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Predicting Long-Term Meat Productivity for the Kingdom of Saudi Arabia

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***Abstract*—**Livestock is one of the fastest-growing sectors in agriculture. If carefully managed, have potential opportunities for economic growth, food sovereignty and food security. In this study we mainly analyse and compare long-term i.e. for year 2030 climate variability impact on predicted productivity of meat i.e. beef, mutton and poultry for the Kingdom of Saudi Arabia w.r.t three factors i.e. i) climatic-change vulnerability ii) CO_2 fertilization and iii) water scarcity and compare the results with two countries of the region i.e. Iraq and Yemen. We do the analysis using data from diverse sources, which was extracted, transformed and integrated before usage. The collective impact of the three factors had an overall negative effect on the production of meat for all the three countries, with adverse impact on Iraq. High similarity was found between CO_2 fertilization (effecting animal fodder) and water scarcity i.e. higher than that between production of beef and mutton for the three countries considered. Overall, the three factors do not seem to be favorable for the three Middle-East countries considered. This points to possibility of a vegetarian year 2030 based on dependency on indigenous live-stock population.

***Keywords*—**Prediction, animal-source foods, pastures, CO_2 fertilization, climatic-change vulnerability, water scarcity.

I. Introduction

THERE is an increased demand for animal source foods in the three countries considered (Saudi Arabia, Iraq, and Yemen) due to increase in population growth and increase in income. This demand may continue to rise as the prosperous population is increasing and may reach a point of saturation. This is described as “income elasticity” by economists. For example, income elasticity in Yemen for fish is 0.995 and for meat is 0.833. This means that for every percentage point increase in income, expenditure on fish and meat will increase by 0.995 and 0.833 percent, respectively [1]. However, between demand, production and purchase many factors can affect the delicate ecosystem negatively or positively.

It is evident that global population will continue to grow in future and world population may increase from 6.8 billion to 8.3 billion by 2030, leading to an expected increase in demand for grain and animal- source foods and dairy products. There is a rising middle class desiring more animal source foods and dairy products; consequently there will be increase in demand for fresh water and arable land, which in the case of Saudi Arabia is on a decline [2], thus there is a need to predict and identify potential cultivable regions that are suitable for further study. Finally, we expect the world’s climate to continue to change in ways that could impede food production and dislocate people [3].

Rest of the paper is organized as follows, in Section II a general background is provided, in Section III related work for the meat forecasting in the region is given, in Section IV materials and methods are discussed which are used in our study, Section V provides the discussion and results and finally, last section conclusions.

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II. Background

Middle-East is considered a suitable region for different main legume crops and cereals. There are different agriculture crops in the Middle-East such as wheat, barley, oats, Arabic coffee, etc., but barley and wheat being the main crops [4]. The region also provides suitable environment for domesticating sheep and goats. There were two main drivers that increased the demand of livestock products i.e. urbanization and population growth during last decades, which is also known as the livestock revolution [5]. During the last decade, the livestock population has rapidly increased in some of the countries of the Middle-East such as Yemen, declined in Iraq and remained almost the same in Saudi Arabia, surprisingly in a region which is affected by many factors, such as scarcity of water, fodder and shelter [6]. There are various factors that affect the livestock population including (but not limited to): climate, diseases and parasites [7]. Climate is the most significant factor where patterns of rainfall and temperature significantly impact the availability of fodder and pasture land that is used for forage, including cultivated crops; throughout the year [8].

Most of the Middle-East region is characterized by a hot and dry climate and the presence of vast deserts and long coast lines [5]. Deserts cover large areas while agricultural lands are defined as the arable land that are under perennial grass pastures or crops, but covering small areas [8]. Climate change is considered the biggest threat on the planet affecting the availability of water and causing food crises while the population is on the rise [9]. There are far-reaching consequences of climate change on meat production, such as drought that can increase the vulnerability of livestock [9]. There are two ways of responding to climate change i.e. adaptation and mitigation. Adaptation helps people to deal with changes in climate while mitigation reduces the impact or magnitude of climate change in the long term [10], adaption being one of the main objectives of this paper.

Due to climate change there will be frequent droughts and floods resulting in epidemics and vector borne diseases, discussed in Section VI.*A*. These changes may lead to increased food shortage and loss of lives ultimately resulting

in loss of genetic resources. All these factors may impact livestock production and health. If proper adaptations and mitigation measures are not taken, livestock producers may suffer substantial losses [5].

III. Related work

With the increasing requirement and need to predict the animal source food demand, many researchers have addressed the corresponding issues, for example [11]-[16].

In [11]-[13], the rises in atmospheric concentration of CO_2 and subsequent climatic changes have been discussed for 2050. As per [11] climate change may also affect adversely the prospect of achieving food security improvements, since most climate models indicate that agricultural potential of developing countries may be more adversely affected than the world average. The high dependence of several of these countries on agriculture makes them particularly vulnerable in this respect. Different [12], [13] climatic factors will drive global warming, but can also be a positive factor in tree and crop growth and biomass production. Since CO_2 fertilization stimulates photosynthesis and improves water-use efficiency [14], therefore, up to 2030 this effect could compensate for much or all of the yield reduction coming from temperature and rainfall changes but mostly for the countries of the northern hemisphere. Although, these studies discuss the parameters that we have considered; the discussion is not at the country level as per our study.

In [15] forecast of red beef is studied for various Gulf Cooperation Council (GCC) countries from 2012-2015. Population growth in GCC countries predicted to increase by 7% with the total population reaching over 47 million in 2015. According to the growth in GCC region, beef consumption was forecasted to increase to 314,000 tons between 2010 and 2015. The growth in food consumption forecasted for Saudi Arabia to increase by 53.3% in 2017. However, the impact of the three parameters that we have considered was not discussed and the time period considered was significantly less as compared to our study.

In [16] demand for the next five years of the region was forecasted for various grains by-products, some of which being used as animal fodder. It was concluded that the population growth is expected to bolster the demand for livestock products, consequently causing increase in demand for barely especially in Saudi Arabia, which is the largest barely importer. It was expected that Saudi Arabia will be accounting for around 39% of total world barely trade in 2018/2019. However, the impact of the three parameters that we have considered was not discussed and the time period considered was significantly less as compared to our study.

IV. Materials and Method

FAO-2011 report consists of different tables that contain data about production and consumption of mutton, poultry and beef for 104 countries for 2000 and 2030 with predicted change in meat production [17]. The study presents the data for several Middle-East countries, including Saudi Arabia, Iraq and Yemen. In this paper we will discuss the effect of three factors on three countries for the production of meat for 2030. The data has been gathered from diverse sources using the method of extraction, transformation and integration.

This paper will use traditional techniques to analyse the impact of the heterogeneous data collected of the three factors on change in percentage of meat production for 2000 and 2030. In order to make the study manageable we shall not consider data on eggs and milk. Also, milk and meat cannot be compared on the basis of weight, as milk is mostly water [17].

A. Global Climatic-Change Vulnerability

Climate change will not only affect livestock population and health, it may also have significant effect on environment and socio-economic and related sectors, including water resources, agriculture and food security, human health, terrestrial ecosystems and biodiversity and coastal zones. Excess or scant rainfall may lead to floods or droughts. Flooding due to melting of glaciers may cause soil erosion. Crop growing seasons may get affected due to rising temperatures and consequently affect food production.

Around 50 countries in the world are vulnerable to climate change and may suffer by climate impacts. This was revealed in study by [18]. The researchers carried out a study on pre-existing characteristics of society that are known to be affected by climate change and mapped it to the level of vulnerability. The expected climate change impacts were analysed and four factors were considered [18]:

- **Health Impact:** Diseases that are sensitive to climate changes may cause more deaths.
- **Weather Disasters:** Changes in weather, damage due to storms, floods and wildfires may cause additional loss of lives.
- **Habitat Loss:** Rising sea water, reduction of dry/ arid land may lead to loss of human habitat.
- **Economic Stress:** When agricultural land is lost, there will be loss of natural resources which may lead to economic loss.

The impact of these four factors was color-coded qualitatively [18], which we converted into qualitative values ranging from 11 to 1 as Acute (11), Severe, High (with finer gradation of + and –) followed by Moderate and Low (1). The average of the percentage changes of the qualitative values was subsequently taken for each country, and the results of overall vulnerability index determined to be 0.2 for Saudi Arabia, 0.5 for Iraq and 0.64 for Yemen. Note that, the smaller the vulnerability index, the better.

B. CO_2 Fertilization

The structure and functioning of ecosystem and human livelihood are mainly affected by changes in thermal and hydrological systems which are in turn affected by changes in climate. Climate change is mainly caused due to a set of physical coherent changes in meteorological variables, based on the normally accepted levels of CO_2 and other trace gases. To estimate the effects on crop yields, how much land could be cultivated, and the number and type of crop combinations

that can be cultivated, Fisher [19] developed climate change scenarios using AEZ (Agro-Ecological Zone) family crop models. AEZ is a model that uses detailed agronomic-based knowledge to assess options of farm-level management, simulate the availability of land resources and estimate potentials of crop production [19].

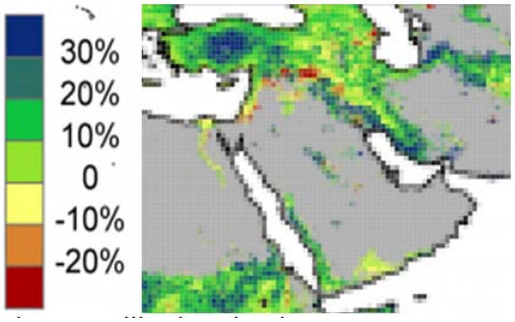

Fig. 1 Mapping Satellite data showing percent amount foliage cover change around Middle-East from 1982 to 2010

As per [19], climate change in 2050's will not have any impact on crop production in Central Asia, however, other developing countries will have a negative impact due to climate change. On the contrary it was predicted that production capacity of rain-fed cultivated land in Europe, Russia and Oceania will increase. From [19], even with CO_2 fertilization for adopted crops there could be a decrease of 8% in cereal production in Middle-East, but there is an increase of 14-19% in Central Asia for crops without CO_2 fertilization. The CO_2 fertilization results for 2050 however do not directly help us; because the level of detail is at the region level i.e. Middle-East instead of an individual Middle-East country level that is the focus of this paper. Therefore, we need average country-level CO_2 fertilization data, which is then mapped to 2030/50.

For CO_2 fertilization at country level, we use the corresponding color-coded image data [20] as shown in Fig. 1 that covers the period from 1982 to 2010 and uses different colors to indicate the increase or reduction in leaf production. We proceed by determining the average CO_2 fertilization for each Middle-East country considered and then adjusting it w.r.t 2030 for the entire Middle-East region.

To get an average value of CO_2 fertilization for each Middle-East country considered, the best way is to determine the change in WUE (Water Use Efficiency) for that country while assuming a universal change in CO_2 concentration for the study period using data available at Mauna Loa [21]. However, this methodology is beyond the scope of this paper, therefore, we performed online image processing and subsequent data mining for each Middle-East country for the percentage amount that foliage cover has changed from 1982-2010 using Red, Green and Blue color values of image in Fig. 1 determined using the Image Color Summarizer [22]. Because of manuscript space constraints we are unable to include further details. The calculated CO_2 fertilization for the three countries considered was found to be 17.35, 24.68 and 21.55 for Saudi Arabia, Iraq and Yemen, respectively.

C. Water Scarcity

Water scarcity is a relative concept which may occur due to imbalance in supply and demand. Scarcity could also be the result of climate change, as the supply pattern gets affected due to excess heat [23]. Water stress occurs when the demand for water exceeds the available amount during a certain period or when water supplies drop below 1,700m^3 per person, or when poor quality restricts its use. When annual water supplies drop below 1,000 m^3 per person, the population is considered to be water scarce, and below 500 m^3 "absolute scarcity" [24]. In this research we will use the water scarcity figures based on [25] given in Fig. 2 for the three countries considered.

V. Results and Discussion

In this section we will analyse the impact of the three factors i.e. water scarcity [25] CO_2 fertilization [19], [20] and the climate change vulnerability [18] for Saudi Arabia and compare the selected two Middle-East countries i.e. Iraq and Yemen; the summarized results are shown in Fig. 2.

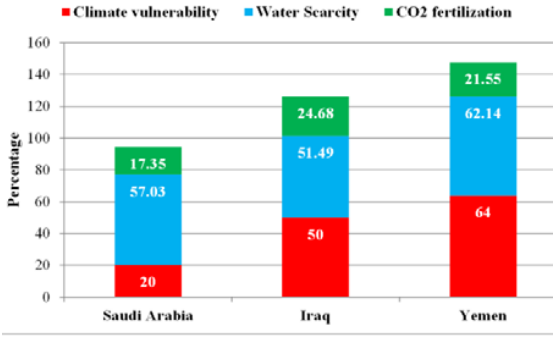

Fig 2 Comparison of Saudi Arabia with Iraq and Yemen for the three parameters considered

We start by exploring the meat (beef, mutton and poultry) consumption for the three Middle-East countries based on the collective effect of three parameters on the percentage change in meat production. We will do this analysis using traditional algebraic techniques with results shown by histograms.

There is a generic relationship between water consumed through transpiration and biomass production. If there is water stress, transpiration will be reduced which will also negatively effect on biomass production, resulting in reduction of yield. As discussed in [24], like the yield response to water, so is possible reduction in evapotranspiration linked to a proportional reduction in yield. Thus, a high WS is undesirable as it indicates weak prospects of crop for humans and fodder for animals. Crop yield generally responds positively to increased atmospheric high CO_2 fertilization and as per [24] higher CO_2 concentration indicates higher yields both for current and adapted crops. Thus increase in yield of crops and corresponding fodder for animals is directly proportional to meat production.

There are four sub-factors that can be considered in the computation of the climate change vulnerability [18] which are: health impact, weather disasters, habitat loss and economic stress. These factors will negatively effect and will cause the loss of production. Therefore, we define the Effective Percentage Change in Production i.e. EPCP as (1):

$$EPCP = (CDF \times (1\text{-}CCV) \times PCMP) / (WS) \quad (1)$$

Here CDF is CO_2 Fertilization, CCV is Climatic-Change Vulnerability, and PCMP is Percentage Change in Meat Production. The corresponding results are shown in Fig. 3.

From Fig. 3, we can observe that the percentage change in production of mutton for Yemen without considering the three factors is expected to be 415.5% for 2030; however, if we consider the three factors then the effective production is expected to reduce to 51.87%. By adjusting the demand using the three factors, we can observe that there will be a reduction in production of beef by 75.7%, reduction in production of mutton by 77.4% and reduction in production of poultry by 75.8% in all the three countries for 2030.

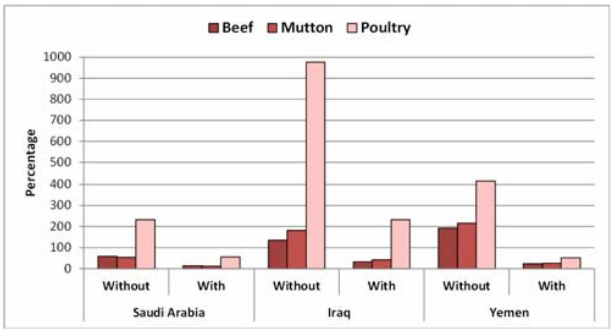

Fig. 3 Percentage change in predicted meat production in 2030 without and with the impact of the three parameters considered

As per [26], dependence on food imports in general is high across MENA (Middle East North Africa) region nearly complete (around or above 90 percent) in all GCC economies, except Saudi Arabia where it is 80 percent. Thus, the impact of world food price fluctuations, the pass through effects from world to domestic prices should be largest in the GCC economies, as well as in some other countries, such as Yemen, Iraq, and Jordan. Observe the similarity of our results (Fig. 3) with that of [26] keeping in view the relationship between production and demand.

VI. Conclusions

Livestock is one of the fastest-growing sectors in agriculture. If carefully managed, have potential opportunities for economic growth, food sovereignty and food security. Middle-East comprises of more than half a dozen countries; however, in this study we cover three countries i.e. Saudi Arabia, Iraq and Yemen. In this paper we mainly analyse and compare long-term i.e. for year 2030 climate variability impact on predicted productivity of meat i.e. beef, mutton and poultry for the Kingdom of Saudi Arabia w.r.t three factors i.e. i) climatic-change vulnerability ii) CO_2 fertilization and iii) water scarcity and compare the results with two countries of the region i.e. Iraq and Yemen. We do the analysis using data from diverse sources, which was extracted, transformed and integrated before usage. As per World Bank these three countries i.e. Saudi Arabia, Iraq, and Yemen are in the category of high, lower middle and low income countries, respectively. Increase in production of meat is projected from 2000 to 2030 for these countries. However, all three countries are expected to be adversely effected by vulnerability due to climate-change impact and water scarcity, the most severe being for Yemen, but in terms of decline in productivity Iraq is projected to be hardest hit, pointing to early mitigation efforts/plans. Therefore, before nature forces us into a vegetarian life-style by 2030 as predicted, we may start adjusting our meat consumption habits from today.

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