Use of APSIM Model for accessing impact of Climate Change on Soybean (*Glycine max* L.) Germplasm in Vindhyan Region of Madhya Pradesh

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Abstract: ***Soybean (Glycine max L.) is an important global legume crop that grows in the tropical, subtropical and temperate climates. Like peas, beans, lentils and peanuts, it belongs to the large botanical family, Leguminosae, in the subfamily Papilionideae. The soybean crops are more sensitive to higher cumulative heat units during cropping season and the yields are affectedsignificantlydue to temporal variations in amount of rainfall and alsofluctuation in occurrence of monsoon.The available simulation studies with the use of APSIM model of the researchers on the crop shows possible effects of future climate change on soybean yields in the selected region for doubled atmospheric CO2 level and with weather variables using the available seasonal projections for the future. The current studies show that response of elevated CO2 concentrations in the atmosphere suggest higher yields for soybean crop. However, a 38C rise in surface air temperature almost cancels out the positive effects of elevated CO2 on the yield. Soybean crops at some sites are more susceptible to increases in maximum temperature than in minimum temperature and the rainfall with uneven distribution during the monsoon season could be a critical factor for positive result. In this study authors have made an attempt to summarise the possible impact of climate change studies on soyabean crop using simulation models like APSIM.***

Keywords: APSIM model Soybean yields; CO2 effects; Climate change; Water and thermal stresses,

1. Introduction

The climate change has widespread impact on agricultural productivity and in the future it will a prominent factor that will shape and control the food security on earth. Agriculture is very much susceptible to climate change and, at the extreme end, it may become one of the major elements for climate change. The greatest challenge of the era is to interpret the weather changes over period of time and to achieve better harvest in by correcting the management practices. The most unavoidable climatic changes in currentperiods is the rise in the atmospheric temperatures due to increased levels of greenhouse gases such as carbon dioxide (CO2), methane (CH4), ozone (O3), nitrous oxide (N2O) and chlorofluoro carbons (CFCs). Due to theproliferating concentrations of these radiative or greenhouse gases, there is increased concern about future changes in our climate and its straight or incidental effect on agriculture **[1].**In India, studies by several authors have shown that during the last century there is observed increasing trend in surface temperature and significant fluctuating trend in rainfall. In recent years the scientific community have come, with the growing awareness about the possibility of global climate changeand their emphasis on world food security in general has increased. And for this they also consider regional impacts in relation to climate change and agriculture **[1-3].**

The weather condition of the region during the growing season govern the growth and development of crop, its water use pattern and yield under normal conditions.A small deviation from the normal weather cause major impact on food production even in the presence and application of extremely applied inputs like fertilizers, pesticides etc.Unto preindustrial period (1850) the carbon dioxide (CO2) concentration was in the stable state at 280 ppm. It is rising since then at the rate of 1.5 to 1.8 ppm per year after the start of industrialization. It is forecasted and assumed that if no proper measures are adopted, the concentration of CO2 is expected to be doubled by the end of 21st century.Various types of the studies including the open top chambers and FACE technology are currently being used check and estimate response of crop plants to the elevated CO2 levels. Results from such studies have revealed an increase in plant photosynthetic rate and crop yield in Kimball. These studies also revealed that increase in net photosynthetic rate results in greater accumulation of sugar which contributed significantly to the accelerated development of leaves and tillers and all this increased grain yield **[4].**The accelerating CO2 concentration in the atmosphere results in global warming. This has anticipated that these climate changeswill most probably affect future global agricultural production through changes in rate of plant growth and transpiration. Agriculture plays an important role in overall economic and social well-being of India. The studies have shown that the share of agriculture in both Gross Domestic Product (GDP) and employment has declined over time, but it is also noted thatdeterioration in its share in employment has been much slower than that of GDP. The statistical data revel thatthe share of agriculture in GDP is declined from 39% in 1983 to 24% in 2000-01 But its share in total employment decreased from 63 % to 57% during this period. This shows that the farming still has much impact on employment besides the fact that agricultural productivity is decreasing. Deteriorations in the share of agriculture in GDP were not corresponding with the fall in dependency in agriculture. The slowdown of agriculture productivity resulted in land fragmentation and small land holding which led to the inefficiency in agriculture, increased unemployment, and low marketable surplus**[5].**These factors have multiplier effect on the vulnerability to global environmental change. In India, average food consumption at present is 550gm per capita per day which is much lower than in China and USA, where the corresponding figures are 980gm and 2850gm, respectively. Present annual requirement based on present consumption level (550gm) for the country is about 210 Million Tonnes (Mt), which is almost equal to the current production. While the area under food grain, for instance, fell from 126.67mha to 124.24 mha during the period from 1980-81 to 2003-04, the production registered an increase from 129.59 Mt to 212 Mt during that period **[4-7].**

Climate change and soybean productivity:

The food production in year 2003-04 was remarkably better and 4 times more than the production of 50.82 Mt in 1950-51. However, due to the overgrowing population of country which is likely to reach 1.30 billion by the year 2020, it is amajor challenge to intensify its food production to the tune of 300 million tons by 2020. To meet this demand for food from this increased population, the country's farmers need to produce 50 % more grain. The problem has been accelerated by urbanization and industrialization due tofastdecrease in the per capita availability of arable land from 0.48 ha in 1950 to 0.15 ha by 2000. It is projected that it will further condense to 0.08 ha by 2020. According to the national average 40 % of the total cropped area are only irrigated and out of it 60 % of the total cropped area is still rainfed and dependent on uncertainties of monsoon. This displays the reliance of Indian agriculture on climate. Furthermore, if certain climate change situationsoccur, agricultural production in most of areas may reduce.**[8].**

Sinha et al. conducted studies and they had a great concern about many limiting factors like decline in soil fertility, change in water table, rising salinity, resistance to many pesticides and degradation of irrigation water quality in north-western India. It is evidenced that more nutrients have been removed than added through the fertilizers in the soil over the time period of 20-30 years, and the farmers have to apply more fertilizers to get the same yield which they were getting with fewer fertilizers in the past. Climate change will further affect and deteriorate soil conditions. Changes in the climatic factors like temperature and in precipitation patterns and amount, will have direct impact on soil water content, run-off and erosion, salinization, biodiversity, and organic carbon and nitrogen content in the soil. The rise in temperature would resultamplified rate of transpiration. According to climate the"Kharif" and "rabi" are two major crop growing seasons in India. The "kharif" also termed as summer crop grow season in the moth between June Septemberduring the southwest monsoon. Rice, maize, sugarcane, cotton, jute, groundnut, soybean and Bajra, etc are the major 'kharif' crops. Depending on crop duration, 'kharif' crops can be harvested during the October-Novemberor winter December-February months. The "kharif" crops accounts for more than 50% of the food-grain production and 65 % of the oilseeds production in the country and the southwest monsoon is important factor that decide the productivity of kharif crop. The inconsistency of inter annual monsoon rainfall in India results to large-scale droughts and floods, which has consequential effect on Indian food grain production and on the economy of the country. The winter or 'rabi' crop-growing season starts after the summer monsoon, and lastsover to the following spring or early summer **[5,9].**

Rainfall occurring at the end of the monsoon season brings stored soil moisture and often irrigation water for the rabi crop sow in the post-monsoon season (October-November). This shows that summer monsoon has major impact for both kharif and rabi crop production in India. The main 'rabi' crops that are cultivated in India includes wheat, mustard, barley, potato, onion and gram, etc. The Indian food security measures are also threatened by the Global warming due to its negative effect on agriculture. At first instance the increasing CO2 concentrations will increase the net primary productivity of plants, but as the climate changes it leads to changes in disturbance regimes associated with them and this may lead to both increase and decrease in net ecosystem productivity. The studies have revealed that the potential yields willprobably to decrease for most projected increases in temperature in many tropical and subtropical regions. There are many other factors which affect the crop's vegetative and reproductive growth like changes in the air temperature especially nocturnal temperature resulting indirectly due to increase in the level of CO2 and other trace gases and changes in the moisture availability. The farm resources like fertilizers, and pest population impacts the crops by developing a new equilibrium between crops and pests **[10].**

Indirectly, there may be significant effects on land pattern use due to melting of snow, submergence of coastal lands, inconsistency in spatial and temporal rainfall, accessibility of irrigation facilities, frequency and intensity of inter- and intra- seasonal droughts and floods, soil organic matter transformations, soil erosion, change in pest profiles, and availability of energy. All these factors have significant impact on agricultural production and hence, food security of any region Aggarwal [4]. The increasing temperatures and carbon dioxide leveland fluctuating in rainfall pattern triggered with global warming may or may not have serious direct and indirect consequences on crop production. It is, therefore, important to have an assessment of the direct and indirect consequences of climate change and global warming on different crops especially on cereals contributing to the food security. Mechanistic crop growth models like APSIM are now routinely used for assessing the impacts of climate change **[11].**

Climate change as Temperature, CO_2 and Rainfall:

The impact assessment of the climate change on the crops can be done with the many available crop models.These Crop models usually integrate current knowledge from various disciplines like agrometeorology, soil physics, soil chemistry, crop physiology, plant breeding, and agronomy and the related impact on growth, development and yield of a crop can be assessed and predicted with the help of set of mathematical equations. In most of the climate change studies these crop models are based on long-term historical weather data. In general, minimum 30 years of historical weather data are ideal to represent annual weather variability and after thisdifferent climate change scenarios can used to these data records for conducting the studies. The modestmethodof conducting such research is to commencewith a fixed climate change factor and to changeits data with a constant number, such as an increase or decrease of 1, 2, 3^{0}C, etc. for temperature. Similarly, rainfall and solar radiation can be changed with a certain percentage, such as an increase or decrease of 10, 20, 30 %, etc. These changes are then applied to the daily water data and the crop simulation models are run with these modified inputs **[13].**General Circulation Models (GCMs) are based on more accurate approach which use the outputs from the modified historical weather data. The studies has revealed that the increasing atmospheric CO2 concentrations has positive impact on crops that utilize the C3 photosynthetic pathway including many staple foods such as wheat, soy and rice but these benefits could counterbalancedby the challenges imposed by climatic stressors, such as heat and drought as there areintensifications in the occurrence and severity of them. It is specific that due to all these climatic stresses initially plants are expected to experience stimulation of photosynthesis that will directly increase yield, and later on it will also result in reduced stomatal conductance that will lower water use and thereby result in drought stress. Still it is too early to forecast these outcomes as most of these studies are conducted and limited relatively cool and wet environments. Sharon Gray from the University of Illinois at Urbana-Champaign, US and co-workers conducted a study with open air field experiment by manipulating precipitation and CO2 concentrations and utilized year-to-year variations in weather conditions for the period of eight-year on soybean crops and collected the data to investigate the interacting effects of these climatic factors on crops.**[12-15].**

In India until 1965 the research on soybean cultivation was minor and had least contribution to crop. The breeding objectives were focused on germinability and longevity, resistance to shattering and lodging, early and medium duration, four seeded pods, profuse podding and quality and resistance to biotic and abiotic stresses. So far there are about 100 improved soybean varieties developed by the modern techniques of hybridization and mutation breeding and these varieties are possessing various improved traits. Important traits such as drought tolerance, photoperiod insensitivity, resistant to diseases such as rust, charcoal rot, and YMV, resistance to insects such as stem borers and defoliators, and food uses such as vegetable types, high oil content, high oleic acid content, low lipoxygenase content and null Kunitz Trypsin inhibitor were identified. To enhance the efficiency of breeding programmes using molecular tools, the QTLs for high seed longevity and markers for YMV resistance genes were identified. For harnessing the optimum productivity for a rainfed crop optimum phenology for harnessing maximum yield of rainfed soybean in Central India has been worked out **[6,16].**

The exaggerated drought and effect of increased CO2 treatments on yield was found to reduce to nil. This unexpected result occurred because elevated CO2 interacted with drought to modify stomatal function, canopy energy balance and nitrogen uptake. The positionof soy production is at concerning point under these interacting global climatic change factors. A study has been conducted by using CROPGRO-soybean model in Central India and it projected 50 % increased yield for soybean for a doubling of CO2. However, a 3˚C rise in surface air temperature almost cancels out the positive effects of doubling of carbon dioxide concentration resulting in reducing the total duration of the crop which impacts the yield by inducing early flowering and reduced the grain filling period. Increase in maximum temperature in Central India during Soybean crops season are found to be more vulnerable to than in minimum temperature. The precipitation and grain are negatively correlated and studies shows that decrease in daily rainfall amount by 10% confines the grain yield to about 32 %. They concluded that this severe water stress as a result ofcontinued dry spells during monsoon season could be a dangerous factor for the soybean productivity even under the positive effects of elevated CO2 in the future **[17].**

General Description Including Taxonomy and Morphology, and Use as a Crop Plant

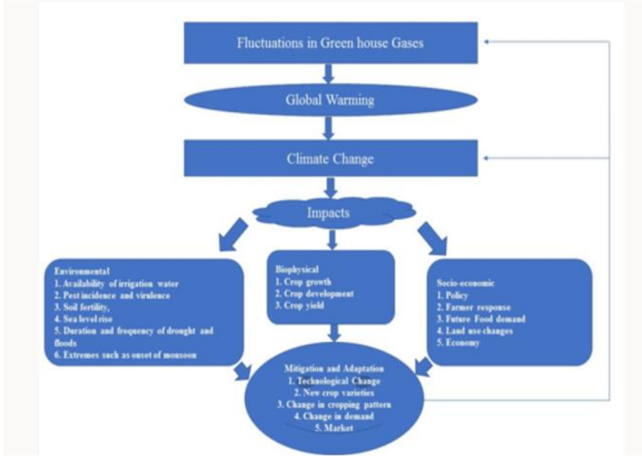
Cultivated soybean, *Glycine max* (L.) Merr., is a diploidized tetraploid (2n=40) plant. It belongs to the family Leguminosae, the subfamily Papilionoideae, the tribe Phaseoleae, the genus *Glycine* Willd. and the subgenus *Soja* (Moench). Morphologically it is an erect, bushy herbaceous annual plant and can reach up to a height of 1.5 metres.There are three types of growth habitfound amongst cultivated varieties of soybean which includes determinate, semi-determinate and indeterminate. The main characteristics of determinate growth is termination ofvegetative growth of the terminal bud when it becomes an inflorescence at both axillary and terminalracemes and these genotypes are primarily grown in the southern United States (Maturity Groups V toX). Indeterminate genotypes have vegetative growth throughout the flowering period and are cultivatedmostly in central and northern regions of North America (Maturity Groups 000 to IV). Semi-determinate types have indeterminate stems that terminate vegetative growth abruptly after the flowering period. Studies shows that the available soybean varieties are not frost tolerant, and they do not survive in freezing winter conditions **[19].**There are three types of the leaves present in the leaves in Glycine max which includes primary, secondary and compound leaves. The primary leaf are characterised by unifoliate, opposite and ovate in orientation, whereas the secondary leaves are trifoliolate andalternate, and compound leaves are in form of four or more leaflets which are only occasionally seen. The rootsystem is tap root system with root nodules from which emerges a lateral root system with nodules. The plants of most cultivars arecovered with fine trichomes, but glabrous types also occur. The flower is papilionaceous and consists of a tubularcalyx of five sepals, a corolla of five petals characterised by one banner, two wings and two keels. These is one pistil and ninefused stamens present inthe form of a single separate posterior stamen. The stamens show a special phenomenon one day before pollination by forming a ring at the base of the stigma and elongating. The elevated ring formed by the anthers around the stigma facilitates the pollination process**[18-20].**

The pod is generally straight or slightly curved in shape and it varies in length from two to seven centimetres. The pod consists of twohalves of a single carpel which are joined by a dorsal and ventral suture. The seeds are generally oval in shape, can vary in shape amongst cultivars from almost spherical to elongate and flattened.Soybean is grown as a commercial crop in more 35 countries and the major producers of soybeans includes the countries likeUnited States, China, Democratic People's Republic of Korea and Republic of Korea, Argentina andBrazil. Soybean serves as one of the major sources of edible vegetable oil and of proteins for livestock feed use. Soybean is grown chiefly for the production of seed, has a many uses in the food andindustrial sectors. It amounts as a major food used in North America and Europe in the forms of purified oil, utilised in margarines, shortenings and cooking and salad oils. It is also used in the form ofsemi processed food products like tofu, soya sauce, soymilk and meat products. To feed the livestock with protein the Soybean meal is used as a supplement. Many industrial usesof soybeans accounts from the production of yeasts and antibodies to the manufacture of soaps anddisinfectants**[21].**

Agronomic Practices

Garner and Allard, 1920 concluded that Soybean is a quantifiableshort-day plant and hence it flowers more quickly in short days. As a result, photoperiodism and temperature response is important factor that impact areasof cultivar adaptation. Soybean cultivars adaptation aredetermined by latitude and day length. In North America from MG 000 in the north (45° latitude) to MG X near the equator, there are thirteen maturity groups (MG) of the soybean cultivars. Within each maturity group, cultivars aredescribed as early, medium or late maturing.The germination of seeds takes place at the 10℃ of soil temperature and seedling will emerge in 5 to 7 day period when the conditions are favourable. The areas where soybean cultivation is new requires an inoculation with *Bradyrhizobiumjaponicum* for optimum efficiency of the nodulated root system. Soybeans do not produce good harvest on acid soils and in such soils the addition of limestone may be required to boost the production. Soybeans are often rotated with such crops ascorn, winter wheat, spring cereals, and dry beans **[22].**

Figure 1: Soybean plant [37].



Global integrated impact assessment models though provide such a framework. These models are not validated at that scale and due to their inherent inter-and intra-sectoral conflict becomes inadequate for regional policy planning **[50].**We need to urgently develop our own integrated assessment simulation models in which cropping systems, water use and socioeconomic parameters need to be brought together for assessing the impact of regional climatic changes in different regions of the country. It may be developed in collaboration with several stakeholders including policy makers, agricultural and environmental scientist, climatologist, economist, administrators, industry and farmer's organization **[49-52].**

2. Conclusion

The changes in the global climate is impacting future production of all food and feed crops. Soybean is no exception of it and to ensure an efficient supply of in future, we must begin to understand how climate impacts both the phenological development of this crop and the productivity. The two climatic factors are temperature and precipitation and these will will have a major impact on phenology and productivity of soybean crop. The warming climate will increase the phenological development because relatively constant number of thermal units required for leaf appearance during phenological development. *Glycine max* (L.) Merr. is the cultivated species of soybean. It is a summer annual herb that has never been found in the wild. This domestication of*Glycine max*is in fact extremely variable across the globe and is primarily an outcome of development of soybean "land races" in East Asia. The subgenus *Soja* contains three species which are *G. max*, G. *soja*, and G.*gracil*. Whereas G.*gracil*is considered as *a* morphologically intermediate form between the other two species.*Glycine soja*,is an annual procumbent or slender twiner that is distributed throughout China, the adjacent areas of the former USSR, Korea, Japan and Taiwan and itis also regarded as the ancestor of cultivated soybean. It is generally found growing in hedgerows, along roadsides and riverbanks.There is need for assessing effect of climate change on productivity of soybeanin different regions and different sectors of Indian economy in order to determine future strategies for sustainable development.

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