Forecasting Model of Wheat Yield in Relation to Rainfall Variability in North Africa Countries

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FORECASTING MODEL of WHEAT YIELD IN RELATION TO RAINFALL VARIABILITY IN NORTH AFRICA COUNTRIES

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SUUMARY

This study investigated the effect of rainfall variations on wheat yield in Morocco, was a case study of North African countries because it cultivates the largest arable and rainfed acreage in North Africa. The data covered the period 2004–2015 from 12 stations for weather forecasting. The estimated coefficient of variation of wheat yield ranged between 79.5% and 38.0%, as it increased in poor-rain years and in the regions of annual rainfall less than 350 mm. the high correlation between the number of rainy days and the annual rainfall in mm, implied to introduce only the later as an explanatory variable in the forecasting model of wheat grain yield. The double-log form was the best fitted model for such model. The wheat yield showed higher significant response to spring months rain fall changes than the annual rainfall. The double-log form of the monthly rainfall model to forecast wheat yield. The estimated elasticity coefficient showed that a 10% increase in March, April and May rainfall would result in 5.9%, -0.1% and 0.2% change in wheat yield, respectively. The estimated response of wheat farm price to grain yield showed that a 10% increase in wheat yield would decrease the farm gate price by 4.1% implying that It is a supply-oriented market. Recommended Policies include generating a national buffer stock and a regional strategic stock of wheat to compensate the negative impacts of rainfall fluctuation and drought years, based upon an integrated program among North African countries. To provide a supplementary water source to secure sufficient water for irrigation. The areas less than 300mm rainfall should be allocated for livestock feeds with economical range management.

INTRODUCTION

CLIMATE CHANGES: CONCEPTS AND IMPACTS

Climate changes include, either the changes in the seasonal and/or annual temperature, regional rainfall rates, drier conditions risk, and increasing emission of the atmospheric greenhouse gas concentrations

Any change in climate is affecting seriously the natural environment and the human activities, including agriculture and alter the global energy budget. Abundant scientific literatures indicated a consensus understanding of such issues **(Anwar, et al, 2015), (Sudmeyer, et al, 2016)**. Accordingly, it is prudent to contemplate and plan for recognition of the global ambitions to limit the climate changes negative externalities on food sector production performances **(Qureshi, et al, 2013)**.

Climate changes impacts include economic pressures and opportunities related to increasing human populations and changing human dietary preferences, increased input costs and energy prices, competing land-use pressures and economic policy-related pressures. The impacts of climate change on agricultural productivity will vary regionally and by enterprise, with some regions and enterprises benefiting and some not. Changing rainfall, temperature, carbon dioxide (CO2) and other climatic variables will affect average crop and pasture productivity, quality and nutrient cycling, pest and disease activity, livestock production and reproductive rates. Whereas increased CO2 concentrations will improve the efficiency of plant use of water, increased temperature could be beneficial or harmful depending on season and location **(Barros, et al., 2014)**

RAINFED AGRICULTURE IS GLOBALLY THE DOMINANT SYSTEM

The world's land and water resources are finite and under pressure from a growing population. Global figures about the shares of land and water used by agriculture, versus non-agricultural sectors show major regional variations and a series of locally important imbalances of demand and supply. The growing recognition of the need to meet environmental requirements has generated further intensifies competition, **(Moeller, 2009), (Oliver, 2010)**

Rainfed agriculture is the predominant agricultural production system worldwide. Of the current 1600 Million ha world cultivated area, about 80 percent are rainfed. Rainfed agriculture produces about 60 percent of global crop output in a wide variety of production systems. The most productive systems are concentrated in temperate zones of Europe, followed by Northern America, and rainfed systems in the subtropics and humid tropics. Rainfed cropping in highland areas and the dry tropics tends to be relatively low yielding and is often associated with subsistence farming systems. Evidence from farms worldwide shows that less than 30 percent of rainfall is used by plants in the process of biomass production. The rest evaporates into the atmosphere, percolates to groundwater or contributes to river runoff, **(Abrahams, et. al.,2012)**.

The extent of rainfed area has not grown in recent years, due to the replacement of some land too degraded for further cropping by lands newly converted from forests and grasslands to arable farming. This process of land degradation and abandonment, and the development of new lands in replacement, is particularly characteristic of low-input, low-management farming systems, or cultivation on steep slopes. However, data on these farming systems are sparse, because some of these lands may not be permanently degraded but may be brought back into cultivation after long fallow. Therefore, it was difficult to estimate the areas involved, **(Ali, et. al., 2012)**.

WATER CONSTRAINT ALLOWS GROWTH IN YIELD RATHER THAN IN LAND

In many of the low rainfall regions of the Middle East, Northern Africa and Central Asia, most of the exploitable water is already withdrawn, with 80–90 percent of that going to agriculture, and thus rivers and aquifers are depleted beyond sustainable levels, Over the last 50 years, the rate of increase in production for globally important crop groups has exceeded the rate of increase of the extent of arable land and permanent crops. Based on total harvested area, cereals are by far the most important crop group and have registered relatively large average increases in yields. More than two-thirds of the increase in production has come from yield increases, especially under irrigated conditions. 77 percent of production increases in developing countries came from 'intensification' arising from increases in both yield and cropping intensities. **(Bennett, 2003)**

In sub-Saharan Africa, yields have changed little since the 1960s. Rainfed maize yields, for example, have remained constant at around 1ton/ha. In Latin America and the Caribbean, by contrast, yields for rainfed maize tripled over the same period, from little more than 1ton/ha to over 3ton/ha. Average wheat yields across Europe more than doubled (2ton/ha to over 5ton/ha). FAO has calculated a 'yield gap' by comparing current productivity with what is potentially achievable assuming that inputs and management are optimized in relation to local soil and water conditions, (**Molden, 2007**).

RAINFED AGRICULTURE SYSTEM IS A RISK AVERSION MODEL

As practiced in highland areas and in the dry and humid tropics, it is the system in which poorer smallholder farmers predominate and where the risks of resource degradation are highest (**Arnell, 2004**). Soil nutrient availability in many rainfed lands tends to be low, and sloping terrain and patterns of rainfall and runoff contribute to soil erosion. High temperatures and low and erratic precipitation often make soil moisture availability inadequate. Even though, techniques to improve water availability, such as water harvesting, are expensive, **(Baek, et al., 2013)**. Higher levels of input and management can increase productivity, but many farmers cannot afford the costs or risks, **(French, 1984)**. As rainfall decreases, a reduction in plant growth and a decline in soil organic carbon would be expected All these factors affecting land fertility and water availability for rainfed agriculture, as practiced by the poor farmers, contribute to their vulnerability of livelihood and to their food insecurity. It is likely that the inter-annual variability of rainfall will increase across most of the rainfed regions, **(Feng, et al., 2013)**.

Declining rainfall is likely to be the dominant factor behind the predominately negative influence on the profitability and financial risk associated with farming enterprises, particularly at the marginal rainfed regions of currently suitable climatic zones **(Potgieter, 2013)**. Thereof, Improvements of the agronomic technology, and Geno-type have effectively increased the rainfall water use efficiency of essential food crops at a rate greater than rainfall decline. Projections of how climate change will affect future crop and pasture yields are constrained by the limitations of climate and crop models. Specifically, most crop models do not capture technology improvements, extreme weather events, and changes in pest and disease activity. However, some broad projections can still be made about the effects of climate change on agriculture, **(Abrahams, 2012)**.

In general, the impact of rainfall pattern on natural resource condition is poorly understood. However, it is possible to identify some broad risks and trends. Declining rainfall will have a profound effect on surface water and groundwater supplies. If rainfall declines by 14%, it has been projected that streamflow will decline by 42% and groundwater recharge will decline by 53%. Declining rainfall associated with increased drought and increased rainfall intensity increase the risks of wind and water erosion, particularly, if drier and more variable conditions caused a reduction in plant cover, **(Asseng, et al., 2013)**. On other hand, depending on temperature and soil conditions, rainfed cropping of some kind is possible where annual rainfall exceeds 300 mm. The distribution of rainfall during the growing season is also a key factor: ample annual averages may conceal poor spacing in relation to the growing season and, combined with uncertainties such as rainfall variability between years. This increases risks and reduces the chances of rainfed agriculture being highly productive, **(Sadras el al, 2005).**

Essential food crops yield and particularly grains will be most affected by changes in rainfall, and particularly the timing of rainfall, despite that increased CO2 improving plant efficiency in water use. Consequently, yields are likely to decline in the drier areas and remain largely unchanged or increase in wetter areas. The plant available water capacity of the soil will become increasingly important to growth, so yield declines are likely to be greater on clay soils compared to sands areas.

Higher temperatures, and to a lesser extent declining rainfall, will hasten development times and reduce the flowering and grain-filling periods, **(Asseng & Pannell, 2013)**. The risks associated with climate variability will increase most in drier, marginal areas (less than 300mm/inch rainfall). Forage production may be reduced by up to 10-20% over the agricultural areas and rangelands. Therefore, there is a need to retain minimum pasture cover to prevent soil erosion, rainfall decline and increased inter-annual variability in pasture production. However, increased CO2 concentrations could reduce pasture digestibility and protein content and if forages with heat-tolerant (tropical plant species) become more dominant, which is likely to place severe stress on rangeland ecosystems and grazing enterprises, **(Schillinger, et al, 2012)**.

Evaluation of the effects of rainfall and temperature on wheat yield in Iran, as the most important crop, showed that wheat yield depended on maximum rather than minimum temperature, furthermore, grain yield was positively correlated with the average annual rainfall. The effect of rainfall and temperature on yield varied considerably between years, **(Dehgahi, et al, 2014)**

. THE STUDY PROBLEM AND OBJECTIVE

The West Asia-North Africa (WANA) region, with a Mediterranean-type climate, has an increasing deficit in cereal production, especially bread wheat. Rainfed cropping coincides with the relatively cool, rainy winter season, usually from October to May. Cereal yields are low and variable in response to inadequate and erratic seasonal rainfall and associated management factors, such as lack of soil nitrogen content and late sowing, **(Oweis, et al., 1997)**.

Therefore, this study was conducted to specify and identify the effect of weather conditions in terms of rainfall variations on wheat yield in North Africa Countries. The estimated forecasting model and other statistical analysis were applied for Morocco as a case study of the North Africa region. The study provides evidences that Morocco is a representative case study of the concerned region.

MOROCCO IS A CASE STUDY OF NORTH AFRICAN COUNTRIES

The North African countries (NACs) are also identified as "South Mediterranean Countries". (SMCs). **(Table 1)** shows that the total agricultural area of NACs was about 29 million hectares in 2016. While the rainfed acreage reached about 64% of the total agricultural land, the fully irrigated acreage was less than 26% and the fallow area occupied the rest, i.e. around 10%. The total water withdrawal of the north Africa region is about 94 km^3/year. While most of this water, i.e. 85% is utilized for irrigation of agricultural sector, about 9% is allocated for municipal and only 6% for industrial sector. Ad most 1% of the total water withdrawal is internal renewable water, while the rest is freshwater, as calculated and compiled from **(FAO, 2017b)**.

Comparison of the land use pattern on country-wise base, provides evidences that Morocco is a very representative case study of the NACs, which fits the objective of the current study, i.e. estimating the yield-rainfall response model. Morocco share in the total agricultural area reached about 33% in the year 2016 and its share in total rained acreage amounted to more than 44%. Even though, Algeria holds about 29% of the total agricultural area of NACs, 37% of Algerian agricultural acreage are left fallow as shown in **(Table 1)**. Thereof, the share of the cultivated rainfed area in Algeria out of the total NACs was less than 22%, i.e., one-half of Morocco share. Whereas, Egypt shares by more than 50% of fully irrigated agricultural land of NACs, its share in rainfed acreage almost nil. Accordingly, Egypt was excluded from the study. By excluding Egypt with its completely irrigated agricultural system, Morocco produces more than two-thirds of NACs' wheat production, **(Table 2)**. However, the domestic production covered only 48% of the Moroccan wheat's consumption in 2016. Thereof, proper management of the risky rainfed model of wheat production in Morocco is a necessary condition via stable higher yield growth.

DATA BASE

The data were collected for the period 2004–2015 from 12 Meteorological stations of Moracin ministry of agriculture for weather forecasting. Such data included the annual and monthly rainfall in mm per inch and the number of rainy days. The monthly precipitation was for the spring months (Spring-May) as in Morocco wheat season is a spring season. The annual wheat-grains yield in ton per hectare was collected from "Agricultural Statistics Book" issued by the Arab Organization for Agricultural Development **(AOAD)** of the Arab League located in Khartoum, Sudan, using several years issues. The data of the farm gate price of wheat-grain in US$ were collected from the Food and Agricultural Organization **(FAO, 2017a)** of the United Nations, using its Internet Site (http://www.fao.org/faostat/en/#data).

ANALYTICAL PROCEDURE

The study tried to achieve its objective through three quantitative approaches, using the collected data. The first approach was to estimate two indicators of variability in both the wheat yield in ton per hectare and the annual rainfall as mm/inch. These indicators are the standard error of the average (SE) and the coefficient of variation (CV).

The second quantitative analytical approach was to estimate the best fitted mathematical form of the forecasting model that explains the variation in wheat grain yield due to the variation in rainfall, either among years or within the years. The specification of the mathematical form for the forecasting model of wheat yield in relation to rainfall variability was identified, considering available literatures, **(Waugh, 1929)**, **(Asseng, et al, 2012)**, The earlier study of **Misner, (1928)** had proved a curvilinear (quadratic) relationship between corn yield and rainfall for nine weather stations scattered through the Corn Belt in U.S.A. **Sanderson (1954)**, had conducted `extensive research on the effect of rainfall on grains yield, using data of many different regions and countries. He emphasized that the independent variables that should be detected and retained as explanatory variables are only those, out of the many, which showed the highest correlation with the dependent variable (grain yield). In most cases annual rainfall rate showed the highest correlation with grain yield. **Ezekiel & Fox, (1959)** discussed, thoroughly, the considerations that should exist with estimating the response of grain yield to applied irrigation water. These considerations would lead to a curve with the following characteristics: (1) It should rise steeply at low rainfall rate, and then less and less sharply, until a maximum yield is reached, (2) it might show a decline after the single maximum yield is reached, either gradual or sharp, and (3) It would have only the single point of maximum yield.

Several elaborated investigations, experimental and statistical, have shown that the effect of rainfall on the yield of the field crops vary at different times of the season, and especially at certain critical times along the growing period of the crops. **Misner, (1928)** studied wheat yields at Rothamatead (U.S.A.). He pointed out that it really made little difference to the growth of a crop whether a given rain occurred on April 30, or May 1. The resulting smooth curve showed that the maximum effect of rainfall on yield was in autumn and in spring. With rainfall distribution as the only weather variables considered, he showed correlations ranged from 0.32 to 0.63. He represented the rainfall by the average of rainfall during June, July, and August per year scattered though the Corn Belt in Mid-West of USA. **Waugh, et. el. (1929)**, confirmed the use of monthly rainfall as an independent variable in their works on potato-yield problem.

Three forms of the concerned model were fitted for selection the linear, the curve-linear (quadratic) and the double logarithmic form. The selection depended upon three criteria, **(Ezekiel and Fox 1959)**. First the logic of the response function, the statistical significance of the estimated response and the significance and magnitude of the estimated coefficient of determination (R^2).

The third quantitative analytical approach was to estimate the best fitted mathematical form of the farm gate price response in US$ to the fluctuations in wheat yield in ton per hectare. The availability of data from The FAOSTAT site of FAO allowed to expand the time series data to include the period (1991-2016). Only two forms were estimated for such relationship. These are the linear and curve-linear (Quadratic) forms. The double log form was not tested as logically such relationship would not be of a type of change that fits the double log function characteristics.

RESULTS and DISCUSSION

DISPERSION IN RAINFALL AND WHEAT YIELD

Within the period (2004 -2015), Estimated average annual wheat-grain yield per hectare (ha) in Morocco over 15 years was about 1206 Kg with a standard error (SE ± 64.37) Kg/ha. The average annual rainfall for Morocco, over 15 years, was about 505 mm/inch with (SE ± 115 mm/inch). The average annual number of rainy days was about 87 days with (SE ± 7.7 days). However, the variability in the rate of rainfall was much higher than the number of rainy days. The coefficient of variation (C.V.) was 37.3% and 0.17%, respectively.

Whereas, the variability in wheat-grain yield was high in very poor rainfall rate regions (less than 300mm/inch. It reached 79.5%. with an annual wheat grain yield of 453kg/ha in less poor regions (300-350 mm/inch) was relatively less, i.e. amounted to 50% With an annual wheat grain yield of 905kg/ha, in regions of higher rainfall rate (>350mm) such variability diminished to a minimum. (38. 0%) with a high average wheat-grain yield of 2466 kg/ha.

ESTIMATED FORECASTING WHEAT YIELD MODEL WITH ANNUAL RAINFALL

The study estimated four forms of the concerned model to identify the best fitted one. The first estimated forecasting model for wheat yield as a function of the annual rainfall in Morocco was linear **(Table 2)**, Two variables were introduced as explanatory variables. The annual rainfall rate (mm/inch) and the number of rainy days per year, **(Equation 1 in Table 2)**. However, testing the hypothesis that the regression coefficients of the population equal zero at Probability 0.05 showed that both explanatory variables, are not statistically different from zero. This result was due to the high correlation between the number of rainy days and the annual rainfall. The estimated correlation coefficient reached 0.7, while, the estimated correlation coefficient between the annual wheat-grain yield and the two explanatory variables was 0.565 with the precipitation and was 0.328 with the number of rainy days. The estimated coefficient of determination (R^2) of this form was about 0.346.

Thereof, the study estimated an alternative model with only the annual rain fall rate, as it showed higher correlation with the grain yield than the number of rainy days, **(Equation 2 in Table 2)**. The estimated response coefficient showed that an increase in the annual rainfall rate by 100mm added about 50.4kg wheat grain/ha, which was highly significant at a probability level less than 5%.

Where the literature cited that the quadratic form would fit for such relationship, **(Ezekiel and Fox, 1959)** and **(Sanderson. 1954)**, the study made a third trail with a quadratic form. **(Equation 3 in Table 2)**. This estimated quadratic form showed a positive regression coefficient with the first order explanatory variable, but it showed a negative regression coefficient with the second order explanatory variable, i.e. indicating a dimensioning return of grain yield with annual rainfall with a maximum point of yield. However, only the first order term had a highly statistical significant response estimate. The estimated regression coefficient of the squared term of the explanatory variable was not significant. It seems that the results cited by **Ezekiel and Fox, (1959)** was under controlled water supply, or at least in regions with higher and less fluctuated average rainfall rate.

The best fitted form for the response of annual rainfall among the estimated four was the double-log model as the estimated coefficient of determination was $R^2 = 0.47$. The reviewed literature from USA, Italy and Australia on the same subject confirmed such nonlinear relation between wheat yield and annual rainfall, **(Schillinger, et al., 2012)**. The estimated response parameter represents the estimated elasticity ($\acute{\varepsilon}$) was derived from **(Equations 5-8)**. It showed that 10% increase in annual rainfall adds about 4.9% to wheat yield per hectare.

$$y = ax^b \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (5)$$

$$\acute{\varepsilon} = \frac{\partial y}{\partial x} = bax^{b-1} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (6)$$

$$\acute{\varepsilon} = \frac{\delta y}{\delta x} = bax^{b/ax^b} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (7)$$

$$\acute{\varepsilon} = b\left(\frac{y}{y}\right) = b \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (8)$$

FORECASTED WHEAT YIELD MODEL WITH MONTHLY PRECIPITATION

The Average monthly rain precipitation for the study period (2004 -2015), was 40.78 mm, while the March precipitation was 59.7mm, April Precipitation was 44.6mm and May precipitation was 25.4mm. Therefore, March, April and May precipitation represented 146%, 109% and 62% of the monthly average per year.

The estimated wheat yield showed more effective significant response to monthly rain fall changes than the annual precipitation, as indicated by the magnitude of estimated R^2 as shown in **(Table 3)**. The Correlation coefficients between grain yield and monthly rainfall were high during spring season, i.e. 0.853 for March 0.547 for April and 0.682 for May. As the estimated forecasting model of wheat yield with annual rain fall showed that the best fitted monthly rainfall model was the double-log form, the study estimated a double log model to simulate the monthly precipitation-yield response forecasting model.

The March's rain precipitation showed a positive and significant effect on wheat yield, **(Equation 9 in Table 3)**. The estimated response parameter showed that 10% increase in March's rain precipitation increased the wheat-grain yield by 4.5%. The goodness of fit of the nonlinear form of the estimated function was proved via the magnitude of the coefficient of determination. The estimate R^2 showed that more than 70% of the variation in wheat yield would be explained by the change in the March's rain precipitation.

The rain precipitation in April as a second variable was introduced into the model **(Equation 10 in Table 3)**. April rain precipitation showed insignificant negative response elasticity with respect to wheat-grain yield. However, still March's precipitation still having a positive effect on the wheat-grain yield. The estimated response coefficient (elasticity) was 0.46, i.e. 10% increase in March's precipitation would lead to 4.6% increase in wheat-grain yield. The estimated value of the coefficient of determination has not almost changed due to insignificant response of April precipitation.

(Equation 11 in Table 3) showed the estimated power function after adding May precipitation, i.e. the three spring season months that supply spring wheat in Morocco. It showed that whereas, March's rain was the critical month for wheat yield with elasticity coefficient amounted to 0.587, May rainfall showed an elasticity of 0.023 which affected positively and significantly the wheat yield changes. However, April precipitation showed a negative insignificant elasticity coefficient of about -0.011. Therefrom, 10% change in rain precipitation in March, and May would result in 5.9%, and 0.2% increase in wheat yield, respectively, while April precipitation has no significant effect. The estimated coefficient of determination showed that the variation in rainfall of March and May, rather than April, would explain 97% of the variation in the wheat yield of rainfed regions in Morocco.

ESTIMATED RESPONSE OF WHEAT FARM PRICE TO GRAIN YIELD

The estimated annual average farm gate price per ton of wheat over the period (1991-2016) was 309.2$/ton (SE ±11.91$/ton). The minimum price was 238.4$/ton and the maximum price was 469.4$/ton and C.V. was 19.7%. Over the same period the annual average wheat yield/ha was 1.41ton (SE± o.11ton/ha). The minimum yield was 0.476ton/ha and the maximum yield was 2.47ton/ha and C.V. was 40.4%. Such estimates showed that the variation in grain yield was much higher than the variation in the farm gate price. **(Fig. 1)**, presents the index of both concerned variables. While the price index showed a sort of cyclical change the wheat yield fluctuated almost annually. The cyclical change pattern in farm gate price supposed to reflect the economic cycles and policies pattern, while the wheat yield reflected the climatic change, particularly, rainfall variation.

(Table 4), presents the estimated response of wheat farm price to variation in wheat-grain yield. Three forms of such relation were estimated. The linear, the quadratic and the power forms. While the estimated parameters of the quadratic form **(Equation 12)** were not significant, the linear **(Equation 11)** and power **(Equation 13)** forms were significant at a probability level less than 5%. Both the linear and the power forms showed a negative relation between the variation in farm gate price and wheat yield. The estimated elasticity of change in farm price of wheat as a relative response to the variation in wheat-grain yield was derived from the linear relation using **(Equation 14)**, which showed that 10% increase in wheat yield would decrease the farm gate price by 4.1%. However, from **(Equation 13),** the estimated regression coefficient represented directly the elasticity coefficient **(Equation 8)**, i.e. 10% increase in wheat yield would decrease the farm gate price by 4.6%.

$$\frac{\partial \rho}{\partial G} = \beta \frac{avr(G)}{avr(P)} \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots (14)$$

As the rainfed area is almost constant in North Africa countries, then the change in the wheat yield per unit of crop area would represent the probable change in the wheat supply. Therefore, the pattern of the higher the wheat-yield the lower would be the farm gate price, provided evidence that the domestic wheat market in Morocco and consequently, the North Africa countries, simulated a supply-oriented market. Accordingly, the probable changes in market price of wheat was oriented by the supply (production of wheat) rather than the demand. Such conclusion to reasonable extend is applicable to the other grains production in North Africa countries.

Unless the concerned administrative and research institutions in North African midetrenean countries gave much attentions and serious efforts to reduce rapidly and actively the vulnerability of the agricultural sector to climate change to increase the sector's adaptive capacity, particularly grain crops the major supply of the demand for food and feeds, the food security would have faced serious negative impacts. Therefore, a set of policies and governmental programs are required to minimize the negative impacts of such risk production model. The following section was allocated for presenting the framework of this package of policies and programs

RECOMMENDATIONS

. Establishment of a Climate Change Response Strategy

A Climate change response strategy should be established to provide strategic direction for climate change activities and to identify and prioritize actions to achieve over the following two decades. Such strategy requires a considerable advance in the scientific understanding of climate change. The proposed program requires the latest scientific information relating to climate change and agriculture in these countries,

The global climate models have a relatively coarse resolution, so they do not account very well for regional variability such as that induced by landforms or distance from the ocean, **(Bennett, (2013).** Therefore, a specific climate projection model is required for NACs as broad pointer for what may happen, providing loose bounds in which to plan for future climate change. For example, field crops, particularly, cereals should be cultivated in regions of an average annual rain fall above 300 mm. The arable areas of less than 300mm rainfall per year should be allocated for livestock under a rational economical rangeland management program. Water points for livestock drinking should be secured. Food grain demand and output of livestock enterprises in such areas showed secured via establishment of an efficient marketing system. **(Soliman I., 1984), (Browne, et. al., 2013)**. A country buffer stock of wheat is required for buffering the impacts of probable poor rainfall seasons and/or drought years supply. It is preferable to be a regional integrated program stock for NACs; such stock would compensate the negative impacts of the probable poor rainfall seasons.

Adaptation of A Farming Practice program with Agricultural Production Under Risk

Under the circumstances of rainfed crop the yields are low in such zones because precipitation is limited and highly variable. Thereof, the producers would suffer from income foregone due to loss in inputs expenses applied per hectare, with almost zero or very little wheat yield. Such losses imply drainage of hard currency due to expansion in wheat imports. Farmers respond to this situation by adoption of alternative approaches that convey a reduction in their unit costs of production to offset the continuous decline in commodity prices. **Oweis, (1997)** provided evidences that with appropriate management, inputs, and varieties, wheat output could be substantially and consistently increased in the semiarid Mediterranean zone. As the yields of rainfed wheat varied with seasonal rainfall and its distribution

One of recommended alternative is a growing interest in adopting reduced tillage systems for seedbed preparation, and a trend to enlarge enterprises by acquiring more arable land either as ownership or tenancy, **(VSánchez-Girón a, 2004)**. A study in Spain measured the economic feasibility of chisel ploughing (CP) and no-tillage (NT) systems compared to moldboard ploughing

(MP) for rainfed winter wheat and forage legume or pea production on different farm sizes ranging from 100 to 1600 ha. On average fuel consumption was 39% and 62% lower in NP than in CP and in MP, respectively. Total variable unitary costs were 1.7% and 5.6% lower in NT than in CP and MP, respectively. The cost of herbicides in NT per ha/year was higher than in MP and CP. However, average unitary gross margins were 11.9% and 10.8% higher in NT than in MP and CP, respectively. MP exhibited the poorest economic results in all farm sizes, while CP performance would improve the gross margin in farm sizes with 200 ha. NT was clearly the most profitable system on farms with 400 ha or more. The 400ha farm enterprise was observed to mark the breakeven point between the two reduced tillage systems, since up to that size CP was found to provide a better economic performance than NT, **(Sánchez-Girón, 2007)**

In addition, attainable water-use efficiency relates attainable yield, i.e. the best yield achieved through skillful use of available technology, and seasonal evapotranspiration in each area. Consequently, where water is limited, small amounts of supplemental irrigation water can make up for the deficits in seasonal rain and potentially produce satisfactory yields. The simulation analysis conducted by **Heng, et al., (2006)** highlighted that 40 mm of Supplement irrigation at sowing significantly improved average grain yields because of enabling early crop establishment. An addition of only limited irrigation (1/3 full irrigation) significantly increased yields, but near maximum yields were obtained by 2/3 of full irrigation, particularly during the growing season., **Kierkegaard, et al., (2010)**, provided via field experiments evidences on increasing productivity of field crops by matching farming system management and genotype in water-limited environments.

While the effect of N fertilizer was minimal or detrimental in dry years, it improved grain yields in wet years, when crops were sown early combined with pre-sown stored plant available water in the soil. There is little difference between grain yields when current practice of about 300 plants/m^2 was compared with a density of 150 plants/m^2. This implies that there is scope for reducing current planting density to save seeds without reducing yields, **(Heng, et al., 2006)**

Table 1 Agricultural Land Use in North African Countries

Country	Agricultural Land		Rain Fed Area		Temporary Fallow		Fully Irrigated Area	
	(000) ha	%	(000) ha	%	(000) ha	%	(000) ha	%
Morocco	9592	32.9%	8,062	43.3%	0	0.0%	1,530	20.5%
Algeria	8462	29.0%	4,048	21.8%	3094	100.0%	1,320	17.7%
Tunisia	5232	17.9%	4,756	25.6%	0	0.0%	476	6.4%
Libya	2050	7.0%	1,650	8.9%	0	0.0%	400	5.4%
Egypt	3820	13.1%	94	0.5%	0	0.0%	3,726	50.0%
Total	29156	100.0%	18,610	100.0%	3094	100.0%	7452	100.0%

Source: Compiled and Calculated from: FAO (2017a) "www.fao.org/faostat"

Table 2. Wheat production and Self-Sufficiency in North African Countries of Rainfed Agriculture Pattern

Country	% of Wheat Production in Grain Crops Production	Production (000) Ton	%	Consumption (000) Ton	Self-Sufficiency Ratio (%)
Morocco	68%	8,065	68%	16,912	48%
Algeria	22%	2,657	22%	11,158	24%
Tunisia	8%	912	8%	2891.41	32%
Libya	2%	200	2%	1353.64	15%
Total	68%	11,834	100%	32,315	37%

Source: Compiled and Calculated from: FAO (2018) "www.fao.org/faostat"

Table 2. Estimated Wheat Grain Yield Response to Annual Rainfall Variation

Equation no.	Estimated Model	R^2
1	$\hat{G}_t = 7.408 + 0.4069F_t + 1.35.37D_t$ (0.3205) (3.7206)	0.3455
2	$\hat{G}_t = 7.9635 + 0.4669F_t$ (0.1817)	0.3420
3	$\hat{G}_t = 3.4182 + 2.3815F_t - 0.0017F^2_t$ (6.715) (0. 70)	0.2732
4	$\hat{G}_t = 0.4620\, F_t^{0.4929}$ (0.2014)	0.4702

Source: Compiled and Calculated from:

The Rainfall crop data source were from: Ministry of Agriculture of Morocco Meteorological Stations' Data over the period (2000-2016),

The Wheat grain yield/ha data source was from AOAD (2018) www.aoad.org/agstat

Where:

D_t = Number of rainy days in the year t.

F_t= denotes the average of annual rainfall in the year t

G_t=denotes the estimated yield in tons of annual wheat grains yield per hectare in year t.

Values between parentheses under the estimated parameters designates the corresponding estimated standard error.

R^2= the determination coefficient.

Table 3. Estimated Wheat Grain Yield Response to Monthly Rainfall Variation

Eq. no.	Estimated model	R^2
9	$\hat{G}_t=1.4481\ M_3^{0.4537*}$ (0.0566)	0.7063
10	$\hat{G}_t=1.4389\ M_3^{0.4572}\ M_4^{-0.0022}$ (0.2259) (0.1519)	0.7050
11	$\hat{G}_t=o.7561 M_3^{0.5868}\ M_4^{-0.0011} M_5^{0.2350}$ (0.0108) (0.0010) (0.0005)	0.9778

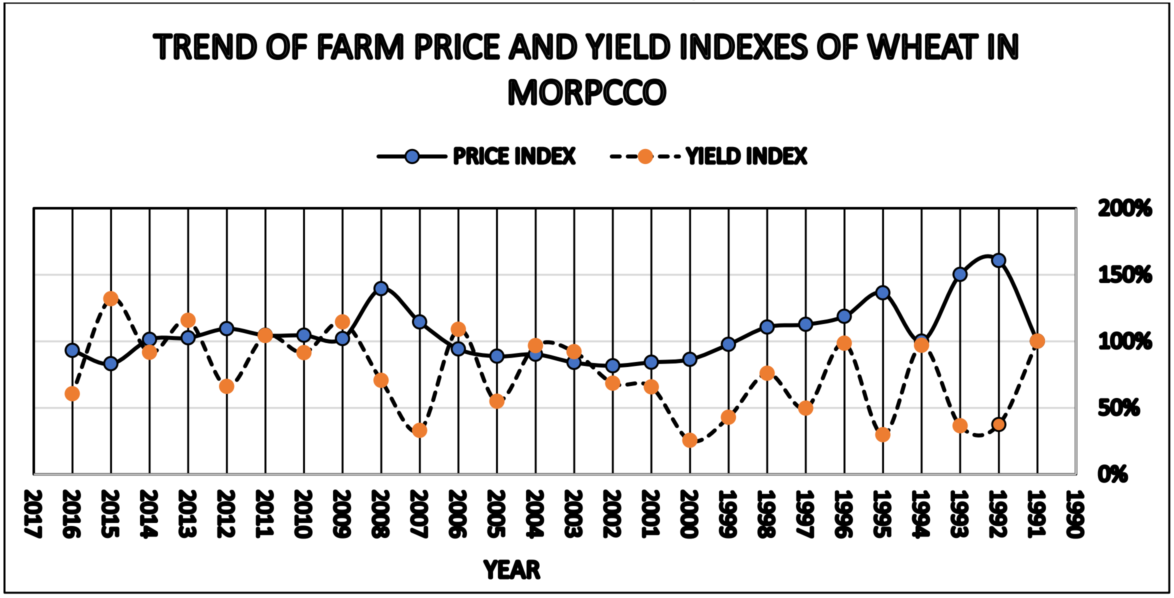
Source: Compiled and Calculated from:

(1) The rainfall per month: Ministry of Agriculture of Morocco Meteorological Stations
(2) The Wheat grain yield/ha data source was from AOAD (2018) www.aoad.org/agstat

Where:

$G`_t$: Denotes estimated yield in tons per hectare in the year t
M_{it}: Denotes the rainfall in the month i, where i = 3 for March 4 for April and 5 for May, in the year t

Figure (1)



Source: Collected and compiled from:
(1) The wheat farm price in US$ and compiled from FAO (2018) www.fao.org/faostat
(2) The Wheat grain yield/ha data source was from AOAD (2018) www.aoad.org/agstat

Table 4. Estimation of the Wheat Farm Price Response to Wheat Yield Variation

Eq. no.	Estimated Model	Estimated R^2
12	$P_{ft} = 371.5464 - 44.2604G_t$ (30.083) (19.8574)	0.2565
13	$P_{wft} = 398.8854 -91.1348G_t +16.8570G^2_t$ (70.1957) (110.1803) (38.9516)	0.2574
13	$P_{wft} = 315.7492\ G_t^{-0.1524}$ (0.0382) (0.0730)	0.1537

(1) The wheat farm price in US$ and compiled from FAO (2018) www.fao.org/faostat
(2) The Wheat grain yield/ha data source was from AOAD (2018) www.aoad.org/agstat

Where:

P_{ft} = Farm Gate Price of Wheat grain per ton in US$

G_t = Wheat Grain Yield per hectare in Tons

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