Impacts of Climate Change on World Food Supply

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Abstract

This project analyses the global consequences to crop yields, production, and risk of hunger of linked socio-economic and climate scenarios. Potential impacts of climate change are estimated for climate change scenarios developed from the HadCM3 and HADCM1global climate model. Projected changes in yield are determined by utilizing CO2 capabilities got from crop model recreations with noticed climate data and projected environmental change scenarios. The Basic Link System (BLS) is utilized to assess ensuing changes in worldwide cereal creation, cereal costs and the quantity of individuals in danger from hunger. When crop yield results are acquainted with the BLS world food trade system model, the joined model and scenarios tests exhibit that the world, generally, seems, by all accounts, to be ready to keep on taking care of itself under the SRES situations during the rest of this century. Nonetheless, this result is accomplished through creation in the developed nations (which generally benefit from climate change) making up for declines anticipated, for the most part, for developing nations. While global production appears stable, regional differences in crop production are likely to grow stronger through time. The two models tested for the selected BLS regions prove to be efficient but not in all scenarios
Keywords: Climate change, experiments, crop, simulations, longitude and latitude, temperature, food system, emissions, scenarios.

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List of Abbreviations

AOGCM Atmosphere/Ocean General Circulation Model or Atmosphere/Ocean Global Climate Model

BLS Basic Linked System

CERES California Environmental Resources Evaluation System

CIESIN Center for International Earth Science Information Network

CMIP6 Coupled Model Intercomparison Project

CMIP Coupled Model Intercomparison Project

CO2 Carbon dioxide

CORDEX Coordinated Regional Climate Downscaling Ex- periment

GCM General Circulation Model

GDP Gross Domestic Product

GHG Greenhouse Gases

HADCM2 Hadley Centre Coupled Model version 2

HADCM3 Hadley Centre Coupled Model version 3

IBSNAT The International Benchwork Sites Network for Agrotechnology Transfer

IPCC Intergovernmental Panel on Climate Change

RCP Representative Concentration Pathways

SRES Special Report on Emissions Scenarios

SRES Special Report on Emissions Scenarios

1 Introduction

Climate is defined by the Oxford Learner's Dictionary as the regular pattern of weather conditions of a specific spot. These atmospheric conditions could be grouped into gentle, mild, warm and wet depending upon season and additionally area. Decisive confirmations anyway show a float from the typical example of weather pattern to a somewhat unsafe and unfavorable pattern as climate is currently known to adversely affect the environment and constantly on the Ecosystem, both animate and inanimate [6]. The Greenhouse effect is normal and large numbers of these ozone depleting substances are really life-enabling, for without them, heat would get away from once more into space and the Earth's average temperature would be significantly colder. However, if the greenhouse effect becomes stronger, and it is, more heat is trapped than needed, and the Earth is becoming less habitable for humans, plants and animals. It can thus be inferred that the ability of greenhouse gases to absorb sunlight is the root cause of global warming. Carbon dioxide (CO2), however not the most intense of ozone depleting substances, is the main one. At the point when trees are reaped and utilized in housing, the carbon stays stored in the wood despite the fact that it is done living yet assuming it burns or rots, the carbon put away in the wood over its life gets back to the environment as CO2 [6]. In this project, we consider the projected impacts of climate change on worldwide food supply under various climate models, Socioeconomic developments, and what they mean for individuals in danger of hunger in the next few decades. This work is an expansion of past investigations that expected a single best-estimate population and economic future. These and other past examinations have shown that climate change related with expanding levels of carbon dioxide is probably going to influence developing and developed nations differently, with significant weaknesses happening in low-latitude districts. The primary drivers of agricultural reactions to climate change are biophysical impacts and Socioeconomic variables. Crop creation is impacted bio physically by meteorological factors, including climbing temperatures, changing precipitation systems, and expanded environmental carbon dioxide levels. Biophysical impacts of environmental change on agrarian creation will be positive in a few horticultural systems and regions, and negative in others, and these impacts will differ through time [1]. Socioeconomic variables impact reactions to changes in crop efficiency, with value changes and changes in near advantage. The power of this work is in the coupling of biophysical (yield capabilities) and financial techniques, yielding responses that are generally difficult to expound while utilizing the two models independently [2]. we look at the transient reaction of two variants of the Met Office's coupled environment sea environment models, HadCM2 and HadCM3, to expanding GHGs and examine the reasons behind contrasts in the reaction by separating large numbers of the progressions to barometrical definitions in a progression of responsiveness tests. Cloud feedback are notable to be quite possibly of the biggest sources of contrasts between model forecasts of climate change and specific emphasis will be given to the job of clouds in the different model reaction. Coupled sea environment models are costly to turn up and run to equilibrium. Nonetheless, we show that large numbers of the fundamental highlights in the reaction of the coupled models can be duplicated in basic blended layer sea models coupled to the atmospheric component of the coupled models ("slab" models) [4]. These models epitomize the atmospheric changes and forced changes in surface temperature, despite the fact that they overlook the impacts of the profound sea and changes in sea dissemination. Notwithstanding, slab models are a lot less expensive to instate and run to equilibrium, and thus by utilizing them, we can convey out a considerably more complete arrangement of sensitive examinations to explore the purposes behind the distinctions in model reactions. We accentuate the patterns of change as opposed to their outright size, as the extent in the transient experiments is a component of time. For a consistent increase in GHG forcing, the patterns of reaction fluctuate minimal in time [5].

2 Literature review (and theoretical framework)

Previous research has been carried out on climate change effects and implications on global food supply with different models, in this section we are going to be reviewing the background research on the study, their methodologies, models implemented and results.

2.1 "Climate Change and World Food Security"

This paper builds on previous work on quantitative estimates of climate change impact on global food production. Comparing the HADCM2 and HADCM3 models, the study examines the potential effects of climate change on crop yields, risk of hunger and food supply. The structure of the study is illustrated in Figure 1.There are two main components, namely: Estimation of world food trade responses and estimation of potential changes in crop yield. Every climate changes, socioeconomic and technology scenario used in the study is based on an IS92a research [2]. Adaptation was thought of and consolidated in the assessments made by the two parts of the climate change study. Farm level transformations were tested out by the harvest models which bring about yield changes, and economic acclimations to the yield changes were tried by the BLS world food exchange model which result national and provincial production changes and cost reactions. Farm level adaptations tested in the crop models incorporate establishing date shifts, all the more climatically adapted varieties, water system and manure application. Monetary changes addressed by the BLS include: expanded farming speculation, redistribution of horticultural assets as per financial returns (counting crop exchanging), and recovery of extra arable land as a reaction to higher grain costs. It is expected that these monetary changes don't to feedback to the yield levels anticipated by the harvest displaying study [2]. The IBSNAT-ICASA in dynamic crop growth models for major grain and soybean were validated and specified for 124 sites in 18 countries [7]. The IBSNAT-ICASA models in Figure 2 were developed by the US Agency for International Development's International Benchmark Sites Network for Agrotechnology Transfer [8]

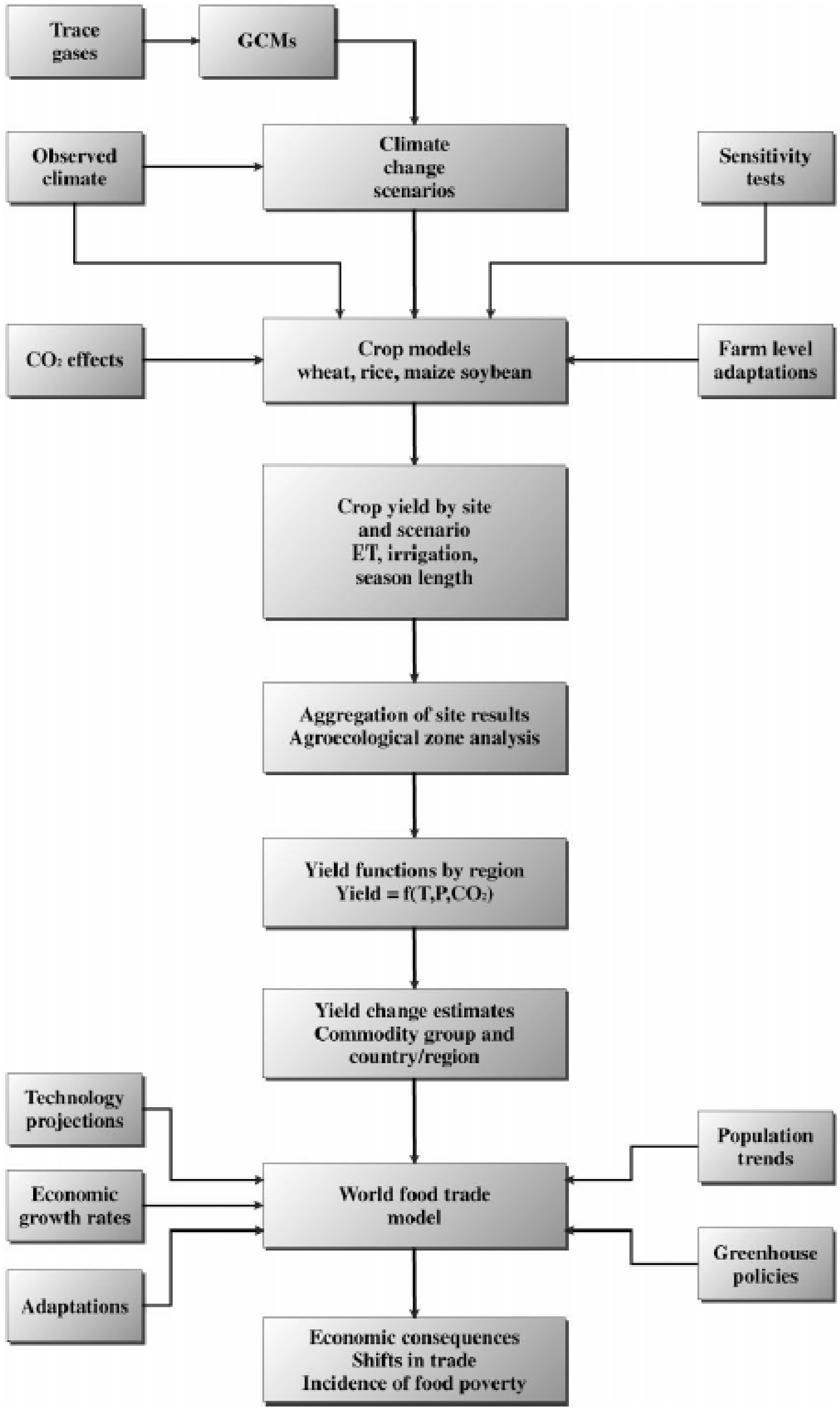


Figure 1: Key elements of the crop yield and world food trade study [2].

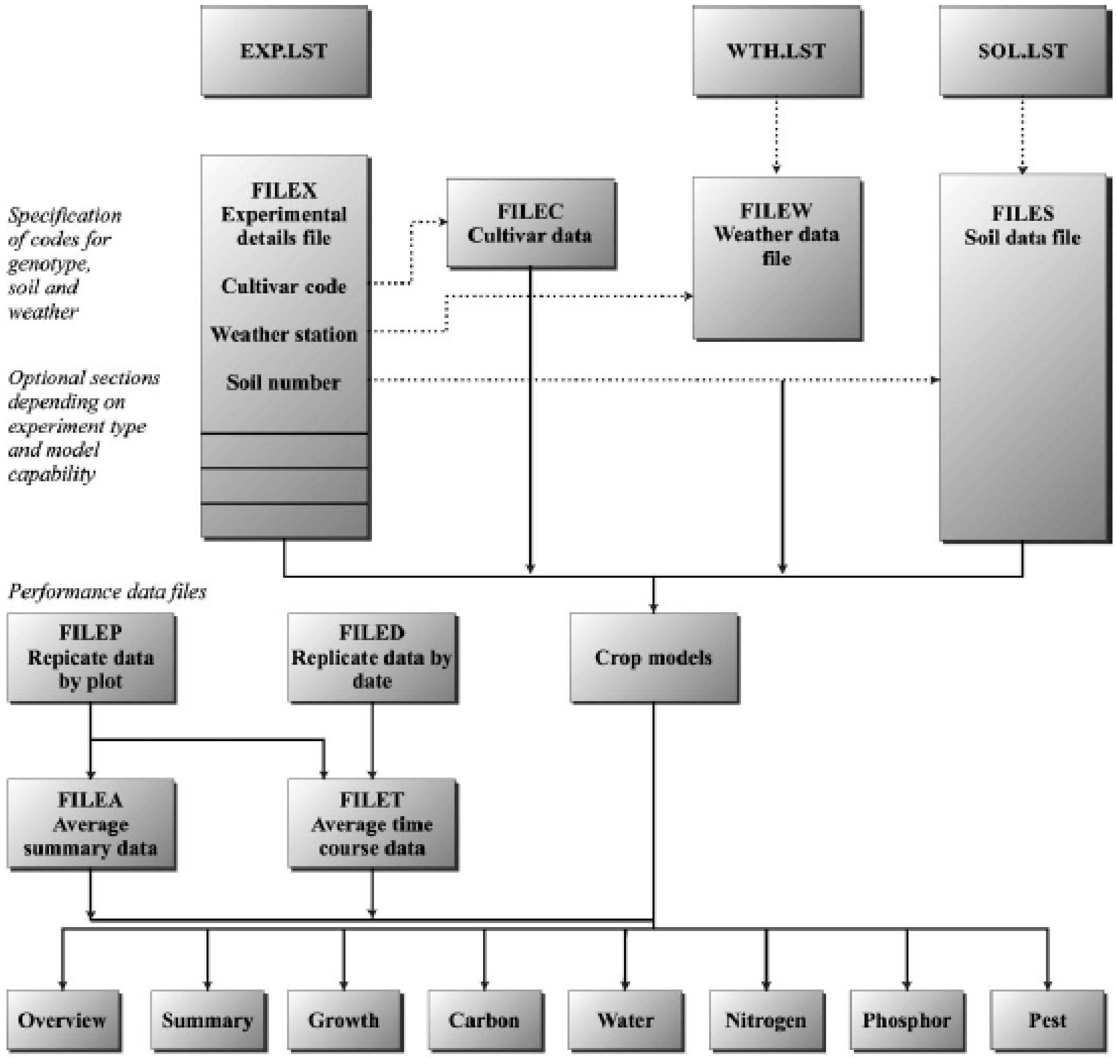


Figure 2: The IBSNAT crop models [2].

Crop model recreation results were amassed and extrapolated to provincial level based on agroclimatic zone examination. Aggregated crop model outcomes under various climate and the board conditions were then used to indicate proper utilitarian structures for local yield reaction to environment boundaries (temperature and precipitation), and ecological changes (air CO2 focus). The resulting functions were then connected to a geologically explicit database base for the assessment of spatial yield changes under the climate and CO2 situations anticipated by Hadley Center's GCMs known as HadCM2 [9] and HadCM3 [5]. Express connections were made among examinations and simulations directed at the approved site level and at the country/local level. The yields simulations (fundamental grain cereals and soybean) represent 85% of the world cereal commodities.

Table 1 shows the ongoing rates of world creation of wheat, rice, maize, and soybean for the nations in which simulations were directed. Simulations were completed

Table 1: Rates of world creation of wheat, rice, maize, and soybean for the nations in which simulations were directed

	Yield *t/ha*	Area ha x1000	Production t x1000	Study countries %
Wheat	2.1	230,839	481,811	73
Rice	3.0	143,603	431,585	48
Maize	3.5	127,393	449,364	71
Soybeans	1.8	51,357	91,887	76

in districts addressing 70 -76% of the ongoing scene creation of wheat, maize, and soybean creation. Rice creation was less all around addressed in the model recreations than different harvests, since India, Indonesia and Vietnam have critical creation regions excluded from the review. Further examination is required in these critical nations to work on the unwavering quality of the projections of environmental change influences on rice creation [5].

2.1.1 Crop Model

The study simulated the principal grain crops with the IBSNAT-ICASA models for wheat , rice , maize , and soybean. The IBSNAT models are involved definitions of significant physiological cycles liable for plant development and advancement, evapotranspiration, and apportioning of photosynthate to create financial yield. The simplified capabilities empower expectation of the development of crops as impacted by the central point that influence yields, for example hereditary qualities, climate(everyday sun oriented radiation, greatest and least temperatures, and precipitation), soils, and the management practices. The models incorporate a soil moisture balance sub-model so they can be utilized to anticipate both rainfed and flooded crop yields. The models mimic the impacts of nitrogen fertilizer on crop development, and these were broke down in a few destinations with regards to climatic change (for instance, Argentina and Uruguay) [2]. Generally, the aftereffects of this study accept ideal supplement levels. The IBSNAT models were chosen for use in this study since they have been approved over a great many conditions and are not intended for a specific area or soil type. They are more qualified for huge region studies, in which crop-growing also, soil conditions vary extraordinarily, than more detailed physiological models that have not been as widely tested. The approval of the crop models over various conditions additionally works on the capacity to assess impacts of changes in environment. Since the crop models have been tried over basically the full scope of temperature and precipitation systems where crops are filled in the present environment, and to the degree that future environmental change brings temperature and precipitation systems inside these ranges, the models might be viewed as helpful tools for evaluation of potential climate change influences [2].

Moreover, because management practices like, the selection of assortments, the planting date, manure application, and water system, might be differed in the models, they license tests that simulate transformation by farmers to climatic change. Most plants filling in exploratory conditions with expanded degrees of climatic CO2 show expanded paces of net photosynthesis (i.e. total photosynthesis minus respiration) and diminished stomatal openings. Partial stomatal closure prompts diminished transpiration per unit area region and, joined with upgraded photosynthesis, frequently makes water-use proficiency better (the ratio of crop biomass accumulation or yield to the amount of water used in evapotranspiration). In this way, without help from anyone else, expanded CO2 can increment yield and decrease water use (per unit biomass). The crop models utilized in this study represent the advantageous physiological impacts of expanded climatic CO2 focuses on crop development and water use [11]. As reproduced in this study, the direct impacts of CO2 might predisposition crop shifts in a positive course, since there is vulnerability with respect to whether trial results will be seen in the open field under conditions liable to be operative when farmers are overseeing crops. Plants filling in experimental settings are in many cases subject to less natural burdens and less rivalry from weeds and vermin than are probably going to be experienced in farmers' fields. Nonetheless, late field freeair discharge studies have found in general certain CO2 impacts under current environment conditions [12].

Crop modelling simulation tests included for the review were performed for: the baseline climate climate; step changes in temperature, precipitation and CO2 levels; and GCM climate change scenario with and without the physiological effects of CO2 [11]. This elaborate the accompanying tasks:

- Meaning of the representative crop the management (for example crop variety, compost inputs, rainfed as well as watered production, number of harvests developed each year) and soils.
- Definition of the benchmark daily climate information for the period 1961-1990, or for however many long stretches of day to day information as were accessible.
- Approval of the crop models under current environment with exploratory information from field preliminaries, to the degree conceivable.
- Recreations of crop reactions with the environment adjusted situations.
- Testing of farm level variations: changes in planting date (1 month); extra utilization of irrigation water to crop currently under the irrigation system ; and changes in crop assortment assuming just the range that exists today.

2.1.2 Limitations of crop yield change estimates

The yield change estimates incorporate various sources of vulnerability. At the site level, the principal source of vulnerability is inherent to the utilization of crop models. The yield models epitomize various improvements. For instance, weeds, illnesses, and bug irritations are thought to be controlled; everything is good to go soil conditions (for example saltiness or corrosive nature); and there are no super climate occasions like dry seasons or extreme tempests. The models are aligned to trial field information, which frequently have yields higher than those at present common under cultivating conditions. Consequently, the absolute impacts of climatic change on yields in farmers' fields might be not quite the same as those recreated by the crop models. The crop models mimic the ongoing scope of farming innovations accessible all over the planet, including the utilization of high-yielding assortments that are receptive to technological data sources, yet by the 2080s agrarian innovation is probably going to be altogether different [2].

The models might be utilized to test the impacts of a few expected upgrades in agricultural production, like assortments with higher warm requirements and establishment of irrigation frameworks, however do exclude conceivable future enhancements. (The BLS financial model utilized in the review includes future patterns for crop improvement, yet not mechanical advancements prompted by bad climate change influences.) At the territorial level, the essential source of vulnerability in the appraisals lies in the meager condition of the harvest displaying destinations to determine provincial yield capabilities and the way that the locales may not enough address the fluctuation of horticultural areas inside nations, the changeability of farming frameworks inside comparative agro-natural zones, or unique agricultural districts. Notwithstanding, since the site results connect with regions that record for around 70% of world grain creation, the ends concerning world sums of oat creation contained in this study are accepted to be validated enough. One more wellspring of vulnerability lies in the recreation of grain crops only, prompting assessment of crop changes for different items, for example, root crops and natural product, dependent basically upon past evaluations. The past evaluations would in general be more positive than the crop reactions displayed in this review, and this presented a predisposition for these different harvests on the planet food exchange model [2].

2.1.3 Estimated Effects on crop yield

Fig. 3-5 show the assessed likely changes in average national grain crop yields for the four HadCM2 and one HadCM3 environmental change scenarios, taking into account the immediate impacts of CO2 on plant development. The maps are created from the nationally averaged yield changes for wheat, rice and maize. Provincial variations inside nations are not shown. The latitudinal variations in crop yields showed in Fig. 3-5 are fundamentally because of contrasts in current developing circumstances. Higher temperatures will quite often shorten the developing time frame. This is particularly evident at low temperatures where crops are presently developed at higher temperatures and are closer to the limits of temperature resilience for heat and water pressure [2].

Warming at low temperatures prompts more extreme heat and water pressure and more prominent yield diminishes than at higher scopes. Under the HadCM2 situation, in numerous mid-and high-latitude regions, where current temperature systems are low, the expansion in surface temperatures will in general extend the growing season subsequently expanding crops. In any case, IPCC Working Group II in its subsequent evaluation report (IPCC, 1996) recognized that a latitudinal change in temperature examples wouldn't stringently compare to a basic change in latitude of suitable regions for common crops. This is on the grounds that many plants are sensitive to photoperiod and have adjusted to a particular mix of temperature and photoperiod ranges [13].

Along these lines, new genotypes will be expected to exploit any possible climate change benefits. In this study the potential for development of developed land is implanted in the BLS world food exchange model and is reflected in shifts in production determined by that model. This possibly useful impact isn't obvious under the HadCM3 situation. The strengthened polar warming experienced under HadCM3 is perfect to the point that the threshold concerning beneficial outcomes of hotter temperatures at higher latitudes is surpassed and a diminishing in yields happens in a portion of these regions. Another distinction clear from Fig 3-5 is, while the area most adversely impacted under HadCM2 is the Indian subcontinent, under HadCM3 it is western Africa and the USA. In rundown the adverse consequences of climate change are undeniably more apparent under the HadCM3 environmental change situation than under the HadCM2 situations [2]. The essential drivers of diminishes in reenacted yields are:

- Shortening of the developing time frame: Higher temperatures during the growing season season speed yearly crops through their turn of events (particularly grain-filling stage), permitting less grain to be created. This happens at all destinations aside from those with the coolest growing season temperatures in Canada and Russia [2].

- Decline in water accessibility: This is because of a mix of expansions in evapotranspiration rates in the hotter climate, upgraded misfortunes of soil dampness and, at times, an extended reduction in precipitation in the environmental change situations [2].

- Unfortunate vernalization: Vernalization is the necessity of a few temperate grain crops, for example winter wheat, for a time of low winter temperatures to start or speed up the blooming process. Low vernalization brings about low blossom bud commencement and eventually diminished yields. Diminishes in winter wheat yields at a few locales in Canada and the previous USSR are because of absence of vernalization [2].

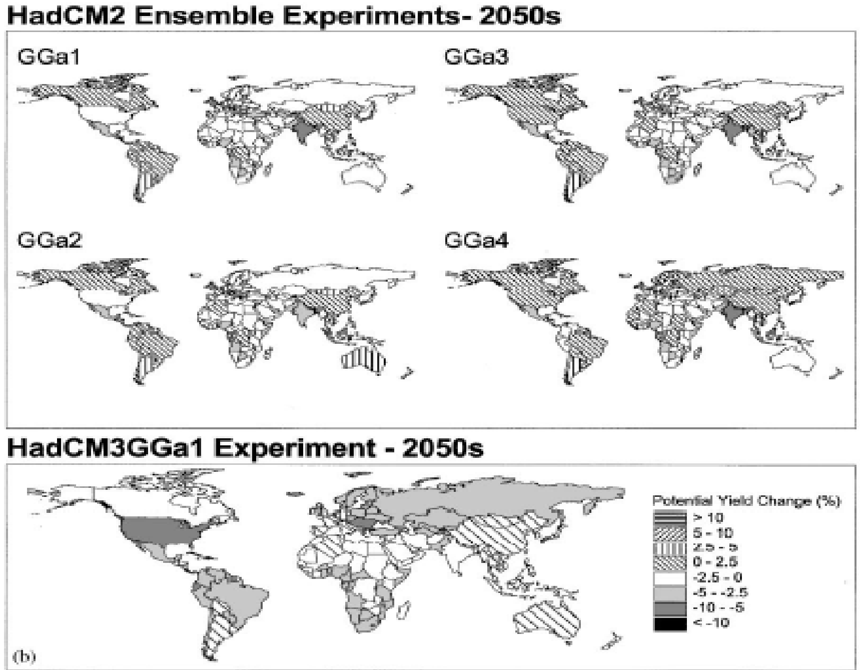


Figure 3: Potential changes (%) in national cereal yields for the 2020s (compared with 1990) [2] .

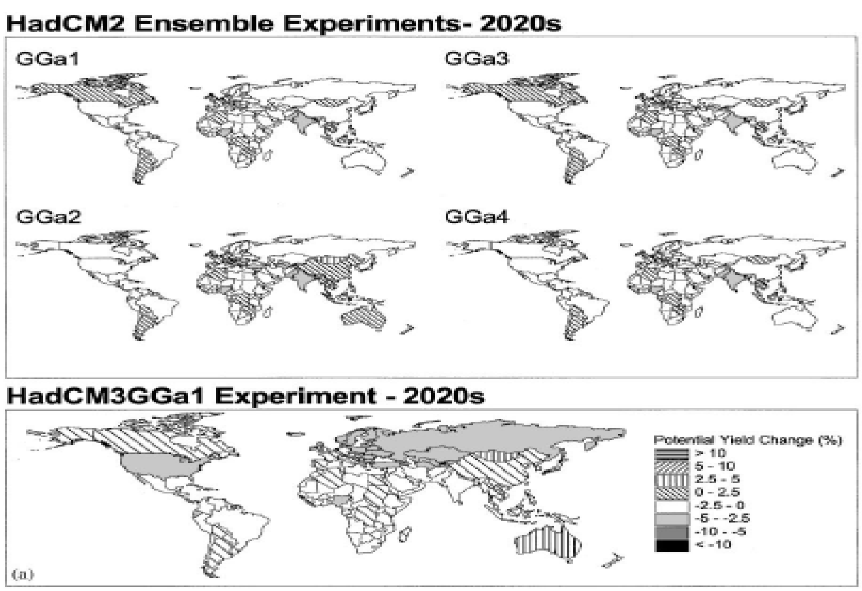


Figure 4: Potential changes (%) in national cereal yields for the 2050s (compared to 1990) [2].

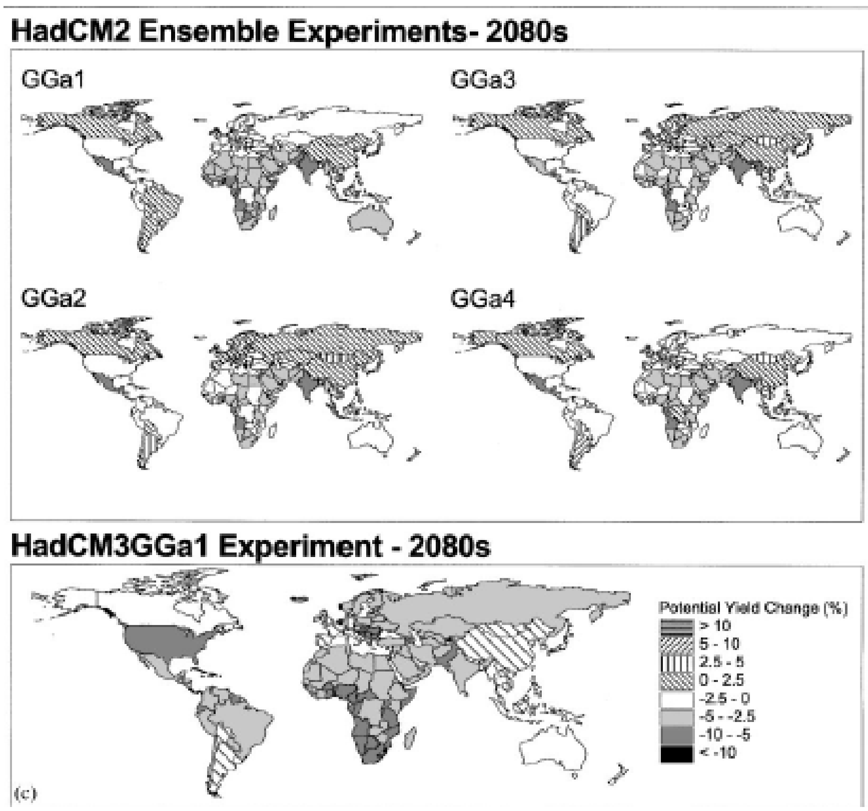


Figure 5: Potential changes (%) in national cereal yields for the 2080s (compared to 1990) under the [2].

2.1.4 Effects of climate change

Changes in cereal prices, cereal production and people risk of hunger approximated for the HadCM2 climate change scenarios (with the direct CO2 e!ects taken into account) display that the world will be able to feed itself in the next thousand years. The only dangerous finding was for cereal production, where the production rate drop to a level of of around 100 mmt (-2.1%) by the 2080s (+/-10 mmt depending on which HadCM2 climate simulation is selected). In comparison, HadCM3 produces a greater disparity between the reference and climate change scenario - a drop of more than 160mm (- 4%) by the 2080s (Fig. 6). Reduced production leads to increases in prices. Under the HadCM2 scenarios cereal prices increase by as much as 17% (+/-4.5%) by the 2080s (Fig.7). The greater negative impacts on crops for the HadCM3 model are predicted to increase by about 45% by the 2080s. In turn these price changes and production are likely to affect the number of people that lack resource to buy adequate amounts of food. Estimations based upon dynamic simulations by the BLS display that the number of people at risk of hunger increases, resulting in an estimated additional 90 million people in this condition due to climate change (above the reference case of 250 million) by the 2080s (Fig.8). The HadCM3 results are again more extreme, and they fall outside the HadCM2 range with an estimated 125 + million additional people at risk of hunger by the 2080s. All BLS experiments allow the world food system to respond to climate-induced supply shortfalls of cereals and higher commodity prices through increases in production factors (cultivated land, labour, and capital) and inputs such as fertilizer [2].

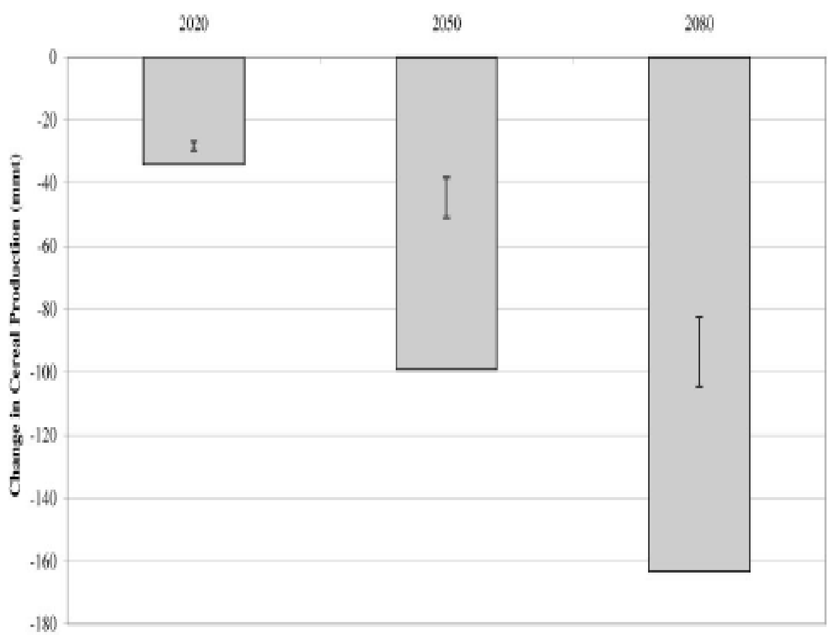


Figure 6: Global Cereal Production (HadCM3-Ref) wrt HadCM2 Range [2].

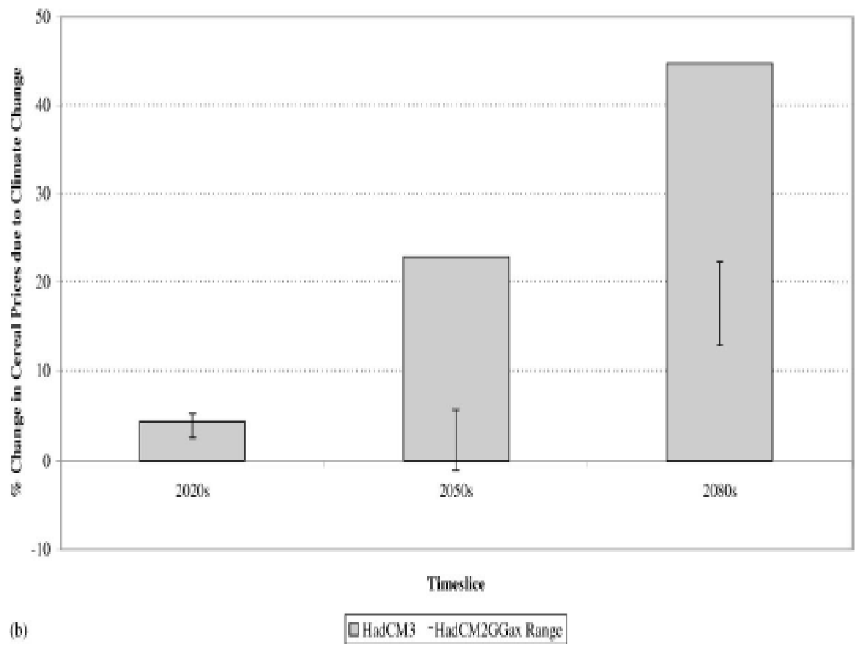


Figure 7: Percentage Change in Global Cereal Prices [2].

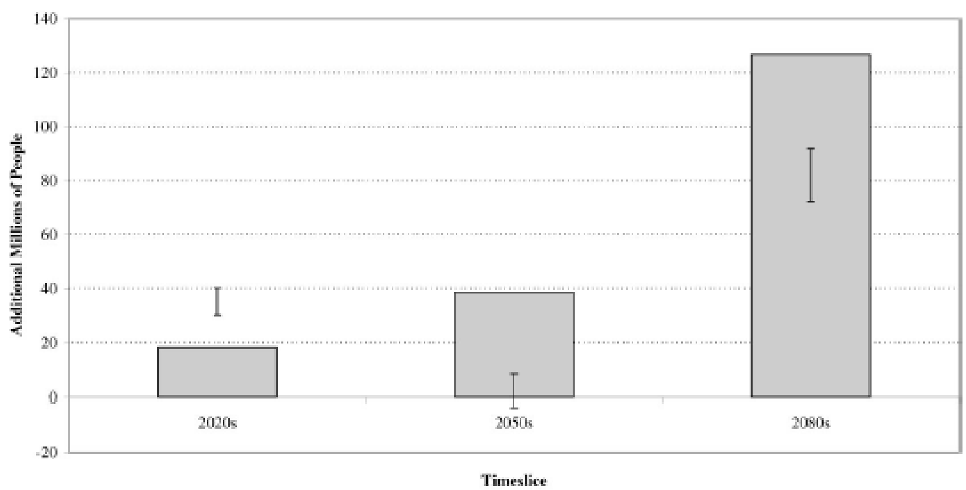


Figure 8: Global Risk of Hunger [2].

2.2 "Effects of Climate Change on Global Food Production under SRES Emission"

This paper examines the worldwide outcomes to crop yields, creation, and risk of hunger of linked socio-economic and climate scenarios. Expected effects of environmental change are assessed for climate change situations created from the HadCM3 worldwide climate model under the Intergovernmental Panel on Climate Change Special Report on Emissions Scenarios (SRES) A1FI, A2, B1, and B2. Projected changes in crop are determined utilizing move capabilities got from crop model reenactments with observed climate information and projected environmental change scenarios. The Basic Linked System (BLS) is utilized to assess subsequent changes in worldwide cereal production, cereal costs and the quantity of individuals in danger from hunger. The crop yield results explain the complex territorial examples of projected climate factors, CO2 impacts, and agricultural frameworks that add to conglomerations of worldwide crop production. The A1FI situation, as expected with its huge expansion in worldwide temperatures, displays the highest declines both provincially and all around the world in yields, particularly by the 2080s [2].

The difference between the yield change in developed and developing countries is biggest under the A2a-c situations. Under the B1 and B2 situations, developed and also developing countries show less difference in crop yield changes, with the B2 future crop yield changes being somewhat greater than those of the B1 situation. When crop yield results are acquainted with the BLS world food exchange system model, the consolidated model and situation tests exhibit that the world, generally, seems, by all accounts, to be ready to keep on taking care of itself under the SRES situations during the rest of the century. Be that as it may, this result is accomplished through creation in the created nations (which for the most part benefit from environmental change) making up for declines anticipated, generally, for emerging countries [2].

While worldwide production shows up steady, local differences in crop creation are probably going to develop further through time, prompting a critical polarization of effects, with significant expansions in costs and risk of hunger in poorer countries, particularly under situations of more noteworthy disparity (A1FI and A2). The utilization of the SRES situations features a few non-linearities on the planet food supply framework, both in the biophysical sense, where the degrees of barometrical CO2 tried arrive at new levels, and the financial sense, where changes in populace elements furthermore, economic and political designs muddle the interpretation of biophysical environmental change influences into social lists, for example, the quantity of individuals in danger of appetite [2].

2.2.1 Methods

There are two fundamental parts of the research: first part is gauging the reactions of crop yield ozone depleting substance actuated climate change, and the second is recreating the agro-economic results of these expected changes in crop yields — changes in territorial efficiency, fluctuations in worldwide commodity costs and the resultant effect on the all out number of individuals considered in danger of hunger around the world. The socio-economic development pathways expected in this study are gotten from the IPCC SRES report and are depicted somewhere else in this issue [14].

Reliable environmental change situations have been taken from SRES-driven tests directed utilizing the UK Hadley Center's third era coupled air sea worldwide environment model (HadCM3). The utilization of a transient AOGCM (HadCM3) permits not just the impact of the size of environmental change on food creation to be surveyed yet in addition the impacts of pace of progress. The design and research strategies continue as before as in past work parry where further insight about the crop modelling strategy can be, while full documentation on the world food exchange model, the basic linked system (BLS) is given in [16].

2.2.2 Estimation of world food trade responses

The BLS of National Agricultural Policy Models is a world-level general balance model framework created by the Food and Agriculture Program of the International Institute for Applied Systems Analysis [1]. It comprises of exactly 35 public as well as local models: 18 public models, two models for districts with close economic co-operation (EC-9 and Eastern Europe and previous Soviet Union), 14 total models of nation groupings, and a little part that records for factual errors and awkward nature during the historical period. For an itemized breakdown of the models see [2].

The singular models are connected together through a world market module. The general equilibrium approach whereupon the BLS is built requires that all applicable economic exercises are comprehensively addressed in the model. Monetary streams as well as product streams inside a nation and at the worldwide level are reliable in the feeling that they balance. Whatever is created will be requested, either for human utilization, feed or intermediate input; it very well may be exchanged or stowed away. Consistency of monetary streams is forced at the level of the financial specialists in the model (individual income groups, legislatures, and so on), at the national as well as the international level. This suggests that total expenditures can't surpass complete pay from monetary exercises and from abroad, as monetary exchanges, short reserve funds. On a worldwide scale, no more can be spent than what is procured. The nation models are connected through exchange, world market costs and monetary streams. The framework is solved in yearly augmentations, at the same time for all nations. It is accepted that supply doesn't change immediately to new financial circumstances. Just stockpile that will be promoted in the next year is impacted by potential changes in the financial climate. A first round of exports from every one of the nations is determined for an underlying set of world prices, and global market freedom is checked for every commodity. World costs are then overhauled, utilizing an optimizing algorithm, and again communicated to the public models. Then, these produce new homegrown equilibrium and change net products. This cycle is rehashed until the world business sectors are cleared in all items. Since these means are taken on a year-by-year premise,, a recursive dynamic simulation results. Albeit the BLS contains various kinds of models, all stick to a few normal determinations. The models contain two fundamental areas: agriculture and non-agriculture. Agriculture produces nine totaled commodities. All non-agricultural exercises are consolidated into one single total area. Production is basically reliant upon the accessibility of the demonstrated essential creation factors, i.e., of land, labour and capital. The previous is utilized exclusively in the rural area, while the last two are determinants of result in both the agricultural and the non-agricultural sectors. For farming products, land or animal numbers and yield are resolved independently. Yield is addressed as a component of manure application (harvests) or taking care of power (animals) [17]. To safeguard these interdependencies, the methodology picked was to orchestrate the rate of monetary development created in the BLS with those projected in the SRES situations through change of creation factors and of expected specialized progress. Development rates in the national models of the BLS are endogenously resolved in view of three components:

- Capital gathering through venture furthermore, devaluation, connected with an investment funds capability that relies upon slacked GDP levels as well as equilibrium of exchange and monetary guide streams;
- Elements of the workforce because of segment changes; and
- (Exogenous) specialized progress. The public level assessments were amassed into 11 wide locales.

The harmonization of production variables and GDP for the period 1990-2080 was then done on a district by-locale premise. Populace levels for each SRES situation for given timetables were taken from the CIESIN information base [17]. These levels, along with pay level, drive assessed future interest for cereal in the BLS. The BLS was first run for a reference case (i.e., expecting no climate change) for each SRES pathway (A1, A2, B1 and B2) where fluctuations in efficiency and costs are exclusively the result of the socio-economic development pathway. The model was then re-run with assessed changes in local cereal yields because climate change went into the model adjusting provincial agricultural efficiency,global food prices and the level of exposure of the global population to the risk of hunger.[16].

2.2.3 Adaptation

The information used to infer the production functions integrated farm-level adaptation techniques, for example, changes in establishing date, and use of extra preparation and irrigation system in the irrigated regions. Also, using territorial scale variation is considered by adjusting the yield changes got from the production functions in developed nations to address potential changes that require ventures like improvement of new cultivars and water system framework. Transformation that suggests economic adjustments to the yield changes is tried by the BLS world food exchange model which result in national and regional production changes and cost reactions. Financial changes addressed by the BLS include: expanded rural speculation, redistribution of farming assets as indicated by monetary returns (counting crop exchanging), and recovery of extra arable land as a reaction to higher oat costs [15].

2.2.4 Global Climate Model

The HadCM3 climate scenarios employ grids of 2 latitude by 2 longitude. At this resolution, many smaller-scale elements of climate are not well depicted, such as warm and cold fronts and hurricanes, as well as the diversities of ecosystems and land-use. Accurate modelling of hydrological processes is extremely important for determining climate change impacts on agriculture, but simulation of infiltration, runoff, and evaporation, and other hydrological processes is highly simplified. Precipitation, in particular, is poorly represented both spatially and temporally in GCMs results. This lack of realism, reduces accurate simulation of crop responses. In addition, global climate models often fail to simulate current climate in other respects, such as high- or low-pressure systems, monsoonal circulations, ocean heat transport, etc [15].

2.2.5 Results

Changes in territorial crop yields under each SRES situation are the consequence of the associations among temperature and precipitation impacts, direct physiological impacts of expanded CO2, and viability and accessibility of transformations. Atmospheric CO2 concentrations help to relieve the adverse consequence of environmental change on crop yield. Each HadCM3 environmental change situation delivered by the four different SRES discharges scenarios instigates a different development path for global crop yields. These ways don't wander, in any case, until mid-century. By the 2020s, little changes in cereal yield are obvious in all situations, yet these fluctuations are inside verifiable variations [18]. Despite the fact that there are contrasts in the mean effects of the SRES situations, the scope of the spatial variability projected is similar [2].

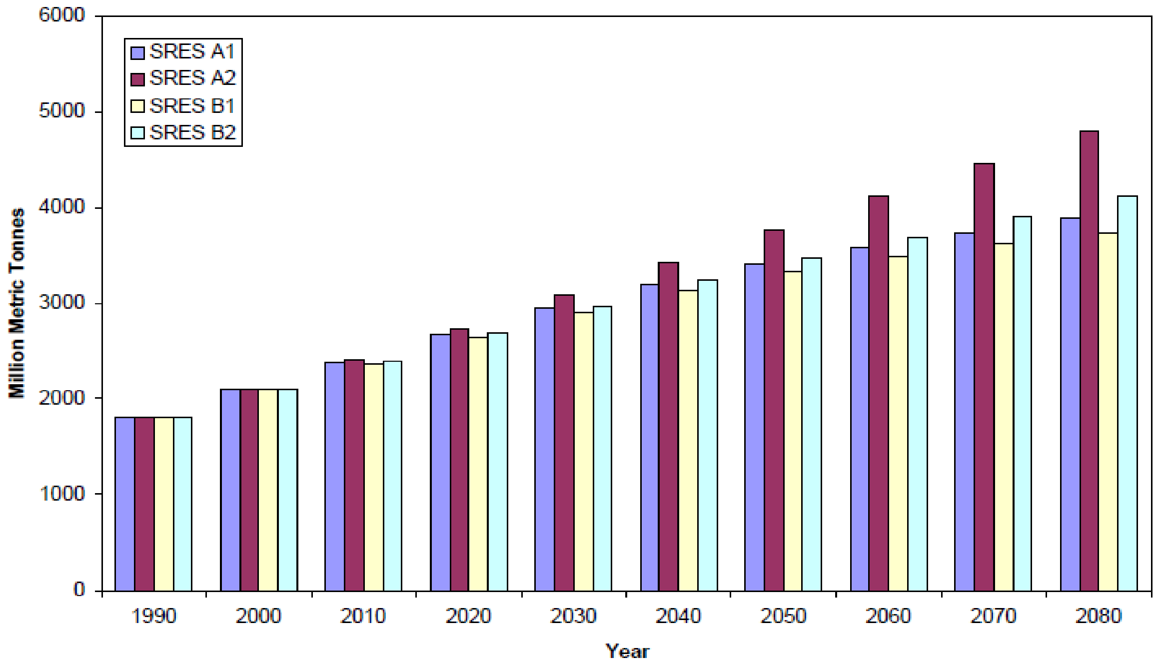


Figure 9: Future reference case estimates of cereal production under the four SRES marker scenarios (no climate change). [19]

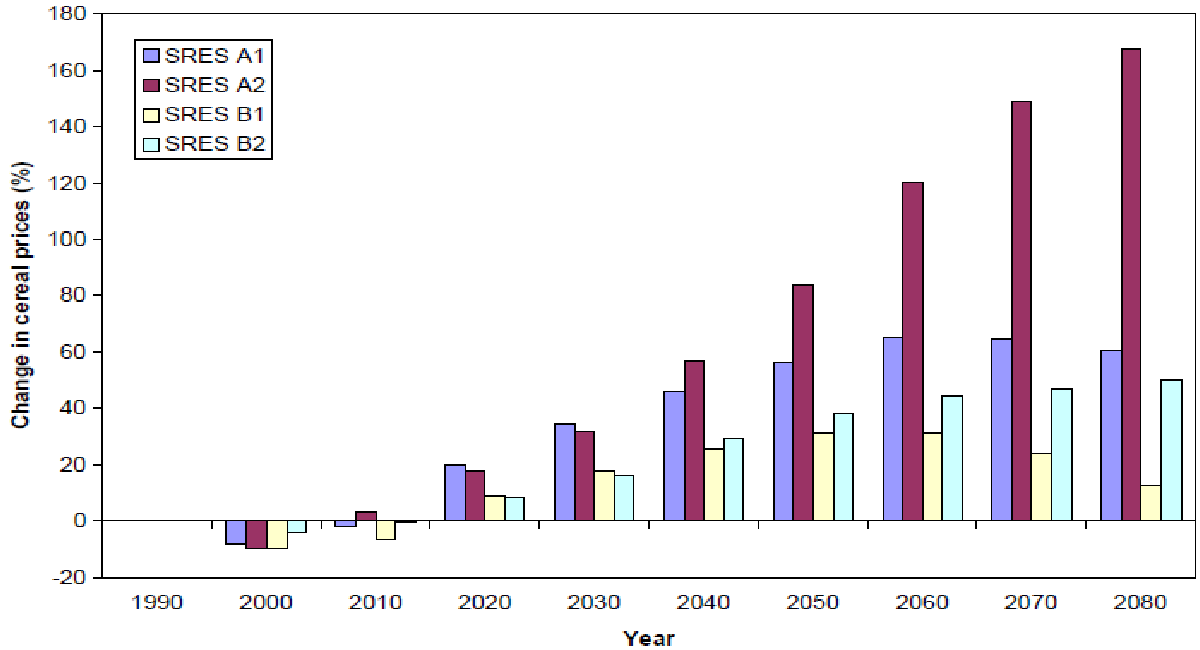


Figure 10: Future reference case global cereal prices, relative to 1990 prices, for the four SRES marker scenarios (no climate change). [19]

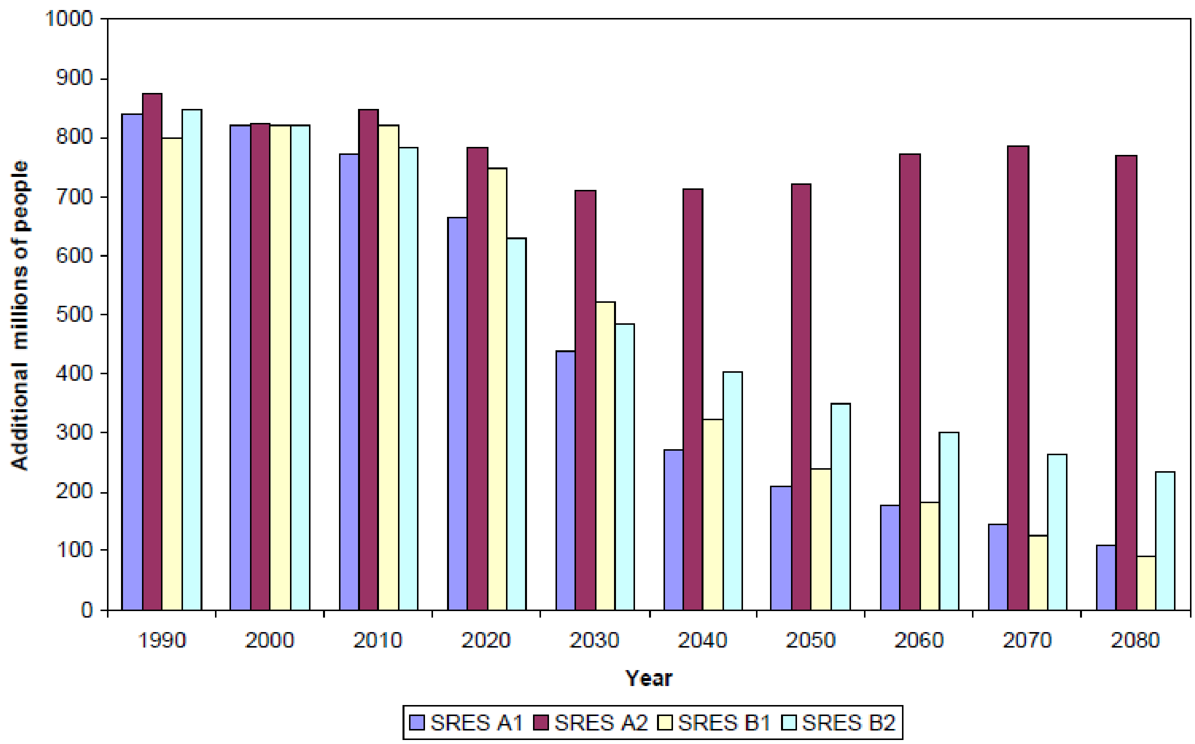


Figure 11: Future reference case estimates of the numbers of people at risk of hunger, for the four SRES marker scenarios (no climate change). [19]

3 Background Study

3.1 Climate Change

3.1.1 What is Climate Change ?

Climate change refers to long-term shifts in temperatures and weather patterns. These shifts may be natural, such as through variations in the solar cycle [20]. Since the 1800s, human practices have been the primary driver of environmental change, essentially because of consuming petroleum products like coal, oil and gas. Consuming petroleum derivatives creates greenhouse gas emissions that carry on like a wrapped blanket over the Earth, catching the sun's intensity and raising temperatures. Instances of ozone harming substance emissions that are causing environmental change incorporate carbon dioxide and methane. These come from involving fuel from driving a car or coal for heating a building, for example. Clearing land and forests can also release carbon dioxide. Landfills for garbage are a major source of methane emissions. Energy, industry, transport, structures, horticulture and land use are among the principal producers [21].

The Sun serves in as the essential energy source for Earth's environment. A portion of the incoming daylight is reflected directly once more into space, particularly by bright surfaces like ice and mists, and the rest is consumed by the surface and the environment. A lot of this consumed sunlight based energy is re-transmitted as heat (longwave or infrared radiation). The atmosphere in turn absorbs and emanates heat, some of which getaways to space. Any disturbance to this equilibrium of incoming and active energy will influence the climate. For instance, little changes in the result of energy from the Sun will influence this equilibrium directly. On the off chance that all the heat energy transmitted from the surface went through the environment directly into space, Earth's typical surface temperature would be many degrees colder than today. Greenhouse gases in the atmosphere, including water vapour, carbon dioxide, methane, furthermore, nitrous oxide, act to make the surface a lot hotter than this since they retain and radiate heat energy this way and that (counting downwards), keeping Earth's surface and lower air warm [figure12].Without this greenhouse effect, life as far as we might be concerned proved unable have advanced on our planet. Adding more ozone depleting substances to the climate makes it considerably more powerful at keeping heat from getting away into space. At the point when the energy leaving is not exactly the energy entering, Earth warms until another equilibrium is laid out [22].

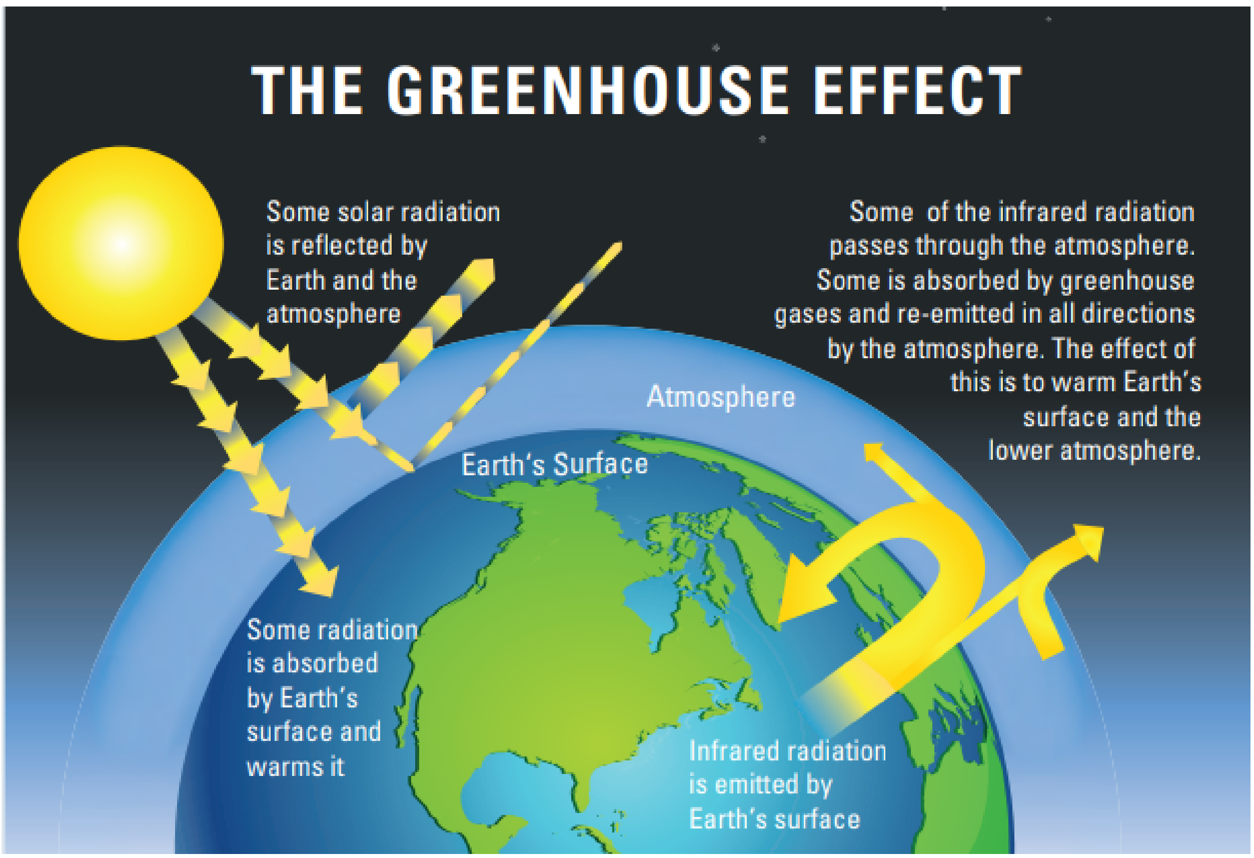


Figure 12: Greenhouse gases in the atmosphere, including water vapour, carbon dioxide, methane, and nitrous oxide, absorb heat energy and emit it in all directions [22]

3.1.2 Main Climate Changes of Importance for the Agricultural Sector

The most recent IPCC report confirms the principal discoveries of past IPCC reports about the development of the climate as well as its really actual main impacts, for example, ramifications for land and sea temperature change, ocean level ascent and sea fermentation. It additionally brings better comprehension of likely spatial changes in precipitation, in intensity and occasional dispersion. Moreover, improvements in modelling as well as in data collection and use enable making better projections on a medium-term perspective and at a much more localized scope. These enhancements are vital to all the more likely to comprehend and extend expected influences on horticultural frameworks. As expressed in the Synthesis of the last IPCC report "flowing effects of environmental change can now be credited along chains of proof from actual environment through to middle of the road frameworks and afterward to individuals [23].

There has been a rise in the comprehension of the scientific basis of what we know about climate change through the five rounds of IPCC reports. The predictions of climate change will be revised in the next few years as the design and organization of the next phase of the Coupled Model Intercomparison Project (CMIP6) was finalized in late 2014 [24].

Until CMIP6 is complete, IPCC AR5 provides the best consensus of climate chance projections. The size of warming towards the end of the twenty-first century depends solely on GHG emissions for the next decades, which are pushed by a lot of technological factors, socio-economic and , and climate policy. The Representative Concentration Pathways (RCPs) describe four different pathways of GHG emissions and atmospheric concentrations, air pollutant emissions and land use, from a stringent mitigation scenario (RCP2.6) to higher GHG emissions (RCP8.5). Regional climates vary strongly by location, especially variables associated with the water cycle (e.g. precipitation) [25].

Climate models come to a consensus that the Mediterranean and Southern Africa will be drier in the future while there is less confidence in model projections in the Sahel and West Africa. Downscaling techniques (dynamical and statistical) have been implemented to produce regional climate change predictions. Many developed countries produce downscaled climate projections on their own. There are several multi model intercomparison projects such as the Coordinated Regional Climate Downscaling Experiment (CORDEX), which covers almost all regions of the world in 14 different spatial domains. Through such initiatives, a large amount of high-resolution climate information is becoming available in regions like Africa where localized future climate information had been scarce [26].

4 Implementation

4.1 Tool Used

4.1.1 Microsoft Excel

Microsoft excel is a software program created by Microsoft that uses spreadsheets to organize numbers and data with formulas and functions. Excel analysis is ubiquitous around the world and used by businesses of all sizes to perform financial analysis. Excel is typically used to organize data and perform financial analysis. It is used across all business functions and at companies from small to large.The main uses of Excel include: Data entry, Data management, Accounting, financial analysis, Charting and graphing, Programming, Time management, Task management , Financial Modelling, Customer relationship management (CRM), Almost anything that needs to be organized [27].

4.1.2 SQL

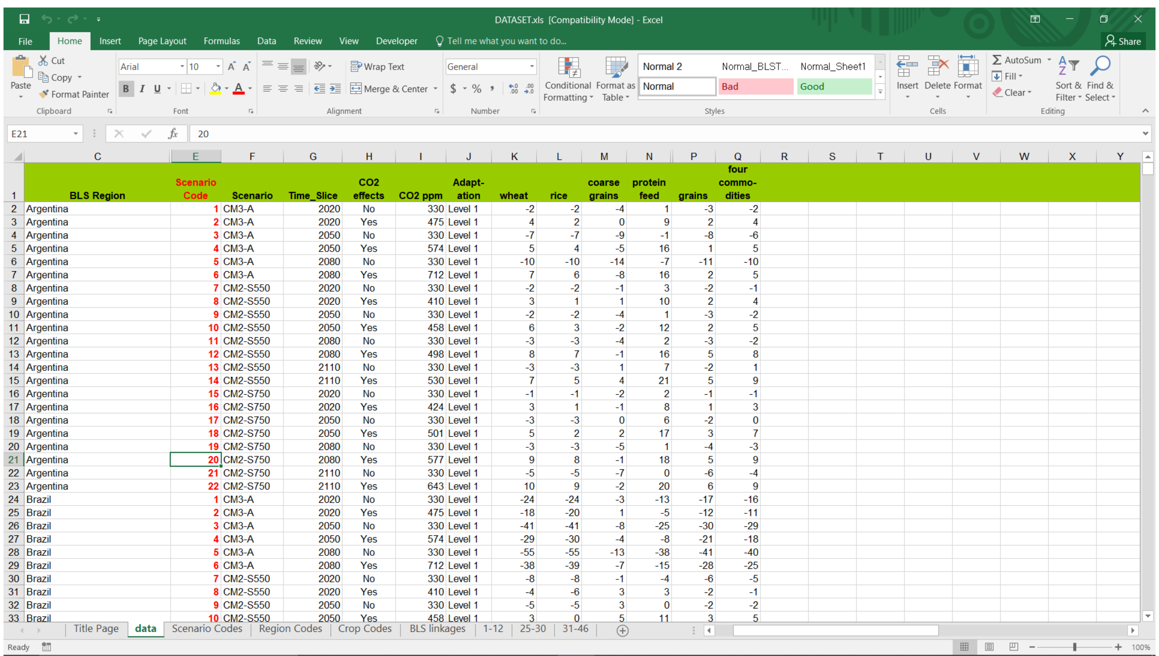
SQL stands for Structured Query Language. SQL is used to communicate with a database. According to ANSI (American National Standards Institute), it is the standard language for relational database management systems. SQL statements are used to carry out tasks such as update data on a database, or retrieve data from a database. Some common relational database management systems that use SQL are: Ingres, Oracle, Microsoft SQL Server, Sybase, Access, etc. Albeit most database frameworks use SQL, the vast majority of them likewise have their own extra proprietary extensions that are generally just utilized on their framework. Notwithstanding, the standard SQL orders, for example, "Select", "Insert", "Update", "Delete", "Create", and "Drop" can be utilized to achieve nearly all that one requirements to do with a database [28].

4.1.3 Power BI

Power BI is an interactive data visualization software product developed by Microsoft with a primary focus on business intelligence [**?**]. It is part of the Microsoft Power Platform. Power BI is a collection of software services, apps, and connectors that work together to turn unrelated sources of data into coherent, visually immersive, and interactive insights. Data may be input by reading directly from a database, webpage, or structured files such as spreadsheets, CSV, XML, and JSON. Power BI provides cloud-based BI (business intelligence) services, known as "Power BI Services", along with a desktop-based interface, called "Power BI Desktop". It offers data warehouse capabilities including data preparation, data discovery, and interactive dashboards [**?**].In March 2016, Microsoft released an additional service called Power BI Embedded on its Azure cloud platform. One main differentiator of the product is the ability to load custom visualizations [31].

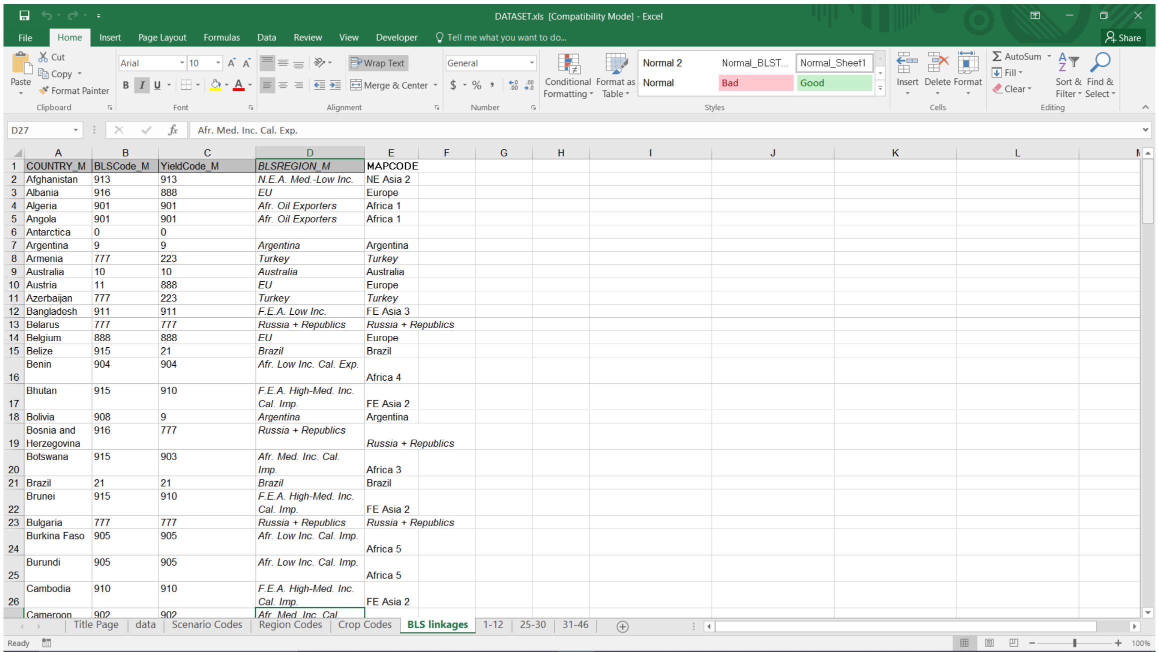
4.2 Workflow

The first step involved the the development of the project was obtaining a climate change and world food supply dataset from Kaggle. The dataset covered 8 countries, namely: Argentina, Brazil, Turkey, Russia, USA, India, Kenya and Nigeria. It contained crop data for wheat, rice, coarse grains and protein feed, time slices (2020, 2050, 2080 and 2110), models and scenarios used, CO2 effects and ppm level. Each model has been tested for each crop in all the countries with the different levels of CO2 injection at different ppm levels.



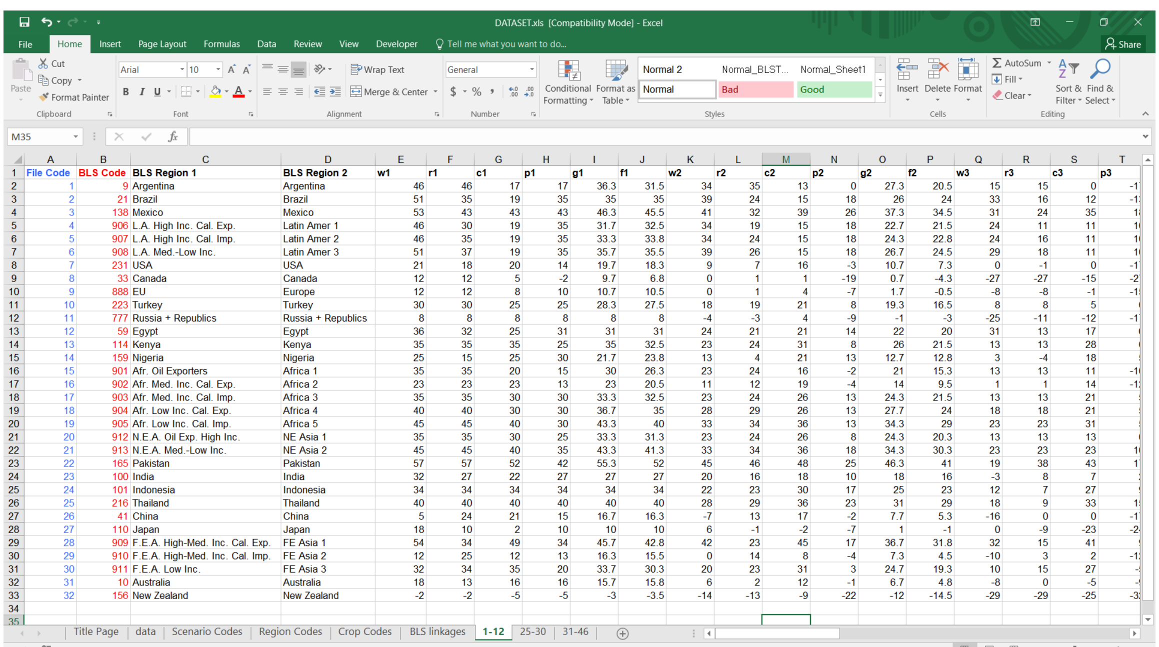
	BLS Region	Scenario Code	Scenario	Time_Slice	CO2 effects	CO2 ppm	Adapt-ation	wheat	rice	coarse grains	protein feed	grains	four commo-dities
2	Argentina	1	CM3-A	2020	No	330	Level 1	-2	-2	-4	1	-3	-2
3	Argentina	2	CM3-A	2020	Yes	475	Level 1	4	2	0	9	2	4
4	Argentina	3	CM3-A	2050	No	330	Level 1	-7	-7	-9	-1	-8	-6
5	Argentina	4	CM3-A	2050	Yes	574	Level 1	5	4	-5	16	1	5
6	Argentina	5	CM3-A	2080	No	330	Level 1	-10	-10	-14	-7	-11	-10
7	Argentina	6	CM3-A	2080	Yes	712	Level 1	7	6	-8	16	2	5
8	Argentina	7	CM2-S550	2020	No	330	Level 1	-2	-2	-1	3	-2	-1
9	Argentina	8	CM2-S550	2020	Yes	410	Level 1	3	1	1	10	2	4
10	Argentina	9	CM2-S550	2050	No	330	Level 1	-2	-2	-4	1	-3	-2
11	Argentina	10	CM2-S550	2050	Yes	458	Level 1	6	3	-2	12	2	5
12	Argentina	11	CM2-S550	2080	No	330	Level 1	-3	-3	-4	2	-3	-2
13	Argentina	12	CM2-S550	2080	Yes	498	Level 1	8	7	-1	16	5	8
14	Argentina	13	CM2-S550	2110	No	330	Level 1	-3	-3	1	7	-2	1
15	Argentina	14	CM2-S550	2110	Yes	530	Level 1	7	5	4	21	5	9
16	Argentina	15	CM2-S750	2020	No	330	Level 1	-1	-1	-2	2	-1	-1
17	Argentina	16	CM2-S750	2020	Yes	424	Level 1	3	1	-1	8	1	3
18	Argentina	17	CM2-S750	2050	No	330	Level 1	-3	-3	0	6	-2	0
19	Argentina	18	CM2-S750	2050	Yes	501	Level 1	5	2	2	17	3	7
20	Argentina	19	CM2-S750	2080	No	330	Level 1	-3	-3	-5	1	-4	-3
21	Argentina	20	CM2-S750	2080	Yes	577	Level 1	9	8	-1	18	5	9
22	Argentina	21	CM2-S750	2110	No	330	Level 1	-5	-5	-7	0	-6	-4
23	Argentina	22	CM2-S750	2110	Yes	643	Level 1	10	9	-2	20	6	9
24	Brazil	1	CM3-A	2020	No	330	Level 1	-24	-24	-3	-13	-17	-16
25	Brazil	2	CM3-A	2020	Yes	475	Level 1	-18	-20	1	-5	-12	-11
26	Brazil	3	CM3-A	2050	No	330	Level 1	-41	-41	-8	-25	-30	-29
27	Brazil	4	CM3-A	2050	Yes	574	Level 1	-29	-30	-4	-8	-21	-18
28	Brazil	5	CM3-A	2080	No	330	Level 1	-55	-55	-13	-38	-41	-40
29	Brazil	6	CM3-A	2080	Yes	712	Level 1	-38	-39	-7	-15	-28	-25
30	Brazil	7	CM2-S550	2020	No	330	Level 1	-8	-8	-1	-4	-6	-5
31	Brazil	8	CM2-S550	2020	Yes	410	Level 1	-4	-6	3	3	-2	-1
32	Brazil	9	CM2-S550	2050	No	330	Level 1	-5	-5	3	0	-2	-2
33	Brazil	10	CM2-S550	2050	Yes	458	Level 1	3	0	5	11	3	5

Figure 13: Crop Data in Excel



COUNTRY_M	BLSCode_M	YieldCode_M	BLSREGION_M	MAPCODE
Afghanistan	913	913	N.E.A. Med.-Low Inc.	NE Asia 2
Albania	916	888	EU	Europe
Algeria	901	901	Afr. Oil Exporters	Africa 1
Angola	901	901	Afr. Oil Exporters	Africa 1
Antarctica	0	0		
Argentina	9	9	Argentina	Argentina
Armenia	777	223	Turkey	Turkey
Australia	10	10	Australia	Australia
Austria	11	888	EU	Europe
Azerbaijan	777	223	Turkey	Turkey
Bangladesh	911	911	F.E.A. Low Inc.	FE Asia 3
Belarus	777	777	Russia + Republics	Russia + Republics
Belgium	888	888	EU	Europe
Belize	915	21	Brazil	Brazil
Benin	904	904	Afr. Low Inc. Cal. Exp.	Africa 4
Bhutan	915	910	F.E.A. High-Med. Inc. Cal. Imp.	FE Asia 2
Bolivia	908	9	Argentina	Argentina
Bosnia and Herzegovina	916	777	Russia + Republics	Russia + Republics
Botswana	915	903	Afr. Med. Inc. Cal. Imp.	Africa 3
Brazil	21	21	Brazil	Brazil
Brunei	915	910	F.E.A. High-Med. Inc. Cal. Imp.	FE Asia 2
Bulgaria	777	777	Russia + Republics	Russia + Republics
Burkina Faso	905	905	Afr. Low Inc. Cal. Imp.	Africa 5
Burundi	905	905	Afr. Low Inc. Cal. Imp.	Africa 5
Cambodia	910	910	F.E.A. High-Med. Inc. Cal. Imp.	FE Asia 2
Cameroon	902	902	Afr. Med. Inc. Cal.	

Figure 14: All existing BLS regions with yield and map codes



File Code	BLS Code	BLS Region 1	BLS Region 2	w1	r1	c1	p1	g1	f1	w2	r2	c2	p2	g2	f2	w3	r3	c3	p3
1	9	Argentina	Argentina	46	46	17	17	36.3	31.5	34	35	13	0	27.3	20.5	15	15	0	[illegible]
2	21	Brazil	Brazil	51	35	19	35	35	35	39	24	15	18	26	24	33	16	12	[illegible]
3	138	Mexico	Mexico	53	43	43	43	46.3	45.5	41	32	39	26	37.3	34.5	31	24	35	[illegible]
4	906	L.A. High Inc. Cal. Exp.	Latin Amer 1	46	30	19	35	31.7	32.5	34	19	15	18	22.7	21.5	24	11	11	[illegible]
5	907	L.A. High Inc. Cal. Imp.	Latin Amer 2	46	35	19	35	33.3	33.8	34	24	15	18	24.3	22.8	24	16	11	[illegible]
6	908	L.A. Med.-Low Inc.	Latin Amer 3	51	37	19	35	35.7	35.5	39	26	15	18	26.7	24.5	29	18	11	[illegible]
7	231	USA	USA	21	18	20	14	19.7	18.3	9	7	16	-3	10.7	7.3	0	-1	0	[illegible]
8	33	Canada	Canada	12	12	5	-2	9.7	6.8	0	1	1	-19	0.7	-4.3	-27	-27	-15	[illegible]
9	888	EU	Europe	12	12	8	10	10.7	10.5	0	1	4	-7	1.7	-0.5	-8	-8	-1	[illegible]
10	223	Turkey	Turkey	30	30	25	25	28.3	27.5	18	19	21	8	19.3	16.5	8	8	5	[illegible]
11	777	Russia + Republics	Russia + Republics	8	8	8	8	8	8	-4	-3	4	-9	-1	-3	-25	-11	-12	[illegible]
12	59	Egypt	Egypt	36	32	25	31	31	31	24	21	21	14	22	20	31	13	17	[illegible]
13	114	Kenya	Kenya	35	35	35	25	35	32.5	23	24	31	8	26	21.5	13	13	28	[illegible]
14	159	Nigeria	Nigeria	25	15	25	30	21.7	23.8	13	4	21	13	12.7	12.8	3	-4	18	[illegible]
15	901	Afr. Oil Exporters	Africa 1	35	35	20	15	30	26.3	23	24	16	-2	21	15.3	13	13	11	[illegible]
16	902	Afr. Med. Inc. Cal. Exp.	Africa 2	23	23	23	13	23	20.5	11	12	19	-4	14	9.5	1	1	14	[illegible]
17	903	Afr. Med. Inc. Cal. Imp.	Africa 3	35	35	30	30	33.3	32.5	23	24	26	13	24.3	21.5	13	13	21	[illegible]
18	904	Afr. Low Inc. Cal. Exp.	Africa 4	40	40	30	30	36.7	35	28	29	26	13	27.7	24	18	18	21	[illegible]
19	905	Afr. Low Inc. Cal. Imp.	Africa 5	45	45	40	30	43.3	40	33	34	36	13	34.3	29	23	23	31	[illegible]
20	912	N.E.A. Oil Exp. High Inc.	NE Asia 1	35	35	30	25	33.3	31.3	23	24	26	8	24.3	20.3	13	13	13	[illegible]
21	913	N.E.A. Med.-Low Inc.	NE Asia 2	45	45	40	35	43.3	41.3	33	34	36	18	34.3	30.3	23	23	23	[illegible]
22	165	Pakistan	Pakistan	57	57	52	42	55.3	52	45	46	48	25	46.3	41	19	38	43	[illegible]
23	100	India	India	32	27	22	27	27	27	20	16	18	10	18	16	-3	8	7	[illegible]
24	101	Indonesia	Indonesia	34	34	34	34	34	34	22	23	30	17	25	23	12	7	27	[illegible]
25	216	Thailand	Thailand	40	40	40	40	40	40	28	29	36	23	31	29	18	9	33	[illegible]
26	41	China	China	5	24	21	15	16.7	16.3	-7	13	17	-2	7.7	5.3	-16	0	0	[illegible]
27	110	Japan	Japan	18	10	2	10	10	10	6	-1	-2	-7	1	-1	0	-9	-23	[illegible]
28	909	F.E.A. High-Med. Inc. Cal. Exp.	FE Asia 1	54	34	49	34	45.7	42.8	42	23	45	17	36.7	31.8	32	15	41	[illegible]
29	910	F.E.A. High-Med. Inc. Cal. Imp.	FE Asia 2	12	25	12	13	16.3	15.5	0	14	8	-4	7.3	4.5	-10	3	2	[illegible]
30	911	F.E.A. Low Inc.	FE Asia 3	32	34	35	20	33.7	30.3	20	23	31	3	24.7	19.3	10	15	27	[illegible]
31	10	Australia	Australia	18	13	16	16	15.7	15.8	6	2	12	-1	6.7	4.8	-8	0	-5	[illegible]
32	156	New Zealand	New Zealand	-2	-2	-5	-5	-3	-3.5	-14	-13	-9	-22	-12	-14.5	-29	-29	-25	[illegible]

Figure 15: Crop Data against BLS Regions

4.3 Visualization

Power BI was used to visualize the analyzed results from the dataset.

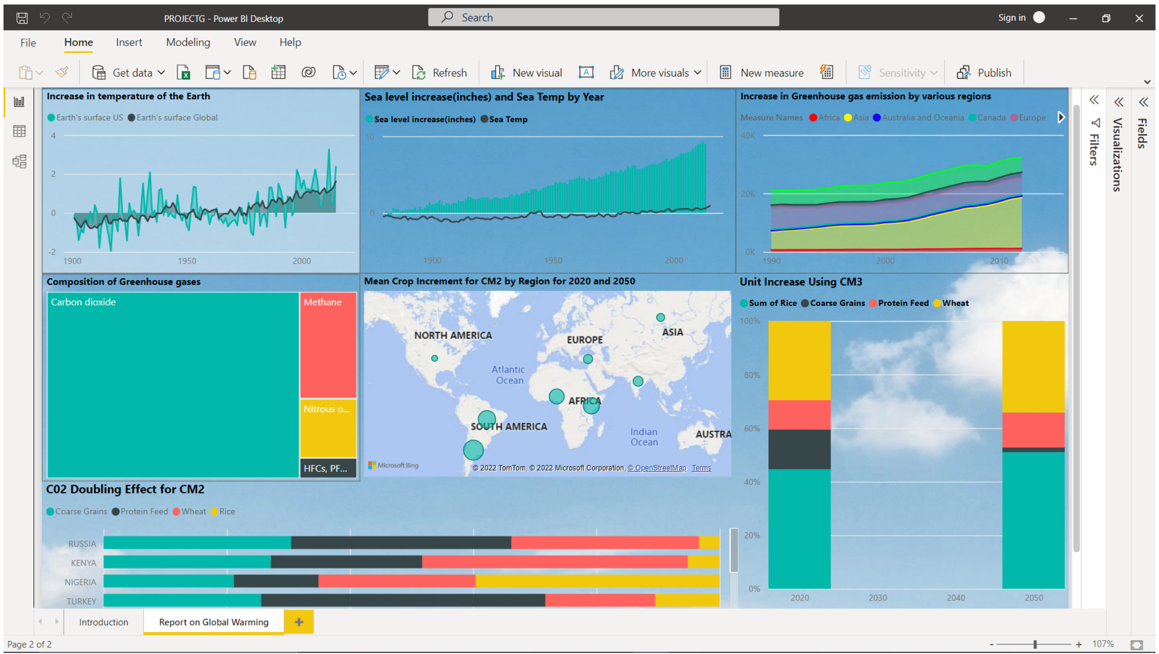


Figure 16: Full view of dashboard

Looking at Figure 17, we notice in the CM2 map representation, bubble size increases the further down you go. This is due to the fact that the CM2 model performs best with the position of the region it is tested on. The lower down in the southern hemisphere you go the better the reactions and output that will be gotten. The average percentage increase is lowest in Russia because it is highest up the the northern hemisphere among all the countries and highest is in Argentina.

Figure 17: Map representation of results

Figure 18 shows the % increment of crop production when tested with the CM3 model. Rice and Wheat are the top gainers, this is due to the low level of amino acid contain in the crops. It shows that the CM3 model is not concerned with the position or region of crop, rather it deals more with the constituents of the crops seeing as it is a combination of an ocean model and atmospheric model.

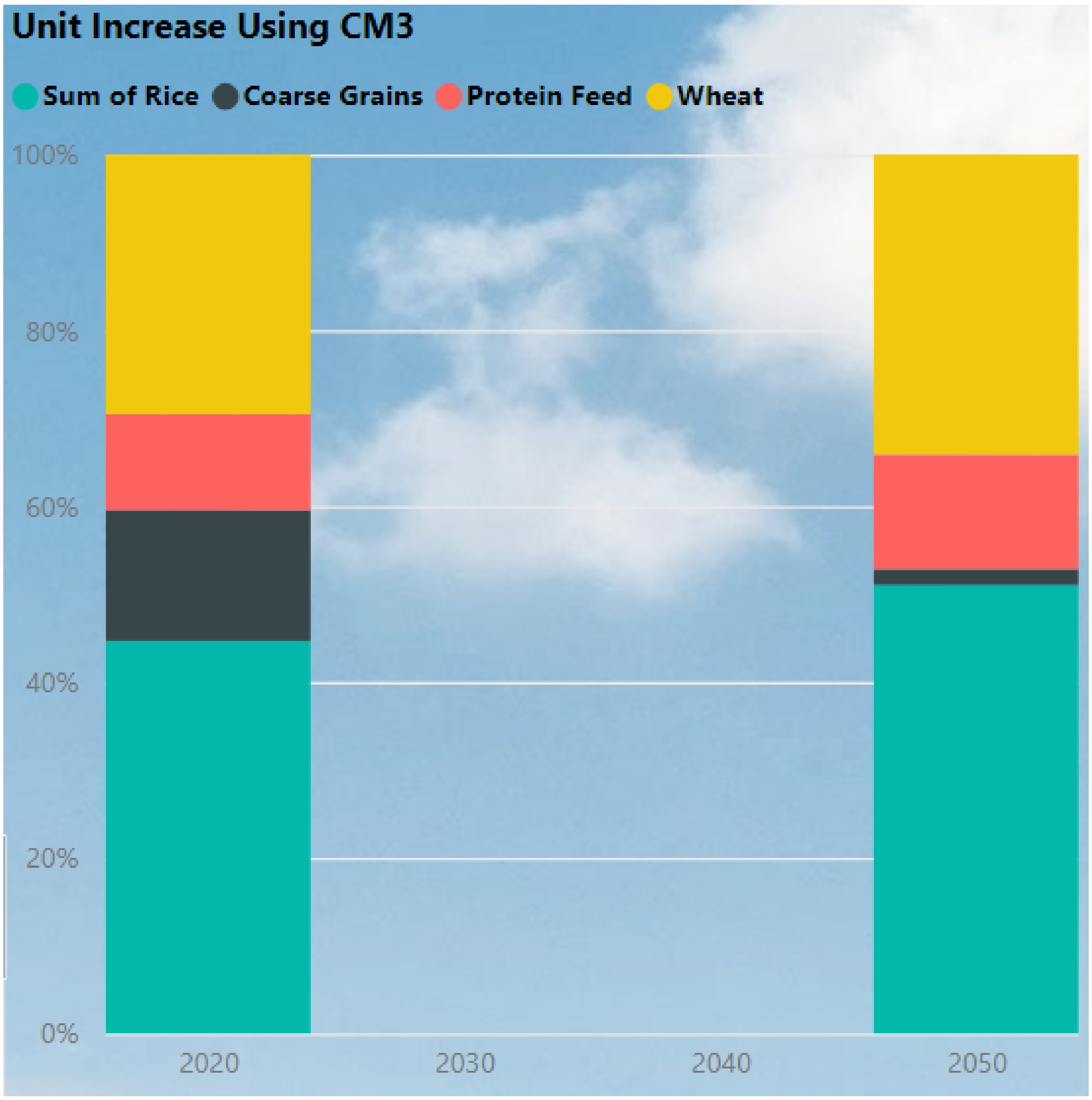


Figure 18: CM3 Barchart

5 Conclusions

This research has focused on determining the impact of climate change of world food supply using global climate model in different conditions. When using the HADCM2 model, the focus crops reacted well but the rate of production didn't meet expectations. The crops had higher output for the model only when C02 levels were double whereas the HADCM3 model did not need any doubling. The rate of production increased exponentially with no harm to the crops.
Both models are good depending on how and where you want to implement them but the HADCM3 model outperforms HADCM2.

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I thank God Almighty for giving me the strength and grace to be able to complete my research, none of this would be possible without God.

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