parametry, změna klimatu, srážky, extrémní sucho, zemědělství, společnost, ekonomika, propojení, interpolace

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1. Introduction:

1.1. Overview:

In 2011, beginning as part of Arab spring, uprisings in Syrian Arab Republic occurred against ruling Ba'ath regime which later transformed into full-scale civil war with brutal conflicts between different religious and ethnic groups. This civil war was also influenced by tensions and conflicts in other countries, both regional and distant, for fulfilling of their own purposes. Direct causes and deep social reasons for the military rivalry vary, however it is currently understood that multiple factors as unemployment, poverty, worsening of social and economic situation due to poor management of state, each at least played some role. Some social and economic preconditions to war might be correlated to climatic conditions as it was guessed by some scientific articles, although details are matter for disputes. One of main climatic events before civil war was drought of 2006-2010 years which caused decrease of output in agricultural industry and caused transformations in society. This was seen by many researchers as indirect reason of further political struggle. However, this is yet topic for discussion among different researchers.
Consequent aim of current research is to determine degree of influence of climate fluctuations (with usage of precipitated related indicator) on social and economic parameters within direct or indirect link. Additionally, target is to estimate indicators which can be used to track that influence. Furthermore, goal of study is trial of application of resulting methodology on different states with varying inclination to dry climate to estimate hypothetical possibility of social instability as alteration process of global climate is still continuing.

1.2. Objectives:

In this thesis, I would like to evaluate already circulated suggestions for connections between such climatic factor as drought and societal stability. Area of original case from real history on which this study will be based is located in Syria - place of still ongoing civil conflict (as of 2022) (UN, 2022).
Consecutive targets of this report are therefore following:

- Exposition of potential causal chains of drought (on historical examples) – to demonstrate mechanism of drought (on examples of earlier societies and modern ones)
- Statistical assessment of consequences of drought – with coefficient of determination and significance value
- Identification of probable correlations within two consecutive approaches
- Analysis of relationship between drought and political instability

Details of analysis are explained in "Methodology" section.

1.3. Syria:

Syrian Arab republic is located on Middle East, bordering Turkey on North, Iraq on East, to the West country is locked by Mediterranean sea. Climate of Syria can be characterized as diverse with majority of country being in arid zone, majority of population lives in coastal area. Important water source of country is Euphrates river, water sanitation in both urban and rural areas was assessed to be satisfactory.

Country can be splitted in four geographic regions (FAO, 2008):

- the coastal region between the mountains and the sea;
- the mountains and the highlands extending from north to south parallel to the Mediterranean coast;
- the plains or interior, located east of the highlands and including the plains of Damascus, Homs, Hama, Aleppo, Hassakeh and Dara;
- the Badiah and the desert plains in the southeastern part of the country, bordering Jordan and Iraq.

From beginning of functioning of country, it has undergone political turmoils of different scale. Important ones to acknowledge in context of research are political challenges of recent generations. Country was subjected to authoritarian regime from 1970, with restriction of political freedoms. In 2000s with change of political leadership minor relief of regime occurred but without significant changes in internal politics (Commins et al., 2021).
Pre-war state has already been burdened by growth of population, low degree of environmental protection, poor management on level of state administration. Currently (2021) country can be considered as fractioned state with political and ethnoreligious divisions (Ulker et al., 2018).

Economy of Syrian Republic was comprised as following: (CIA, 2021g)

Sector	GDP fraction (2008 data)	Labour force (2008 data)
Agriculture	18.5%	17%
Industry	26.9%	16%
Services	54.6%	67%

Table 1. Distribution of GDP and labour force before civil war.

Therefore, economy of Syrian arab republic can be considered as moderately industrialized. Economic value equivalent to about one-third of GDP (before war) consisted of exports and slightly bigger value was imported goods and services (Worldbank, 2021d). Main center of industry is located in Damascus which is also political center of country. Oil fields were discovered in large quantities in 1956 and peak of oil production occurred between 1990s (Commins et al., 2021) and 2001 (Selby J., 2019). This facilitated construction of electrical power plants. Oil exports allowed Syrian regime to strengthen development in agronomic sector. In last quarter of 20th century agricultural industry of Syria experienced growth of farm households with most noticeable growth seen in number of households with focus in agriculture, although a decade earlier state supported pre-existing monopolies inside of the country (Abbas and Procházka, 2010). This coincided with increase of total population size while total agricultural area fluctuated in small amounts (FAO, 2021e). From that time oil extraction decreased which forced Ba'ath government to cut subsidies for agricultural industry of the state as before Syrian republic sponsored agricultural producers. They were weakened by this policy and made more susceptible to any external negative impact, demanding necessity of further support (Selby J., 2019). Country also has internal natural gas sources which also assisted oil exports by replacing oil products on power stations. Transportation system of country is relatively well developed (Commins et al., 2021). However, it should be noticed that economical and societal development was unequal among provinces, it can be characterized that eastern edges of country developed at lesser rates that the rest of the republic (Balanche and Kalbach, 2018).

Before civil war Syria had diverse ethnic and religious groups with uneven distribution of quantitative minorities. Decades earlier, pan-Arabic secular principles were put as core values of society by Ba'ath regime which was accompanied with conflicts with Israel. During one of them loss of control over Golan heights occurred due to defeat in 1967, these territories are still under Israeli control as they are important in supply of water (Murphy & Gannon, 2008). However, traditional distribution of societal roles was left almost unchanged by any reforms from pre-independence period (Rousseau, 2014). After stable increase in earlier decades urbanization has slowed down. Moreover from beginning of 2000s, level of urbanization changed by low amounts (<5% of total population) – staying on level of little less than 55%. Population of country was steadily rising from around 6 mln in 1968 to 18 mln in 2006 (Worldbank, 2021e; CIA, 2021e).

In 2006, Syria experienced serious drought from decreased precipitation which caused increase of unemployment and internal migration. This drought lasted until 2010 and was heavy burden on private agricultural enterprises (farmers), many of which even before such extreme drought were vulnerable to any fluctuation due to relatively obsolete agricultural technologies used (Ulker et al., 2018). As an example, wheat production dropped to 55% from usual mean value and noticeable consumer prices inflation occurred (Hasakah, 2009). However, this inflation was relatively weak in terms of annual statistics (Worldbank, 2021e). Drastic decrease of livestock was noticed. Even though country as a whole was affected by drought, degree of impact and level of damage was diverse. Increase of nutritional diseases among children in northern parts of country together with displacement of at least 1.5 million people from affected rural areas was detected. As additional observation, it should be written that humanitarian situation in some parts of Syrian republic has already been affected by influx of refugees from Iraq after political turmoil of 2000s. (Kelley et al., 2015). Eastern part of country which is already far away from sea with lesser water resources available was especially hit by drought in second half of considered dry period as mean precipitation values reduced (Selby et al., 2017).

This is in match with article of Hoerling et al. (2011), according to which entire Mediterranean region experienced change in precipitation compared to levels of beginning of XX century. Syria as part of Middle East region experienced decrease of precipitation, if mean value for period of 1971-2010 is subtracted from mean value for period of 1902-1970.

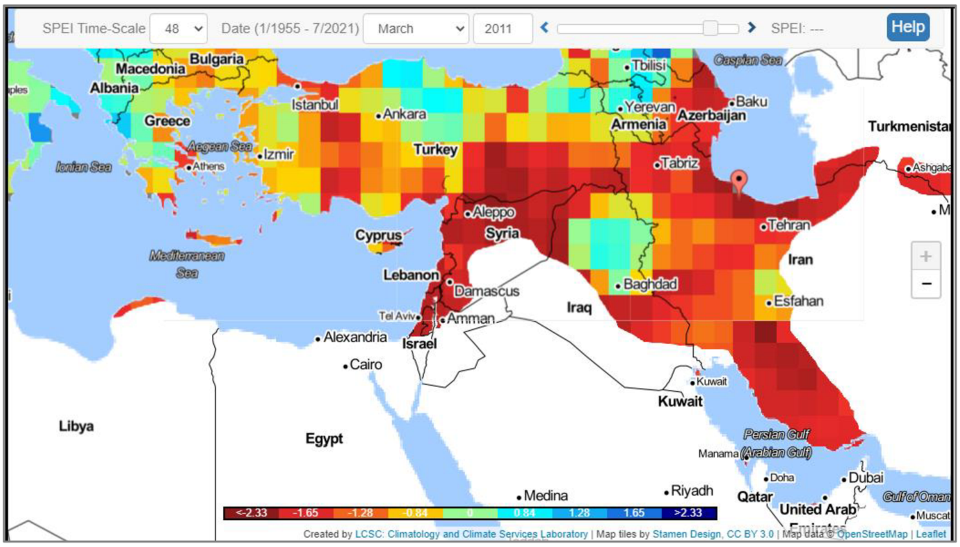

Figure 1. Averaged SPEI over 4 years prior to 2011 (negative values of index represent dry conditions, positive values symbolize wet conditions). Source: Begueira Santiago et al., (n.d.)

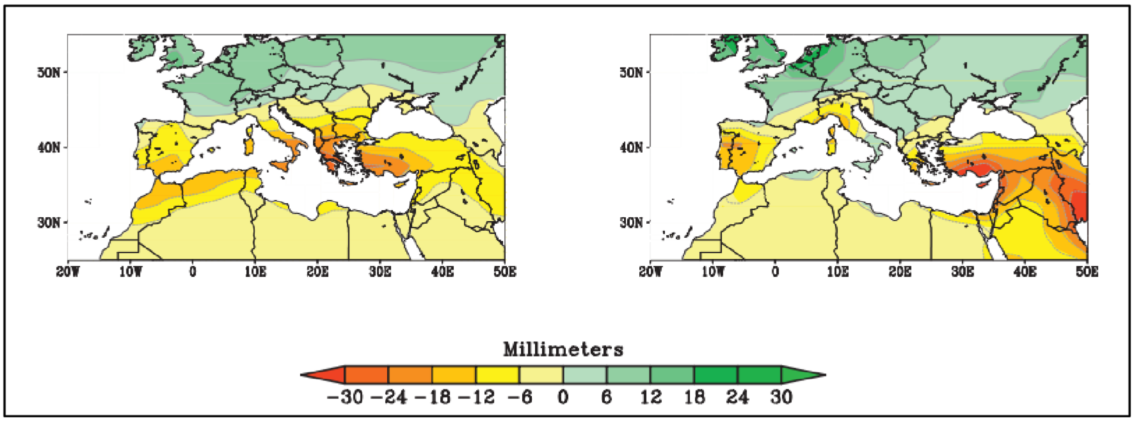

Figure 2. Change of precipitation level from 1902-1970 to 1971-2010 period. Left image represents IPCC models, right – AMIP models. Source: Hoerling et al. (2012)

Subsequently, it could be possible that internal situation in the state was worsened by combination of impacts. Many districts saw increase of crime rates and poverty as a side effect of drought. Such reduction of economic potential which results in decrease of capabilities of individuals has been hypothesized to be additional surplus of social strifes (Ulker et al., 2018; Kelley et al., 2015) and to have possible links with political unrest, however discussion on this topics are still in process and strong dependence is thought by part of researchers to be exaggerated (Selby, et al., 2017). Another noticeable issue which enhanced drought in Syria was long-term negative balance of usable groundwater which combined with catastrophic impact on water resources on land, as water flow some river basins decreased. Majority of water was used in agricultural irrigation and total annual consumption overtook sustainable demand by 20%. This problem in fact has been slowly going from 1980, and severity of impact differed based on overall situation in agricultural industry (Selby, 2019). Already before 2006 drought, increasing population was worsening the water stress. Unsustainable state policies did not improve the situation. Ministry of Agriculture of the state was forced to limit groundwater usage as aquifers were overused. But in practice this was not universal rule as some farm groups which were tied with state were weakly impacted by these legal circumstances. Such de-facto unequal policy assisted in causing additional distress among local communities (Balanche and Kalbach, 2018; Ulker et al., 2018). Even after hard phases of drought, agricultural yields remained lower than usual (Gleick, 2014).

In Syrian Arab republic, pre-war ethnic and religious distribution was diverse, however majority of population consisted of Sunni Arabs (Rousseau Elliot, 2014).

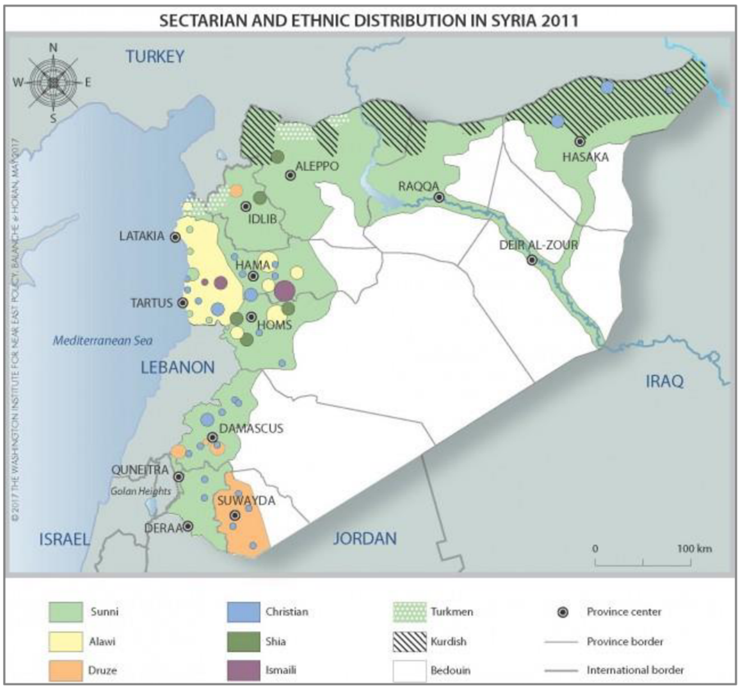

Figure 3. Religious and ethnic division of Syrian Arab republic in 2011. Source: Balanche and Kalbach (2018)

It should be noted that territories where drought was most severe (eastern parts of Syria) were predominantly populated by Sunni Arabs and Kurds. This could be connected to the fact that tensions between Alawite-headed regime and local population have already existed before civil war. As example, Euphrates river basin is located in eastern part of Syrian Arab republic. Area was majorly hit on later stages of drought (Ulker et al., 2018).

Countries which are near Syria also are affected by drought related issues. As an example, Iraq experienced early stage of drought in same way as Syria. However, later on most important agricultural areas level of precipitation loss decreased (Shean, 2009).

1.3.1. Characteristics of ongoing civil war:

Even though, civil conflict would start later, drought (2006-2010) was hypothesized to be seen as threat multiplier. Core principle of threat multiplier hypothesis is that climate change affects social systems with other non-climatic factors in a way that social systems experience period of exacerbated stresses which might be manifested in form of political unrest. Radicalization of tensions occurs through influence on economics. Tensions (ethnic, religious, religious, social) which already exist might escalate into further downward spiral of conflict (CNA, 2007). There could be different scenarios of tension development based on different economic and political circumstances but different researchers hypothesize that already existing struggles could be worsened by alterations of climatic conditions.
In case of Syria, main pre-war antagonism to the ruling regime was from opposition with diverse political views, Kurds (who suffered some discrimination) and some part of Sunni Arabs (Balanche and Kalbach, 2018).

Overall history of armed struggle between fractions in Syria could be reduced to following picture. In 2011, on the chain wave of political revolutions in countries of the region (later called Arab Spring) in Northern Africa and Middle East, tensions in Syria escalated to full-scale civil war which initially was directed for political change. However, as opposition groups were common only in one goal to remove Ba'ath regime and were fragmented by their long-term interests, they did not succeed to overturn Assad government. In some regions (Kurdish and Sunni Arab dominance regions) character of war later acquired ethnoreligous context where loyality is often expressed to ethnic or religious identity rather than political beliefs. War is on multiple sides with each one having their own goals: state rule is controlled by Ba'athist party (with Alawites representatives as ruling group), Sunni Arabs, Kurds, and other minor groups. Wary opinions of some minorities towards Sunni Arabs forced them to be at least loyal to official government but many pragmatically hold neutrality whenever it was possible. Ruling regime in their turn used suitable ethnic and religious tensions to manipulate different political fractions (Rousseau, 2014). In general, strategy of ruling regime is to preserve control over communications, hold control over major population centers in order to restrict abilities of opposition and counterbalance rebel activity wherever it is possible with their limited military capabilities. Heavy influence and even direct interference of other countries (regional and remote) is noticed (Holliday, 2011). As an example, rich Arab countries as Saudi Arabia, Qatar supported mainly Islamic opposition of all levels of radicalism and trained their representatives among rebel groups. Other countries which as well have been interfering in war - USA, Turkey, Iran and Russia; they all have different conflicting interests (Rousseau, 2014; Balanche and Kalbach, 2018). As a consequence of the conflict millions of refugees left country. Annual value of recorded net migration reached 5.3 million people (Worldbank, 2021e).
It should be noted that major armed resistance on ethnic or religious grounds occurred among Sunni Arabs and Kurds, even though other ethno-religious groups could be dissatisfied by regime as well their potential impact was lesser of issue for

Ba'athists, but this did not help ruling regime as it was not capable to suppress in short time all protests and effectively prevent foreign support of opposition (Balanche and Kalbach, 2018).

1.4. Historical examples:

It can be demonstrated from history that climatic events (short-term processes together with long term trends) shaped societal dynamics on regional scales. In fact simple common sense suggests that flooding or extremely dry season impacts ability to collect food or available amount of animals to hunt in affected region. The technical questions which arise from this assumption are severity of influence, duration of negative effects, ability for recovery of ecosystem. Next examples generate implications for further analysis.

1.4.1. Pre-industrial epoch:

In order for proper analysis of possible influence of extremely dry time periods, comparison with pre-industrial cultures can be made. (Kaniewski, Guiot & Van Campo, 2015).
In Central America, in time period between AD 760-930, Maya culture experienced multiple-year droughts on wide regional scale. One of evidences for dry period are sediment layers from lake Chichancanab. Evaporation related changes of trace isotope ratio (oxygen-18 to oxygen-16) suggest for negative balance of water in the lake (Hodell et al., 1995). As a result, activity (from last written hieroglyphic date) in population centers of that civilization stops between AD 761 and AD 909 (around half of large settlements was left by their inhabitants in first three decades). This means that decay process of Mayan civilization was prolonged for many generations, signifying by itself end of Classic Era and abandonment of settlements (Gill et al., 2007; Kenneth et al., 2012). For time periods before end of Mayan Classic era, droughts in Maya inhabited parts of Central America were noticed in 150-200 AD and 535-590 AD. In fact, some major shifts of influence between cities or dynasties (in Mayan culture) can be traced to droughts (Kennett et al., 2012; Gill et al., 2007).

In biological terms, drought would impact food cultures grown or collected and indirectly animal husbandry. This could mean increased starvation or increase in disease rates. Also crops storage might be affected, due to faster rate of food deterioration under higher temperatures. Although optimal humidity conditions are different for diverse crop cathegories, higher temperatures would definitely increase water evaporation. This would lead to inability to store food in meaningful quantities (Kader and Rolle, 2004). Competition for water sources is also likely. In combination, this could lead to competition over available resources, expressed as social struggle. Some degree of societal damage (with loss of ability to control on state level) can be expected. For technologically primitive societies, impact is greater due to limited abilities of adaptation to changing environment. More time drought persists, more severe impacts might be noticeable. Aside difference in technologies between societies of modern time and considered example, main feature of Mayan culture is isolation of that society from other civilizations or cultures of same societal level. While in modern epoch global economic system allows to be able to import production which is insufficiently produced or even not produced in some country, this was not the case for earlier epochs. This could mean that it would be much more difficult for Mayas to lessen impact of drought by trade due to inability of import from remote areas unaffected by drought. Unfavourable climatic conditions would make it less likely for regional civilization to remain united. Decentralization was also noticed in case of cultures of Central America in general combined with increase of evidences of unrest traces (Kennett and Marwan, 2015).

Weather system of Maya lowlands is on present stage is thought to be linked to Atlantic weather system. This means that majority of precipitation and corresponding humidity is also related to water coming from Atlantic ocean by means of atmospheric advection. In more precise context, precipitation in considered region is correlated to atmospheric condition in North Atlantic ocean. Position of North Atlantic anticyclone (also known as Azores High) affects rainfall rate in Maya lowlands (Gill et al., 2007, Maldonado et al., 2017). While for region in general (Central America) combination of Pacific ocean conditions and mentioned North Atlantic ocean contributes to precipitation and humidity. Although, impact of Pacific ocean anomalies is less in magnitude (Maldonado et al., 2017). Additional evidence for drought in Central America present correlations, by means of Atlantic weather system, between and cold periods in Europe might be constructed, due to location of North Atlantic anticyclone. Climatic system of Azores High is related to Hadley cell expansion and contraction. When North Atlantic anticyclone is shifted northeast – warm weather is more likely to be on European subcontinent. In reverse case (southwest shift) – cold weather is more probable in Europe and dry conditions is noticeable in Central America (Gill et al., 2007). Moreover, it was hypothesized that links of dry weather with anomalies in North Atlantic SST could exist also further to the north on USA soil, including, which could suggest that bigger area of the region is affected by this hypothesized correlation (Cook et al., 2006).
Sutton and Hodson et al., (2005) in fact demonstrate that possibility of random character of link between weather anomalies in Northern part of Atlantic ocean, Europe, North and Central Americas is low. Despite the fact that paper was focused on precipitation patterns, it was also suggested that weather conditions in Atlantic ocean are those ones which trigger previously referred correlations.

Aforementioned drought events in places of Mayan culture (in 150-200 AD, 535-590 AD, 760-930 AD) can be correlated with cold periods in Europe (Labuhn I. et al., 2016). This interrelationship is an indirect testimony that weather conditions in Central America were dry in contemporary time periods.

On chart demonstrated below relationship between geological record of level of oxygen-18 isotope (lowest chart of figure) which indicates average precipitation level in qualitative terms. Higher oxygen-18 level in sediments from bottom of water reservoirs signify that more water was evaporated at researched time period due to the fact that oxygen-18 based water is less likely to convert to steam (based from mass of corresponding water molecule). Chronological span of each drought period was on order of many decades which in rough terms corresponds to chronologically matching changes in Mayan society (Kennett et al., 2012; Hodell et al., 1995).

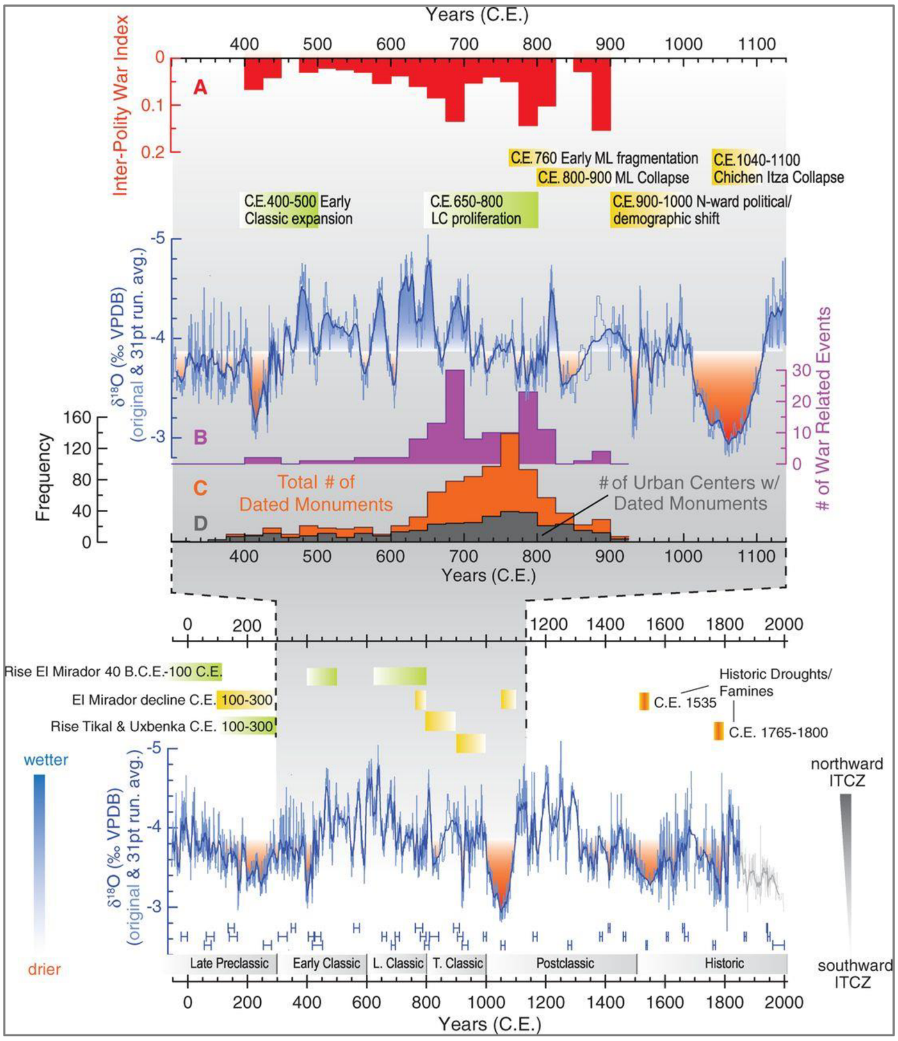

Figure 4. Correlation between estimations of internal political situation in Mayan culture and climatic data. Source: Kennett et al., (2012)

To sum up, decade-long climatic calamity might have caused cultural decay in central America (X$^{\underline{th}}$ century). This led to decrease of number of urban centers and societal collapse.

Correlation would not mean that only drought as sole reason was responsible for decay of civilization. Societal struggles and economical problems are also important to take into consideration. However, correlation might suggest that climatic circumstances are able to influence in worse turn whole situation in corresponding state or society, expressed as additional social strain and economic burden. This might be key for application of this causality link even in modern epoch. The only question is reasonable timescale to consider for prognosis.

1.4.2. Industrial epoch:

Compared to less technologically advanced eras, modern industrial age is characterised by increase of economic and social connections between countries some of which can be situated on different continents. Market economy in addition to access to resources and technologies might be thought as inhibitor of many types of crises which any community would experience. It can be suggested that mutual dependencies (primarily economic links) between states could on one side decrease impact of any serious natural or artificial disaster as country could by financial reserves or state budget (acquired through taxes or trade with other states) restore affected area or economic field faster than in case of complete isolation. On the other hand, political or economic instability could spread among co-dependent, neighboring or culturally similar societies as it was with chain reaction of political uprisings during Arab Spring.

Australia:

Australian continent is relatively frequently subjected to droughts. Some of megadroughts impacted significant part of the continent. Period between such events affecting agricultural productivity was between 4-22 years (Marangos and Williams, 2005). Long term impacts of global warming were observed in Australia since 1970. North-Western part of country had unaltered trend towards more precipitation while rest of country had different pathways with strongest reduction in precipitation on South-Western and South-Eastern parts of country. Increase of precipitation in corresponding areas is correlated with increase in agricultural productivity while decline of precipitation has reverse effect. Nevertheless increase of evapotranspiration from higher temperatures in all areas is noticed. In addition to other consequences, reduction fraction in soil moisture content from intermediate effects of global warming was between 5% to 40%. This all would mean that in modern technological age mankind is still dependent on climatic factors. Also it is further expected that these trends are to be continued in future. For a reference point, analysis in this example is concentrated on Millenium drought which extended from early 2000s to early 2010s (McKeon et al., 2009).
That drought resulted in pollution of water supplies, necessity to restrict water usage, decrease of economic incomes for local farmers. All subsectors of agriculture experienced problems in their work. Reduction of economic growth was around 0.7%. Consequences of drought caused investors to halt further significant investments in agrarian sector of Australia (Marangos and Williams, 2005). Overall drought caused fall of total agricultural productivity increase from 2.3% per year down to 0.7% per year. It was suggested that such extreme weather events alos affect long-term trends (Sheng and Xu, 2019).

Figure 5 shows impact of different SPI (precipitation) index values on agricultural productivity:

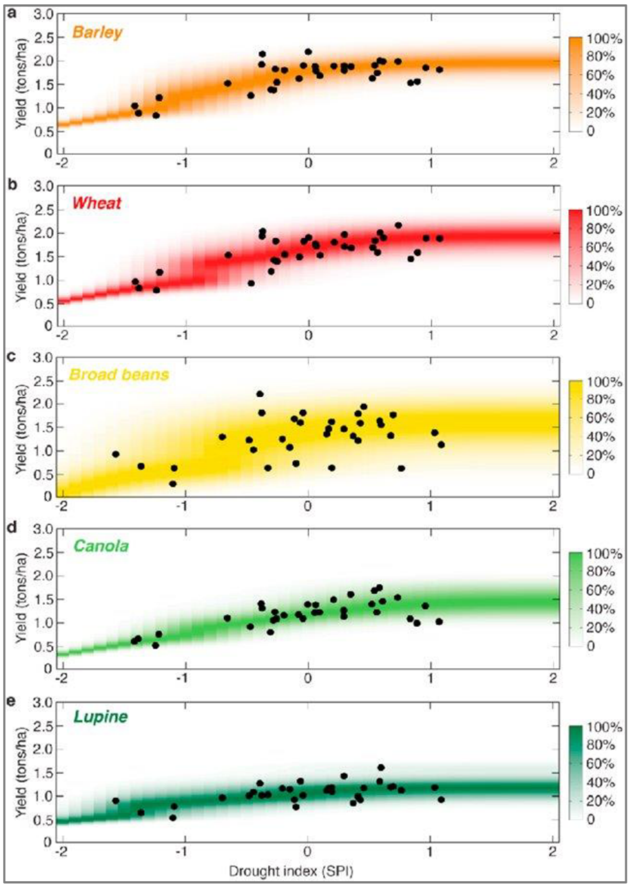

Figure 5. Distribution of crop yields in Australia vs precipitation index. Source: Madadgar et al., (2017)

In general, approach of Australian government towards water security can be described as weak intention to reform the irrigation industry together with optimization of agronomical industry in total. Rather than investing directly for wiser water usage policy, situation was basically left at will of private entrepreneurs. However, it was not rare circumstance that farmers of any scope of activity were forced to abandon their occupancy due to harsh conditions even though state assistance was not uncommon (Marangos and Williams, 2005).
Therefore in modern epoch drought still plays negative role in agricultural industry.

Texas:
During 2011, Texas was subjected to extremely dry conditions with damage to economics around $7.62 billion in agricultural industry. Roughly half of expected precipitation values has been noticed. Subsequently agricultural crisis followed. Around 166 thousand people lost their jobs. Both indirect and induced impacts of drought were responsible for approximately one-third of job losses and their economic result was around the same value as direct impact (Ziolkowska, 2016). Direct financial damage for livestock industry was around $3.23 billion. Detailed analysis of reduction of productivity for crops gives values between 47-60% (Anderson et al., 2012). Cotton growth area was reduced, although for other agricultural crops trend is not so unambigious (Ray et al., 2015).

Main outcome which can be traced to this drought is that climatic conditions by financial and trade chains can affect economics in spheres which are close to agricultural industry and also there are potential indirect effects of drought.

1.5. Societal impact of drought:

Analyzed consequences of drought include social and economic spheres. These spheres are dependent one on another. Ding et al. (2010) suggest that economic effects of drought could be cathegorized as:

- direct – exposure of economic sector to climatic event such as agricultural sector together with induced issues
- indirect – arising from links between society and economic sectors, highly dependent on structure of economy of considered state

Local economic issues which are to follow droughts can include business interruptions, bankruptcy of private entities, costs of business restart. Additional hidden costs which are not obvious but still would persist – livestock productions where several years after original negative effect problem could be consequences. This is also can be related to groundwater resources as well. It can be thought that surface water resources might be not enough for communities and additional strain might be put on water in underground aquifers. For indirect impact, production chains could be damaged, resulting in temporary termination of economic activity. Drought factor could be not the major one in some economic branches, however due to large amounts of other factors to consider it might be not possible to provide adequate estimate of degree of drought impact for all sectors of economics.
From economic problems social issues are expected to arise and strengthen already existing tensions. It was remarked earlier that Syrian Arab republic already before drought had low sustainability of usable water, both from ground and river basins. Long-term food and water insecurity concerns could undermine confidence in capabilities of states to manage their functions (CNA, 2007; Koren et al., 2021; Omelicheva, 2011). Short-duration unrests have been found to weakly correlate with precipitation changes in primitive tribal economies on example of Sub-Saharan Africa. In more precise terms, alteration of SPEI index by one long-term standard deviation is likely to have correspondence with 8% increase of possibility of rioting in provided area (Almer et al., 2017).

In general damage from impacts of extreme weather events has been growing over several decades while global warming trends lays additional risks for rebalance of regional climates (IPCC, 2014)

1.6. Current trends:

Impact of greenhouse gases on the planet leads to global warming with corresponding consequences. Majority of these greenhouse gases are most likely result of agricultural, industrial and transport activity (IPCC, 2014).
Global climatic trends are directed towards global warming with as many as +8°C in polar regions (mean expectation). In such warmer environment evaporation from water bodies would increase. Additionally, polar ice caps are observed to decrease in area. Subsequently, hydrological cycle is likely to accelerate. Some regions of planet are expected to experience increase of precipitation while some would see decrease (Beck et al., 2018; IPCC, 2014). Precipitation change could be suggested to be result of increased rate of convection cycle. Full picture is presented on Fig. 6.

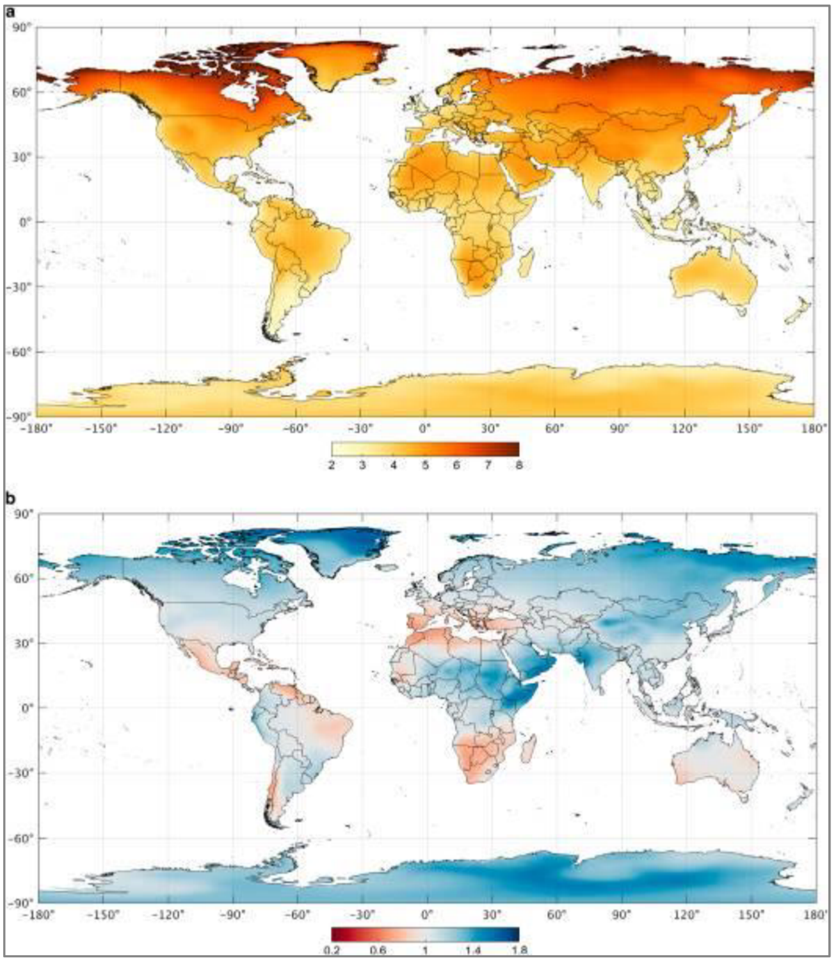

Figure 6. Change of average temperature (above) and relative precipitation (below) due to global warming. Source: Beck et al., (2018)

According to figure presented above, dry climate trends can be noticed for Central America, parts of South America, parts of Africa together with entire Mediterranean region and Australia. Authors (Beck et al., 2018) expect this projection to occur under RCP8.5 climatic scenario. This might negatively impact weakly developed countries with agriculture as main branch of economics. Consequently, additional social strife can be expected, due to shrinkage of opportunities and climate related economic damage, with corresponding long-term increase trends for frequency and severity of extreme weather events (e.g. as droughts or floods). It should be mentioned also that migration (internal and external) also takes place and is likely to grow due to sea level rise together with impact of global warming on weather patterns. Weak governments with lack of adequate policies might be overwhelmed by impact of global warming, so cascade of political instabilities might rise around the globe (CNA, 2007). The only question is how significant such impact would be for geographically related communities. It might be the case that some societies would experience minimum impact. For rest of the world, increase of precipitation of diverse strength is forecasted (IPCC, 2014).

Less severe warming scenario (RCP 2.6) is provided by IPCC report (2014). It presents figures which on large scales demonstrate same areas to be affected by drought. Main difference between precipitation levels for both scenarios is degree of severity of climate change impact, although details might vary. Mean precipitation level for weaker degree scenarios is suggested to increase for wet regions and decrease for regions which have been already experiencing dry conditions. Additionally, increase of frequency of droughts is suggested to occur with higher rate as mean degree of global warming is larger.

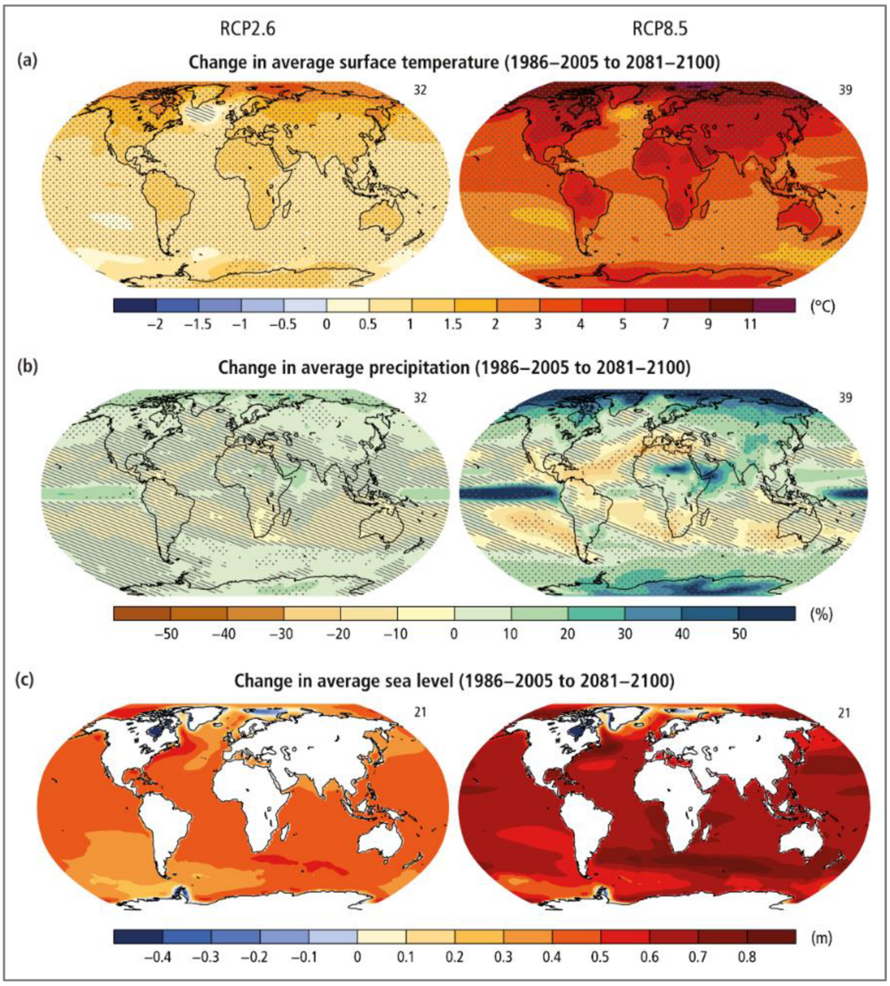

Figure 7. IPCC climate change report. Source: IPCC (2014)

Specifically for Mediterranean region (where Syria is situated) long-term drying trend in the nearest future is a big concern (Cook et al., 2016). This claim is also supported by IPCC (Akesson and Falk, 2015), who evidence that between 5%-25% decrease of rainfall from mean values for region are expected to occur until mid-XXI century. Akesson and Falk (2015) further demonstrate that in fact this trend was observed for this geographical region (Middle East) in general for about four decades which suggests that already existing climate related stress will not be reliefed. There is also further suggestion that this actually continued for time period since Mid-Holocene (Black et al., 2010)

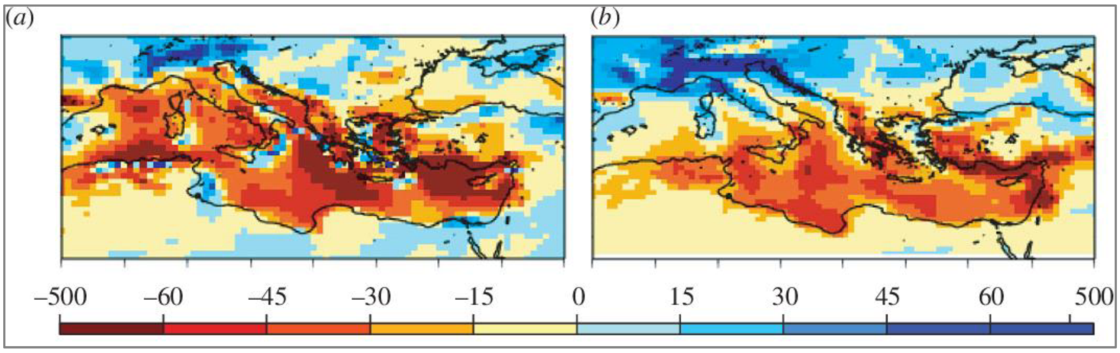

Figure 8. Change of precipitation from pre-historical period compared to present (left); projected change in the future compared to present (right). Units: millimeter of rainfall per year. Source: Black et al., (2010)

About two-thirds of arable land in Syrian republic used are dependent on precipitation. Furthermore, as it was already mentioned, other areas use unsustainable irrigation systems where half of all water comes from groundwater sources with disbalance (Akesson and Falk, 2015). That would mean that in a long-term future Syria is likely to be more dependent from rains. As an additional stress point, considered RCP8.5 scenario suggests that this territory would experience slightly less precipitation on average in XXI century (Beck et al., 2018). Including the fact that number of dry days per year is supposed to increase in future, it is more likely that climate will be more extreme as any potential precipitation is likely to drop in lesser timeframe of year (Lelieveld et al., 2012).

1.7. Research approach:

Grey-box modelling is applied as methodological pathway for this analysis. Grey-box model differs from data-driven black-box approach by taking into consideration some initial assumption of causal chain links between data parameters. It also differs from white-box model which has pre-determined logic and causal chain between data systems is an exact connection, both in qualitative and quantitative ways. By common sense, it can be seen that grey-box model is effectively middle position between black and white box models. Constraints on possible dependencies in grey-box approach are conditioned by prior theoretical judgement (Thordarson, 2011). In this regard, grey-box model allows to incorporate expected hypothetical pathway or behaviour of researched processes together with openness to analyze required system or medium. Acceptance of the fact that within the studied aspect of the problem under consideration, other aspects of the process can be considered as background random noise which is out of focus of study. In other words, grey-box model research allows for flexibility of hypothesis under outcomes from experimental practices and research observations.

For considered hypothesis grey-box model approach provides capability to take into close review that datasets which could be correlated with assumed connections. Datasets which are to be analyzed are from social and economical indices. For basic dependency of the concept of drought impact on state, it is implied that influence is carried through agricultural sector of economics. It can be thought that this could affect political stability by means of economics, additionally expressed in social terms as unemployment and increase of crime rates. Target of evaluation is to obtain list of indices which might evidence about interconnections, and analyze these correlations on their degree of influence.

In fact, it could be said that intrinsic nature of current grey box model is empirical analysis with some conceptual reasoning for resulting behaviours.

For the purposes of determination of initial dependencies, one-indice polynomial fits were examined.

Cause-effect mechanisms:

Key hypothesis consists of suggestion that change in medium-term parameters is to cause distress in considered society that leads to quantitative change in economical and social indicators which in qualitative terms would mean transform to increased instability (civil unrest) stage. Any pre-existing antagonisms and struggles are to be amplified by increased risks and insecurity. Timespan for such chain of actions is to be several years (considering historical data).

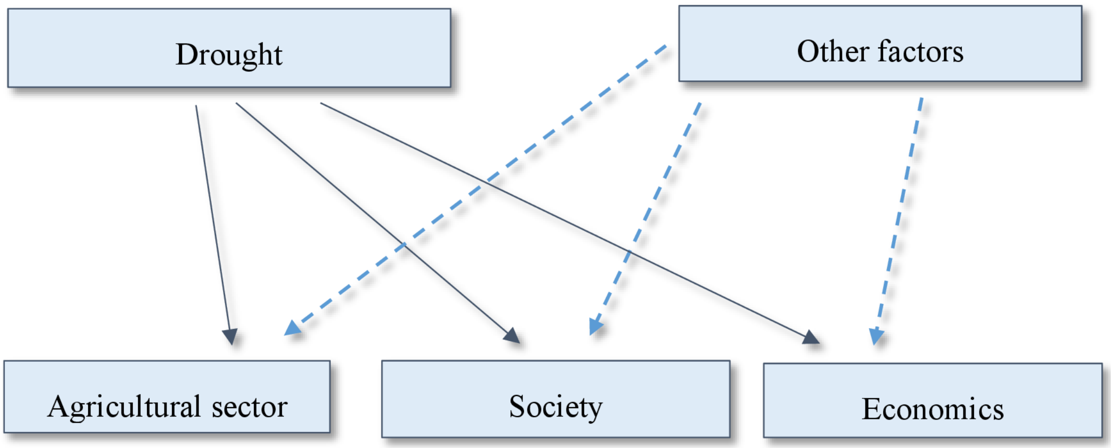

Figure 9. Theoretical dependency (first approach).

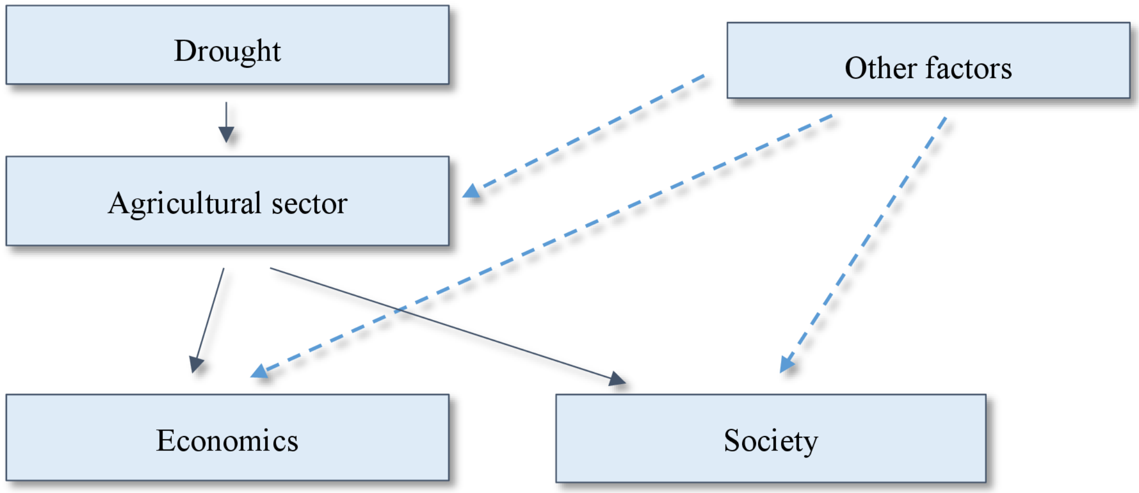

Figure 10. Theoretical dependency (second approach).

Two approaches are used. First is direct connection (fig. 9) between climatic index and socio-economic factors. Another way is two-stage approach (fig. 10). As the intermediate link between climate change (or long-term weather deviation) and societal impacts – agricultural industry is proposed. This would mean that basic insecurity which is to be taken – food insecurity. However, other potential cause-effect mechanisms can also take place (through climatic impact on other branches of industry/economics) even though these ones could be not easily recognizable. Grey-box model approach is considered for current study as these other causal chains may appear.

2. Methodology:

One of feature of current analysis can be described - partial segmentarity of database for research as analysis deals with states which might lag behind other developing countries (for different reasons) in terms of statistics. This results from lack of statistical information for specific time periods or non-systematic approach for data collection. In order to describe hypothesized expectation for behaviour of statistical data with drier climatic trends, it should be taken into account that data is summarized for each year for statistical reasons as majority of original data (such as GDP, social indices) are presented on yearly basis. Choice of time interval for analysis was based on assumption that socio-economic should not differ drastically in considered (pre-crisis) temporal period which puts natural restrictions. Therefore it was considered that time period should not be large, for example, spanning less than several decades, as economic crises or similar events which could happen on shorter time intervals, could significantly influence the dataset, introducing random bias; on the other hand interval could not be very small in order to be able to examine polynomial dependencies.

Statistical data for analysis is collected from Worldbank (2021e) and FAO (2021e).

For the time period taken into consideration (mid-1990 until 2010), SPEI index was averaged for entire Syria. Main idea of hypothesis is that correlations between climatic factors and social and economical indices may be due to causal link between agricultural sector and state of society. Due to annual character of majority of other analyzed indices, SPEI index was adopted in evaluation of dependencies on yearly basis. This implies that under conditions of problem for considered time periods relatively small data sample will be available. It would be necessary for further evaluations to find general trendline in the form of mathematical correlation to be able to reapply method on other datasets.

Due to distinctness of long-term situation in evaluated societies it is highly doubtful even impossible to directly insert correlations and statistics from tested example and apply to another society. However, it could be suggested that initial steps of methodology is to find indicators which might show dependencies between climatic data and general state of society. Then from these indicators particular correlations can be taken.

2.1. Data for analysis:

Choice of social and economic indices was based primarily on availability of data. Issue with data might be that significant part of indices are based on annual release. Impact of drought would be most noticeable in agriculture. First group of s Therefore subsequent causal chain of value behind an index and extreme dry conditions:

Index [units]:	Type of index:	Theoretical reaction to drought:
Food production economic variability [thousand $ per capita]	Agricultural	Less precipitation would decrease production in total which would decrease subsequent economic output
Arable land used per person [hectars per capita]	Agricultural	Long-term drought might decrease total area which agricultural industry is able or has will to use
Mean agricultural yield (cereals per used land area) [hectograms per hectar]	Agricultural	For area with non-advanced or straightforwardly primitive agriculture (in terms of irrigation) less precipitation would decrease total output
Ratio of agricultural, forestry and fishery in GDP [%]	Agricultural	If sectors of economics not related to agriculture are assumed to maintain same economic output, then smaller output of agricultural industry would result in smaller portion of GDP (as agriculture)
Producer prices index []	Agricultural	Food producers might increase prices in order to reduce financial losses from drought
Crop production index []	Agricultural	Dry conditions would decrease output due to crop failures
Food production index []	Agricultural	Dry conditions would decrease output due to impact on livestocks and crops

Consumer inflation [%]	Economic	Some increase in prices might be expected
Employment in agricultural sector [%] (from total available workforce)	Economic	Long-term drought can negatively impact stability of agricultural enterprises and leave part of population unemployed
Unemployment fraction [%] (from total available workforce)	Economic	Long-term drought can negatively impact stability of agricultural enterprises and leave part of population unemployed
Human development index []	Social	Long-term drought would damage society by means of worsening standards of life, deterioration of health conditions and economics (for example: increase of unemployment might occur)
Political stability index []	Social	Long-term drought vould damage society by means of worsening overall conditions in society, causing additional social strain and increase of crime level
Homicide rate [per 100'000] (does not include politically motivated violence)	Social	Increase of crime level could be expected due to higher unemployment and deterioration of economics
Infant mortality rate [per 1000]	Social	Long-term drought could lead to increase of health issues in society, decrease available usable water resources and increase of mortality rate
Mortality rate (among children under age of 5) [per 1000]	Social	Long-term drought could lead to increase of health issues in society, decrease available usable water resources and increase of mortality rate

Table 2. Impact of drought on statistical parameters (direct correlations).

2.2. *SPEI:*

SPEI (precipitation & evapotranspiration) is climatic index which represents dryness of climate in a given time period for discrete place. Positive values of SPEI mean wet climate while negative values represent dry climate, with severity being as more as index value is far from zero (extreme drought is for values of SPEI < -2). Drought severity which is to be considered is averaged for entire year (Begueria et al., n.d.).

Main difference between SPEI and another precipitation related index SPI is that latter index is based only on precipitation amount in the same time as first one takes into account total hydrodynamic balance where evapotranspiration (water removal from surface and biologically constituted transpiration by plants) is also considered (Abiodun et al., 2019). SPEI index is useful for aims in this study for a reason that it takes into account also the temperature in given location (Begueria Santiago et al., n.d.).

2.3. *Statistical modelling:*

Initial assumption of research methodology is that socio-economical index is to have latent value which is not significantly changing in examined period of time. As it was mentioned before, this puts restriction on time period depending on various reasons.

Form of dependency is expressed as:

$$a(x) = a_{latent} + G(x_1, x_2, \dots x_n)$$

Here, the grey-box model manifests itself in the fact that the constant indicated here in the equation as *"a_{latent}"* is responsible for the behavior of the system in the absence of the challenges of drought or excessive precipitation (SPEI equivalent to zero). It is the index value which is assumed to represent dormant value of indicator for time period which is under consideration. As it can be understood, this could be valid for relatively short period of time but longer considered time period more and more deviation with real data would occur. Latent value would be unique for each indicator. *"x"*-parameters is climatic data. In this research drought related indicator is to be examined.
G-function is equation which is to be found. For current study, regression analysis is provided up until to fifth degree of power (consequently this is highest degree of polynomial term). In general, upper restriction of powers of index is dependent on number of data values which are taken into consideration. It can be seen that this is a bivariate methodology (as one climatic variable is used). For each provided parameter in social/economic data, independent correlation is applied.

For evaluation of found interconnections, adjusted R-squared and P-value (statistical significance) are to be viewed. In order to avoid statistical misinterpretation, for given set of data adjusted R-squared is to be above 0.3, and simultaneously p-value to be less than 0.5, to be able to take parameters into further consideration.

For following tables, based on behaviour of linear trendlines:

- – positive correlation trendline (trend fitting suggestion), while for best-fit models:
  - if as expected and if P-value < 0.05 and $R^2 \geq 0.3$
- – negative correlation trendline (trend non-fitting suggestion), while for best-fit models:
  - if inverse of logical expectation is a result, or if P-value < 0.05 and $R^2 \leq -0.3$ for logical expectation
- – no significant correlation (neutral or lack of data):
  - if P-value ≥ 0.05, independently of R^2 value
  - if condition: $-0.3 < R^2 < 0.3$ is not satisfied, independently of P-value

2.4. Study area:

For Syria, in terms of climate consequences of global warming lead to drier climate in the future of region (Kelley et al., 2015; Hoerling et al., 2012). Additionally, it has to be noted that for overall trends in observed history, Skaf and Mathbout (2010) indicate that in general mild tendency towards drier climate can be observed on temporal scale of many decades.

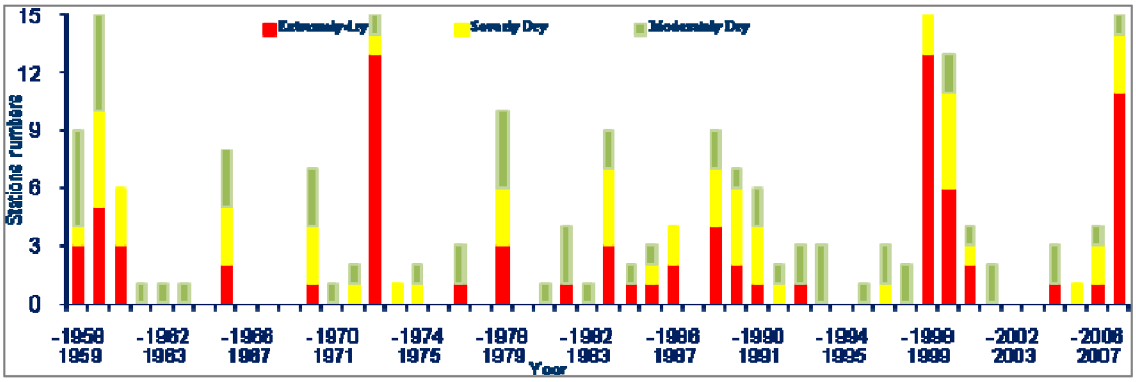

Figure 11. Distribution of drought events in Syrian Arab republic across decades. Source: Skaf and Mathbout (2010)

This relatively slow and gradual process over long period of time continues to deliver increasing stress for republic as groundwater reserves are insustainable in long period (Akesson and Falk, 2015). Increase of reuse of municipal wastewater was noticed (FAO, 2008). One of evidences is increase of dry days, especially of consecutive dry days from 1969 to 2008 (Skaf and Mathbout, 2010).

Mathbout et al. (2018) suggests that drought of 2006-2010 years was longest in pre-war history and more severe than similar events in the past. This could indirectly imply that impact of this drought was more catastrophic.

Majority of rainfall in the area of Syrian republic occurs in November-April period of year (Akesson and Falk, 2015). Rainfall patterns during 2006-2010 drought decreased by large ratios on big parts of Syria (Shean, 2008).

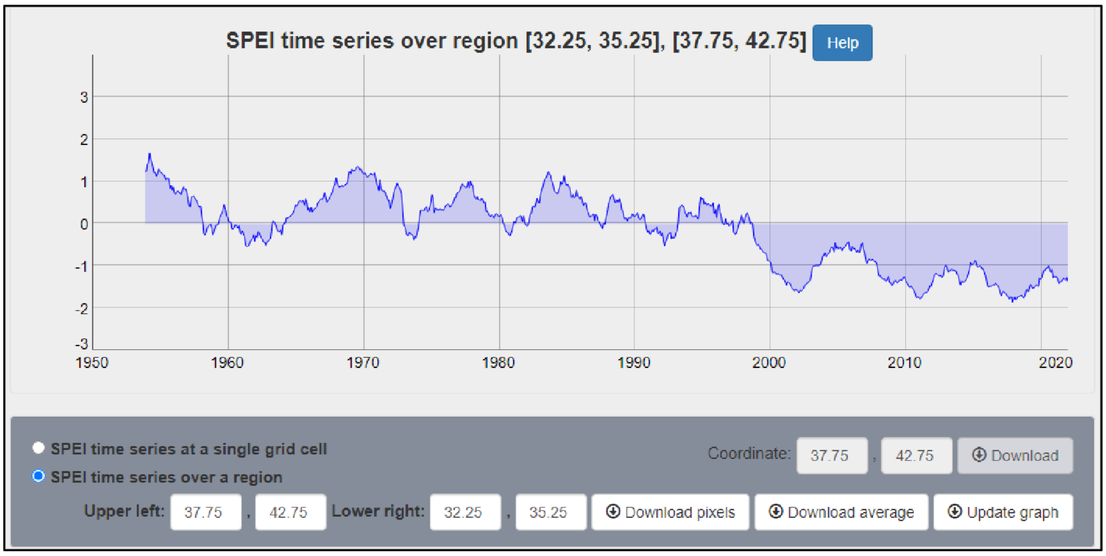

Figure 12. Syrian SPEI index figures.

Figure 12 demonstrates drop of rainfall during drought from average of previous years (compared to 1990s). It might seem to be only slight drop, however, this began as a regional disaster (fig. 13). It could be seen that most affected areas are those in eastern part of Syria.

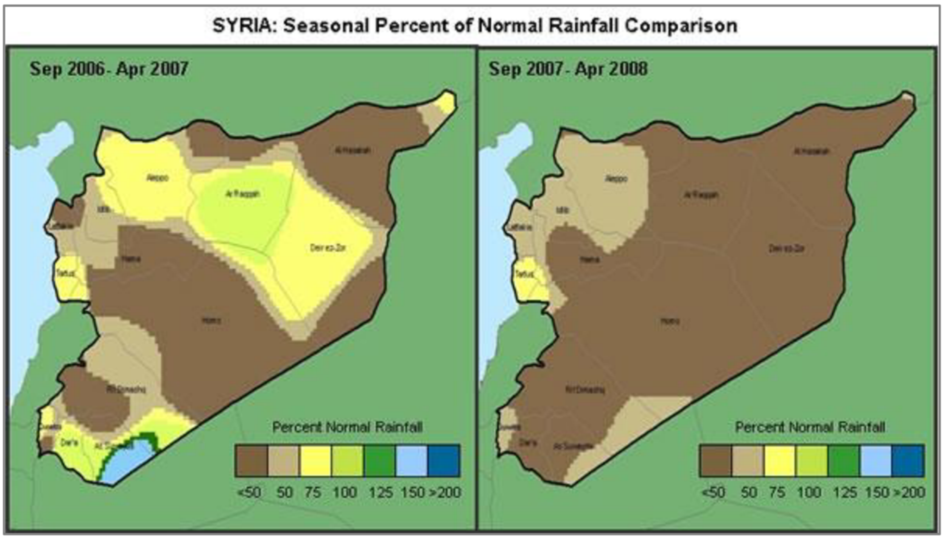

Figure 13. Precipitation levels during 2006-2010 drought. Source: Shean (2008)

Summarized information suggests potential areas with bigger probability of extreme drought events. Supplementary materials provide following information about these areas:

- Central America and parts of South America:
  - Slight decreases in precipitation patterns were projected by estimations of Marengo et al. (2012).
- Coastal areas around Mediterranean sea:
  - On the order of several percents of decrease of precipitation in cold seasons are estimated for difference between pre-industrial epoch and modern parameter (Hoerling et al., 2012). Climate is expected to have more extreme character in the future as precipitation patterns are supposed to weaken in dry season (Giorgi and Lionello, 2008).
- South Africa:
  - It needs to be mentioned that estimated changes in weather patterns over South Africa with help of computer modelling suggest that main characteristics of climate drying in the region is that decrease in SPEI would be more significant in magnitude than change in precipitation. This could be additionally worsened by human activity (Abiodun et al., 2019).
- Australia:
  - Rainfall patterns in southwestern and southeastern parts of Australia are projected to continue already existing trends for lesser precipitation (CSIRO, 2020).

The final choice of countries for further consideration in the research:

- Côte d'Ivoire:
    - It was suggested that climatic instability might be less influencing precipitation but evapotranspiration could be accelerated due to global warming (Laderach et al., 2013). While SPEI figures from below demonstrate that decrease in index value occurred, although nowhere felt under -2.

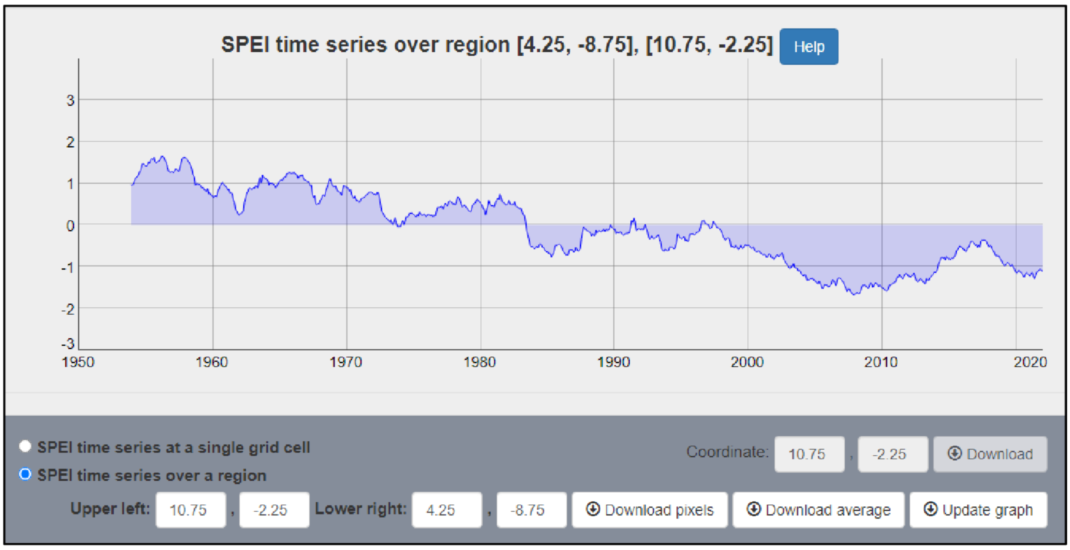

Figure 14. Côte d'Ivoire SPEI index figures.

- Namibia:
    - Abiodun et al. (2019) suggest that drought intensity (SPEI) for region where Namibia is located could be lower than -0.9. Increase of frequency of droughts up to one event per decade is conjectured. Country has not yet experienced struggles, resulting from water shortage or other potential impacts of droughts. In recent years, drastic drought started to occur.

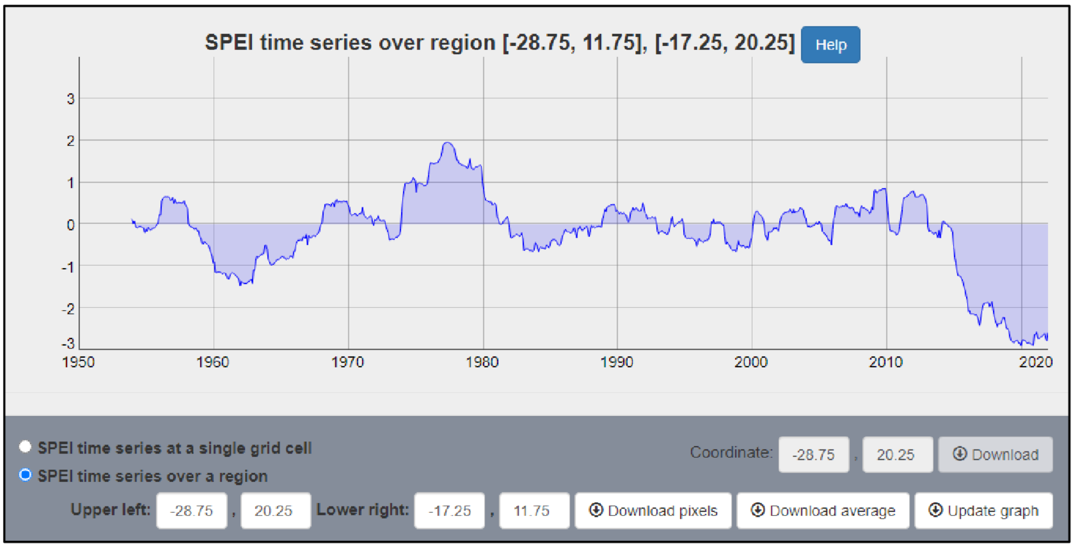

Figure 15. Namibia SPEI index figures.

- Nicaragua:
    - Gourdji et al. (2015) proposes drying tendency in winter season of country. Due to more agrarian nature of economics of this state, it can be thought that drier weather could lead to severe consequences for long-term future. Furthermore, deforestation is expected. Quiroga et al. (2020) hypothesizes that as majority of local agrarians are small private entities they will be more vulnerable to climate change related issues. Country has not yet encountered internal political crisis, resulting from water shortage or other potential impacts of droughts, although one particularly drastic drought event appeared in 2015.

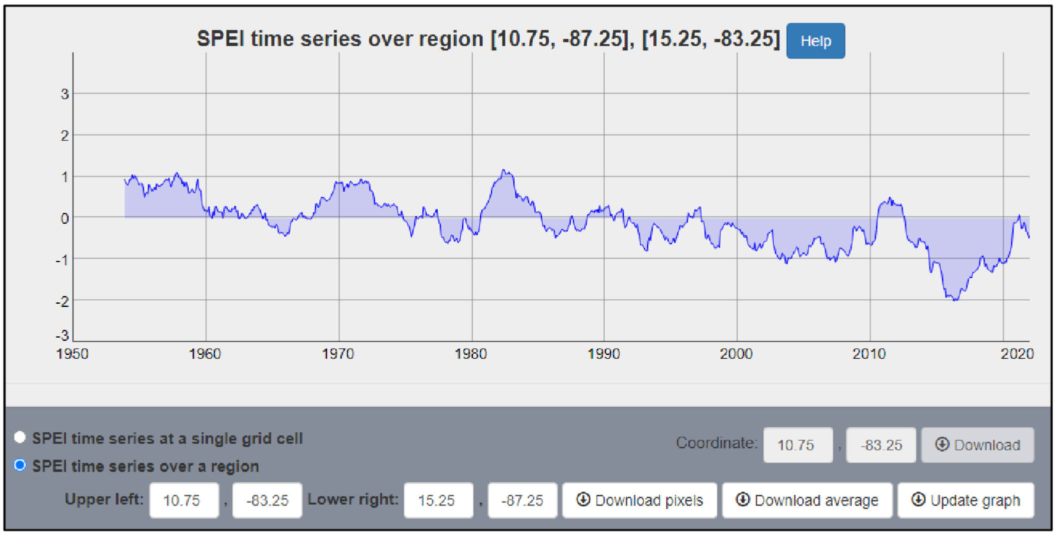

Figure 16. Nicaragua SPEI index figures.

- Nigeria:
    - Shiru et al. (2020) projects that decrease of SPEI index can follow as global warming processes. In western part of country, even though precipitation patterns could suggest otherwise, SPEI index is conjectured to decrease in future.

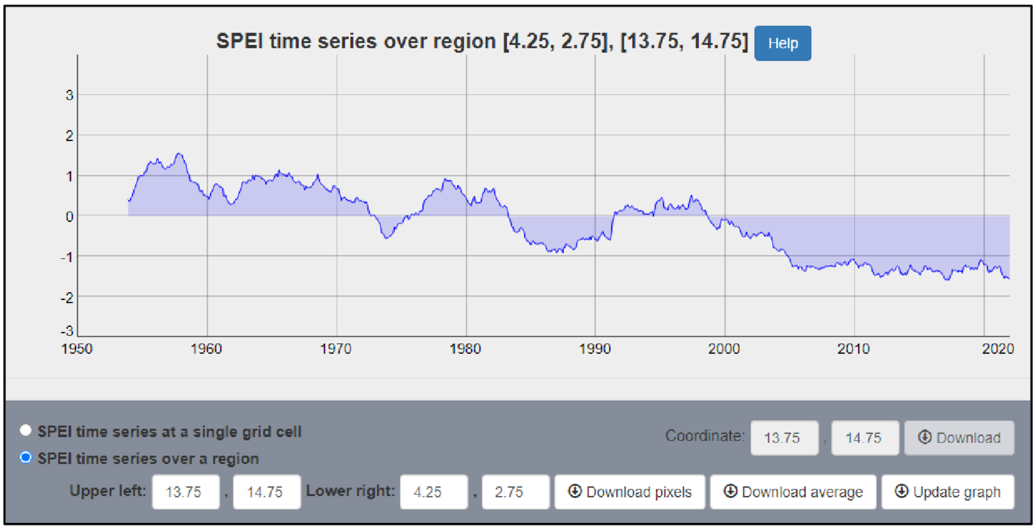

Figure 17. Nigeria SPEI index figures.

- Paraguay:
    - Country has not yet experienced military conflicts, resulting from water shortage or other potential impacts of droughts. Drought trend is noticeable towards end of timescale.

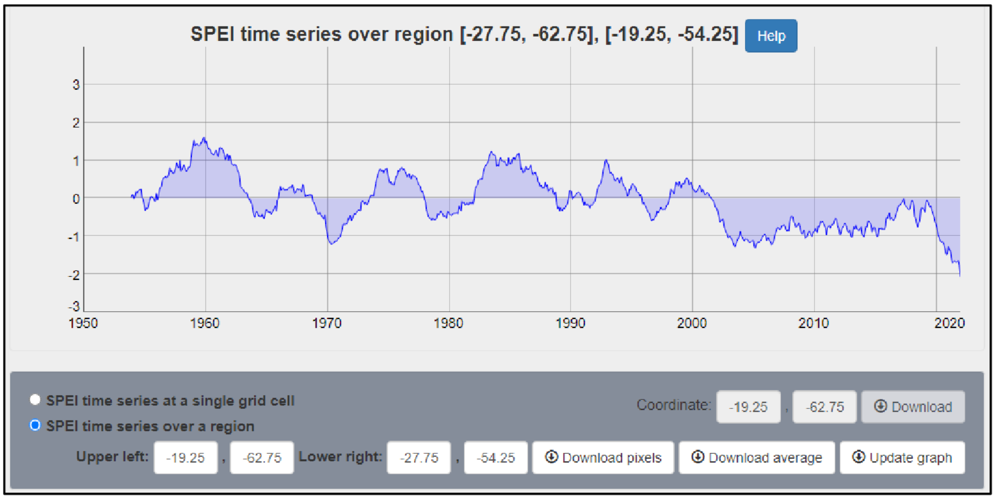

Figure 18. Paraguay SPEI index figures.

- Philippines:
    - Areas of country which were climatologically dry in the past are expected to have further exacerbations of a dry climate (Villafuerte et al., 2014).

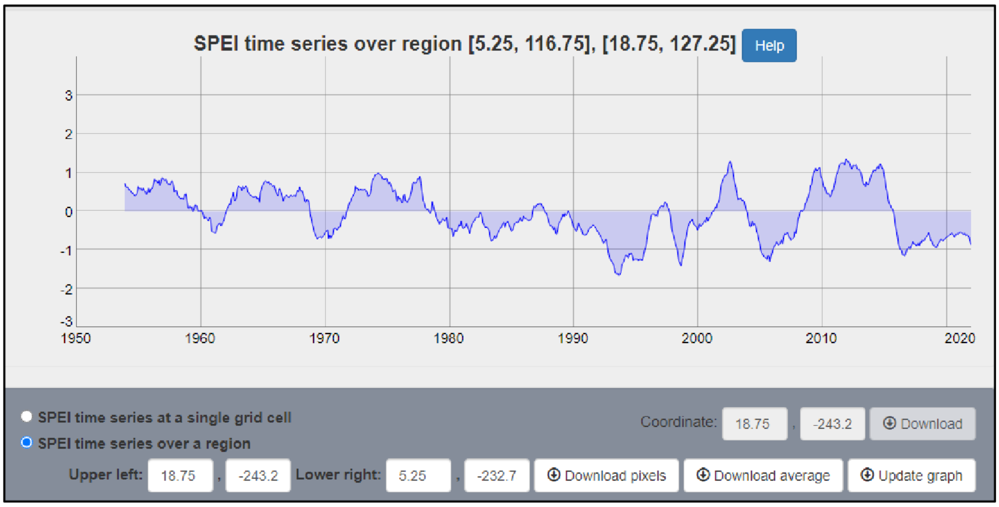

Figure 19. Philippines SPEI index figures.

Choosen countries have close levels of urbanization (~50%) and labour force fraction employed in agriculture (20-30%) higher than for Syria, although agricultural fraction of GDP varies (CIA, 2021a-g). This means that for these sample countries, dependence on agriculture could be even higher than for Syrian republic with increase of risks of societal collapse. Any consequences of droughts are to be expected to occur within several years, therefore optimal timeframe of choice needs to be slightly more than one decade. Data-driven interconnection is to be reapplied on statistical data for other countries in order to estimate data using hypothetical proposals.

3. Results:

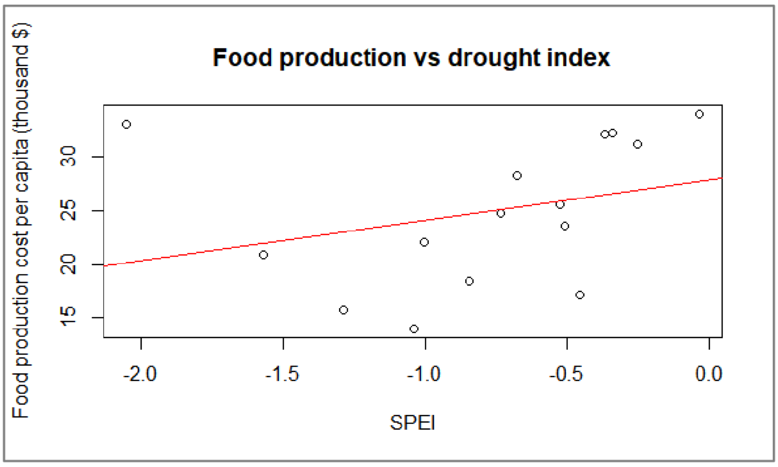

Figure 20. Food production economic variability vs drought index (linear).

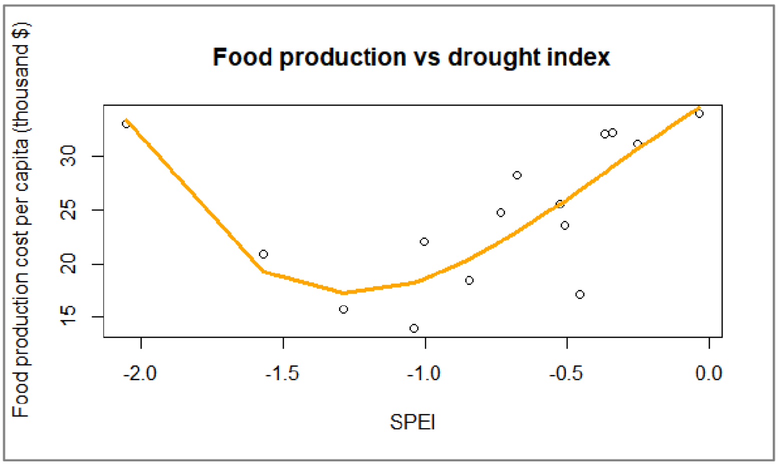

Figure 21. Food production economic variability vs drought index (best fit).

Polynomial power	Adjusted R-squared	P-value
1 (linear)	0.02025	0.2767
2	0.5907	0.001865
3	0.606	0.003835
4	0.5675	0.01254
5	0.5242	0.03257

Table 3. Food production economic variability vs drought index.

Food production economic variability represents estimation of net food production value per capita in economic terms. Figure and table demonstrate 3rd degree polynomial dependenc is most appropriate. Low P-value indicates that it is more probable that dependency between parameters is non-random, although anomalous deviation on right can be noticed.

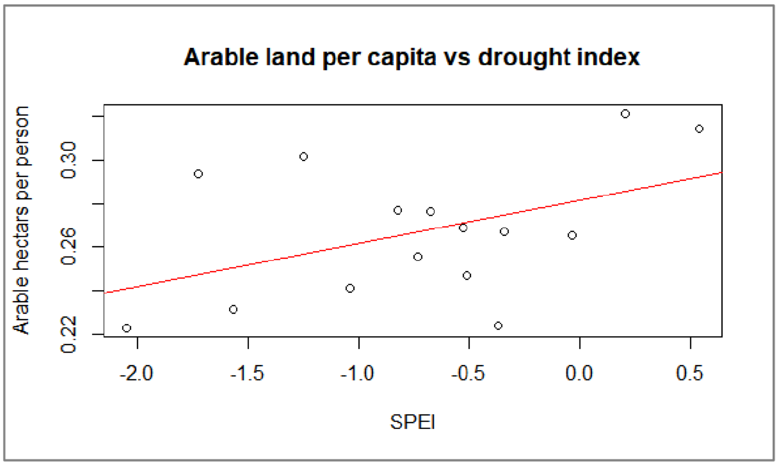

Figure 22. Arable land used per person vs drought index (linear).

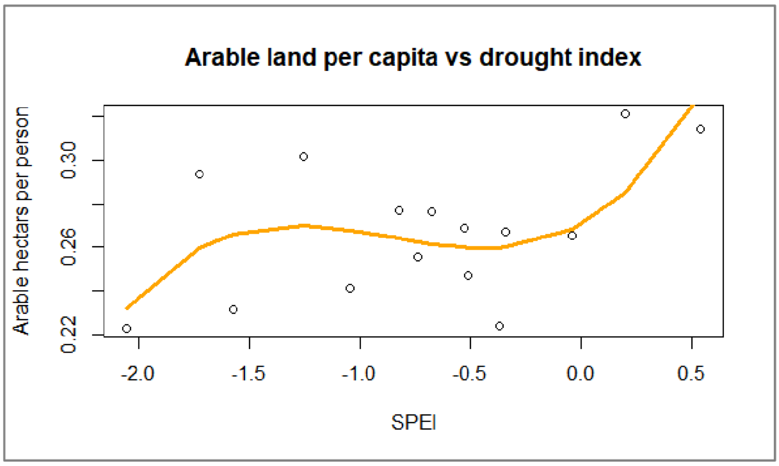

Figure 23. Arable land used per person vs drought index (best fit).

Polynomial power	Adjusted R-squared	P-value
1 (linear)	0.1458	0.08856
2	0.1429	0.1572
3	0.2739	0.09245
4	0.2605	0.1381
5	0.2253	0.2062

Table 4. Arable land used per person vs drought index.

This index provides data about land area which was used by agricultural sector per capita. Even though P-value is relatively high, it might be thought that some weak dependence exists.

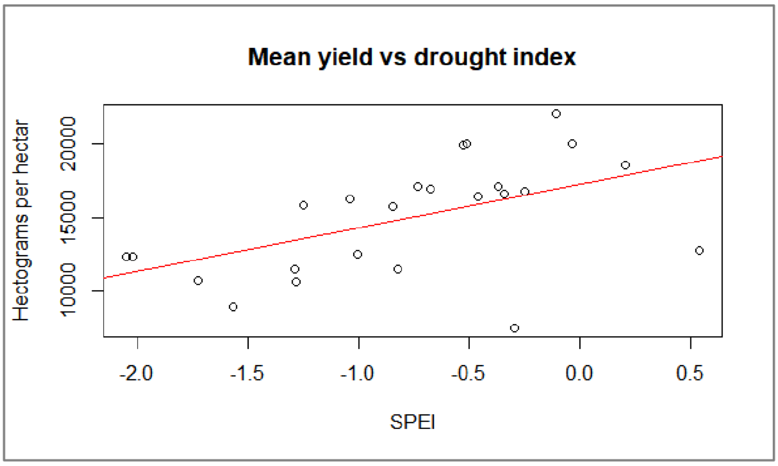

Figure 24. Mean cereal yield (per used land area) vs drought index (linear).

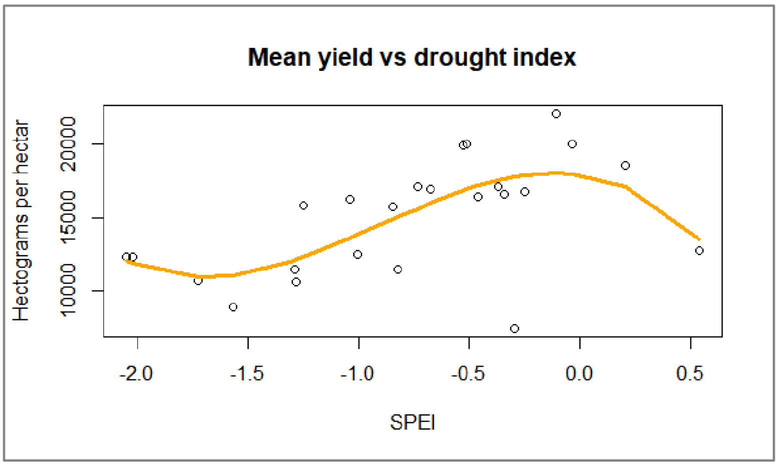

Figure 25. Mean cereal yield (per used land area) vs drought index (best fit).

Polynomial power	Adjusted R-squared	P-value
1 (linear)	0.2317	0.01004
2	0.2298	0.02481
3	0.338	0.01019
4	0.3033	0.02646
5	0.3104	0.03544

Table 5. Mean cereal yield (per used land area) vs drought index.

Index provides quantity of collected cereal (as mass) per operated land area. Best fit line follows cubic law. Some deviation from expected behaviour is seen on right end of curve. From given data, it can be said that correlation with drought index follows expected behaviour.

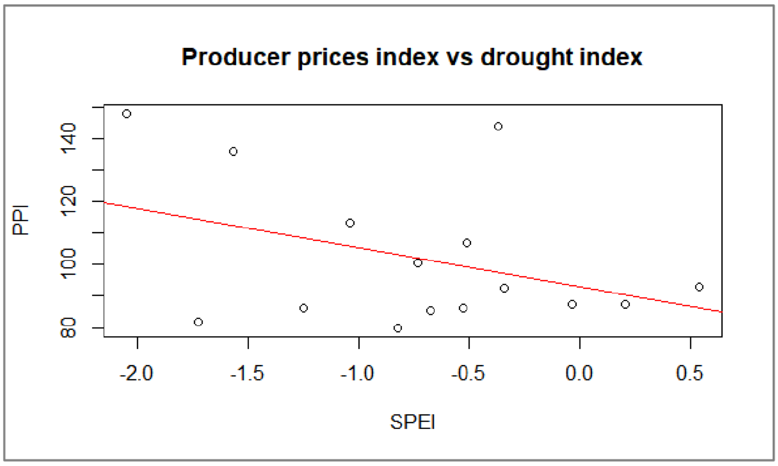

Figure 26. Producer prices index vs drought index (linear – best fit also).

Polynomial power	Adjusted R-squared	P-value
1 (linear)	0.08222	0.1571
2	0.06203	0.2701
3	0.07633	0.2986
4	0.01222	0.4323
5	-0.09281	0.599

Table 6. Producer release prices index vs drought index.

Producer price index is average for all kinds of agricultural production. Dependence is relatively weak. It could be suggested that any increase of prices which is observed by other scholars was of relatively short duration.

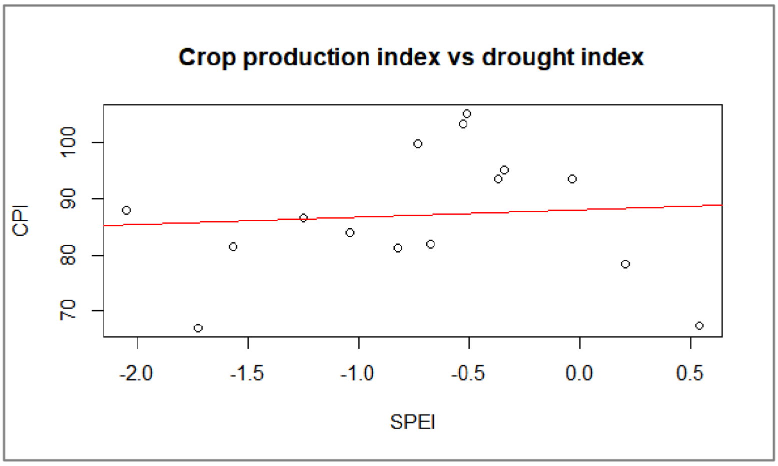

Figure 27. Crop production index vs drought index (linear).

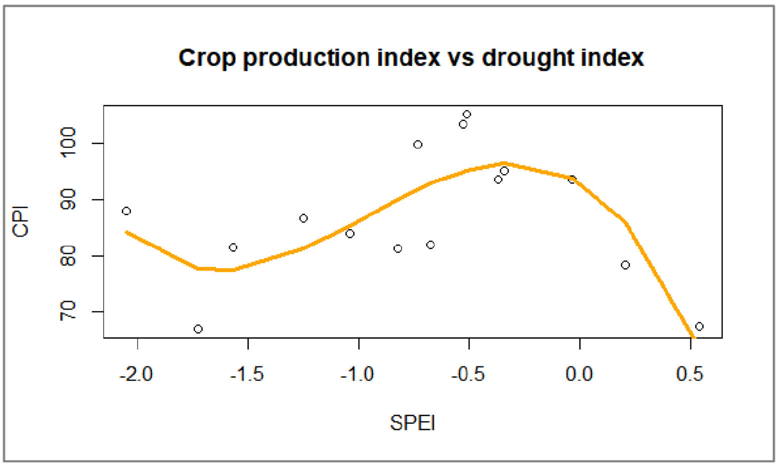

Figure 28. Crop production index vs drought index (best fit).

Polynomial power	Adjusted R-squared	P-value
1 (linear)	-0.07024	0.7802
2	0.23	0.08264
3	0.5301	0.009751
4	0.5292	0.01857
5	0.4795	0.04651

Table 7. Crop production index vs drought index.

Crop production index demonstrates ratio of crop output to that one of average for 2004-2006 years. Dependency has low P-value. This could explain necessity for import of wheat in Syria which was observed in the beginning of drought (Kelley et al., 2015).

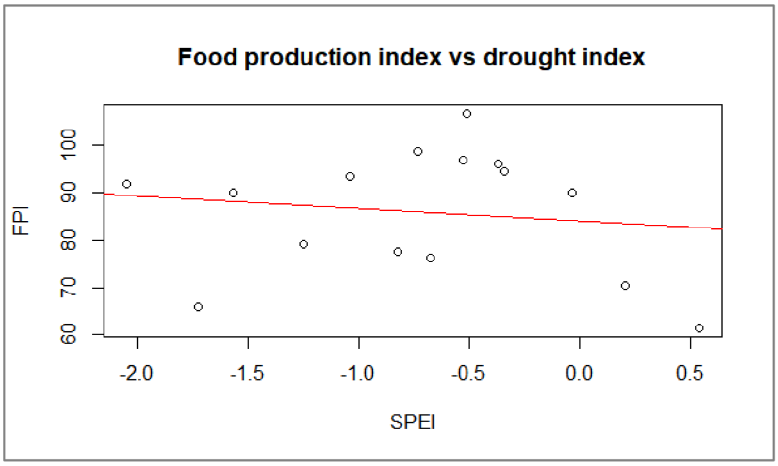

Figure 29. Food production index vs drought index (linear).

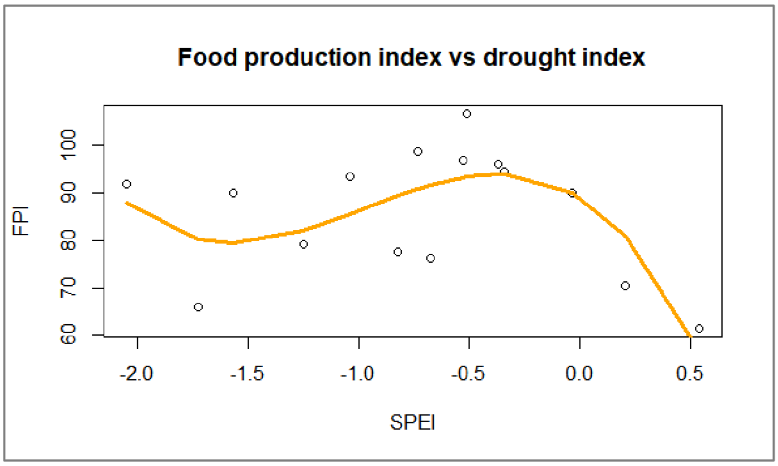

Figure 30. Food production index vs drought index (best fit).

Polynomial power	Adjusted R-squared	P-value
1 (linear)	-0.05457	0.6084
2	0.1783	0.1221
3	0.3952	0.03641
4	0.3716	0.06843
5	0.3118	0.1349

Table 8. Food production index vs drought index.

Food production index represents total amount of food produced inside of country. For best fit, P-value is low. Anti-correlation curve form is observed for linear trendline of this index. It could be said that impact of drought on this index was insignificant and other factors were more important.

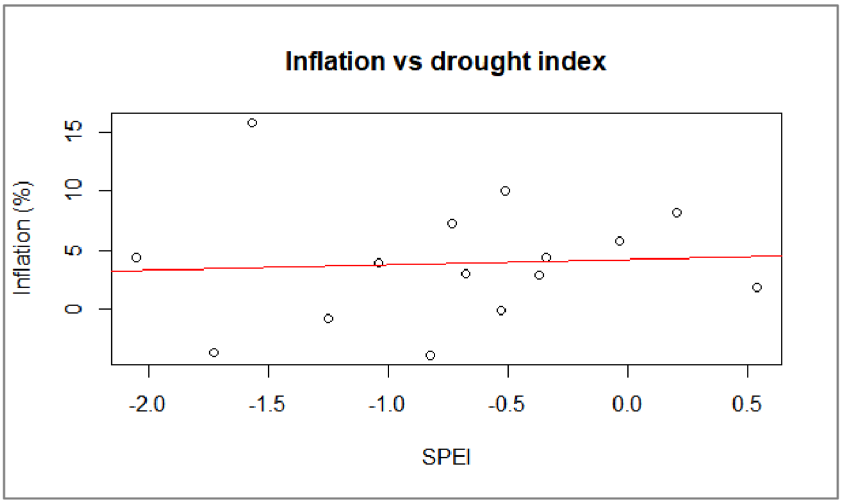

Figure 31. Consumer inflation vs drought index (linear – best fit also).

Polynomial power	Adjusted R-squared	P-value
1 (linear)	-0.07282	0.827
2	-0.1597	0.9648
3	-0.2439	0.9668
4	-0.2684	0.8973
5	-0.4041	0.9571

Table 9. Household/consumer inflation vs drought index.

Inflation parameter takes into account consumer costs. No dependency is noticed for annual scale. Therefore, most probable explanation of inflation rise observed by other scholars (Kelley et al., 2015) is that any increase of prices was unstable and short-lived. This means that inflation could be flattened for annual timescale.

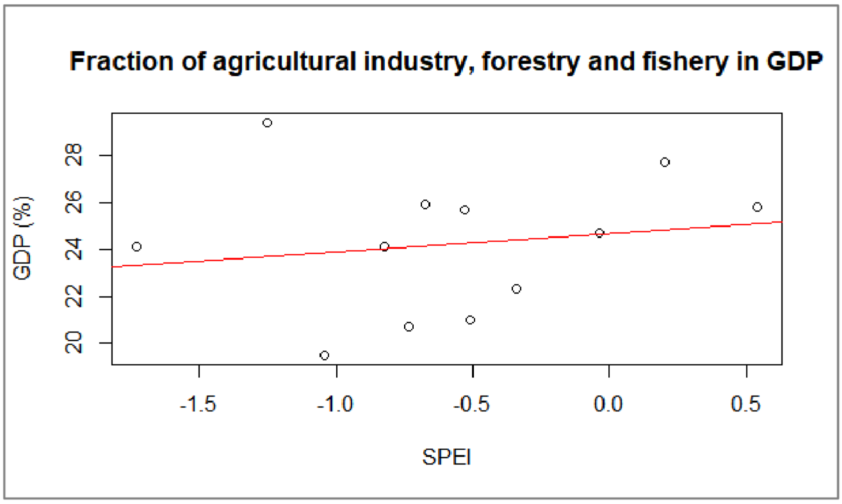

Figure 32. Ratio of agriculture, forestry and fishery vs drought index (linear).

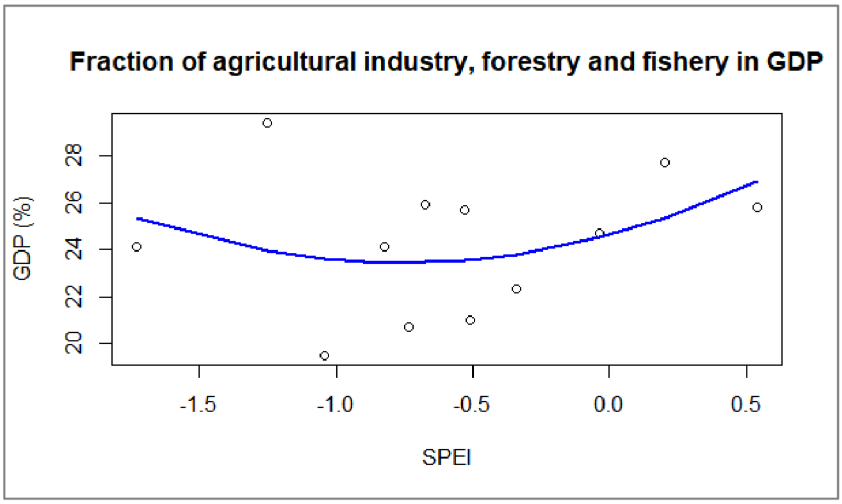

Figure 33. Ratio of agriculture, forestry and fishery vs drought index (best fit).

Polynomial power	Adjusted R-squared	P-value
1 (linear)	-0.06903	0.6022
2	-0.05673	0.5196
3	-0.1878	0.7435
4	-0.102	0.5908
5	-0.2458	0.7257

Table 10. Ratio of agriculture, forestry and fishery to GDP vs drought index.

This index demonstrates fraction of GDP which comes from agricultural field and related economic spheres. Even though some trends can be noticed, in general deviations are extreme. This results in high P-value. Therefore, no reliable dependency can be constructed.

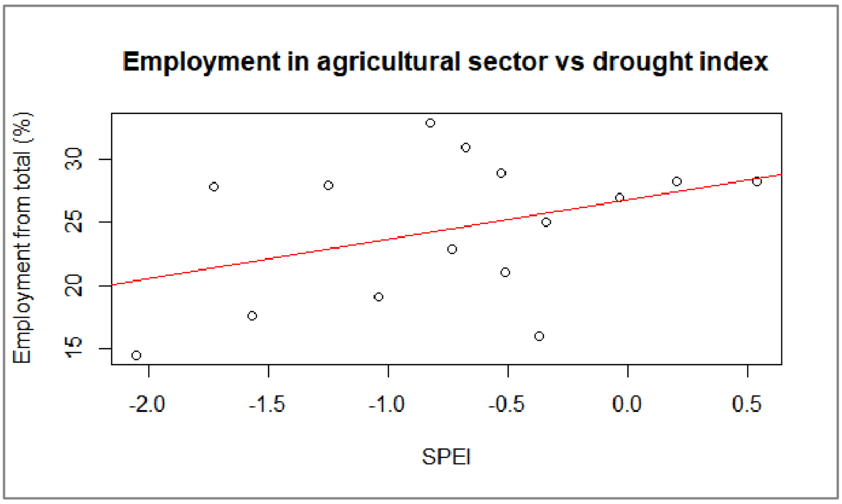

Figure 34. Employment in agriculture vs drought index (linear – best fit also).

Polynomial power	Adjusted R-squared	P-value
1 (linear)	0.09052	0.1458
2	0.04061	0.3092
3	0.0597	0.3244
4	-0.0291	0.4989
5	-0.1383	0.663

Table 11. Employment in agricultural sector vs drought index.

Employment index shows percentage of people who are employed in agriculture. Inconsistency of this parameter with observed unemployment trend which was observed to increase might be from incomplete availability of information or weak dependency.

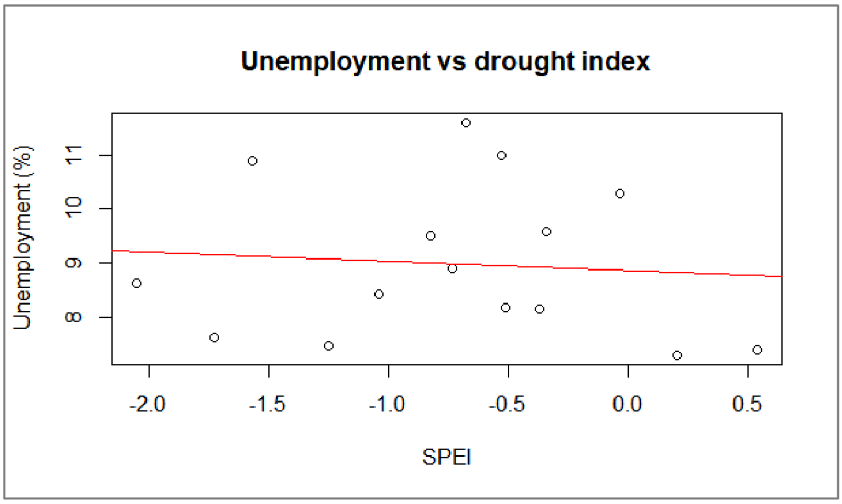

Figure 35. Unemployment fraction vs drought index (linear).

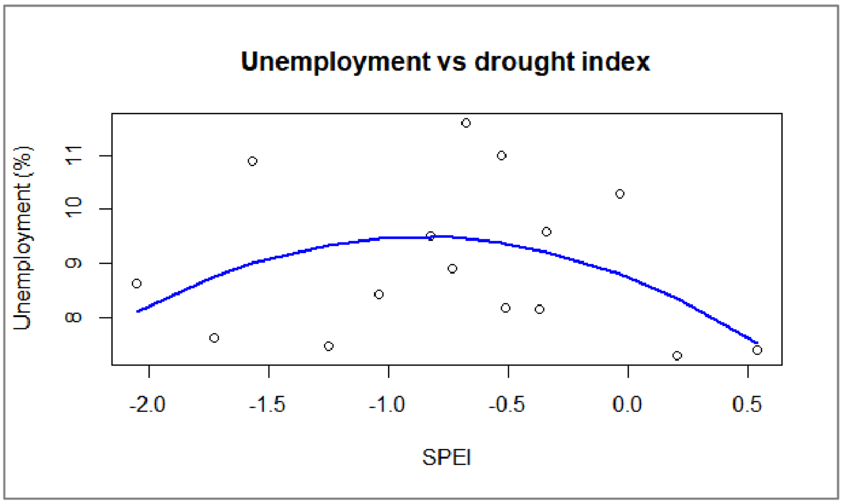

Figure 36. Unemployment fraction vs drought index (best fit).

Polynomial power	Adjusted R-squared	P-value
1 (linear)	-0.06897	0.7608
2	0.03394	0.3224
3	-0.004335	0.4373
4	-0.1029	0.6253
5	-0.1645	0.6991

Table 12. General unemployment vs drought index.

Originally, it was thought that unemployment increases observed in Syria mentioned before would leave some trace. However, as it can be seen from charts, dependence is very weak. High P-value would mean that other factors were more significant.

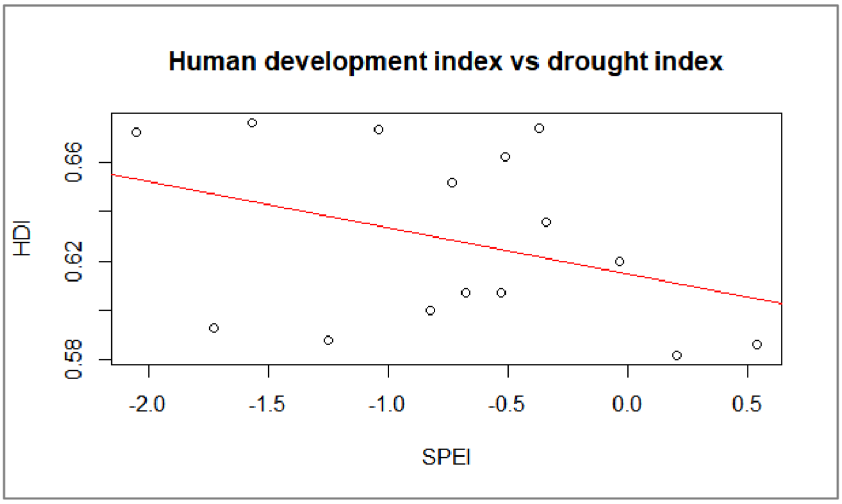

Figure 37. Human development index vs drought index (linear – best fit also).

Polynomial power	Adjusted R-squared	P-value
1 (linear)	0.06868	0.1775
2	0.0274	0.3357
3	0.055	0.332
4	-0.002708	0.4559
5	-0.0949	0.6019

Table 13. Human development index vs drought index.

Human development index consists of life expectancy, education and level of income (Worldbank, 2021e). Negative correlation together with high dispersion is noticed which implies that behaviour of this parameter is opposite to what was proposed. This could be result of external factors which overwhelm influence of climatic parameter. Nevertheless, it is unlikely that direct correlation with drought degree is possible for this index as it would be influenced more by other possible factors.

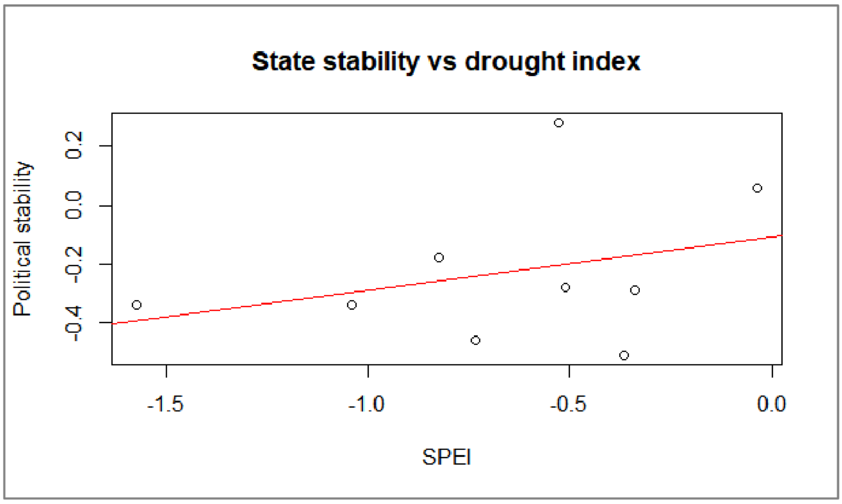

Figure 38. Political stability index vs drought index (linear – best fit also).

Polynomial power	Adjusted R-squared	P-value
1 (linear)	-0.02597	0.4015
2	-0.1651	0.6672
3	-0.3718	0.8399
4	-0.5067	0.8475
5	-0.5356	0.8011

Table 14. Political stability index vs drought index.

In theory, polynomial for political stability index should have same direction as it was expected. Observed linear trend could mean that climate change with decrease of precipitation and availability of water in general would cause decline of stability of country.

However, dataset is disperse. Inconsistent correlation parameters may suggest that dataset is more likely to have no strong relationship. Reasonable the explanation for the absense of a significant dependency in this pair may be that the effect of weather/climate change in case of Syrian drought is lesser than the influence of other (economic and political) factors

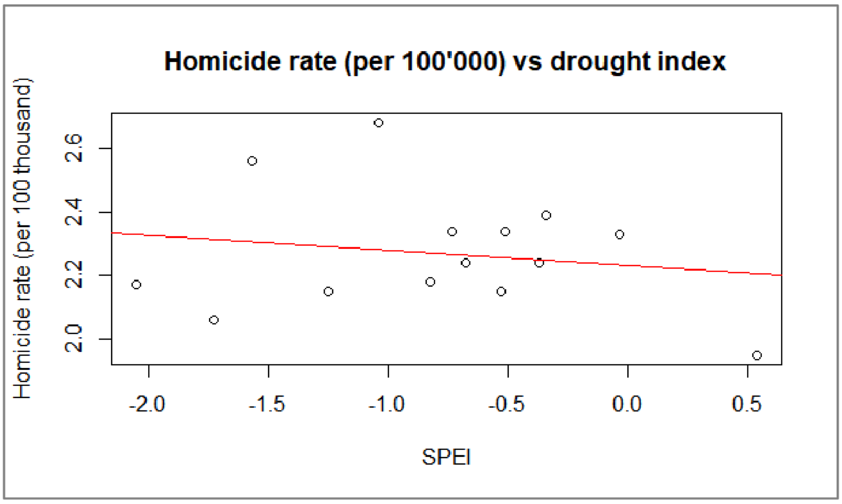

Figure 39. Homicide rate vs drought index (linear).

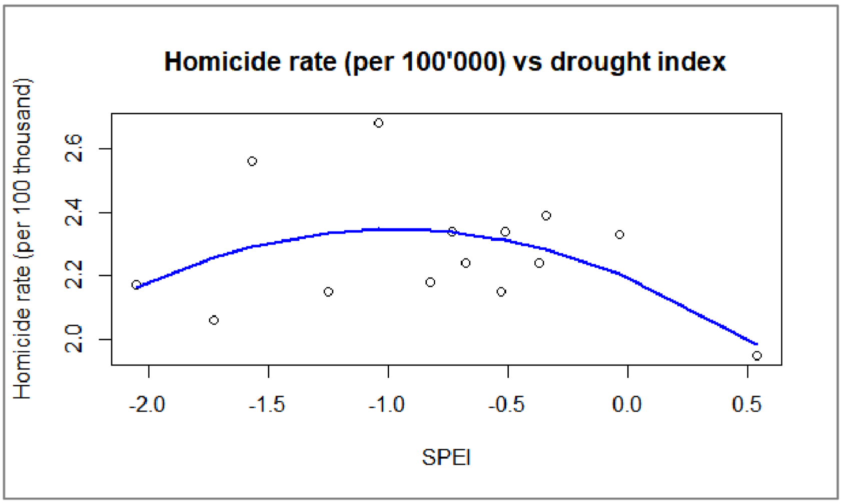

Figure 40. Homicide rate vs drought index (best fit).

Polynomial power	Adjusted R-squared	P-value
1 (linear)	-0.0506	0.5523
2	0.1284	0.1874
3	0.04131	0.3635
4	-0.02342	0.4904
5	-0.02973	0.5118

Table 15. Rate of homicides vs drought index.

Homicide rate represents rate of intentional killings in population. Insufficient correlation coefficient does not provide data about any meaningful correlation or anti-correlation.

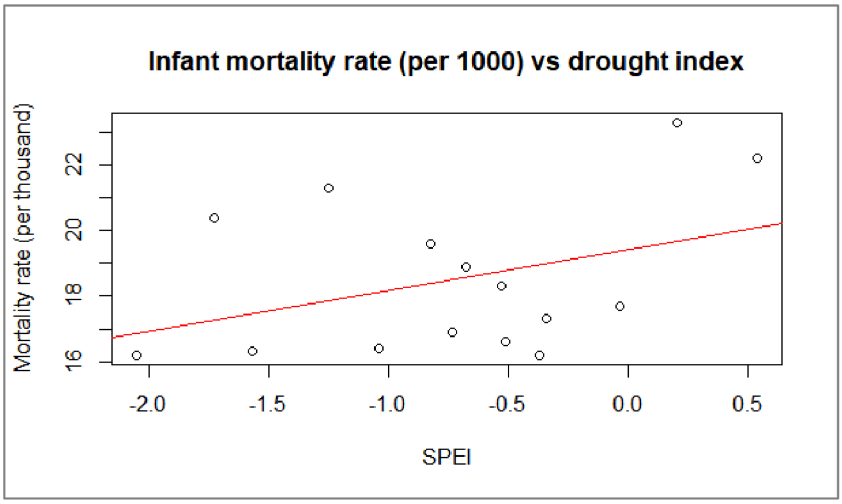

Figure 41. Infant mortality rate vs drought index (linear).

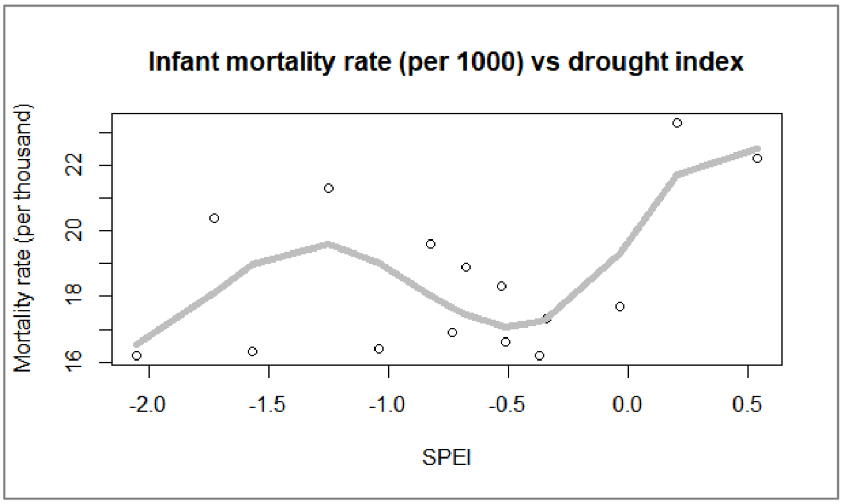

Figure 42. Infant mortality rate vs drought index (best fit).

Polynomial power	Adjusted R-squared	P-value
1 (linear)	0.07914	0.1616
2	0.1557	0.1436
3	0.2845	0.08582
4	0.2722	0.1291
5	0.5184	0.03417

Table 16. Infant mortality rate vs drought index.

Index represents mortality rate for children who did not proceed after first year of their post-birth life. Moderate anti-correlation can be noticed for general trend.

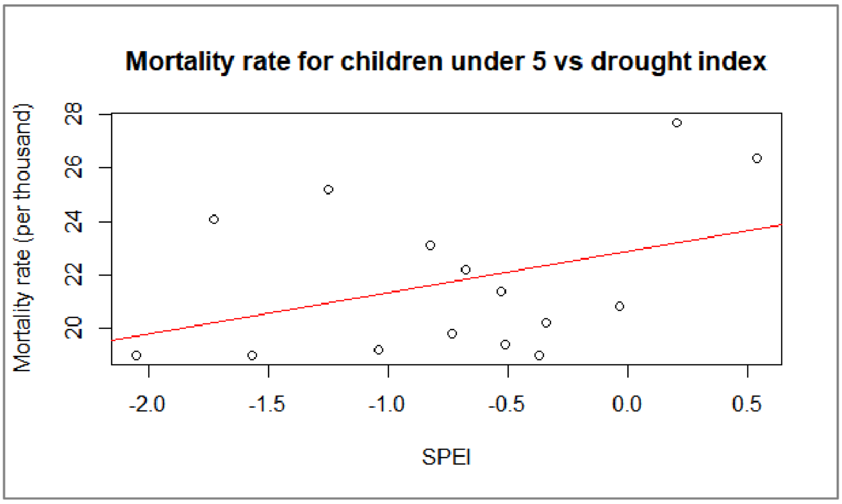

Figure 43. Mortality rate (of age under 5 years) vs drought index (linear).

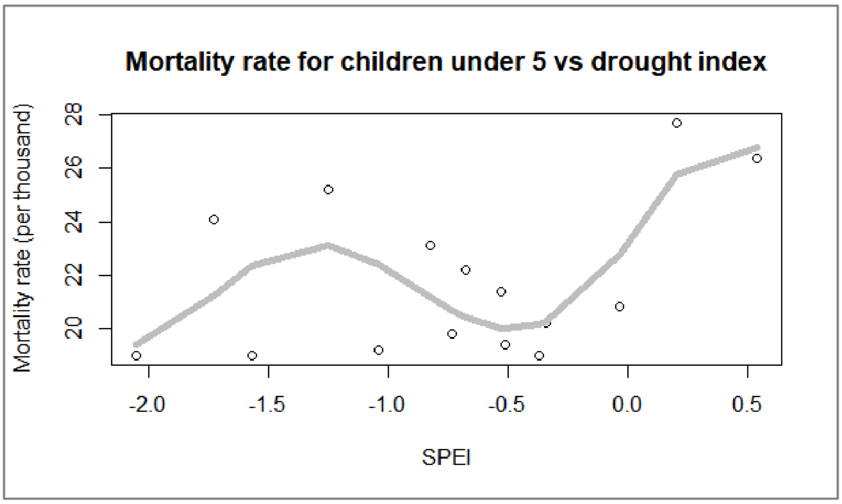

Figure 44. Mortality rate (of age under 5 years) vs drought index (best fit).

Polynomial power	Adjusted R-squared	P-value
1 (linear)	0.07998	0.1604
2	0.1656	0.1338
3	0.2941	0.08018
4	0.2809	0.1227
5	0.3005	0.1432

Table 17. Mortality rate (among children under age of 5) vs drought index.

Index represents total mortality for minors in population of country. Anti-correlation between indices is found. However, P-value and spread of data points make correlation less likely.

All this information, based on data from Worldbank (2021e) and FAO (2021e), can be summarized into the following table:

Index	Polynomial degree	Adjusted R-squared	P-value
Food production economic variability	3	0.606	0.003835
Arable land used per person	3	0.2739	0.09245
Mean agricultural yield (cereals per used land area)	3	0.338	0.01019
Ratio of agricultural, forestry and fishery in GDP	2	-0.05673	0.5196
Producer prices index	1	0.08222	0.1571
Crop production index	3	0.5301	0.009751
Food production index	3	0.3952	0.03641
Consumer inflation	1	-0.07282	0.827
Employment in agricultural sector	1	0.09052	0.1458
Unemployment fraction	2	0.03394	0.3224
Human development index	1	0.06868	0.1775
Homicide rate	2	0.1284	0.1874
Infant mortality rate	5	0.5184	0.03417
Mortality rate (among children under age of 5)	5	0.3005	0.1432
Political stability index	1	-0.02597	0.4015

Table 18. Table of correlations between indices vs SPEI (Syria).

Color:

- ☐ – positive correlation (as expected)
- ☐ – negative correlation (inverse of expectation)
- ☐ – no correlation (neutral or lack of data)

Thick cell borders (in this table and further ones) mean positive correlation for statistical data (from Syrian republic).

3.1. Preliminary analysis:

The charts presented above are plots of linear and best fit curves. From them, it can be seen that for some parameters correlation with drought index can be drawn, even though relatively large deviations are noticed. For other datasets, weaker correlation parameters are produced under polynomial interpolation assumption. This would suggest either that there is null hypothesis is correct (no correlation) or that the dependency is less straightforward (non-polynomial forms of dependence) and weaker. Negative correlation might suggest that inverse interrelation to what was proposed can be suggested for real data.

Several logical pathways can be undertaken in order to understood such difference:

- No correlation – dataset has low degree of interconnection and any potential dependencies are random.
- Weak correlation – suggested cause of behaviour of system (drought impact on index) could be less significant than other factors.
- Causal chain is not straighforward and is carried to the researched factor by another one which is significantly affected by original variable suggested and more complex connections should be built. Under this logical approach it could be suggested that in first step influence.

Detailed analysis of correlations:

Food production economic variability	Direct proportional correlation can be seen which also has low probability of being explained by random non-correlated distribution
Arable land used per person	Correlation is very weak, although P-value is relatively low
Mean agricultural yield (cereals per used land area)	Direct proportional correlation can be seen which also has low P-value
Ratio of agricultural, forestry and fishery in GDP	Most probable explanation is null hypothesis (absense of dependence)
Producer prices index	If correlation exists, it is very weak (on scale of years)
Crop production index	Direct proportional correlation can be seen which also has low P-value
Food production index	Weak anti-correlation together with low P-value is observed
Consumer inflation	On scale of years no correlations are found. Most probable explanation is null hypothesis (absense of dependence)

Employment in agricultural sector	Correlations are weaker then the threshold
Unemployment fraction	Correlations are weaker then the threshold
Human development index	Most probable explanation is null hypothesis (absense of direct dependence)
Political stability index	Most probable explanation is null hypothesis (absense of direct dependence)
Homicide rate	Most probable explanation is null hypothesis (absense of direct dependence)
Infant mortality rate	Relatively strong anti-correlation is observed with low P-value, although this could be the result of combination of drought related effect with long-term decrease in infant mortality with development of healthcare (Worldbank, 2021e)
Child mortality rate	Relatively strong anti-correlation is observed, although this could be the result of combination of drought related effect with long-term decrease in infant mortality with development of healthcare (Worldbank, 2021e)

Table 19. Correlations analysis.

Next series of tables are about secondary correlations of agricultural and socio-economic data.

Following steps in evaluation would be application of this methodology on datasets from other countries (section 3.2).

Mean deviation tables which are listed further would show projections on last comparable year of database.

Correlations among secondary parameters:

This subsection deals with potential correlations among agricultural parameters with social and economic indices. Choice of parameters is based on correlations found from preliminary analysis. Resulting logical chains for second contour:

Influencing parameter:	Dependent indice:	Relationship:
Mean agricultural yield (cereal)	Political stability	Stability would drop with drop of agricultural yield
	Producer prices	Producer prices would drop with increase of agricultural yield (inverse proportion)
	Crop production	Crop production would be directly proportional to agricultural yield
	Food production economic variability	Variability would drop with drop of agricultural yield
	Food production	Food production would be directly proportional to agricultural yield
	Infant mortality rate	Mortality rate would drop with growth of yield (inverse proportion)
	Child mortality rate	Mortality rate would drop with growth of yield (inverse proportion)
	Consumer inflation	Inflation would increase with drop of agricultural yield (inverse proportion)
Food production economic variability	Political stability	Stability would drop with drop of variability
	Infant mortality rate	Mortality rate would grow with drop of variability (inverse proportion)
	Child mortality rate	Mortality rate would grow with drop of variability (inverse proportion)
	Consumer inflation	Inflation rate would be inversely proportional to variability (inverse proportion)
Crop production index	Political stability	Stability could drop with drop of crop production
	Infant mortality rate	Mortality rate would grow with drop of crop production (inverse proportion)
	Child mortality rate	Mortality rate would grow with drop of crop production (inverse proportion)
	Consumer inflation	Inflation rate would be inversely proportional to crop production (inverse proportion)

Table 20. Secondary connections between agricultural data and socio-economic indices.

Influencing parameter:	Dependent indice:	Polynomial degree	Adjusted R-squared	P-value
Mean agricultural yield (agricultural)	Political stability	5	0.6908	0.1203
	Producer prices	1	-0.01226	0.3787
	Crop production	1	0.4238	0.005108
	Food production economic variability	5	0.1807	0.2498
	Food production	1	0.1437	0.09026
	Infant mortality rate	1	-0.07184	0.8078
	Child mortality rate	1	-0.07136	0.7992
	Consumer inflation	5	0.5724	0.02115
Food production economic variability	Political stability	1	-0.1151	0.6891
	Infant mortality rate	3	0.7222	0.0005892
	Child mortality rate	3	0.7266	0.0005417
	Consumer inflation	1	0.1267	0.1053
Crop production index	Political stability	1	-0.06865	0.5082
	Infant mortality rate	1	0.3254	0.01549
	Child mortality rate	1	0.3327	0.01433
	Consumer inflation	1	0.008547	0.309

Table 21. Table of correlations (Syria)

3.2. Application of methodology:

Côte d'Ivoire:

Data sources: Worldbank (2021b) and FAO (2021b)

Index	Polynomial degree	Adjusted R-squared	P-value
Food production economic variability	3	0.04664	0.4207
Arable land used per person	1	-0.005675	0.3585
Mean agricultural yield (cereals per used land area)	3	0.7775	0.00673
Ratio of agricultural, forestry and fishery in GDP	5	0.1376	0.3843
Producer prices index	4	0.9258	0.1819
Crop production index	2	0.08421	0.305
Food production index	2	0.09352	0.2943
Consumer inflation	1	-0.01574	0.3838
Employment in agricultural sector	1	-0.08308	0.6409
Unemployment fraction	1	-0.05916	0.5485
Human development index	3	-0.06729	0.5369
Homicide rate	N/A	N/A	N/A
Infant mortality rate	3	-0.0286	0.4844
Mortality rate (among children under age of 5)	3	-0.0276	0.4831
Political stability index	1	-0.01186	0.372

Table 22. Table of correlations between indices vs SPEI (Côte d'Ivoire).

Color:

- ☐ – positive correlation (as expected)
- ☐ – negative correlation (inverse of expectation)
- ☐ – no correlation (neutral or lack of data)

Correlations among secondary parameters:

Influencing parameter:	Dependent indice:	Polynomial degree	Adjusted R-squared	P-value
Mean agricultural yield (agricultural)	Political stability	1	0.1224	0.1716
	Producer prices	4	0.9904	0.06585
	Crop production	1	0.4181	0.02575
	Food production economic variability	2	-0.105	0.5692
	Food production	1	0.4338	0.02285
	Infant mortality rate	1	0.4414	0.02154
	Child mortality rate	1	0.4394	0.02188
	Consumer inflation	5	0.8167	0.02671
Food production economic variability	Political stability	5	0.7013	0.1147
	Infant mortality rate	5	0.5584	0.1957
	Child mortality rate	5	0.56	0.1948
	Consumer inflation	1	0.04777	0.2751
Crop production index	Political stability	5	0.9292	0.004197
	Infant mortality rate	2	0.9665	2.862e-06
	Child mortality rate	2	0.9637	3.787e-06
	Consumer inflation	1	0.1488	0.1474

Table 23. Table of correlations (Côte d'Ivoire)

Namibia:

Data sources: Worldbank (2021a) and FAO (2021a)

Index	Polynomial degree	Adjusted R-squared	P-value
Food production economic variability	1	0.5384	0.01477
Arable land used per person	1	0.2978	0.05947
Mean agricultural yield (cereals per used land area)	1	-0.1408	0.9145
Ratio of agricultural, forestry and fishery in GDP	3	0.7031	0.008724
Producer prices index	4	0.9809	0.0926
Crop production index	1	0.3716	0.06392
Food production index	1	0.2942	0.0951
Consumer inflation	5	0.6404	0.06063
Employment in agricultural sector	1	0.2066	0.09014
Unemployment fraction	1	-0.08524	0.72
Human development index	4	0.5334	0.06935
Homicide rate	2	0.3112	0.4792
Infant mortality rate	1	0.5196	0.007417
Mortality rate (among children under age of 5)	1	0.4384	0.01576
Political stability index	1	0.3273	0.0385

Table 24. Table of correlations between indices vs SPEI (Namibia).

Color:

- – positive correlation (as expected)
- – negative correlation (inverse of expectation)
- – no correlation (neutral or lack of data)

Correlations among secondary parameters:

Influencing parameter:	Dependent indice:	Polynomial degree	Adjusted R-squared	P-value
Mean agricultural yield (agricultural)	Political stability	1	0.09881	0.213
	Producer prices	3	0.9842	0.009486
	Crop production	5	0.8357	0.1133
	Food production economic variability	5	0.7662	0.0813
	Food production	5	0.37	0.3911
	Infant mortality rate	5	0.2928	0.3585
	Child mortality rate	5	-0.07234	0.5763
	Consumer inflation	4	0.7876	0.03145
Food production economic variability	Political stability	1	0.3291	0.06195
	Infant mortality rate	4	0.6855	0.06639
	Child mortality rate	5	0.7922	0.06876
	Consumer inflation	5	0.986	0.001288
Crop production index	Political stability	1	0.2844	0.09981
	Infant mortality rate	1	0.4873	0.03257
	Child mortality rate	3	0.4156	0.1841
	Consumer inflation	5	0.7603	0.1625

Table 25. Table of correlations (Namibia)

Nicaragua:

Data sources: Worldbank (2021b) and FAO (2021b)

Index	Polynomial degree	Adjusted R-squared	P-value
Food production economic variability	1	-0.08981	0.5777
Arable land used per person	3	0.001146	0.4534
Mean agricultural yield (cereals per used land area)	1	0.0498	0.2867
Ratio of agricultural, forestry and fishery in GDP	1	-0.04966	0.4863
Producer prices index	1	-0.06659	0.4535
Crop production index	1	0.1165	0.2149
Food production index	2	-0.06082	0.4998
Consumer inflation	1	-0.09001	0.6861
Employment in agricultural sector	1	0.08455	0.1988
Unemployment fraction	1	-0.04232	0.4741
Human development index	5	0.03706	0.4686
Homicide rate	1	0.1363	0.197
Infant mortality rate	1	0.007412	0.3269
Mortality rate (among children under age of 5)	1	0.01136	0.3185
Political stability index	5	0.2397	0.3024

Table 26. Table of correlations between indices vs SPEI (Nicaragua).

Color:

- ☐ – positive correlation (as expected)
- ☐ – negative correlation (inverse of expectation)
- ☐ – no correlation (neutral or lack of data)

Correlations among secondary parameters:

Influencing parameter:	Dependent indice:	Polynomial degree	Adjusted R-squared	P-value
Mean agricultural yield (agricultural)	Political stability	4	0.8457	0.04082
	Producer prices	3	0.9441	0.03336
	Crop production	2	0.6931	0.0225
	Food production economic variability	2	0.393	0.1238
	Food production	4	0.8982	0.02218
	Infant mortality rate	4	0.8355	0.04483
	Child mortality rate	4	0.8457	0.04084
	Consumer inflation	4	0.7572	0.07866
Food production economic variability	Political stability	5	0.97	0.004012
	Infant mortality rate	4	0.8242	0.02183
	Child mortality rate	4	0.8155	0.02396
	Consumer inflation	3	0.1042	0.3684
Crop production index	Political stability	5	0.515	0.3113
	Infant mortality rate	5	0.6714	0.2185
	Child mortality rate	5	0.689	0.2075
	Consumer inflation	5	-0.1508	0.6309

Table 27. Table of correlations (Nicaragua)

Nigeria:

Data sources: Worldbank (2021c) and FAO (2021c)

Index	Polynomial degree	Adjusted R-squared	P-value
Food production economic variability	2	0.07964	0.3289
Arable land used per person	4	0.07498	0.4194
Mean agricultural yield (cereals per used land area)	5	0.8255	0.05351
Ratio of agricultural, forestry and fishery in GDP	1	-0.1008	0.7777
Producer prices index	2	-0.3055	0.6933
Crop production index	3	-0.06719	0.5333
Food production index	3	-0.08403	0.5471
Consumer inflation	1	-0.01158	0.3713
Employment in agricultural sector	2	-0.1166	0.6367
Unemployment fraction	2	-0.02361	0.4502
Human development index	2	-0.09304	0.5847
Homicide rate	N/A	N/A	N/A
Infant mortality rate	1	-0.07861	0.6151
Mortality rate (among children under age of 5)	1	-0.07978	0.6216
Political stability index	1	-0.06656	0.555

Table 28. Table of correlations between indices vs SPEI (Nigeria).

Color:

- ☐ – positive correlation (as expected)
- ☐ – negative correlation (inverse of expectation)
- ☐ – no correlation (neutral or lack of data)

Correlations among secondary parameters:

Influencing parameter:	Dependent indice:	Polynomial degree	Adjusted R-squared	P-value
Mean agricultural yield (agricultural)	Political stability	5	0.04435	0.5093
	Producer prices	1	0.1733	0.2256
	Crop production	3	-0.01398	0.4902
	Food production economic variability	3	0.06844	0.4006
	Food production	5	0.1386	0.5065
	Infant mortality rate	5	0.04462	0.5091
	Child mortality rate	5	0.03107	0.5171
	Consumer inflation	1	0.2455	0.09949
Food production economic variability	Political stability	1	-0.02709	0.4039
	Infant mortality rate	5	0.9619	0.005722
	Child mortality rate	5	0.9625	0.005593
	Consumer inflation	4	0.3348	0.2583
Crop production index	Political stability	2	0.1118	0.3206
	Infant mortality rate	1	0.7781	0.002323
	Child mortality rate	1	0.7761	0.002389
	Consumer inflation	1	-0.1467	0.7576

Table 29. Table of correlations (Nigeria)

Paraguay:

Data sources: Worldbank (2021b) and FAO (2021b)

Index	Polynomial degree	Adjusted R-squared	P-value
Food production economic variability	5	0.6838	0.1241
Arable land used per person	4	0.8876	0.003258
Mean agricultural yield (cereals per used land area)	5	0.4731	0.1863
Ratio of agricultural, forestry and fishery in GDP	1	-0.08435	0.712
Producer prices index	4	0.9892	0.06979
Crop production index	5	0.6582	0.08609
Food production index	5	0.6789	0.07676
Consumer inflation	5	0.3666	0.1731
Employment in agricultural sector	5	0.7063	0.03802
Unemployment fraction	2	0.4461	0.0284
Human development index	5	0.7546	0.02498
Homicide rate	5	0.6029	0.113
Infant mortality rate	5	0.5787	0.08673
Mortality rate (among children under age of 5)	5	0.5992	0.07753
Political stability index	4	0.586	0.04987

Table 30. Table of correlations between indices vs SPEI (Paraguay).

Color:

- ☐ – positive correlation (as expected)
- ☐ – negative correlation (inverse of expectation)
- ☐ – no correlation (neutral or lack of data)

Correlations among secondary parameters:

Influencing parameter:	Dependent indice:	Polynomial degree	Adjusted R-squared	P-value
Mean agricultural yield (agricultural)	Political stability	2	0.5854	0.01904
	Producer prices	3	0.2273	0.4257
	Crop production	1	0.7666	0.0005546
	Food production economic variability	3	0.326	0.1292
	Food production	1	0.7538	0.0006907
	Infant mortality rate	4	0.7293	0.0274
	Child mortality rate	4	0.7136	0.03133
	Consumer inflation	2	0.01919	0.3877
Food production economic variability	Political stability	1	0.1566	0.1589
	Infant mortality rate	1	0.3462	0.05594
	Child mortality rate	1	0.3607	0.05124
	Consumer inflation	3	0.06718	0.4497
Crop production index	Political stability	5	0.7451	0.04993
	Infant mortality rate	4	0.971	0.0001137
	Child mortality rate	4	0.9757	7.306e-05
	Consumer inflation	2	0.07981	0.3101

Table 31. Table of correlations (Paraguay)

Philippines:

Data sources: Worldbank (2021d) and FAO (2021d)

Index	Polynomial degree	Adjusted R-squared	P-value
Food production economic variability	1	-0.1421	0.9463
Arable land used per person	1	0.1542	0.1428
Mean agricultural yield (cereals per used land area)	1	-0.1033	0.6317
Ratio of agricultural, forestry and fishery in GDP	1	0.2791	0.05471
Producer prices index	3	0.7584	0.1414
Crop production index	5	0.7498	0.1693
Food production index	5	0.8001	0.1367
Consumer inflation	1	0.2921	0.04985
Employment in agricultural sector	1	0.1459	0.1342
Unemployment fraction	1	0.1273	0.1377
Human development index	1	0.196	0.0967
Homicide rate	1	-0.07941	0.577
Infant mortality rate	1	0.1571	0.1249
Mortality rate (among children under age of 5)	1	0.1582	0.1239
Political stability index	5	0.6064	0.07445

Table 32. Table of correlations between indices vs SPEI (Philippines).

Color:

- ☐ – positive correlation (as expected)
- ☐ – negative correlation (inverse of expectation)
- ☐ – no correlation (neutral or lack of data)

Correlations among secondary parameters:

Influencing parameter:	Dependent indice:	Polynomial degree	Adjusted R-squared	P-value
Mean agricultural yield (agricultural)	Political stability	4	0.7937	0.02971
	Producer prices	3	0.7751	0.1319
	Crop production	1	-0.04072	0.4268
	Food production economic variability	2	0.3071	0.1403
	Food production	2	0.3588	0.142
	Infant mortality rate	1	0.7706	0.00115
	Child mortality rate	1	0.757	0.001414
	Consumer inflation	3	0.402	0.1487
Food production economic variability	Political stability	3	0.08981	0.3812
	Infant mortality rate	2	0.1662	0.2445
	Child mortality rate	2	0.1763	0.2358
	Consumer inflation	1	-0.12	0.7168
Crop production index	Political stability	1	0.02129	0.3243
	Infant mortality rate	1	-0.1529	0.798
	Child mortality rate	1	-0.149	0.7714
	Consumer inflation	1	-0.1238	0.6491

Table 33. Table of correlations (Philippines)

Further tables represent mean deviations of projected value for last year of applied model from real values, compared to residual standard errors.

Mean deviation for indices (Côte d'Ivoire):

Index:	Projection on last comparable year in database (best model fit):	Real value:	Resulting deviation:	Absolute value of residual standard error for best model fit:
Food production economic variability	8.953245	7.8	1.15325	2.014
Arable land used per person	0.1451733	0.14	0.0051733	0.007091
Mean agricultural yield (cereals per used land area)	22422.34	22780	-357.66	89.96
Ratio of agricultural, forestry and fishery in GDP	22.28902	20.7	1.58902	2.254
Producer prices index	178.9038	178.9	0.0038	3.655
Crop production index	96.58616	109.8	-13.2138	14.06
Food production index	96.76703	109.1	-12.333	13.12
Consumer inflation	1.473028	2.43	-0.956972	1.493
Employment in agricultural sector	44.63203	40.2	4.43203	2.811
Unemployment fraction	8.467028	9.03	-0.562972	0.2559
Human development index	0.5024521	0.538	-0.0355479	0.02753
Homicide rate	N/A	N/A	N/A	N/A
Infant mortality rate	66.76007	58.6	8.16007	6.018
Mortality rate (among children under age of 5)	93.05962	79.3	13.7596	10.21
Political stability index	-1.169655	-0.96	-0.209655	0.241

Table 34. Table of deviation analysis (Côte d'Ivoire).

Mean deviation for indices (Namibia):

Index:	Projection on last comparable year in database (best model fit):	Real value:	Resulting deviation:	Absolute value of residual standard error for best model fit:
Food production economic variability	8.566301	2.4	6.1663	4.502
Arable land used per person	0.3438575	0.33	0.0138575	0.01543
Mean agricultural yield (cereals per used land area)	3979.788	4359	-379.212	743.9
Ratio of agricultural, forestry and fishery in GDP	6.535607	6.61	-0.074393	0.459
Producer prices index	184.8128	185.1	-0.2872	5.062
Crop production index	116.4393	121.4	-4.9607	5.898
Food production index	91.62096	92.6	-0.97904	0.9755
Consumer inflation	3.724983	3.72	0.004983	1.016
Employment in agricultural sector	22.19892	21.9	0.29892	3.348
Unemployment fraction	20.41345	20.4	0.01345	1.895
Human development index	0.6473363	0.646	0.0013363	0.0166
Homicide rate	16.87799	17.7	-0.82201	2.433
Infant mortality rate	30.92782	30.7	0.22782	1.848
Mortality rate (among children under age of 5)	43.72209	42.4	1.32209	2.526
Political stability index	0.6044665	0.53	0.0744665	0.1282

Table 35. Table of deviation analysis (Namibia).

Mean deviation for indices (Nicaragua):

Index:	Projection on last comparable year in database (best model fit):	Real value:	Resulting deviation:	Absolute value of residual standard error for best model fit:
Food production economic variability	6.096592	7.5	-1.40341	1.561
Arable land used per person	0.243092	0.23	0.013092	0.01699
Mean agricultural yield (cereals per used land area)	19332.06	17680	1652.06	1195
Ratio of agricultural, forestry and fishery in GDP	15.94636	15.4	0.54636	1.241
Producer prices index	188.5239	223.7	-35.1761	27.84
Crop production index	123.9858	137.7	-13.7142	9.546
Food production index	126.9449	128.5	-1.5551	4.911
Consumer inflation	5.107376	5.38	-0.272624	1.646
Employment in agricultural sector	30.7264	30.6	0.1264	0.7132
Unemployment fraction	6.122612	5.82	0.302612	1.471
Human development index	0.6605278	0.66	0.0005278	0.01594
Homicide rate	10.69355	7.19	3.50355	2.363
Infant mortality rate	16.4974	14.3	2.1974	2.237
Mortality rate (among children under age of 5)	19.27338	16.6	2.67338	2.731
Political stability index	-1.068924	-1.03	-0.038924	0.2985

Table 36. Table of deviation analysis (Nicaragua).

Mean deviation for indices (Nigeria):

Index:	Projection on last comparable year in database (best model fit):	Real value:	Resulting deviation:	Absolute value of residual standard error for best model fit:
Food production economic variability	10.09796	6.9	3.19796	3.012
Arable land used per person	0.1737197	0.17	0.0037197	0.01452
Mean agricultural yield (cereals per used land area)	15031	14620	411	418.8
Ratio of agricultural, forestry and fishery in GDP	21.9757	21.9	0.0757	2.015
Producer prices index	96.6541	120	-23.3459	25.22
Crop production index	111.5001	118.9	-7.3999	11.33
Food production index	116.218	124.6	-8.382	12.57
Consumer inflation	12.08326	11.4	0.68326	2.767
Employment in agricultural sector	37.56749	35	2.56749	2.596
Unemployment fraction	5.433402	9.01	-3.5766	2.321
Human development index	0.5197521	0.539	-0.0192479	0.02086
Homicide rate	N/A	34.5	N/A	N/A
Infant mortality rate	80.1075	74.2	5.9075	3.841
Mortality rate (among children under age of 5)	127.9158	117.2	10.7158	6.949
Political stability index	-2.028826	-1.93	-0.098826	0.1025

Table 37. Table of deviation analysis (Nigeria).

Mean deviation for indices (Paraguay):

Index:	Projection on last comparable year in database (best model fit):	Real value:	Resulting deviation:	Absolute value of residual standard error for best model fit:
Food production economic variability	89.03394	76.6	12.4339	11.78
Arable land used per person	0.6914824	0.68	0.0114824	0.01034
Mean agricultural yield (cereals per used land area)	43793.6	42260	1533.6	4883
Ratio of agricultural, forestry and fishery in GDP	10.83717	10.80	0.03717	1.535
Producer prices index	184.5842	184.6	-0.0158	2.287
Crop production index	107.0502	111.5	-4.4498	11.64
Food production index	104.8901	109.2	-4.3099	9.871
Consumer inflation	1.7696	1.77	-0.0004	1.326
Employment in agricultural sector	20.37068	18.7	1.67068	1.681
Unemployment fraction	7.572622	7.61	-0.037378	0.7547
Human development index	0.7222733	0.728	-0.0057267	0.007555
Homicide rate	8.580117	7.14	1.440117	1.142
Infant mortality rate	18.04412	16.6	1.44412	1.278
Mortality rate (among children under age of 5)	21.11661	19.4	1.71661	1.547
Political stability index	-0.2464215	0.00	-0.2464215	0.2753

Table 38. Table of deviation analysis (Paraguay).

Mean deviation for indices (Philippines):

Index:	Projection on last comparable year in database (best model fit):	Real value:	Resulting deviation:	Absolute value of residual standard error for best model fit:
Food production economic variability	5.087181	8.3	-3.21282	1.611
Arable land used per person	0.05519943	0.05	0.00519943	0.004749
Mean agricultural yield (cereals per used land area)	34524.96	36920	-2395.04	1757
Ratio of agricultural, forestry and fishery in GDP	10.28636	8.82	1.46636	1.661
Producer prices index	165.6995	165.3	0.3995	5.846
Crop production index	110.0953	109.6	0.4953	1.784
Food production index	113.3437	114	-0.6563	1.585
Consumer inflation	2.01602	2.48	-0.46398	1.163
Employment in agricultural sector	26.81365	22.9	3.91365	3.514
Unemployment fraction	3.36	3.065979	0.294021	0.5241
Human development index	0.7152136	0.718	-0.0027864	0.01782
Homicide rate	9.164326	6.46	2.70433	1.216
Infant mortality rate	22.86686	21.6	1.26686	1.014
Mortality rate (among children under age of 5)	28.98395	27.3	1.68395	1.418
Political stability index	-0.9306796	-0.88	-0.0506796	0.2022

Table 39. Table of deviation analysis (Philippines).

4. Discussion:

Choice of socio-economic statistical data for analysis was based on accessibility of information on yearly basis. Original intention of analysis was to be able to process two approaches. Therefore, during choice of parameters this factor was considered. In the first instance, as high-priority data from agricultural information cereal yields were taken together with employment figures, as causal link would be straightforward. Additionally such derived parameters as relative production indices were incorporated as basis for comparison. More macroeconomical statistics was included in analysis as supplementary tool to be able to use them further in the analysis of secondary correlations (however majority of parameters did not show significant correlation). Social data (homicide and death rates) was taken in analysis as mark of potential instability in regards to consequences of impact in economics. This would demonstrate that dry period would bring health consequences for population through different ways. Most complex indicators were human development index and political stability as they consist of multiple socio-economic factors; first one was used as composite value which represents income together with mean health of population of specific state. In secondary correlations indices which were logically closer to agricultural indices as child mortality together with political stability value were applied.

It needs to be mentioned that aside economic and social effects of any extreme weather phenomena (in this case drought) there are can be also long-term consequences. Most importantly, in terms of ecological damage. These could in their way cause indirect disturbances to economics and society.
Main direct mechanism of damage to economics is effect on agriculture. Water shortage can lead to crop failure and widespread loss of livestock. Indirect mechanism could be the result of connections in economics. From datasets it can be said that for non-developed countries these relationships were found to be less pronounced while for example drought in Texas demonstrated impact of extreme climatic event. Induced mechanisms are those which appear from changes in economic structure for example under effect of unemployment (Ray et al., 2015; Ziolkowska, 2016). Decades long reduction of precipitation in Syria has been happening well before considered drought which might suggest that such climatic trends were causing damage (albeit lesser in magnitude) and reduction of potential.

Resulting trends in data sample might imply that any potential intercorrelation with climatic data for non-agricultural index is non-straightforward. For Syrian Arab republic, from variety of considered indices, agricultural data for related parameters were most ones which were affected by drought which has logical correlation with assumed suggestions. For other data parameters, correlation in majority of indices was majorily weak or indistinguishable from null hypothesis. Low-order of polynomial fits were used to be able to compare trendlines of dataset. In this regard, linear (first-order) approximation has provided case of simplest dependence and wherever it has demonstrated behaviour where it followed expected behaviour these indices were choosen for primary analysis. However, initial guess that with increase of order of polynomial more accurate results would be accessible was not generalizable fact. In some cases, linear (first-order approximation) was most adequate. Correlations which are found to be opposite of expectations (based on rational cause-effect chains) were not rare instances. In addition, correlations were complicated with the fact that in some cases database is incomplete, although this is most likely to be more influential for mean standard error than general trendline (as dispersion of datapoints). It can be suggested that more complex functions to be used for estimations of dependencies.

Agriculture related data indices were diverse in their dependency from drought index. Dependency of mean yield of cereals from drought index can be easily explained as plants needs water (as all living organisms) in order to survive.
Area of arable land used in agriculture has been found no correlation, differing with anticipated behaviour. Ratio of agricultural, forestry and fishery in GDP has also found in some cases no correlation while for case of Namibia – strong dependency was found, although ratio of standard deviation to mean value has been more than 5%. This could be the result of activity in other spheres of economics as well, subsequently it is hard to attribute this only to dry weather. In the study striking differences for some cases between trendlines for crop production index and food production index were encountered. Despite the fact that for intermediate range of cubic model fit behaviour was comparable to assumed hypothesis, linear trendlines which are taken as first-order approximations had not only different slope magnitudes but also different directions (signs of trendline gradient).

Non-agricultural parameters in the datasets, have demonstrated lesser potential dependency form SPEI which is attributable to international trade. It needs to be said that some incompleteness of data can be presented in existing databases. As an example, consumer inflation has displayed neutrality to changes in SPEI index while food prices are mentioned to increase during drought (Akesson and Falk, 2015; Kelley et al., 2015; Ulker et al., 2018). Although, it can be also the case that potential correlations of inflation are most probably result of short term regional increases of prices. Agricultural employment and total unemployment figures have demonstrated relatively poor trendline fit in all cases despite spike of unemployment in Syrian state more than 10% of potential workforce (Worldbank, 2021e). Mortality figures (infant and for children of age below 5) in general had no correlation and partially demonstrated anti-correlation trends which is easily attributable to development of healthcare. Subsequently, these both indices could not be used for comparison for considered purpose in cases where some society or community has general growth of quality and standards of life. For homicide rate it was thought that this indicator could be influenced by drought in terms of increase of crime rates due to rise of unemployment. However, only Namibia demonstrated regression parameters which is also can be attributed to be random coincidence due to high P-value. Therefore, index of homicide rates is most likely not to have correlation with drought parameter.

Unexpectedly (based on values of R-squared and P-value), deviations from projected values for such indices as mortality rates, homicide rates, political stability score were relatively low in magnitude when comparisons of projected data values with real values had been provided. On the other hand, most drastic difference occurred for best case (in original Syrian example) linear model of food production economic variability. This could mean that this index might be more dependent on economic factors. Analysis of deviations of estimations (with the usage of SPEI values for last comparable year) suggest that in majority of cases projection value differs from real numbers by about one mean standard deviation or more. This could be partially explained by the forementioned incompleteness of available dataset. Another possible (and more probable) explanation is that other economic and social factors were also influential and they also had their own complex progressions, so the constant term in original equation (which was put in initial assumption) has in fact some time-dependent form. This might be more appropriate cause as other potential factors could be randomly influenced by external factors as well as internal ones. As an example, impact of financial-economic crises is also possible to induce unemployment and deficites despite there might be no shortages of material resources, food, available workers or extreme weather events.

There has been found no direct correlation with political stability index for case of Syria. This can be attributed to the fact that while economic situation deteriorated the significant fraction of people were occupied with internal migration (Kelley et al., 2015). Main phase of turmoil began on chain wave of Arab Spring. For case of Namibia, correlation between SPEI index and stability index is observed, however other non-climatic factors could also contribute. For other states, no significant correlation was found.
Main difference between Syria and other considered countries is that in other states degree of civil struggles for selected time periods was either minimum or at least did not reach same catastrophic degree as with case of Ba'ath regime.

Poor policy during Syrian drought and years earlier could be explained by agriculture being supported earlier through oil exports which would mean that in years of drought there were less potential financial resources to weaken effects of drought. As it was mentioned before, water deficite could not be sustainably solved with groundwater in Syria, moreover legal limitations on usage of groundwater were placed, therefore many researchers made suggestion that drought was leading condition of civil war. However, food and water deficite by itself would not induce social unrest. Supplementary factors to take into consideration are pre-existing contradictions inside of society of any origin: economic, political, social, religious, ethnic and racial (Patel and McMichael, 2009). Syrian Arab republic had such internal tensions before civil conflict which helped political rivalry to evolve further with more lethal consequences. For example, pan-Arabic ideology which Ba'ath regime followed alienated Kurdish minority from the state and put settlement of people of Arabic origin in context of erasure of ethnic identity. This additionally included economic restrictions which did not ease the situation (Balanche and

Kalbach, 2018). This means that drought played role of trigger which did not cause civil conflict directly but increased probability of it and accelerated potential timeframe which could lead to the open military conflict. Extreme climatic events would cause economic consequences. Existing states which have unsolved internal conflicts or social struggles might anticipate modern situation to become more harmful in the future even if on territories of their states impact of climate change is not so noticeable. This is especially more impactful for countries where state hierarchy is based on archaic forms of government (CNA, 2007; Omelicheva, 2011). Hendrix and Brinkman (2013) emphasizes that short-term food deficite which is usual issue during droughts can have double effect on political unrest in society. On one side, if government has already been unpopular, conditions could enhance political stress and inspire rebellions of any nature. On the other side, same food deficite might be influential also for militant rebel forces, limit amount of available military force as biological survival is issue of primary significance and weaken their abilities.

Criticism of emphasis of climate as primary factor in Syrian crisis is noticeable. Conflict might not be attributable only to a single factor, as there are many stress points between diverse ethnic and religious groups (Akesson and Falk, 2015; Selby et al., 2017). It needs to be noticed that Syria already had an islamist uprising in 1976-1982 which was more than series of terrorist attacks (Lia, 2016). It is unlikely to attribute to consequences of any drought or other weather phenomenon.
As additional distress, economics of state also experienced decrease of oil exports. This led to decrease of subsidies for agricultural industry as state used external incomes from export to maintain agricultural sector. All this started several years before drought (Selby, 2019). It should be also mentioned that resource mismanagement and neglective attitude to overexploitation of groundwater played important role in deterioration of situation. Officials were hesitant to improve water and land usage policies. Collectively, this would mean that water management. Additionally, Syrian government tried to downplay impact of 2006 year drought on agricultural sector (Chatel, 2014). Furthermore, population figures for Syrian republic increased 1.5 times comparing to 1995, reaching approximately 21 mln people in last pre-war year (FAO, 2021e). In the same time, it would mean that stress on agricultural lands, water resources, infrastructure increased. Critics suggest that drought could at most simply accelerate already existing trends in society, emphasizing necessity in caution about far-reaching conclusions.

In order for proper analysis, arguments for skeptical viewpoints on topic issue should be taken into consideration. While majority of notable academic articles with criticism towards direct correlation of drought argues with considered hypothesis, it has to be noted that they mostly emphasize that already existing struggle inside of state play more important role, however this would not completely remove impact of climate fluctuations. Instead more likely some degree of influence of drought on political stability can take a place. This would mean that any correlation hypothesis would have not a deterministic but probabilistic character.

5. Conclusions:

The study which I have conducted is about impact of drought on state of society. The research process was accomplished within stated objectives, although direct correlation of political stability with drought was not detected.

Objectives:

1. It was demonstrated that causal chains between drought and societal collapse exist.
2. Statistical evaluation of data was performed with outputs being able to be used for logical deductions.
3. In original case study, there were found these indices which could be used for analysis, however only partial concurrence was found on other states.
4. No noticeable correlation was found in case of Syria, while third of treated countries have demonstrated causally correlated link.

In this study I have found 3 statistical parameters which might be used to trace consequences of drought from Syrian example - food production economic variability, mean agricultural yield, crop production index. The impact of drought on social and economic indicators were observed on timescale of several years, as on longer timescale other factors, both climatic and non-climatic (economic crisis, external politics), could become more important. The monitoring was done on annual basis, with potential of forecast on timescale of 1-2 years.

I observed that these indices were primarily agricultural. This provides additional evidence to that drought effects society by connection of agriculture to economics.

The statistical information that was added consists of available agricultural and socio-economic information from publicly accessible databases. Datasets were choosen in way that information can be analyzed on annual basis.

During research, from datasets analyzed some indices were found to have attributable statistical correlation with climatic factor used. In general, part of agricultural indices in case of Syria were found to have correlation with used drought index. Non-agricultural indices demonstrated low degree of correlation (expressed as high magnitude of P-values or non-applicable R-squared parameter). Reasonable explanations for these behaviours include weak level of influence of drought, absense of correlations, significant influence of non-climatic parameters (in terms of economics and society). There has been found no direct link between long-term dry weather conditions and index of political stability, however it can be suggested that indirect connections can be used with other indices as mediators.

In the later stages, methodology was re-applied on 6 other countries with reasonable output values, although low degree of correlation parameters might suggest that found correlations might be weaker than influence of other (non-climatic) parameters. Therefore, it could be supposed that patterns of dependencies are more complex than used polynomial forms. For majority of statistically important relationships indices the deviations of real values from expected ones were within one standard deviation. This does not mean that there were not an abnormalities after detailed analysis.

Restrictions of methodology consist of difficulties of analysis based on low order of magnitude of dataset, due to per-annual basis of this research. Limitation of applicability could be due to complications of climate forecast for some geographical area and necessity to be able to rationally guess potential trends in economics and social sphere of societies on considered timeperiods. As recommendation for further research it could be suggested that more detailed statistical databases could be used. There is also might be necessity to interpolate data on monthly basis to be able to use machine learning.

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