Chapter 15
Adapting Improved Agricultural Water Management and Protected Cultivation Technologies—Strategic Dealing with Climate Change Challenge

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15.1 Introduction

15.1.1 The Essence of Food Production

The Food and Agricultural Organization (FAO) of the United Nations has conducted a study and suggested that by the year 2050, the population may increase by 2.3 billion; hence, food production should be increased to meet the growing demand of the estimated population. Standards of living in the developing countries are expected to improve along with the economic growth and uplifting poverty levels, which may tend to increase the food demand in the market continuously. As a basic need, the food supply, according to the demand, is a major concern to all the countries. However, food is a resource that mainly depends on climatic conditions, available natural resources and growers' economic status.

15.1.2 Climate Change and Agriculture

Climate change indicates a change that occurred in global air temperature, the pattern of precipitation and wind and other climatic parameters that took place over a number of decades or longer.

A general increase of average earth temperature affects weather and environmental ecosystem for an extended period due to increasing greenhouse gases in the atmosphere, which causes the greenhouse effect. According to the United Nations' Intergovernmental Panel on Climate Change (IPCC 2001 report), the average global

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A. Pandey et al. (eds.), *Hydrological Aspects of Climate Change*,
Springer Transactions in Civil and Environmental Engineering,
https://doi.org/10.1007/978-981-16-0394-5_15

temperature has increased by 0.8 °C in comparison with the end of the nineteenth century. Researchers expect an increase in average global temperature in the range from 1.5 to 5.3 °C by 2100 due to the current pace of CO_2 emissions. If no action is taken, it would have harmful consequences to humanity and the biosphere.

Agriculture and climate change are inseparably linked with each other, which may affect the yield, pattern and water requirement of crops. The exploitation of fossil fuels is a primary reason for climate change, which affects global temperature, precipitation and hydrological cycles. Constant changes in the rainfall intensity and frequency, waves of heat and other severe events are likely to take place, all of which will influence crop production. Moreover, augmented climate change factors may shrink crop productivity, resulting in an increase in the cost of cultivation for many important agricultural crop production systems. The following are the critical challenges of climate change in the context of agriculture.

- Interruption in the regular farm practice schedule
- May spoil the standing crop
- Upsurge attack of pests and diseases
- The threat of non-availability of water
- Degradation of quality natural resources.

Adoption of both short- and long-term agricultural plans should be the strategy to deal with the effect of climate change. In agriculture, cost-effective water infrastructure, preparedness to mitigate the severe weather conditions, development of drought-resistant crop varieties and modern land use and management practices are required. Effective use of natural resources such as water, solar radiation, other weather parameters and soil using improved irrigation method practices and protected cultivation structures have been presented in this paper to deal with changing climate situations.

15.2 Climate Change Effects on Cultivation Practices

The present agriculture production system has already started facing the effect of projected climate change. To deal with the changing agriculture scenario, suitable crop management practices are of supreme importance. Cropping patterns and crop management practices include adapting different sowing periods in accordance with the thermal time requirements of cultivar to minimize losses of crop yield (Zimmermann et al. 2017).

15.3 Crop Variety and Sowing Time

The amount of radiation required to grow crops is a determinant key to choose the crop variety and sowing date to achieve potential yield levels of a crop. Changes in climate and crop management tend to change in crop phenology and its stages (Craufurd and Wheeler 2009).

A study conducted in Germany on winter wheat shows that the sowing date was advanced by five days. During the study period from 1951 to 2009, Ray et al. (2012) reported that the sowing date was extended by 13 days for the wheat crop. However, the rapeseed sowing date remained almost the same for winter (Rosenzweig et al. 2015). According to Ding et al. (2016), the wheat sowing date might be postponed by 10–20 days for wet as well as for medium years, and for the dry years, it could be postponed by 20–25 days in comparison with the existing sowing date to obtain maximum yield under climate change. This study shows the climate change effect on the date of sowing and varietal choice of a crop. However, other climatic factors, including temperature (e.g. drought threat), influence the choice of variety according to crop and location. Economic factors are also related to the timing of various field operations and crop variety. Hence, climate change impact studies are complex and not a straightforward answer.

15.3.1 Crop Disease and Pests Management

A steep increase in the concentration of carbon dioxide causes variation in temperature and precipitation due to climate change. This may modify crop growth stages and likely to enhance the pathogenic activity. Climate change most likely influences the incidence and occurrence of pest and the severity of plant diseases. Change in climate will influence disease management, such as time of application, choice and the efficacy of chemicals, physical and biological control measures. This will be used as part of integrated pest management (IPM) strategies. Forecasting of the future plant diseases and their management are of larger interest to agriculture-related industries and agricultural extension workers to disseminate information among farmers.

In the present scenario, knowledge on the influence of climate change on disease management is limited and fragmented. Therefore, a comprehensive study of the effects of climate change on plant disease is important. Effective crop protection technologies are required to deal with altered climatic conditions. The longer growing seasons, fog, fewer frosts and shifting precipitation patterns are some of the major consequences of climate change. These changes do affect the incidence and enhancement of containing diseases (Juroszek and Von Tiedemann 2011).

15.4 Agricultural Water Management and Climate Change

The consequence of climate change is probably deepening the risk in the regions where water scarcity is already a significant concern. Efforts to expand or water management strategies in agriculture can manage risk and protect against crop damage. To deal with climate change scenario, planned agricultural water management adaption strategies are required to minimize the risks of crop failure and crop growth dynamics due to climatic fluctuations (Mo et al. 2017). Cultivation of less water-consuming crops and reducing the adaption strategy deal with the water shortage due to climate change.

15.4.1 Improved Irrigation Techniques

Precision irrigation is the need of time as many states in India get severely affected by climate change and facing a continuous drought-like situation and water scarcity. Precision irrigation allows accurate application of water to meet the specific requirements of individual plants without adverse impact on soil and the environment. The information on the quantity of water required for a crop grown at a particular location, crop growth stage and soil condition is needed to communicate with the crop growers at an appropriate time, which is lacking in Indian agriculture. Precision irrigation is the solution to this issue. The precision irrigation involves drip or sprinkler (micro-irrigation) along with sensor-based automation, which ensures an appropriate amount of water application at an appropriate time as per the crop evapotranspiration requirement or available soil moisture status at the crop root zone. Furthermore, micro-irrigation also delivers an appropriate amount of fertilizers along with irrigation depending on the nutrient status of soil within the root zone of a plant(s)/tree. Precision irrigation methods need to be developed and demonstrated at a large scale to deal with climate change issues.

15.4.1.1 Drip Irrigation

Drip irrigation has been recognized as a tool for saving water and increasing crop yield. Drip irrigation is a suitable method of water application to almost all kinds of crops, especially for wide-spaced high-valued crops such as orange, grapes, coconut, banana and mango. This is also suitable for commercial crops like sugar cane, cotton, flowers and chilly. In this method, water is applied at a slow rate near the crop root zone. The results of experimental studies are conducted by the author and his research team at Precision Farming Development Centre, IIT Kharagpur, on establishing the crop water requirement and to study the effect of drip irrigation on yield of different fruit (mango, guava, banana, sapota, litchi, pineapple, cashew nut) crops and vegetable (cabbage, cauliflower, tomato, okra, brinjal, lettuce, capsicum, cucumber

Table 15.1 Water requirement of various fruits and vegetable crops and their response due to drip irrigation

Crops	Water requirement (L Plant^{-1} day^{-1})	Yield increment due to drip (%)	Benefit–cost ratio
Fruit crops			
Mango	16.6–47.4	128.0	6.27
Guava	11.9–34.5	164.0	3.17
Banana	4.0–18.6	39.1	2.55
Pineapple	0.16–0.55	22.8	5.88
Sapota	16.3–36.8	96.7	3.21
Litchi	9.3–33.2	41.0	3.64
Cashew nut	8.2–29.8	46.0	2.02
Vegetable crops			
Cabbage	1.2–1.7	62.5	5.40
Cauliflower	0.7–1.4	22.3	4.20
Tomato	0.9–2.3	44.1	6.42
Okra	0.6–1.9	54.9	2.70
Brinjal	0.8–3.4	25.6	3.27
Broccoli	0.7–1.3	33.5	4.54
Lettuce	0.6–0.9	19.6	2.3
Capsicum	0.5–0.9	36.4	2.6
Cucumber	0.5–0.6	24.6	2.8
Turmeric	0.1–0.5	85.1	4.76

and turmeric) crops. The results are summarized in Table 15.1. The overall water saving is about 40% as compared to the traditional irrigation method. It shows the importance of drip irrigation for the judicious use of water when there will be water scarcity due to climate change.

In another study, Rajwade et al. (2016) conducted a drip irrigation experiment for rice production under climate change scenarios in sub-tropical India. The effect of varying N nutrient levels on crop yield, water productivity and N nutrient use efficiency of rice was experimentally evaluated using subsurface drip irrigation. The field experiments included two different spacings of drip lateral (40 and 60 cm) and four N nutrient levels, i.e. 0 (N0), 50, 75 and 100% of normal N recommendation with three replications. Experiments were conducted at IIT Kharagpur, India, in dry and wet seasons from 2012 to 2014. Both the lateral spacings resulted in similar growth and yield of rice due to uniform distribution and movement of water and N fertilizer through subsurface drip inline lateral system. Under drip irrigation, increasing the N fertilizer level from N0 to N50 and N75 increased the grain yield and water productivity of rice significantly. However, no significant changes were observed with further N fertilizer addition. The drip irrigation saved 32% irrigation water in the dry season compared to the conventional puddled transplanting with marginally reduced yield (8%) as averaged over two years.

The influence of varied scenarios of climate change on the yield of rice grain for selected places in sub-tropical India was simulated. The CO_2 content was taken as 380 ppm for the base period (1961–1990). The future periods in 2020 (2010–2039), 2050 (2040–2069) and 2080 (2070–2099) were considered as 423, 499 and 532 ppm, respectively, for representative concentration pathway (RCP) 4.5 and 432, 571 and 801 ppm for RCP 8.5 (Rosenzweig et al. 2015). The yield of a dry season rice grain under drip irrigation (DIR) and puddled transplanted rice (PTR) system was simulated using location-specific soil properties, calibrated cultivar genotype parameters and using the standard established crop management practices. For different climate change scenarios, the percentage change in the simulated rice grain yield was estimated in comparison with the yield obtained for both the DIR and PTR systems under the base period. The response of different N nutrient levels (75, 100 and 125% of the normal recommended dose) on the rice grain yield in both DIR and PTR systems was simulated under different climate change scenarios for the selected areas. The effect of different sowing dates on the yield of a rice grain under DIR and PTR was simulated for the selected locations in India. Twenty-one days before and after the existing sowing date (December 22) were chosen for sowing during the dry season. Accordingly, December 1, December 22 and January 15 were the considered sowing dates. The rice grain yield simulations were carried out for the base period (1961–1990) and for future periods (2020, 2050, and 2080), with the above-mentioned sowing dates keeping other management practices constant.

Simulation using the CERES model resulted in a reduction in the rice grain yield by 3–10%, 7–16% and 9–15% in RCP 4.5 and 11–16%, 13–15% and 38–41% in RCP 8.5 scenarios during 2020, 2050 and 2080, respectively, in comparison with base period (1961–1990) rice grain yield using drip irrigation. The combination treatments of 25% increment in the application of N nutrient level in comparison with the normal recommended dose and early sowing were able to compensate for the adverse impact of rising temperature (up to +3.3 °C) in future climate on the rice production (Rajwade et al. 2016).

15.4.1.2 Sprinkler Irrigation

Sprinkler irrigation system sprays water in the form of droplets emerging out of a nozzle attached with a riser pipe connected to a network of pipes. These systems are suitable for irrigating crops where the plant density is very high, where the adaption of the drip irrigation system may not be economical. This system of irrigation has been in vogue in the country for more than forty years. The sprinkler method is technically feasible and economically viable for a large number of crops grown in the country. This method can be adapted in the crops such as cereal, pulses, vegetables, flowers, fruits and plantation crops. Summarized results of sprinkler irrigation experiments conducted by the Precision Farming Development Centres (PFDCs) located in different parts of India are given in Table 15.2. There is considerable water saving

Table 15.2 Saving of water and percentage increase in production using a sprinkler irrigation system

Crops	Water saving (%)	Yield increase (%)	Crops	Water-saving (%)	Yield increase (%)
Bajra	56	19	Gram	69	57
Barley	56	16	Groundnut	20	40
Bhindi	28	23	Jowar	55	34
Cabbage	40	3	Lucerne	16	27
Cauliflower	35	12	Maize	41	36
Chilli	33	24	Onion	33	23
Cotton	36	50	Potato	46	10
Cowpea	19	3	Sunflower	33	20
Garlic	28	6	Wheat	35	24

in comparison with conventional irrigation. Sprinkler system protects crops from fog and frost during winter and also creates a cooling environment surrounding crops during summer.

15.5 Protected Cultivation Technologies

Protected cultivation is a technique used to grow crops with fully or partially controlled micro-climate surrounding plants as per the crop species requirement at their growth period. With the progress in agriculture and horticulture, large numbers of protected cultivation techniques appropriate for a specific type of climatic conditions have emerged.

15.5.1 The State of the Art

15.5.1.1 Low Tunnels

Low tunnels are a tiny form of the greenhouse to protect the crop from extreme rains, winds, cold, frost and another oddity of weather conditions. However, inside low tunnels, completely altering micro-climate artificially is not possible. Inside the low polytunnels, seedlings can be grown in a short duration and can be protected from the rain and storm during the rainy season. The polytunnel seedlings can be transplanted 7–15 days earlier than that of grown in open field conditions. Generally, the cladding film is made up of UV-stabilized LDPE films.

15.5.1.2 Polytunnels

Polytunnels are the protected cultivation structures made from locally available wood or bamboo and covered with UV-stabilized plastic sheet. It facilitates to entrap carbon dioxide and save crops from extreme climatic conditions. Naturally ventilated low-cost polytunnel of the size 9 m long, 3 m wide and 2 m height was constructed with locally available bamboo, and UV-stabilized film was used as a cladding material. An insect-proof net was provided at the side of the structure to prevent the entry of insects. The polytunnels were constructed by the author and his team of researchers at the Precision Farming Development Centre, IIT Kharagpur. These polytunnels were used for the production of off-season vegetables and raising seedlings of vegetables, flowers and hardening of mango grafts. These structures had a working life span of 2.5–3 years. Farmers can fetch annual profit ranging from Rs. 5,000 to Rs 20,000 from 27 m^2 area. Farmers were trained to fabricate and use low-cost greenhouse structures for raising nursery of vegetables, paddy and other seasonal crops and also grow off-season vegetables. The results of a few crops grown under experimental polytunnel structures are given in Table 15.3.

15.5.1.3 Greenhouse/Polyhouse

A greenhouse is a framed structure envelope cladded with a transparent LLDPE film in which crops can be grown in a partially or fully controlled environment. The structure is provided with adequate space to allow entry of person (s) to work and carry out cultural operations. Greenhouse provides favourable micro-climatic conditions to the crop to achieve greater yield and better-quality produce. The structure provides opportunities to grow crops year-round, thereby increasing land productivity. The structure protects plants against biotic (pests, diseases and weeds) and abiotic (temperature, humidity and light) stress grown, especially during off-season.

Table 15.3 Water requirement and crop response in the polytunnel and open field conditions

Sl. No	Name of crop	Water requirement (L day^{-1} $plant^{-1}$)		Average weight (g)		Yield (t ha^{-1})	
		T_1	T_2	T_1	T_2	T_1	T_2
1	Cauliflower	0.74–1.01	0.42–0.63	600	1100	24	44
2	Cabbage	0.76–0.97	0.45–0.60	2000	2750	66	91.66
3	Tomato	0.63–0.82	0.41–0.52	45	80	20	110
4	Broccoli	0.71–0.99	0.46–0.61	730	1400	29	66
5	Capsicum	0.58–0.84	0.37–0.52	170	380	44	124
6	Cucumber	0.29–0.40	0.19–0.25	184	270	35	110
7	Rose	1.28–3.11	0.86–3.00	–	–	12*	19 *

T_1 = Open field; T_2 = Greenhouse
*No. of flowers/plant/year

Table 15.4 Structural design of greenhouses of different floor area and height

Sl. No	Floor area, m^2	Height, m	Gutter height, m	Arch pipes, No	Side sash, No	Columns, No	Polythene area, m^2
1	100	5	2	6	12	–	316.0
2	200	4	2	11	22	–	386.7
3	200	5	2.5	17	34	–	575.0
4	500	4	1.5	45	18	36	1051.7
5	500	4.5	2	88	22	77	2060

15.5.1.4 Design of Greenhouse

A study was conducted to design a greenhouse considering local wind load, live load and dead load. A MATLAB-based programme was developed for the structural design of the greenhouse and to determine the quantity and size of structural component requirement. The programme was run for different wind speeds and for different floor areas of the greenhouse. The results of outer diameter (OD) and thickness (t) of the columns and arches and the number of pipes needed for various positions and sizes of the greenhouse are presented in Table 15.4 (Gupta et al. 2019).

15.5.1.5 Shade Net House

Shade net house is a framed structure made up of GI pipes, angle iron, timber or bamboo. The structure is cladded with a plastic net, which is made of UV-treated LLDPE thread having different shade percentages. Shade net is used to guard the plants against the scorching sunlight, extreme winds, direct impact of rainfall as well as insects and pests. This structure provides the facility to control micro-climate partially by reducing light intensity and provides adequate temperature during day time. Due to these advantages, shade net house structure is used. The structure is also used to produce seasonal and off-season crops. Shading in the structure reduces the crop water requirement and increases water productivity (Moller and Assouline 2007). Shade nets are mainly being used to raise nursery, secondary hardening of tissue-cultured plantlets and cultivation of vegetables and flower crops.

15.5.1.6 Modified Greenhouse

The modified greenhouse is a hybrid concept of shade net house and polyhouse. It is well-framed structure made up of GI pipes covered with nets of different shades and UV-stabilized polyethylene. The poly film is placed beneath shade net (around 1–2 m below shade net), which increases the temperature during winter and creates a favourable environment during the summer season. This structure also protects the crop from rains and hails storms. The author and his team constructed a modified greenhouse structure to grow Dutch Roses.

15.5.1.7 Micro-climate of Different Protected Cultivation Structures

The cladding of protected cultivation structures (PCS) causes a change in the climatic conditions compared to outside for all the seasons. The debarring entry of rainfall, entrapment of the carbon dioxide within the structures, lesser entry of solar radiation and maintaining higher relative humidity in comparison with open field are the major micro-climatic changes that occur inside PCSs. The change in each of these climatic parameters has its own effect on the crop development, yield and quality of the crop inside the protected cultivation structures.

Temperature

The temperature of a location plays an important role in designing protected cultivation structures and control systems. The temperature has a direct impact on the physiological development phases of the plant. It also regulates plant transpiration rate and plant water status through stomatal control during the photosynthesis. Daily maximum and minimum temperature variation in different PCS were recorded on a daily basis and are presented as monthly average in Fig. 15.1. Air temperature recorded in these structures showed that the use of different covering materials for structure makes an impact on temperature. Air temperature recorded under the shade net house was always lower in comparison with that of temperature at an open field and other types of structures. This is due to the partial passage of solar radiation and the exchange of air by the perforations of the shade net. Shade nets also interrupt the entry of wind flow (Stamps 1994) that influences temperature inside the structure. Higher values of maximum and minimum temperatures were observed inside the polytunnel during summer and monsoon months (April–November) in comparison with other PCS and open field conditions. The cladding of structure with poly film increases the temperature due to the entrapment of solar radiation inside structures (Santosh et al. 2017).

Relative Humidity

Relative humidity (RH), ranging between 60 and 90%, is most optimal for the plants and their growth. Figure 15.2 shows that the monthly average daily RH values are significantly lower for open field conditions compared to the monthly average daily RH values observed in the PCSs. The values of RH in walking tunnels increased by 19–25% in comparison with the open field, which is followed by polyhouse (17–23%), modified greenhouse (15–21%) and shade net house (10–17%).

Solar Radiation

Solar radiation is the most important parameter for the photosynthesis process in plants. The accumulation of plant dry matter linearly reduces with solar radiation values. The monthly average of daily net solar radiation values for different PCS is

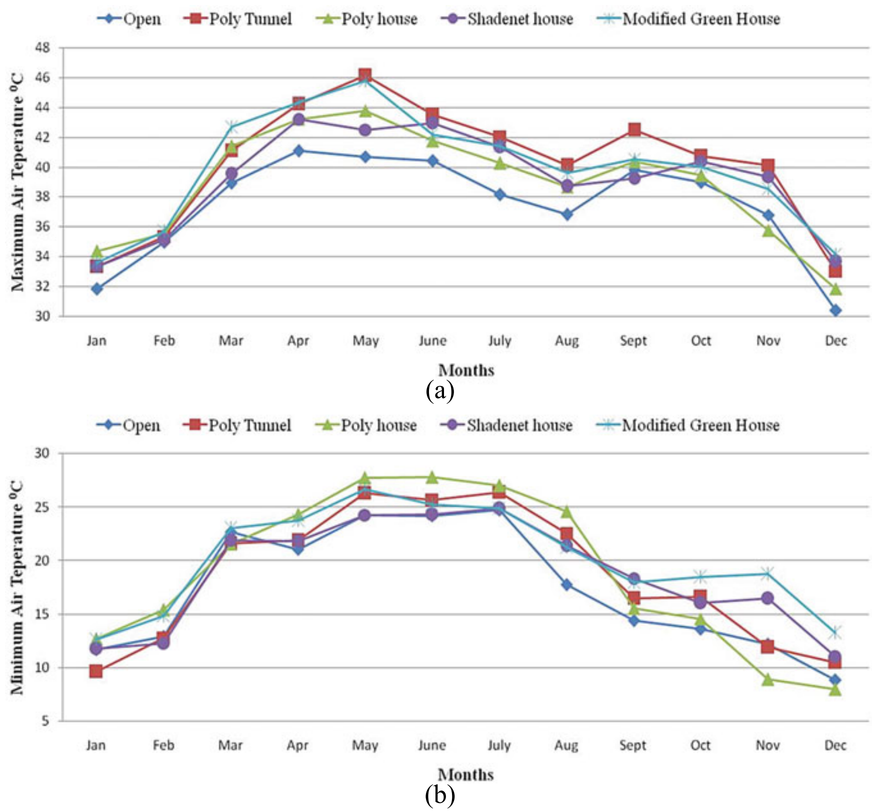

Fig. 15.1 Monthly average of daily maximum **a** and minimum, **b** temperature recorded in different protected cultivation structures and open field condition

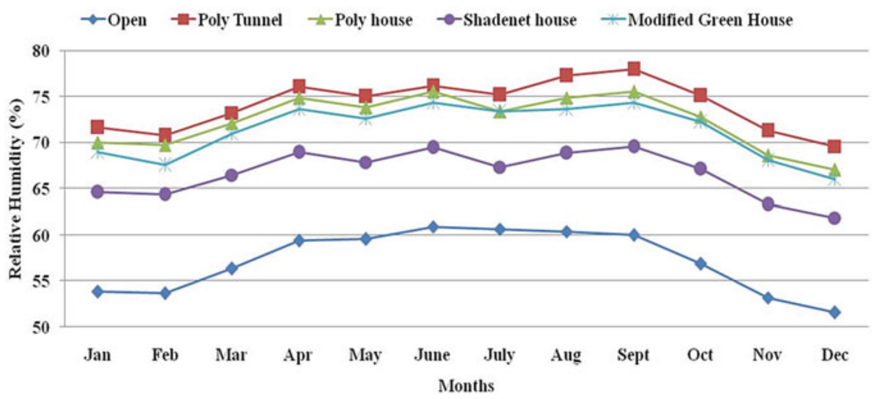

Fig. 15.2 Monthly average of daily mean relative humidity (%) recorded in different protected cultivation structures and open field condition

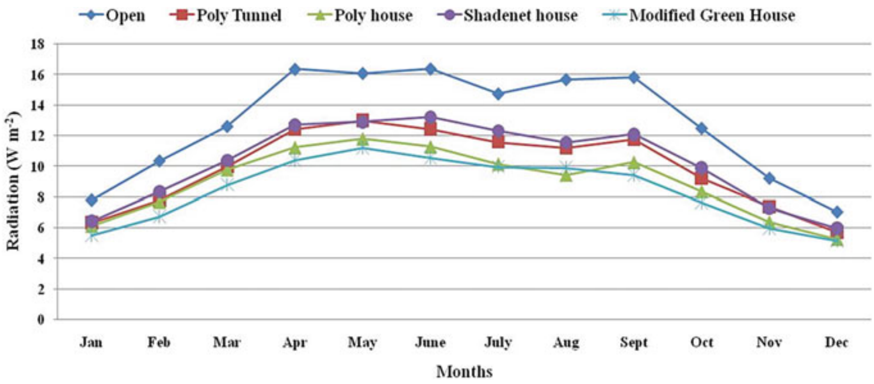

Fig. 15.3 Monthly average of daily net solar radiation (W m-2) recorded in different PCS and open field conditions

presented in Fig. 15.3. The greenhouse film transmits about 60–80% solar radiation depending on the solar intensity, time, season and sunshine hours. The difference in solar radiation values in the PCS and open field during winter months (November to February) was lesser in comparison with summer and monsoon months (March to October). The type of cladding material used in PCS significantly changes radiation balance relative to the external environment. Among all PCSs, the solar radiation transmitted inside shade net house was maximum (74–85%) followed by walking tunnel (71–81%), polyhouse (60–78%) and modified greenhouse (60–73%) in that order (Fig. 15.3). This may be due to the fact that the modified greenhouse cladded with a shade net on the top and UV stabilized at the bottom reduced the transmittance of solar radiation.

Reference Evapotranspiration

The micro-climate formed in PCSs due to different cladding materials influences the evapotranspiration of the crop. The micro-climatic data recorded in the protected cultivation structures was used to estimate the reference evapotranspiration by FAO-56 modified Penman–Monteith (PM) model. The monthly average of daily estimated ET_0 values for all the PCS is presented in Fig. 15.4. The values of reference evapotranspiration (ET_0) under different structures were observed to be lesser in comparison with the open field due to lesser vapour pressure deficit and higher relative humidity in these PCS structures. The values of ET_0 in open field conditions are always higher in comparison with the ET_0 values inside different protected cultivation structures during the entire crop season. The ET_0 values are lesser as there is very less transport of water vapour due to the low entry of wind in these structures.

Crop Water Requirement

Experiments were conducted to determine the water requirement of important crops in the sub-humid climate region of Kharagpur at Precision Farming Development Centre, IIT Kharagpur, under protected cultivation structures and in an open field. The

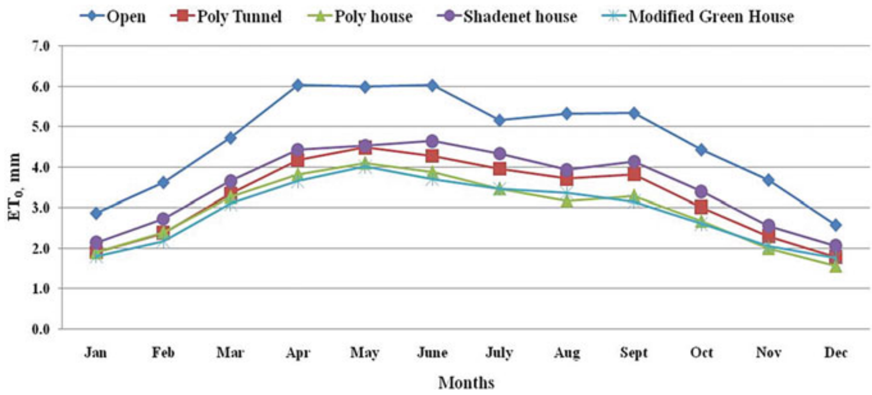

Fig. 15.4 Monthly average of daily reference crop evapotranspiration (mm) estimated for different PCS and open field conditions

Table 15.5 Estimated water requirement of crops in different protected cultivation structures

Sl. No	Crop	Season	Water requirement (L day^{-1} Plant^{-1})		Seasonal water requirement (mm)	
			Polyhouse	Open field	Polyhouse	Open field
1	Capsicum	Nov–Feb	0.37–0.52	0.49–0.84	218.6	339.8
2	Cucumber	Nov–Feb	0.31–0.41	0.50–0.64	201.2	311.9
3	Lettuce	Nov–Feb	0.24–0.33	0.57–0.89	219.1	339.9
4	Gerbera	Year-round	0.18–0.59	0.29–0.91	858.4	1353.0
5	Rose	Year-Round	0.18–0.59	0.32–0.88	991.5	1048.5

monthly average of estimated daily water requirement and seasonal water requirement of the crops under study is presented in Table 15.5. It can be seen from the results that the water requirement of crops inside the greenhouse is always lower than the open field. Hence, there is a considerable saving in water for greenhouse crops. These water requirement values can be used to design in the design water storage structures for cultivating a crop(s) in protected cultivation structures or in open field condition.

15.5.1.8 Mulching

Application of drip irrigation along with plastic mulch film has shown outstanding results in terms of crop productivity, moisture conservation and weed control. Covering soil surface with straw, plants leaves or plastic film is mulching. UV stabilizer is added with the polymer to manufacture UV-stabilized plastic mulch film. These are available in different colours, transparent and silver top and black bottom. It has been found very useful in controlling weed growth and conserving moisture.

Transparent plastic mulch is used for soil solarization to kill soil-borne bacteria. Table 15.6 shows the crops recommended for the use of plastic mulch of different thicknesses.

The yield response of different crops and the corresponding water saving due to plastic mulch are shown in Tables 15.7 and 15.8 (Anonymous 2010).

Table 15.6 Recommended thickness of plastic film suitable for different crops

Thickness (Microns)	Crops recommended
25	Short duration crops, vegetables (3–4 months)
50	Medium duration crops (11–12 months) Early stage of fruit crops, coffee, papaya, sugarcane
100	Mango, citrus fruits and medium-grown trees

Table 15.7 Increase in yield, weed control and water saving due to the application of plastic mulch in different crops

Crop	Weed control (%)	Yield increase (%)	Water saving (%)
Kinnow	55	18	25
Lemon	51	14	30
Cotton	60	25	46
Pineapple	61	32	35
Ginger	99	28	30
Turmeric	94	21	25
Brinjal	90	20	12
Coconut	80	75	25

Table 15.8 Influence of plastic mulch on fruit and vegetable crops

Crop	Increase in yield due to plastic mulch (%)	Crop	Increase in yield due to plastic mulch (%)
Mango	9.90	Cabbage	10.00
Guava	67.13	Tomato	14.82
Pineapple	15.71	Okra	14.92
Banana	23.80	Brinjal	31.05
Litchi	32.80	Broccoli	26.42
Turmeric	28.30	Cucumber	34.70

15.5.2 Role of Protected Cultivation in Mitigating Climate Change Effects

Protected cultivation has tremendous scope to protect crops due to climatic change. Experimental studies have shown about 20% saving in water and a 15% increase in the yield of many crops. These structures protect the standing crop from a sudden wind and rainstorms, high temperature, dew and frost. Due to a controlled and favourable environment, protected cultivation will be one of the most important climate change mitigating tools in the farming operation.

The open field cultivation or natural vegetation such as forest and pasture is highly dependent on climate, unlike crops under protected cultivation. Protected cultivation is less dependent on local climate conditions, and the micro-climate inside structures can be partially or fully controlled by means of appropriate devices. However, the inside climate, energy balance and consequently, the economic models are deeply influenced by external climatic conditions (Boulard et al. 2011). The area of shade net house and naturally ventilated greenhouses in the Mediterranean region and countries with mild climate conditions have been continuously expanding (Gruda et al. 2019) due to favourable climate and economic consideration. The major effect of climate change is a rise in temperature and unexpected high magnitude rains, which are detrimental to the nursery, field crops and high-value commercial crops. The protected cultivation structures have a great future to get fresh and high-value vegetables round the year.

15.6 Conclusion

This research paper presents adaptable technologies to mitigate the effect of climate change on agriculture by giving special attention to agricultural water management and protected cultivation structures. The adaptation of improved irrigation techniques like drip and sprinkler along with the polyhouse, shade net house and modified greenhouse has shown a positive impact on the sustainable production of agriculture and horticulture. The research findings of the Precision Farming Development Centre, IIT Kharagpur, for adapting improved irrigation and protected cultivation techniques are useful and relevant to deal with climate change. The key challenge for the research community is to move beyond the current simplistic understanding of smallholder that is inherently nature-protecting, but unable to adapt to climate change because of their overwhelming vulnerability.

Acknowledgements The author is thankful to the National Committee on Application of Plastics in Horticulture (NCPAH), Ministry of Agriculture and Farmers Welfare, Govt. of India, for providing financial support to the Precision Farming Development Centre, IIT Kharagpur, for conducting research experiments. The author acknowledges researchers working in this area as their researches and literature have provided a path to prepare this manuscript.

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