Chapter 3: Panel data analysis on the Moroccan regional level

Chapter introduction:

Morocco has been experiencing more frequent drought events over the last two decades. Drought frequencies have risen from one event every 10 years at the beginning of the 20th century to 5 or 6 events every 10 years at the beginning of the 21st century (Agoumi, 2003). Besides, many regions in Morocco (namely Oujda, Taza, Kenitra, Rabat, and Meknès) have become more arid between 1961 and 2008, (Driouech, 2009). The table below lists some of the important drought events during the last two decades. It can be observed that drought has considerable negative impacts on the economy and Moroccan population in terms of crop production losses, reduction in GDP, and loss of livelihood. It also demonstrates that drought is a major obstacle for agriculture and food security in the country. With several indications suggesting an increased frequency in drought events in Morocco, the average annual impact might become even greater in the future (explained more in the conclusion).

Drought event	Remarks
1994-1995	Reduced incomes due to drought caused GDP to fall by 7.6% in 1995 The production of cereals fell from 9.5 million tons in 1994 to 1.6 million tons in 1995 due to drought
1996-1997	Reduced incomes due to drought caused GDP to fall by 2.3% in 1997
1998-1999	Reduced incomes due to drought caused GDP to fall by 1.5% in 1999
1999-2000	275,000 people affected. Economic Damages: USD 900 million
2000-2001	The country imported about 5 million tons of wheat in 2001 (compared to 2.4 million tons in normal years).
2004-2005	Reduced economic growth rate from 4.8 to 3.3 % for 2005
2006-2007	700,000 people affected. Cereal production reached only half of the normal year's levels.

Table 1: socioeconomic Impacts of recent droughts in Morocco (RMSI, 2012)

In this section, we’ll carry out a macroeconomic analysis based on green water drought. As mentioned in the previous chapter, detailed approaches are limited by data availability, which is why the precipitations and temperature of the 12 Moroccan regions will be used to estimate the impact of dry years - according to the SPI index – on the GDP of each region.

1. Methodology and Data :

Panel data regression is applied in this study. Morocco is composed of 12 regions where each one is characterized by unique activities and added value structure. The table below is mostly made from data gathered manually using the Higher Planning Commission's annual reports from 2009 to 2019, in additions to metrological data that has been modified to become relevant to this macroeconomic analysis.

$$LOG(GDP_{it}) = \alpha + \beta LOG(FHCE_{it}) + \gamma LOG(Prim_{it}) + \theta LOG(Sec_{it}) + \delta LOG(Ter_{it}) + \vartheta SPI_{it} + \varphi Temp_{it} + \varepsilon_{it}$$

Region	Year	GDP	FHCE	Prim	Sec	Ter	SPI	Temp
Tangier	2009	62828	48407	8325	17080	28834	2.09	19.36
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
Tangier	2019	125785	74673	14396	38850	56737	0.06	19.54
Eastern	2009	39953	28483	5433	9314	20074	2.25	19.64
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
Eastern	2019	59278	45757	9636	14292	26933	0.97	20.87
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
Dakhla	2009	5761	2406	745	741	4128	2.01	29.56
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
Dakhla	2019	14802	4561	4035	1394	9229	-0.66	29.11

Table 2: Data and variable structure (author)

Our model consists of 7 variables in total:

GDP: The Gross Domestic Product per region is the dependent variable of our panel data model. The aim is to find the effect of other variables on the wealth of each region, thus forming a picture describing the entire situation of the Moroccan territory.

FHCE: Final household consumption expenditures is the first independent variable. It represents all of the expenditures made by resident households to meet their daily needs: food, clothing, housing (rents), energy, transport, durable goods (especially cars), health, leisure and various services.

Prim: Morocco is a country with 40% of the active population living from its primary sector, that is the agricultural sector. It has an UAA (Utilized Agriculture Area) estimated at approximately 9,500,000 hectares which represents 95,000 km², the equivalent of 3.11 times the surface area of a country like

Belgium. The main agricultural productions of the country consist of cereals (wheat, barley and corn), sugar beet, sugar cane, citrus fruits (oranges, clementines, etc.), grapes, vegetables, tomatoes, olives, and breeding. Cereal production in particular and general agricultural production remains very dependent on the conditions and climatic hazards encountered by the country.

Sec: The industrial sector (secondary sector) represents nearly 28% of the GDP. Long dominated by the agro-food, textile and leather industries, the industrial sector has diversified rapidly thanks to the growth of the chemicals and para-chemicals, paper and cardboard, automotive equipment and vehicle assembly sectors, business services, IT, electronics and the aviation industry. In general, it is still a sector that is highly dependent on water availability and hydraulic capital.

Ter: The service sector (Tertiary sector) in Morocco is relatively developed. Services are very dynamic thanks to the tourism sector in particular (hotels, tourist services, leisure services, etc.), and to the banking and finance sectors. Today, Casablanca is the largest financial and industrial center in Morocco and the Maghreb. Many multinational companies operating in the Maghreb and West Africa have their headquarters in Casablanca. In 2008, Casablanca became the second financial center on the African continent and represents 48% of investments and 60% of Morocco's GNP.

12-month SPI: The Standardized Precipitation Index (SPI) is the most commonly used indicator worldwide for detecting and characterizing meteorological droughts. The indicator measures precipitation anomalies at a given location, based on a comparison of observed total precipitation amounts for an accumulation period of interest (e.g. 1, 3, 12, 48 months), with the long-term historic rainfall record for that period. The SPI at these timescales reflects long-term precipitation patterns. A 12-month SPI is a comparison of the precipitation for 12 consecutive months with that recorded in the same consecutive months in all previous years of available data. Because these timescales are the cumulative result of shorter periods that may be above or below normal, the longer SPIs tend to gravitate toward zero the less a distinctive wet or dry trend is taking place.

Anomaly	Range of SPI values	Precipitation regime	Color
Positive	2.0 < SPI <= MAX	Extremely wet	Purple
	1.5 < SPI <= 2.0	Very wet	Plum
	1.0 < SPI <= 1.5	Moderately wet	Lilac
None	-1.0 < SPI <= 1.0	Normal precipitation	White
Negative	-1.5 < SPI <= -1.0	Moderately dry	Yellow

	-2.0 < SPI <= -1.5 MIN <= SPI <= -2.0	Very dry Extremely dry	Orange Red

Table 3: SPI interpretation (EDO, 2020)

Temp: This is calculated using the average temperature in degrees Celsius for each region. Similar to the SPI, the data is collected on a daily basis, and then averaged accordingly on an annual basis.

2. Descriptive analysis:

	GDP	FHCE	PRIM	SEC	TER	SPI	TEMP
Mean	77900.53	45248.74	13813.00	27142.02	28337.41	-0.01	22.01
Median	59450.50	39170.00	11450.50	16966.00	14441.50	-0.17	21.64
Maximum	366211.0	163821.0	117294.0	157662.0	181933.0	2.81	29.56
Minimum	5761.000	1219.000	745.0000	584.0000	673.0000	-1.79	17.25
Std. Dev.	77801.57	36605.82	18559.09	34020.55	34738.04	0.87	2.84
Skewness	1.951764	1.104567	4.185722	2.239229	2.464379	0.88	1.08
Kurtosis	6.764663	4.218729	22.46773	7.593573	9.307667	3.38	4.09
Jarque-Bera	161.7563	35.01065	2469.904	226.3662	352.4362	17.99	32.35
Probability	0.000000	0.000000	0.000000	0.000000	0.000000	0.00	0.00
Observations	132	132	132	132	132	132	132

Table 4: Descriptive Statistics of the study variables (author)

The mean and median provide an overall idea about the regions. The relatively low value of the average GDP explains the major differences that exist between those regions, which is a topic that recently caught the attention of many Moroccan economists. The maximum GDP value was registered in the Casablanca region in 2019, while the minimum value is that of the Dakhla region in 2009, which almost tripled its wealth in 2019 with a value of 14802.

The FHCE is the highest in the Casablanca region in 2019, which is to be expected since the region has the highest population density in the country, that is 9.2% of the overall population. Dakhla region has the lowest value of FHCE since it only takes 0.33% of the Moroccan population. More details can be found in the data table appendix that incorporates the demographic factor with per capita variables.

The primary, secondary and tertiary sectors all have maximum values that are registered in the Casablanca region, while the minimum values are registered in the Dakhla region. The standard deviation and mean show a great deal of difference between the regions, which is mainly the cause of the concentration of activities and population in certain areas without others.

The SPI and temperature variables indicate a stable metrological situation in Morocco from 2009 to 2019. The minimum SPI value was registered in Laayoune region in 2018 reflecting a severe drought situation, while the maximum value was that of Rabat in 2009 reflecting an extremely wet situation.

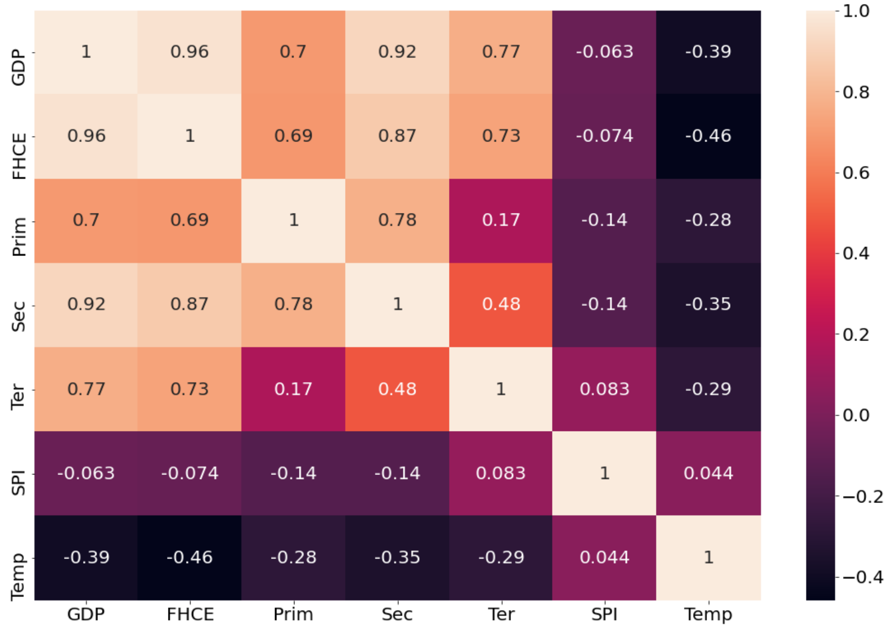

Figure 25: Correlation heatmap of the model's variables (author)

The figure above shows that all of the economic variables are highly correlated which each other, while the metrological variables display poor correlations with each other and with other variants.

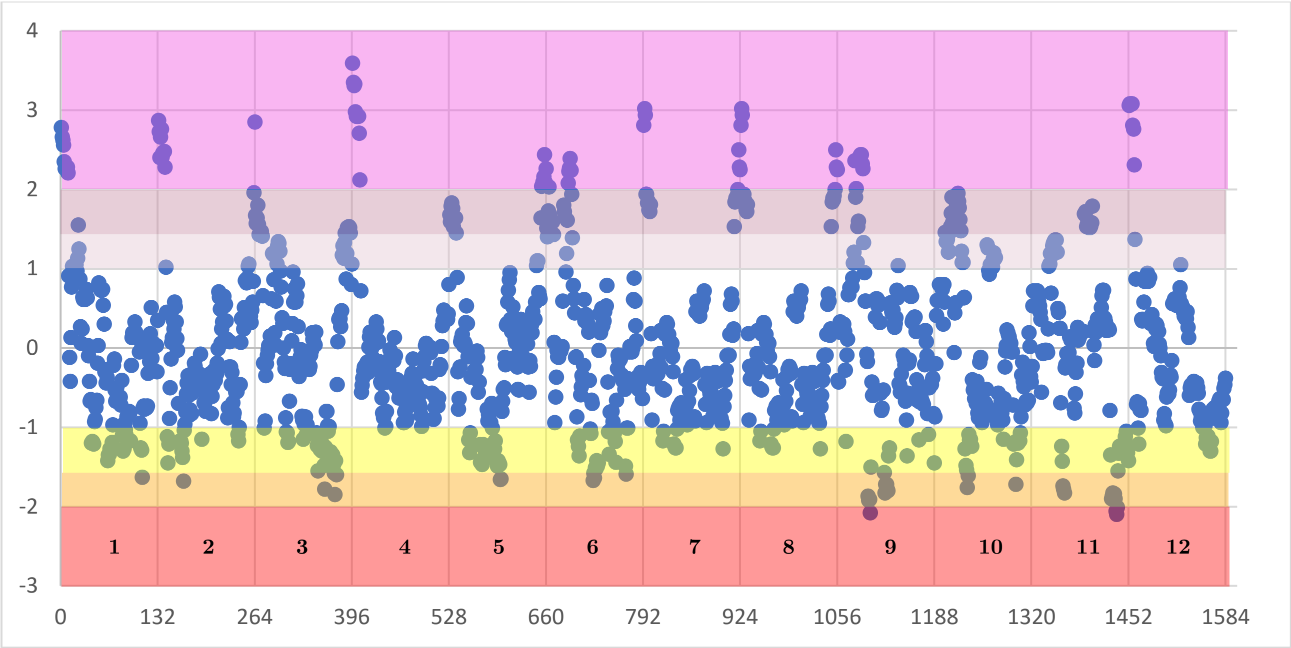

Figure 26: Monthly SPI with range and region (author)

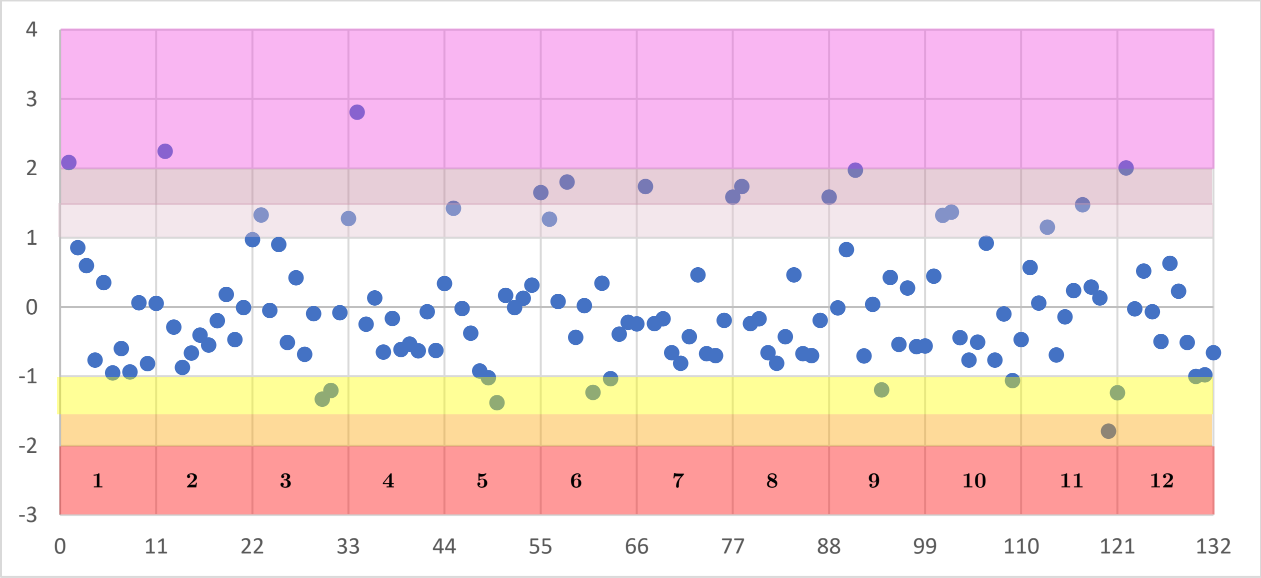

Figure 27: Annual SPI with range and region (author)

The Data in figure 26 was used in the calculation of the annual SPI that will be used in the panel model. As displayed in table 3, the SPI is interpreted using five classes ranging from extremely wet (purple) to extremely dry (red). The scale of the horizontal axis presents all region in 12 months. We can notice that the Moroccan regions have seen many dry months during the study period, but the overall situation seems to be quite normal – considering drought's temporal factor – which is presented in the figure below.

The annual SPI shows that the average situation each year is highly normal. We can also notice that there are almost no consecutive dry years in all of the region. One might wonder why do southern regions such as Laayoune and Dakhla have normal precipitations when they get hardly little or no rainfall at all. This is thanks to the relative nature of the SPI-12 calculation. In other terms, it tries to find the norm for each region and then compute other months based on that norm. In this case, the norm in southern regions is having an average of 1mm of rainfall per year. The year is considered dry when literally no rainfall has been recorded throughout most months.

A detailed python script to calculate the SPI based on daily precipitations is provided in the appendix.

3. Hypothesis testing and multivariate Analysis:

In this order, we will successively perform the Fisher test to validate the fixed effect model, the Breusch - Pagan (LM-test) for the random effect model, used the Hausman test to discriminate between both models and at the end carryout the tests serial autocorrelation, heteroskedasticity, multicollinearity and explain stationarity relevance.

3.1. Fisher test:

We use Fisher's test to discriminate between the fixed-effect model and the non-fixed-effect model. Concretely, we seek to determine whether we are entitled to assume that the theoretical model is perfectly identical for all regions, or on the contrary whether there are specificities relative to each region.

The hypotheses of the test are:

H_0: absence of individual effects

H_1: Presence of fixed effects

F-statistic	2591.948	Prob(F-statistic)	0.000000

The probability of chi2 is less than 10%, thus the null hypothesis cannot be accepted. We can conclude that there is an individual effect in the model.

3.2. Breusch -Pagan test (LM-test):

The Breusch -Pagan test (LM-test) is used to discriminate between the random effect model and the non-random effect model.

The assumptions are:

H_0: absence of random effects

H_1: Presence of random effects

	Value	Prob.
Breusch-Pagan LM Test:	256.3526	0.000000

The p-value is less than 10%; we can conclude that there is a random pattern. The Hausman test will allow us to discriminate between the two validated models.

3.3. Hausman test:

It makes it possible to discriminate between the fixed effect model and the random effect model. It is based on the following assumptions:

H_0: Presence of random effects

H_1: Presence of fixed effects

Test Summary	Chi-Sq. Statistic	Chi-Sq. d.f.	Prob.
Cross-section random	7.363700	6	0.2885

The probability of Hausman's test is higher than 10%, we accept reject H_0. The random effect model is therefore preferable to the fixed effect model. We will therefore use the random effects model.

3.4. Heteroscedasticity test:

Heteroscedasticity qualifies data that does not have a constant variance, i.e., $Var(e) = \alpha$. In fact, heteroskedasticity does not bias the estimation of the coefficients, but the usual inference is no longer valid since the standard deviations found are not the correct ones.

$$H_0:\ \sigma_1^2 = \sigma_2^2 = \cdots = \sigma_N^2$$

$$H_1:\ \sigma_i^2 \neq \sigma_j^2\ \ with\ i \neq j$$

Dependent Variable: RESID^2	
=====================	
F-statistic	0.656929
Prob(F-statistic)	0.684483

The probability of the test is higher than 10%, the null hypothesis is strongly accepted; we are entitled to conclude that there is no heteroscedasticity.

3.5. Serial autocorrelation:

The aim of this test is to check of the error for one time period is correlated with the error for another subsequent time period. We can run a regression with the residuals to check this hypothesis.

$$H_0:\ \rho_1 = \rho_2 = \cdots = \rho_N = 0$$

$$H_1:\ \exists\ \rho_i \neq 0$$

Dependent Variable: RESIDUALS				
==				
RESIDUALS(-1)	0.070155	0.104454	0.671638	0.5035
RESIDUALS(-2)	-0.018891	0.107584	-0.175596	0.8610
RESIDUALS(-3)	-0.091660	0.109737	-0.835270	0.4057

We cannot reject the null hypothesis since all of the coefficients are not significant, thus we can conclude that there is no serial correlation.

3.6. Multicollinearity:

Multicollinearity is when there's correlation between predictors (independent variables) in a model. Its presence can adversely affect the regression results. The Variance Inflation Factor (VIF) estimates how much the variance of a regression coefficient is inflated due to multicollinearity in the model.

Variable	Coefficient Variance	Centered VIF
C	0.086882	NA
LOG(FHCE)	0.000958	3.078422
LOG(PRIM)	0.000205	1.784912
LOG(SEC)	0.000249	3.166896
LOG(TER)	0.000127	2.711726
SPI	3.51E-05	1.158693
TEMP	4.30E-05	1.229174

The centered VIF values are lower than 10, which means that multicollinearity is absent in this model.

3.7. Stationarity test:

In order to carry out a stationarity test in panel data, the number of regions N must be significantly higher than the overall number of years T. In this particular case, we have 11 years from 2009 to 2019 and 12 regions, thus stationarity and cointegration are not necessary. This is because the problem of autocorrelated disturbances is unlikely to be serious to invalidate the results. In addition, the small sample size per region does not require such process, namely since it might lead to multiple integrations.

4. Results and Discussion

Dependent Variable: LOG(GDP)
Method: Panel EGLS (Cross-section random effects)

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	1.707703	0.294758	5.793582	0.0000
LOG(FHCE)	0.142292	0.030953	4.596970	0.0000
LOG(PRIM)	0.211528	0.014305	14.78689	0.0000
LOG(SEC)	0.335243	0.015773	21.25433	0.0000
LOG(TER)	0.260119	0.011251	23.11945	0.0000
SPI	-0.014771	0.005923	-2.493876	0.0139
TEMP	0.001523	0.006557	0.232319	0.8167

R-squared	0.957060	Mean dependent var	2.107452
Adjusted R-squared	0.954999	S.D. dependent var	0.261599
S.E. of regression	0.055494	Sum squared resid	0.384948
F-statistic	464.3427	Durbin-Watson stat	1.290816
Prob(F-statistic)	0.000000		

The random effects panel data model was the best choice of this particular study. We can notice that it's globally significant with an R-squared of 95% and null Fisher probability.

However, both of the metrological variables (SPI and TEMP) are not significant since their probabilities are higher than the tolerated error margin for this study, which is no more than 10%.

Variable	**Expected signs**	**Obtained signs**
LOG(FHCE)	+	+
LOG(PRIM)	+	+
LOG(SEC)	+	+
LOG(TER)	+	+
SPI	+	-
TEMP	-	+

Table 5: Expected vs obtained variable signs (author)

All of the economic variables displayed consistent signs with the theoretical model, however an increase SPI was supposed to lead to an increase in the GDP, since the higher the SPI gets the more wet the time period. The mean temperature seems to be not a good predictor in this model as well.

In other terms, the impacts of green water drought are not clearly visible on the macroeconomic level. This means that Morocco has been making use of its blue water reserves in order to mitigate green drought impacts. The table below presents the water reserve and recharge rate in the Souss-Massa region. Even though the SPI indicated that this region was moderately dry in 2014 (SPI of -1.19), we can observe that the lack of rainfall has been compensated thanks to a very common type of hydraulic capital, that is dams.

Dam	**2015 Reserve (Mm3)**	**2015 Recharge Rate (%)**	**2016 Reserve (Mm3)**	**2016 Recharge Rate (%)**	**Change in Reserve Levels from 2015–2016 (%)**
Idrissi 1er	885.0	78.4%	636.0	56.3%	-28%
Allal Fassi	57.3	89.9%	49.6	77.4%	-13%
El Wahda	2173.3	58.5%	1631.5	44.0%	-25%
El Kansra	195.8	88.7%	101.3	45.9%	-48%
Abdelmoumen	126.4	62.9%	73.1	36.4%	-42%
Aoulouz	88.4	92.2%	53.4	55.8%	-40%
Y.B. Tachfine	262.7	87.0%	164.9	54.6%	-37%
Mohamed V	175.5	75.0%	67.8	28.0%	-61%

Table 6: Water Availability in Souss-Massa Region from Large Dams as of February 2016 (World bank 2020)

Moreover, the Moroccan government has been giving aid and incentives to farmers as far as hydraulic capital is concerned. For example, since the “Green Morocco Plan” in 2008, almost every farmer in the Rabat region is making use of the underground water using drip irrigation (Mohamed El Ansari, 2021).

This leads us to another conclusion, which is that only rainfed crops display signs of water deficiency such as cereals, citrus and olives. The figure below displays the sensitive variations in cereal production from 1970 to 2013. It clearly shows major losses in drought seasons.

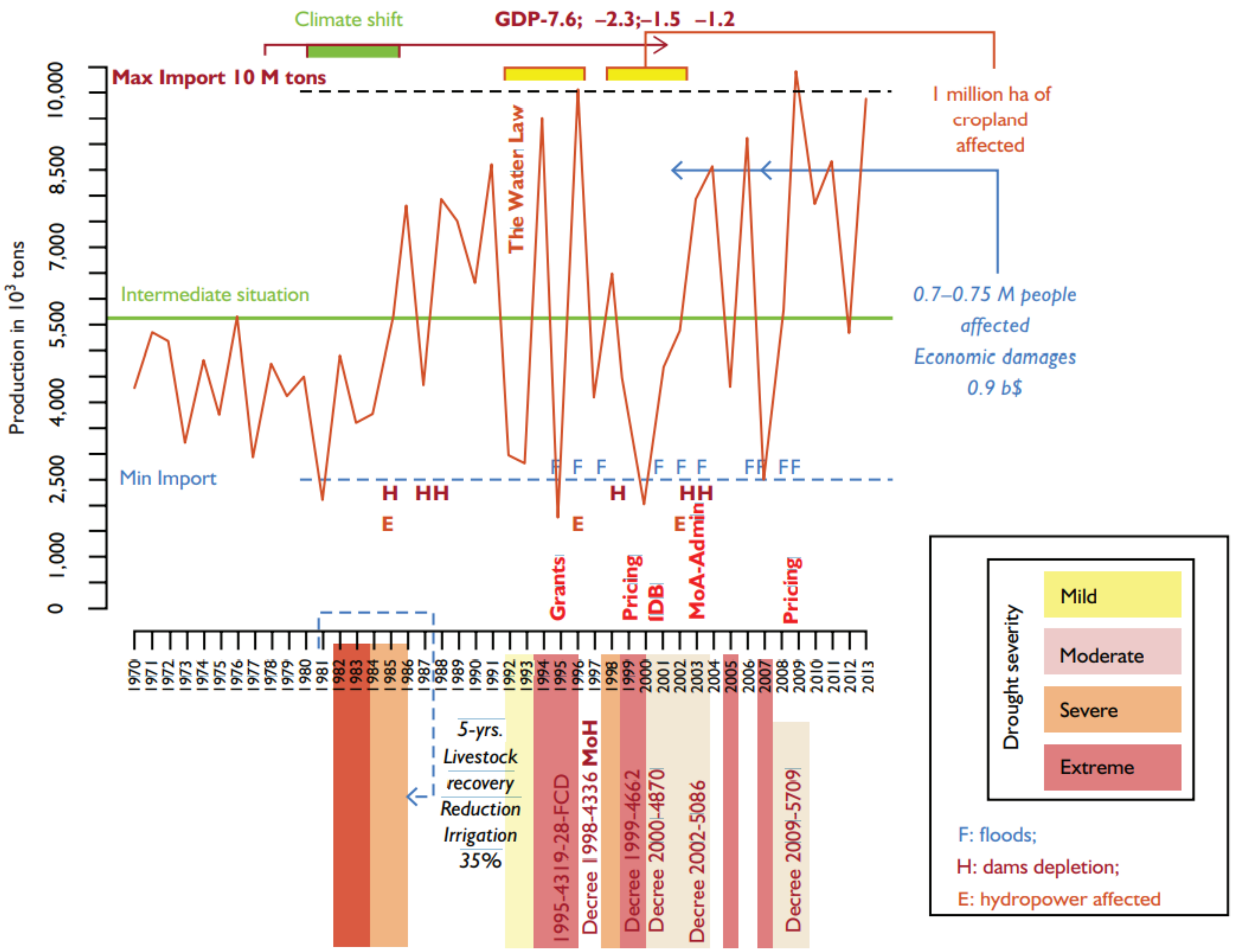

Figure 28: Cereal production in Morocco (World bank 2020)

Chapter conclusion:

We can draw two main conclusions from the analysis concerning drought impact assessment in Morocco.

First, the development of hydraulic capital and the constant increase of supply makes it easier to mitigate drought impacts in Morocco. In other words, an analysis based on precipitations on the macroeconomic level remains quite limited. A more detailed analysis that incorporates lower categorical level variables such as crop production, crop yield, underground water level, number of jobs per activity and so on is necessary and will surely bring more value to the topic.

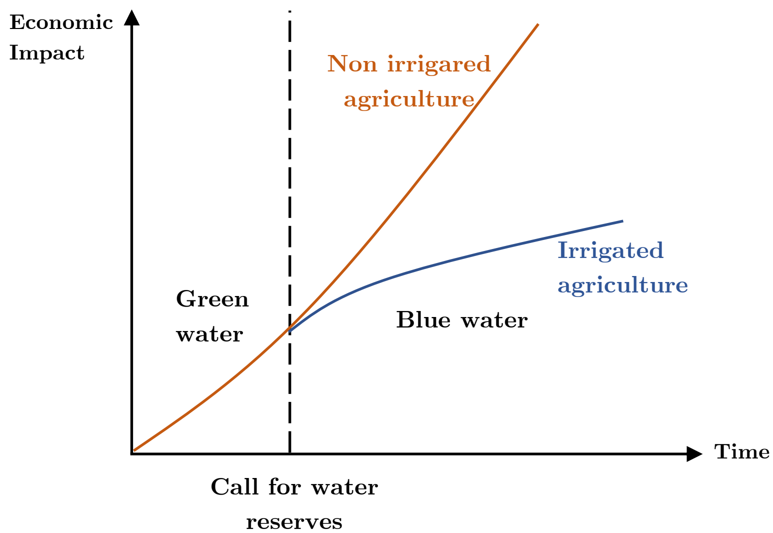

Figure 29: Summary of drought impacts in Morocco (author)

Second, the major impact that drought has inflicted upon the Moroccan territory is the constant use of blue water reserves. This proves to be very dangerous on the long run since water reserves are being consumed rapidly with decreasing recharge levels.

Finally, the Moroccan authorities should invest more in modern hydraulic capital such as recycling facilities in order to keep the consumption of blue water to a minimum over the years.