15 Climate Change and Agriculture: A Review of Crop Models

S. Mulla, Sudhir Kumar Singh, K. K. Singh, and Bushra Praveen

Abstract

The clear evidence of climate change impact demands proactive role by scientists, agronomist and meteorologist for upscaling agricultural production, precision forecast and food safety, especially in the tropical region. The crop simulation model suggests probable growth, development and crop yield for soil-plant-atmosphere dynamics assessment. Decision Support System for Agro-Technology Transfer Model (DSSAT) is an application-based model that gives the best-suited recommendations to achieve sustainability in the agriculture by means of simulation of users' minimum experimental data that includes weather data pertaining to site, crop growth period, and data concerning the soil, crop management practices, etc.

Identification of the weather and climate-sensitive problems due to extreme weather events on agriculture in any region can be achieved by crop model. Validation and calibration of crop simulation model is necessary with the help of field experimental data which will contain sensitive analysis, impact of epochal (temperature time period), various temperature ranges, different levels of radiation and CO_2, different dates of sowing and various nitrogen and water treatments. Extreme climate change impacts on phenological stages, the growth of a plant, dry matter partitioning to different plant organs for all seasons also need to

S. Mulla
India Meteorological Department, Pune, Maharashtra, India

S. K. Singh (✉)
K. Banerjee Centre of Atmospheric and Ocean Studies, University of Allahabad, Prayagraj, Uttar Pradesh, India

K. K. Singh
India Meteorological Department, New Delhi, India

B. Praveen
IIT Indore, Indore, Madhya Pradesh, India

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be studied. Validation, linking and analysis of climate change data for different Representative Concentration Pathway (RCP) with bias-corrected climate change data and crop model data using Decision Support System for Agro-Technology Transfer Model (DSSAT) and probability distribution model will be required to investigate climate change impacts on crops. Based on these results, the formulation of:

(a) A multi-pronged plan of using local coping machinery, wider adoption of the existing technologies and/or concerted research and development efforts for evolving new technologies needed for adaptation and mitigation in rainfed and irrigated areas.
(b) More precise weather-based agromet advisories for soil, crop yield, crop condition on a spatial and temporal basis to minimize losses and increase the economy of farmers and country. Optimized inputs like land preparation, selection of crop and cultivars, date of sowing, date of harvesting, irrigation scheduling, pesticide and fertilizer application, crop growth, extreme weather events, adaptation and development of flexible and dynamic Farm Management Information System (FMIS) strategies and other value-added services, etc. can be provided for farming community.

The research can also be extended by doing a detailed analysis of estimation of soil moisture, evapotranspiration, insolation, vegetation index, growing degree days, standard precipitation index, and land surface temperature. The statistical study of estimated values of above said parameters using probability distribution model, root means square error and bias value of simulated data will be helpful for the development of a hydro-meteorological model, agriculture applications, irrigation planning over arid/semi-arid zones and forecasting systems.

Keywords
Decision Support System for Agro-Technology Transfer Model (DSSAT) · Crop simulation model · Climate change · Adaptation · Mitigation · Sustainability · Agromet advisories · Farm management

15.1 Introduction

The successful application of crop development models in agricultural meteorology and climate change studies are important in the present scenario. Agriculture is susceptible to climate inconsistency and predictable climate change. The combination of the crop simulation model and worldwide climate models predict an increase of global warming leading to the exposure of major crops to temperature stress and a decrease of yields of an uncertain magnitude for every region. Unlike in the fields of physics and engineering, universal models does not exist within the agricultural sector. Therefore, crop yields expressed as a polynomial or exponential mathematical function of defined variables, with regression coefficient analysis, are site-specific. The information obtained can only be applied to a site where climate, soil parameters and crop management practices are similar in nature to those used during developing of original functions. Several models are built to simulate crop to achieve an enhanced harvestable yield. Application-based crop simulation model which incorporates intensive data on biological and crop phenology provide more accurate results. Most of the farmers in developing countries particularly in India experience socio-economic backwardness, fragmented land holdings, rainfed farming and limited adaptive capacity impel the farmers to yearn for sustainable agricultural practices. The issues of agricultural sustainability, food security, adaptation methods and strategies to increase food productivity, farmer's income, conservation of water/environment, policy decisions, researcher, economics, environmental studies, etc. can be articulated with climate modelling and crop simulation modelling. This chapter provides a comprehensive overview of the crop simulation model, climate change assessment and mitigation and adaptation strategies and policies.

Agriculture sources are accountable for 18% of worldwide greenhouse gases (GHGs) emissions and are the potential threat to the stratospheric ozone layer. An estimation is made that emission ranges from 32.84 Gg (1980–1981) to 93.82 Gg (2000–2001) per year, and it may occur in the Indian continent which is likely due to rise in the expansion of cropping area, use of nitrogen (N)-fertilizers and animal population (Bhatia et al. 2004). The regional patterns of climate change are altered by radiative forcing associated with anthropogenic emissions and related negative effects of climate conditions. Variations at all levels include modification of the length of growing season, water availability and the creation of disturbance by extreme weather regimes (heat/cold waves, flood, drought, fires, pest outbreaks and diseases). World's livestock and paddy cultivation are the major sources of emission of methane gas, and about 35% of gas liberation is mainly contributed by India (Bhatia et al. 2004). Deforestation is also a key source of Greenhouse Gases (GHGs). During the past 100 years, more than 60% of greenhouse gases are added to the atmosphere (WRI 2001) amongst which Indian agriculture emanates about 0.23% (Bhatia et al. 2004).

The changes in rainfall pattern (south-western/north-eastern monsoon) will result in the reduction in yields over rainfed areas because of increased crop water demand. The subdued effects of climate change on the quality of fruits, vegetables, tea, coffee, aromatic, cereal crops and medicinal plants have been observed. The more frequent extreme weather events such as floods, droughts, cyclones and heat/cold waves will have unfavourable effect on agricultural productivity. The occurrence of cold waves and frost events may decrease in the future due to global warming and it would lead to a decreased probability of yield loss associated with frost damage. Climate change will check the nutritional and food security of agriculturally important animals like livestock because an increase in temperature would increase the lignifications of plant tissues, lower the digestibility, increase the water scarcity, etc. The decrease or scanty rainfall, the rise of mean temperatures, sea level, severe frequent occurrences of drought, cyclones, floods, heat/cold waves are also a great threat to agricultural biodiversity. The comprehensive rise of CO_2 concentration is remunerative because it increases photosynthesis in most of the crops, especially for C3 plants like wheat and rice. Amongst the majority of cereals crops, wheat crop was observed to show marked reduction in yield due to decrease of grain filling duration, higher respiration rate of the plant and/or lowering of rainfall/irrigation supplies. Amount of severe soil erosion or frequent change in it may happen due to alteration in the rainfall pattern, volume and frequency as well as wind intensity. The aggravation of heat stress in dairy animals will negatively affect their reproductive performance. Alteration in the rainfall pattern may influence and enhance vectors during wetter years causing large epidemics of diseases. In India, organic matter content of the soil is low and it will be further degraded. As regards the higher C:N ratio in crop plants, the decomposition rate and nutrient supply rate were found to be reduced markedly. High soil temperatures will enhance the nitrogen mineralization and its accessibility may lower due to nitrogen losses through volatilization and de-nitrification process. Conventional agricultural practices in the coastal region will be hampered badly by an increase in the sea level caused due to inundation of salty water in the coastal lands. The rise in the temperature of sea, ocean and river may likely affect the breeding, migration and harvests of fishes. Also, the cyclonic activities would have an impact on their capture, production and marketing.

15.2 Impact of Climate Change on Agriculture

Worldwide majority of the population mainly depends on rice as a daily food intake. There is evidence of negative impacts of climate variability on crop growth and yield. Mean temperature above threshold value results in the reduction of rice yield. In case of rice crop, the variability in minimum temperature is found to be more significant than the variation in the maximum temperature. "For every 1 °C increase in the growing season's minimum temperature above 32 °C lowers the grain yield by 10%" (Pathak et al. 2003). Aggarwal (2008) showed that rice yield in Punjab (India) decreases by 5.4%, 7.4% and 25.1% for every increase in temperature by 1 °C, 2 °C and 3 °C, respectively, by keeping all other climatic variables constant. Further, growth and development of rice and wheat crop are found to be negatively affected by increases in minimum and maximum temperature (Venkatramanan and Singh 2009a, b). During maturation and ripening phase of wheat crop, high temperature has proven to be disadvantageous for wheat crop production because of terminal heat stress. Intermittently more than normal temperature regimes, scanty rainfall or poor irrigation condition restricts the grain maturity phase and resulted in shrinking grain size. Degradation of wheat yield (q/ha) around 10–15% is caused by terminal heat stress. Each growth stage of plant receives a certain amount of heat energy necessary for growing called as "Heat Unit" and depends upon the base temperature. Early sown crop like wheat, barley, peas, oats, etc. have a base temperature of 40 °F, for corn 50 °F and for cotton 60 °F, and at these temperatures crop growth is appreciable. Crop base temperature is subtracted from actual daily mean temperature. Summation of this daily heat unit is known as "day-degrees/degree-days/heat-unit/thermal unit".

When the standard mean temperature is more than the base temperature, the heat unit gets accumulated. As regards the sugarcane crop, the base temperature of 70 °F is found to be suitable for crop establishment. Within the range of 80–90 °F growth becomes optimum at which absorption of nutrients and growth are at the best level. Below 70 °F, growth is reduced, phosphorous and nitrogen intake is decreased, and above 100 °F, the growth is detrimental. Komuscu et al. (1998) suggested a rise of 4–43% soil water deficit by experiencing the warming of 2 °C and 8–91% for a warming of 4 °C by applying the Thornthwaite water balance model plus boosting of evapotranspiration considering hydrological simulation model. It is also projected that the climate change will increase the frequency of weather hazards which will further decrease the mean yield of vulnerable crop plants.

15.3 Role of Crop Model in Climate Change Scenario

In tropics and sub-tropics, the useful effects of carbon dioxide will be compensated by means of the boosting in temperature, resulting in crop yield loss and increased demand for irrigation. An appropriate understanding of climate change impact will help aid to scientists, agronomist, meteorologists to advise farmers in a suitable way and provide crop managing decisions, viz. choice of crops, probable dates of sowing and irrigation scheduling. Farmers' suitably modify and adopt appropriate agricultural technologies that can in effect lessen the negative impacts of climate change. The crop simulation model has potential to be used in climate change studies to understand the potential impacts of changing climate on food system. DSSAT CROPGRO is a primary package which modifies weather simulation generators. Ignoring few limitations of GCMs, it would be in the better interest of world's farming community that the DSSAT modellers consider precise plus acceptable weather generator parameters, i.e. outcomes of GCMs for further application in the simulation models. This will facilitate in finding out the solution under the climate change scenario for creating an excellent quality crop production, specifically in underdeveloped and developing countries.

It is necessary to understand the relationship between crop growth and yield behaviour under climate change. Modelling approach could contribute towards a more efficient research model in form of a tool as crop planning. Crop modelling is increasing day-by-day and is applicable in research, teaching, farm and resource management, policy analysis, crop yield forecasting, etc. Simulation model permits the integration of knowledge across crops and in disciplines for a specific crop, e.g. productivity analysis, alteration of soil fertility status over time. A particular and precise knowledge can be achieved on genetic traits of economic yield which includes integrated genetic improvement programs already available in the model. Presently, a crop simulation model and its results became the boon in agricultural research and for farming applications. The two famous models frequently used in agro-meteorological studies are the De Wit School of models and the IBSNAT and DSSAT models. A brief discussion about simulation models and their utility for yield analysis are explained below.

15.3.1 The CANEGRO Model

CANEGRO is a leading sugarcane crop simulation model and has been used extensively in agronomic research and management. The model has been under development since the late 1980s at the South African Sugarcane Research Institute (SASRI).

15.3.2 The Erosion-Productivity Impact Calculator (EPIC) Model

Beginning in 1981, a mathematical model called the erosion-productivity impact calculator (EPIC) model was developed to determine the relationship between soil erosion and soil productivity throughout the USA. Soil attrition risk caused by cropping practices and tillage can be evaluated by the EPIC model. The model provides five evapotranspiration equations, namely, Penman-Monteith, Penman, Priestley-Taylor, Hargreaves and Baier-Robertson. Optional choice is reserved with EPIC modeller to opt for any suitable and appropriate simulation exercise. Using the same single data file, the model is capable enough to simulate and observe the growth of many crops. The model is applicable in the tropical areas and it is possible to do the multi-and-intercropping rather than mono-cropping. The model run provides the output of yields for early and late crops, chief and small crops, both heliophytic (light loving) and sciophytic (shade loving) crops, creeping and climbing crops. EPIC also supplies information of simultaneous modelling for changes in the crop environment like moisture and nutrients as these are the limitations on the productivity of tropical agricultural crops. The EPIC crop model is used for estimation of agricultural yield per unit area as well as total crop area of land planted and assessment of strategies for management of climate variability and climate change on harvest yields, the vulnerability of agricultural production and adaption option.

15.3.3 The NTKENAF

NTKENAF (Version 1.1) simulates the growth of kenaf under rainfed conditions in tropical Australia. In daily time steps, the model simulated the phenology, leaf area development, biomass accumulation and partitioning, soil water balance and dry matter yields of kenaf plants based on climatic and management inputs. The model assumes adequate nutrition and no effect of pests and diseases. The model uses daily maximum and minimum temperature, solar radiation and rainfall. The duration from sowing to flowering is predicted using temperature and photoperiod. Leaf growth is described as a function of node production (as determined by temperature), leaf area per node and leaf area senescence. Potential daily biomass is predicted from the leaf area index, the light extinction coefficient and radiation use efficiency and partitioned to the economic stem yield. Soil evaporation is predicted using a two-stage evaporation model, and plant transpiration is predicted from the daily biomass accumulation, a transpiration efficiency coefficient and predicted daily vapour pressure deficit.

15.4 DSSAT Model

Crop simulation model mainly DSSAT is the most suitable and capable of superior functioning compared to other models like an analytical, statistical, empirical and combination of two. Historic simulation models used to simulate only two parameters such as photosynthesis and carbon balance. Moreover, the statistical models were used to correlate the approach and were giving yield estimates for a large area but only restricted to use final yield data for correlation with mean weather parameters on a regional basis. To overcome these shortcomings of old models, the DSSAT model was invented which facilitates maximum input details for all crops. Thus, the total model approach has been updated in the DSSAT crop simulation model.

15.4.1 Features of DSSAT Simulation Model

Agriculture is a backbone of major parts of the world and livelihood of millions of people. In the direction to meet up these necessities, IBSNAT (International Benchmark Sites Network for Agrotechnology Transfer) has started to use the model from 1982 onwards under the agreement received from the "U.S. Agency for International Development" to "the University of Hawaii" at Manoa, USA. IBSNAT is the project on analysis and simulation system to give various choices to user end regarding alteration which ultimately focus on the production as "decision support system" competent of simulating the future threats and on the sequence of optional choices, through a multi-institute and multidisciplinary approach. To run the DSSAT model needs a number of data in order to simulate outcomes, testing and implementation of output to resolve the global agricultural issues for particular sites. DSSAT has maximum utility with respect to other simulation models.

15.4.2 DSSAT as a Tool

DSSAT used as a driver to propose for crop management, examine ecological similarities, the natural constraint of crops, material features of soil plus giving them the management alternative for better land use preparation and matchless sustainability issues.

15.4.3 DSSAT as a Business Tool

It develops effectiveness and improvements in input marketing. While, the conventional testing is time taking and expensive, use of DSSAT reduces the cost and time involved in evaluation of newly developed cultivars. In the projected climate change situation, fresh outcomes for prediction of accurate cultivar coefficient and dynamic of crop models will identify narrow crop gaps in biophysical aspects. Such effect will surely increase agricultural productivity.

The two-stage approach in DSSAT model is adopted to evaluate the crop simulation model as sensitivity analysis and validation. The sensitivity evaluations facilitate to find out as whether the crop model under consideration possibly will be used for examination of an a priori *hypothesis.* The evaluation shows the estimated output harvest specified by the model is acceptable although by doing modifications in the environmental parameters, viz. appropriate use of fertilizers by which enhancement of yield production may be expected.

15.4.4 Calibration and Validation in DSSAT

Calibration, or parameter estimation, is a difficult but critical aspect of a crop modelling project. Predictions from a model are heavily dependent on calibration of models. Adjustment of input parameters is required in order to match the simulated results with observational results. Validation is a precise test which compares the original interpretation with the model output results obtained with similar environments existing at the time of original data were prepared. For further precise as well as reasonable outcome, no gaps amongst observations and forecast are typically illustrated within the model calibration. Validation method includes qualitative as well as a quantitative comparison of virtual production and experiential production. As regards the water-soil-crop model, it is very crucial to authenticate the extractable wetness and leaf region constituents because the biomass accreditations are mainly dependent on these factors. Crop data reveals the soil heterogeneity along with the changes in environmental parameters during the growing phase of the crop.

15.4.5 Potential Heat Unit Calculation of DSSAT

A meticulous quantity of potential heat units (PHU) is compulsorily needed for the different growing stage and in the ripening stages of any crop variety under consideration. The choice of PHU is therefore depended upon the user at the time of generating the new operations schedule file (OPS). In case of unknown or anonymous crop type, the modeller can reduce the gap amongst the virtual and experimental yield observation thereby regulating the amount of PHU in the operation schedule file (OPS) (Easterling et al. 2000). Simultaneously modeller can add phenological data of the unknown cultivar type.

15.4.6 Sensitivity Analysis in DSSAT

The assumptions of work are concerned about whether the model possibly will repeat the sensitivity of the original information systems or not. During the sensitivity experiment, archival of weather data is used. However, for climate change scenario, those weather data/variables will no more exist. In such circumstances, mock data can be accessed via GCM and these data are within the tolerance and in the satisfactory range. Since there exist a few uncertainties related to the prediction of climate change, researchers make use of projected climate scenarios to give an approximation of how the climate is likely to affect a particular targeted system. In case of farming production, scenarios are being derived from GCMs and random sensitive tests, for example, +2 and + 4 °C temperature changes and +/−10% precipitation change are suggested for the approximation of probably expected changes in yield and other important relevant variables of agronomical type.

15.4.6.1 Sensitivity Analysis for Seasonal Rainfall Data

For sensitivity analysis of seasonal rainfall data, one has to obtain climate and daily weather data records from the station. For example, in the simulation model, if the particular crops are sown on 1 June for each year and then the same crop is harvested on 30 August. The normal practice of farmer is to wait for the initial intense rainstorm to sow the crops. Additional delay may create the risk of harvest failure as a consequential effect of sudden termination of the rainy season later on in the current season of the year. Furthermore, during the progressive rainy season, there is less reception of solar radiation at the earth's surface causes the lessening effect of vegetative and reproductive growth which ultimately give a considerable decrease in yield. Therefore, farmers can choose an option to simulate crop for early-maturing varieties which will be popular on local levels. For example, a few types of maize crop grown-up within 120 days from sowing and other varieties mature within 90 days.

DSSAT sensitivity analysis is not restricted to rainfall data only but also includes temperature, radiation and carbon dioxide concentration using anticipated incremental scenarios for climate change impact assessments. In view of this, it is suggested that "incremental changes in temperature and precipitation is supposed to be combined with the baseline climate data to create incremental scenarios".

15.4.7 Application of DSSAT Model

DSSAT applications range from real-time decision support for crop management to assessing the potential impact of climate change on global food security. Crop models are also invaluable as heuristic devices that help to identify research problems where our current knowledge has limits and further research is needed. The ability of crop models to simulate how different weather years or soil conditions affect crop performance make models especially useful in research involving climatic uncertainty or geospatial variation. Recent advances in field phenomics and crop genomics are opening opportunities for crop models to support research in fundamental plant science.

15.4.7.1 CERES-Maize Model

CERES-Maize model is modified to improve the simulation of the site-specific crop development and yield. It is a prognostic and deterministic model intended towards simulation of maize development. Soil, water, temperature and soil nitrogen dynamics are at a field level for the single growing season. CERES-Maize model in DSSAT needs the set of six numbers of cultivar specifications and its relevant parameter used for calibration purpose. Amongst six cultivars, four types, namely, P1, P2, P5 and PHINT, manage the timing of phonological phase, while the remaining two cultivar types, namely, G2 and G3, are the characteristics to characterize the prospective yield under most favourable environment. The GLUE model is being run and simultaneously performed the sensitivity analyses with the same crop coefficients. Also, the tested cultivar's coefficients were calculated through the calibration process available in the model.

Upon the introduction of hybrid genotypes, maize has an important position amongst the cereal crops. Under the future climate change assessment, it is essential to identify the detail crop growth behaviour of the hybrid crop model for a variety of environment. The DSSAT model is calibrated and validated by using the actual field data; therefore, the crop growth model is vital in describing the study of changeability performance. The model performance is assessed through phenology, biomass at harvest phase, leaf area index and grain yield performance. The simulated outcomes were in good agreement by means of the experimental value and also these are within the statistical significance limit. Biomass, to some level, was the above forecasted value in the model simulation output but within the significant limit. Simulated and practical phenologies, as well as yields, were also in close concurrence with the experimental values. Decision Support System for Agro-Technology Transfer Model (DSSAT) version 4.6 have been successfully applied for simulation of growth and yield of hybrid maize developed under different biotic and abiotic stresses, including evaluation of the climate change impact.

15.4.7.2 CANEGRO Model

Singels et al. (2008) have shown that there is a satisfactory forecasted value of Brazilian sugarcane in southern Brazil (Marin et al. 2011; Nassif et al. 2012). The model calculated the daily increase of entire biomass by utilizing the radiation use efficiency approach (Singels and Bezuidenhout 2002), CO_2 concentration and CO_2 fertilization effect algorithm. In addition to the photosynthesis, DSSAT/CANEGRO also simulates the effect of CO_2 on stomata resistance and transpiration (Long et al. 2004) method of Allen et al. (1985).

15.4.7.3 SALTMED Model

Models are convenient tools in agricultural aspects of an irrigation scheduling, estimation of crop water requirement, prediction of yields and soil salinization for distinct irrigation systems, soil categories, crops and trees. The current version, SALTMED 2015, contains extra sub-models, crop growth as per the heat units/degree days, crop rotations, nitrogen dynamics, soil temperature, dry matter and yield, subsurface and deficit irrigation with the partial root drying (PRD), drainage flow to tile or open drain systems, presence of shallow groundwater and evapotranspiration (ET) using Penman-Monteith equation. It has numerous options for acquiring the canopy conductance. The current version permits up to 20 fields or treatments to run simultaneously.

15.5 Uncertainties in the Assessment of Climate Change

The key areas of uncertainty that are possibly to impact on worldwide scales are agricultural productivity, meteorological, hydrological and plant physiological as per the illustration received from the model performance. In global-scale assessments, it is found that there is inadequate capability to confine the uncertainty in projected climate extreme weather hazard and that of in pests and diseases. Agricultural reliance on the regional rainfall, glaciers melting and pollution has added extra complexity in the climate uncertainties. Meandering impact of an increase in sea level, storm surges, diseases to plants and human have also not yet been quantified. In the current scenario, the collective effect of climate change on a global scale agricultural efficiency cannot be consistently quantified.

Under climate variability scenario, scientists, meteorologists and researchers have a great challenge to know the requirement of crop growth, yield production, identification and potential use of agricultural land in order to maintain the sustainability of agriculture. These weather scenarios are highly uncertain about their occurrences and impacts. The literature showed that these high winters (October–December) or post-monsoon temperature detriments the rabi crops production especially wheat crop due to terminal stress. Also a remarkable increase in temperature during winter season, intense and more foggy days and extreme rainfall (cloud burst, snowfall, hailstorm etc.) are projected impacts caused by climate change and climate variability during the second half of the twenty-first century. Indian states and city, viz. Kerala, Uttarakhand and Mumbai city, recently showed extreme rainfall occurrences due to cloud burst and vigorous SouthWest-monsoon systems which caused a lot of living and non-living losses. As such, there is no considerable change or enhancement in the temperatures during SouthWest-monsoon season (June–September). But, the erratic and uncertain behaviour of monsoon rainfall will adversely affect the agriculture, livelihood and economy.

15.6 Mitigation and Adaptation of Agriculture

With the help of national governments, mitigation and adaptation are the main tasks as considered by international bodies (Ali et al. 2017). Equally important mitigation and adaptation methods are needed in the present scenario to diminish the impacts of climate change. Mitigation refers to the prevention or reduction of emission of heat-trapping GHGs in the atmosphere. Other meaning of mitigation is to apply advance technology or renewable energy sources for improvement in efficient agricultural management system.

Adaptation is not at all a substitute for mitigation because we know that quick climate change is still sustained and stabilization of GHG concentrations will go beyond an optimistic evaluation capacity to regulate. Adaptation is equally important and in numerous cases, it provides a significant decrease in adverse impacts. A measure of such adaptation offers co-benefits to progress goals by making them principally more attractive. The way to lower "Urban Heat Island Effect" is to enhance greenery by tree plantation. Urban heat island effect also increases the threat from severe heat waves to biodiversity (Kikon et al. 2016; Nhemachena and Hassan 2007).

Modification according to present & future climate change is known as "adaptation". Adaptation includes increase capacity to face adverse climate change impact and lowering the susceptibility of agriculture. However, there are scientific and economic constraints which impede the timely needed actions of adaptation. The main aim is to diminish susceptibility which has a destructive impact specifically on agriculture caused by climate change. Mitigation and adaptation to climate change depend on availability and access to quality seeds, resource-efficient crop cultivation practices, conservation and management of agricultural biodiversity and pro-active extension system delivering innovative technologies from lab to land and empowering the farmers through awareness and training.

15.7 Conclusion

Climatic changes and climatic variability are the greatest challenge for soil, food and water system. Uses of crop simulation models and climate change scenarios with higher spatial and temporal resolution are significant to dissect the impacts of climate change on water availability, crop yield, crop water productivity and soil water balance. Crop yield will be restricted by crop selection, sowing zones, soil deficiency, changing climate and water accessibility throughout the crop growth period. DSSAT is a deterministic, dynamic, specified and optimized crop model. DSSAT identifies optimise crop management plan to stimulate biomass accretion, forewarns pest & diseases, compares actual and simulated grains yield, provides detailed crop characteristics etc.

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