

# Integration of technologies under climate change for profitability in vegetable cultivation: an outlook

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## Abstract

Climate variation and change are an unavoidable phenomenon faced by the natural habitat of this planet. For getting potential yield from vegetable crops under the changing climate conditions, the practical strategies at field level can serve as a guideline for the farmers. Moreover, there are several strategies available for mitigating the harmful effects of climate change. In this manuscript, efforts have been made for reviewing the mitigating strategies against the impact of climate change in vegetable crops via conventional approaches. Considering the situation, the information reviewed revealed that significant result of conventional approaches with climate-smart adoptions strategies has a direct bearing on vegetable production for the increasing population in frenziedly changing climate scenario.

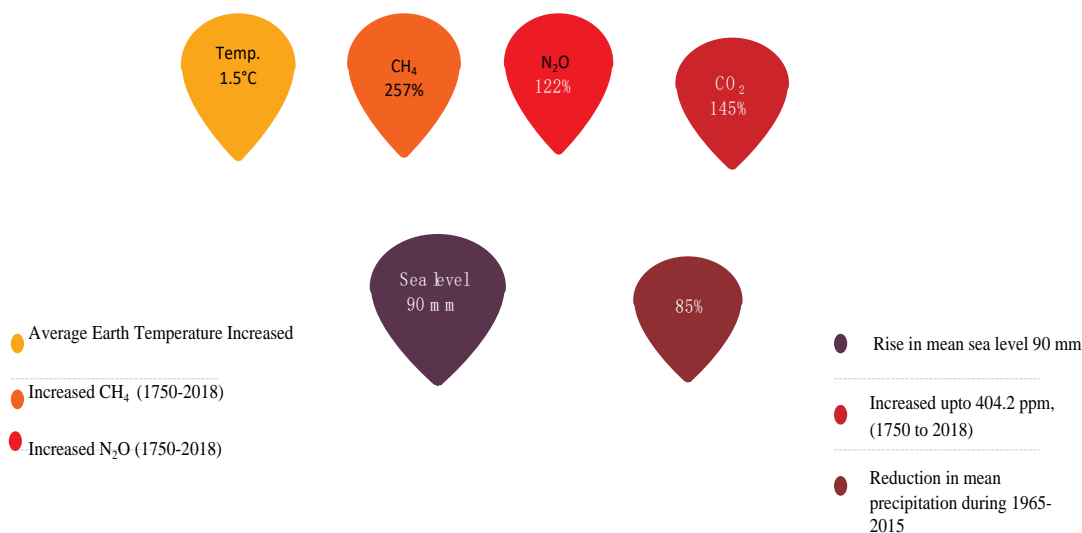
**Keywords:** climate change, vegetables, crop wild relatives, nitrogen use efficiency

## 1. Introduction

Boosting agricultural production to meet up with the dietary tendencies of a growing population with resources that are limited at the time of climate change will require novel solutions (Beilfuss and Nhemachena 2017; Chadha, 2015). Climate change renders one of the most substantial threats to vegetable production. Most importantly, vegetable production is vulnerable to a broad spectrum of these climate induced abiotic stresses. In this direction, the expected impacts of global climate change on vegetable production have grown to be a primary emphasis of the researchers. Approximately 392 different vegetables are cultivated worldwide, representing 70 plant families as well as 225 genera. Global change in climate has a considerable effect on vegetable crops on account of their succulent nature. Vegetable crops are vulnerable to environmental problems which are impacted by both long-term and short-term seasonal changes. Nevertheless, elevated mean air temperature enhances the activity of previously present insect pests and stress conditions (La Pena and Hughes 2007). Overall, the significant highlights of climate change are presented in Figure 1.

## World Climate Change Highlights

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**Figure 1.** Key highlights of climate change.

Moreover, vegetables are an abundant source of vitamins, protein, and carbohydrates, along with numerous bioactive compounds (Ayyogari et al. 2014). Climate change could be aggressive as per different climatic factors, for instance, temperature, precipitation, and relative humidity, etc. in situations over a prolonged time and over a significantly larger geographical region (Brimblecombe and Camuffo 2003). Furthermore, the uncertainty may be referred to as a fusion of magnitude of the impact with the probability of its occurrence and captures anxiety in the underlying tasks of climate change, publicity, impacts and adaptation. The changing patterns of climatic details such as rise in atmospheric heat, changes in precipitation, high UV radiation and the higher likelihood of severe weather events such as droughts and floods are emerging main threats for vegetable production within the exotic zone (Newell 2006; Sunstein 2009). In this manuscript, we have discussed the technologies that could be advantageous for securing a successful vegetable production under the present scenario of climate change.

### 2. Status of climate change and its impact on vegetables

Whereas, climate variability is the change in the intermediate state and other aspects of the climate over space and time beyond that of the individual weather events (WMO). Changes in climate have already started affecting biological systems worldwide (Walther et al. 2002; Cannone et al. 2007; Kelly and Goulden 2008). The effect of climate change on vegetable farming is likely to be negative (Bisbis et al. 2018), although some regions and crops will benefit most will not (Table 1).

**Table 1.** An outlook of climate change and variability (WMO, 2020).

Factor	Status change
Temperature	Warmest five year period (2015-18) after the pre-industrial era (1885-1990).

CO <sub>2</sub>	Increased from 395.5 ppm (2011-15) to 404.2 ppm (2015,-18) <i>i.e.</i> , (+18% last five years), it has increased by 145% (1750 to 2018)
CH <sub>4</sub>	Increased CH <sub>4</sub> rate by 257% during 1750-2018
N <sub>2</sub> O	Increased rate by 122% during 1750-2018
Ocean level	Rise in mean sea level by 90 mm (1993-2018) and overall sea-level rise of 5 mm/year
Wind and Rainfall	Reduction in mean precipitation during 1965-2015 but event of extreme rainfall has increased (>150 mm/ day) in central India (Roxietal.1 2017).
Highest extreme events reported 2015-18 The	<ul style="list-style-type: none"> <li>➤ The Year 2018 reported number of tropical cyclones and resulted in floods</li> <li>➤ A higher temperature during snowfall and cold events in North America during 2015-19</li> <li>➤ Wildfires and heatwaves during June-July,2019 (Europe), May-June, 2015 (India and Pakistan), Summer 2015-16 (South Africa and Europe), Summer 2018-19 (Australia)</li> <li>➤ A storm during May 2018 in North India</li> <li>➤ Drought (2018 in Europe; 2017-19 in Australia; 2015-18 in Africa; 2015-16 in South America)</li> <li>➤ Wildfire (2019 in Australia; November 2018 in California; July 2018 in Greece)</li> <li>➤ Cold waves (2015&amp;2019 in Canada, 2015 in East Asia)</li> </ul>

Climate variability and climate change have an enormous impact on the farmer's social and economic conditions (Mittler 2006; Fadairo 2019). Abiotic factors are ultimately responsible for the existence of any natural flora and fauna. Presently, various natural disasters occurring on the planet have resulted in climate inconsistency and changes. In another study, it was projected that climate change would result in a decline of 18-32% world potato yield production in future till 2040-2069 due to living and nonliving factors (Hijmans 2003). Although crop plants respond to climate change by shifting their geographical range. The need of the hour is to find out the solution by directly integrating farmers' practices with the latest agricultural technologies (Chauhan et al. 2020).

Vegetable crops are vulnerable to the sudden rise and fall in temperature in addition to high precipitation at any stage of crop growth which can influence the normal development, pollination, flowering, fruit development and also consequently reduce the crop yield (Spaldon et al. 2015). Changing weather patterns has threatened farming efficiency through low and high-temperature regimens and considerable rainfall variability. The problem of climate change, as well as climate variability, has tossed up risks and uncertainties, further imposing constraints on vegetable production cycles and thereby a price rise of vegetable produce (Malhotra. 2017). Therefore, useful techniques are required to handle such abiotic stresses. Various methods have been tested, like breeding, genetic engineering and resistant cultivars. Still, the increase of these technological advances is limited as a result of the physiological and genetic complexity of abiotic strain opposition traits (Burroughs and Burroughs. 2003). Conventional breeding methods involving long breeding cycles are time-consuming as well as progress gradually (Hall and Richards 2013). Presently, many cultivated plants are also acclimatizing in its prevailing environment by responding accordingly as per its physiology (Table 2).

**Table 2. Climatic change variables and their impact on vegetables.**

Abiotic factor	Studied by on Impact analysis
Temperature	Low temperature affects tomato, muskmelon (reticulates group), watermelon (Bouzo&Küchen. 2012; Manolopoulou & Varzakas. 2016)
	High-temperature stress in Chinese cabbage (Datta. 2013). pepper (Erickson &Markhart. 2002).
	Pollination activities disturbed, which resulted in yield reduction (Memmott et al. 2007; Hegland et al. 2009, Schweiger et al. 2010, Willmer& Stone 2004).
Relative Humidity	Low Temp and High RH Low Temp and Low Humidity (It can lead to chilling and freezing injury) Cold nights, warm days, and high humidity are favourable for late blight in potato (Lehsten. 2017). Ascochyta blight in pea (Roger et al. 2006).
	High Temp and Low RH High Temperature and High humidity Both can lead to sucking pest incidence
Frost	All temperate vegetables have reduced yield and quality.
Flooding	Yield reductions in tomato (40%) (Renuka Rao &Yuncong Li 2003).
Drought	Vegetables are succulent (80-90% water content) in nature, and drought condition directly reduces produce and quality (AVRDC 1990).
Salinity	Affects the plant physiology of vegetables like tomato (Maggio et al. 2004) and peas (Maksimovic et al. 2008).
Others (Soil erosion, Strom, Wind, Hail damage, landslides)	Outdoor farming damaged by hail storm up to25-50% (Singh et al. 2009; Panday, 2012).

- High temperature + low water table=Drought
- Low temperature +Low humidity=Chilling/freezing injury/frost
- Rain decreased in monsoon and hot days increased, (As per geographical and ecological conditions less rainfall required areas are receiving more rainy days and vice-versa)
- Changing Water table also areas on Paddy area leads to a deterioration in the water table and cotton field uplifting.

### 3. Limiting factors associated with vegetable production

Plant adapt differently to given environmental conditions. Plant phenology changes accordingly and survives in the available set requirements. Climatic variability will be beneficial for some plant species in a particular area, and some plant species will shift from one place to another as per adaptability to climate change. Some limiting factors for crop production based on a survey in primary vegetables growing areas and based on the reviewed study, details are as under in Table 3.

**Table 3. Limiting factors in vegetable production (surveyed and reported).**

Crop	Limiting factors		References
	Abiotic	Biotic	
Cucurbits	<ul style="list-style-type: none"> <li>• Flower and fruit drop</li> <li>• Late production of pistillate flowers</li> <li>• Loss of tenderness and early development of fibres</li> <li>• Low female: male sex ratio due to high temperature</li> <li>• Crookedness of fruits</li> <li>• Growth reduction due to low temperature</li> <li>• Fruit quality reduction by high rainfall</li> <li>• Leaf damage in pumpkin during high wind velocity</li> </ul>	<ul style="list-style-type: none"> <li>• Increased incidence of fruit fly and sucking pest</li> <li>• <i>Alternaria</i> rotting in shallow temperature</li> <li>• Attack of diseases like powdery mildew</li> </ul>	DeEll 2004
Beans and Pea	<ul style="list-style-type: none"> <li>• Low-temperature injury</li> <li>• Anoxic death of plants and seed size reduction by high rainfall/flooding at physiological to harvest maturity of the crop in pea</li> <li>• Pitting and rossetting in beans at low temperature</li> <li>• Changes in reproductive phases of pea</li> </ul>	<ul style="list-style-type: none"> <li>• Susceptibility to wilt, powdery mildew and bean mosaic virus</li> <li>• High losses due to pod borer</li> </ul>	Patel et al. 2014

Solanaceous crops	<ul style="list-style-type: none"> <li>• Flower and fruit drop</li> <li>• Pre-anthesis in temperature stress</li> <li>• Blossom end rot, fruit cracking, sunscald and improper colour development in tomato</li> <li>• Plants show wilting during flooding in pepper</li> <li>• Drought caused poor tuberization and high rainfall fruit cracking in potato</li> <li>• Mahogany browning and sweetening at low temperature in potato</li> <li>• Physiological wilting in chilli</li> </ul>	<ul style="list-style-type: none"> <li>• Damping-off, blight, root-knot nematode, fruit borer, shoot and fruit borer, thrips, leaf curl viruses, reported mites in chilli and brinjal</li> <li>• Emerging sucking pests incidence is spreading viruses, wilt and dieback</li> </ul>	(Sato et al., 2002). (Erickson & Markhart 2002, Nuruddin 2001, DeEll 2004).
Bulb crops	<ul style="list-style-type: none"> <li>• Bolting, sprouting of bulbs, short shelf life during storage</li> <li>• Poor germination in drought</li> </ul>	<ul style="list-style-type: none"> <li>• Attack of purple blotch and <i>Stemphylium</i> blight</li> <li>• Rotting in storage due to black mould</li> <li>• Problem of thrips</li> </ul>	(Rees.2012)
Okra	<ul style="list-style-type: none"> <li>• Flower and fruit drop</li> <li>• Take more time for flowering</li> <li>• Poor germination in high temperature and drought</li> </ul>	<ul style="list-style-type: none"> <li>• Yellow vein mosaic virus, mites and fruit borer</li> </ul>	(Dhankhar & Singh. 2009).
Tuber crops	<ul style="list-style-type: none"> <li>• Flooding causes rotting at harvest and increased shrinkage in storage</li> <li>• Losses in carotenoid pigments</li> <li>• Dry matter content, and baking quality in sweet potato</li> <li>• Degeneration of the leaf, spot and complete leaf necrosis in Yams</li> </ul>		(Miglietta et al., 2020).

#### 4. Adaptation and Mitigation strategies

Adaptation and mitigation are two crucial areas of combating climate change. Adaptation is labelled as adjustments in natural or human methods in responses to real or expected climatic stimuli, which moderates damage or possibly exploits beneficial opportunities. In contrast, mitigation is referred to as an anthropogenic therapy to dwindle the sources (Pelling 2010; Duguma et al. 2014). Despite intense mitigation initiatives, the weather conditions will continue to change in the subsequent seasons (Laube et al. 2012). Consequently, both adaptation and mitigation are vital to see coming modifications in the weather conditions. In this specific viewpoint, the adaptation and mitigation strategies could be created in such a fashion that they might manage strain in vegetable cultivation. These are as follow:

##### 4.1. Use of crop wild relatives

Crop wild relatives are a crucial source of genetic diversity for compensating for the adverse effects of climate change. Nevertheless, the survival of several of these crop wild relatives (CWR) might be compromised due to climate change (Kaushik et al. 2017, 2016). Climate change is significantly affecting the yield and potential outputs of important vegetable crops. Additionally, for several species, the ideal areas of cultivation are becoming very fragmented. There's an immediate need to identify and adequately save crop wild relatives, which are in danger from climate change. It is anticipated that the usage of CWR breeding is on the rise because of current improvements in molecular technologies that increase the accuracy and efficiency in transferring preferred characteristics from CWR to plants (Ford-Lloyd et al. 2013; Redden et al. 2015). In this direction, the gene banks are saving the genetic variability, which is present in CWR, and just a small proportion of conserved accessions are recognized (Kaushik et al., 2018). Climate change is on the list of main elements governing the distribution of wild plant species, acting right through physiological constraints on reproduction and growth or indirectly through ecological things like competition for energy (de Carvalho et al. 2013).

The reasonably modest climatic changes over the previous century have had a significant effect on crop yields and production (Barrios et al. 2008). Crop wild relatives are crucial for the breeding of novel cultivars with resistance to abiotic stresses. Moreover, detailed information regarding the wild relatives that are poorly conserved is entirely essential (Raza et al. 2019). The main issue concerning the use of wild species is knowing the effects of climate change, and perhaps geographic range may vary because of the more significant landmass in higher latitudes, along with species energy interactions (Pearce-Higgins et al. 2015). Moreover, a scientometric analysis of the publications on the web of the science of databases showed that there is a constant rise in the information regarding the crop wild relatives (Figure 2).

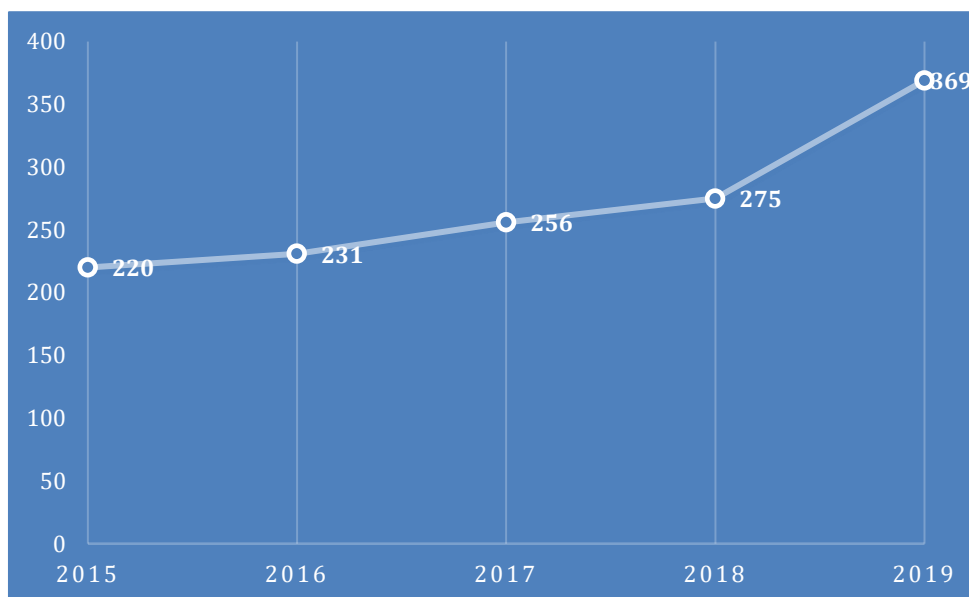


Figure 2. Increase in the number of publications related to crop wild relatives in the web of science database.

#### 4.2. Vegetable Grafting

A grafting method is dependent on the scion and rootstock, and grafting can be used to counter the harmful effects of climate change (Singh et al. 2019). Grafting is a rapid, efficient, and integrative practice where each scion and also rootstock impacts the growing graft (Colla et al. 2010). Grafting of rootstock and the scion of genetically diverse vegetables to mitigate climate change, predicted under a transforming global weather situation, were recorded within the medical literature as a promising method. The new study must be performed to evaluate and test several elite germplasms as a supply of suitable rootstock. Nevertheless, seeing the full potential of the grafting, the strategy is dependent on a few factors, like the correct number of rootstock and scion, and the geographical location (Brar et al. 2019; Ebert et al. 2019). Additional investigation is necessary to develop automated grafting platforms that scale up this particular method so that grafting can easily be an essential element of contemporary vegetable crop production (Edan et al. 2009). Only then progress in modern-day simulation, and automated grafting techniques can be made. Moreover, improvement of grafting technologies for the healthy, year-round, and also economical production of new plants are needed, so that this technology becomes much more available to growers in every component of the planet (Davis et al. 2008; Sabir and Singh. 2013).

### 4.3. Agronomical Intervention

Agriculture is the most vulnerable sector to climate change, and it has adversely affected the farming household. Agronomical management practice is an essential aspect of any crop production. Successful crop production is the result of soil type, fertility and its environment (nutrient, water level) and adaptation of plant physiological response in available environmental conditions (Altieri et al. 2015). Agronomical practices are fundamental to provide favourable environmental conditions for better growth and development of any crop. In the changing scenario, there is need to adopt some modified cultural management practices in a particular environment (Jones et al. 2017).

Uneven rainfalls, fluctuations in high and low temperatures are the main causal factors of any crop loss. Due to climate change, winter season and rainy season, vegetables perform well in raised bed planting system (Raza et al. 2019). It will increase the product due to improved drainage and reduced anoxic stress to the root system with adjustable planting time based on rainfall and temperature. Planting system is also dependent on the soil type. Vegetables perform well on raised bed planting system in heavy soil (Manik et al. 2019).

Modification in sowing time or planting dates in order to combat the likely increase in temperature and water stress periods during the crop-growing season should be adopted (Welbaum. 2015). This technique is useful in indeterminate growth habit vegetables, where uneven rainfall damages fruit quality and yield. Cucurbits crops like ridge gourd (*Luffa acutangula* Roxb.) and sponge gourd (*Luffa cylindrica* L.) under the trail staked method gave 30-35% higher yield and also easy to manage insect and pest protection (Solangi. 2009). These techniques help to prevent fruit damage and during rainfall improve fruit quality.

Manipulation of row spacing and planting orientation will affect the soil water evaporation, transpiration from the canopy and photosynthesis of plants. Plant orientation is significant manipulation towards the use of proper sunlight. East-west oriented strip bed gave the highest yield in the hot and dry growing season (Vincent. 2001). in cucumber, pepper and sweet corn component crops. Planting of



tropical vegetables, in the south side, to improve their yielding ability during the winter season in Sudan (Hassan 1978). Vegetable intercropping methods like spinach-garlic, cotton-vegetable and maize-vegetable, especially systems are popular in China (Feike, 2010). Intercropping is helpful for assured output, nutritional security in adverse conditions and extra income from per unit area can be obtained in the small enterprise with intercropping of leek, garlic and onion as intercrops in cauliflower, broccoli and cabbage (Unlu. 2010). The most common vegetable crops suitable for intercropping in fruit orchard are Okra, French bean, Brinjal, Cauliflower, Pea, bottle gourd, pumpkin and tuber crops like potato, arvi, Elephant foot yam, colocasia, turmeric and ginger (Salam 2017; Swain. 2012 and Kaur. 2015). Some long duration crops, like sugarcane, is found to be a viable option for vegetable intercropping and it was observed that sugarcane + peas/cabbage/garlic had no adverse effect on cane yield and sugarcane + garlic gave good returns (Solangi. 2009).

Physiology-based crop simulation versions are a vital tool in extrapolating the effect of climate change. These models play a crucial part in assisting agriculture in adjusting to these modifications (Ahuja et al. 2016; Ayyogari et al. 2014). In order to deal with adverse impacts of possibilities of these modifications, management options need to be examined, and to a lesser level trait choice for breeding (Hulme. 2005). While these crop simulation models are a simplification of the truth, they let a very first assessment of the intricacy of climate change influence and also adaptation options in farming. Nevertheless, the simulation results must continuously be examined critically via area experimentations for specific conditions (Warren et al. 2012). For instance, some of the models believe a direct connection between elevated CO<sub>2</sub> plus crop response. Field trials with temperature as a critical factor and across various crop development stages has been given paramount consideration in these crop simulation models studies (Fuhrer, 2003). Although for the vegetables, the combined consequences of elevated temperature and high CO<sub>2</sub> remain mostly unknown. The use of these simulation models is to predict the effect of climate change adaptation in advance and to aid in talking to the general public and policymakers. Continuously improving crop models with further biological understanding can boost our performance of potential climate change effects and also adaptation options in vegetable cultivation (Brunner and Lynch. 2013).

Organic farming helpful through in mitigating climate change impact by preventing and reversing soil carbon sequestration with its inputs highest water-holding capacity, lower CO<sub>2</sub> emission in the environment (Muller 2009; Sartaj. 2013). It is also helpful in pest control under bio-diversified organic farms. (Letourneau and Bothwell. 2008). Organic products have higher nutritional/environmental values, and it was also observed that based on new biotechnological and omics technologies (Kesh and Kaushik, 2020; Saini and Kaushik, 2018). There is still a need to investigate organic cultivation concerning fruit quality, especially in vegetables because these are consumed raw and organic farming can become a viable option in changing climate change scenario. Organic produce's nutritional profile examples are as under in Table 4.

**Table 4. Organic product profile based on OMICS technologies.**

Crop	Organic product and it's quality	References
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Endive	Liposoluble antioxidant activity increases in mulching	(Maggio. 2013).
Zucchini	Accumulation of Potassium in clay soil	(Maggio. 2013).
Tomato	Titrateable acidity, phenolic acids, total soluble sugar and Vitamin C, reported highest	(Oliveira, 2013 and Brar et al. 2015).
Potato	Improved stress on based of protein profile in tuber	(Lehesranta. 2007; Rempelos. 2013).
Cabbage	Protein metabolism overexpressed	(Nawrock. 2011).
Carrot	Metabolism of carbohydrates, polypeptides and secondary metabolites differentially expressed, antioxidant activity slightly higher in juice	(Nawrock. 2011; Gąstolet al., 2011).
Beetroot	Soluble solids content high in juice,	(Gąstolet al., 2011).

In the present scenario, organic farming is widespread nowadays because we are facing new challenges, which were non-existent previously. Hypothetically, it can be assumed that organic farming is much beneficial. But a confront is to find out, organic farming output in commercial plant species to meet out the demand of world population in the present set of environmental conditions. Organic farming has the potential to combat climate change, but it requires intergradation approach with all sciences on a large scale from before product to processed food (Muller et al. 2017; Tal 2018).

#### 4.4. Water use efficiency

Water use efficiency of any plants is generally governed and affected by four factors, i.e., increasing carbon dioxide (CO<sub>2</sub>) concentrations, fluctuation in temperatures, more variable rainfall, and variations in relative humidity changing in the climate. Soil moisture is a significant factor, which is mostly delivered by irrigation or rainfall. Its requirement depends on soil type, crop and growing environment. Generally, in low-temperature areas, soil moisture requirement is less. Under high temperature, it requires high moisture during crop growing season, as per changing climate scenario moisture availability is conflicting in two growing regions, i.e. rainfed and irrigated. The emphasis should be on the use of recommended production systems for improved water-use efficiency and to adapt to the hot and dry conditions in a particular area. (Iqbal. 2014). During crop management practices, irrigation at critical crop growth and developmental stages is an essential intervention for saving water. Conservation of soil moistness through narrow row spacing increased WUE by 17% (Barbieri. 2012). Mulching reserves are the most critical interventions based on growing regions for quality fruit production (Harish. 2013). as a result of reduced soil water evaporation and the transpiration of the canopy. Intercropping system gave good response in low fertilizer input area in Texas with peanut, watermelon, okra, cowpea, and pepper planted alone or in intercropping combinations. Peanut showed an increased WUE from 0.00015 kg plant<sup>-1</sup>mm<sup>-1</sup> when grown in monoculture to 0.00022 kg plant<sup>-1</sup>mm<sup>-1</sup> when grown in an intercropping system. Watermelon and okra both showed similar positive responses to intercropping. They suggested

that intercropping system would offer advantages for more efficient water use in water-limited environments (Franco. 2018).

Drip irrigation saves 12-80% of water over furrow methods in different vegetable crops (Narayanamoorthy. 2004). Micro-irrigation systems can also be useful in vegetable crops (Locascio. 2005). with water harvesting methods based on agroclimatic conditions. Noticeable challenges are water scarcity, flooding, salinity, low water quality, crop season drought in rainfed areas, and changing water table where farmers have independent irrigation sources. We can manage the adverse effect of climate change by understanding the based on physical and biological factors of a specific region.

#### **4.5. Nutrient use efficiency**

NUE is a measurement of the utilized available nutrients by the plant with the function of multiple interactions of genetic, soil and environmental factors. There are several methods of analysis of nutrients., NDVI through drones, handheld sensors, and satellite imagery (Lakesh K. 2018). Low nutrient use efficiency cannot be calculated correctly, but it can be enhanced with the use of two or more methods in combination when managing any nutrient. The efficiency of fertilizer generally reported for Nitrogen is 33% (Lakesh K. 2018). Phosphorus 15-20% and Potassium use efficiency is 60-80% in most of the crops (Srivastava. 2015 and Malhotra. 2015). Potatoes provided some promising results in Nitrogen use efficiency using estimated Leaf Area Index from the sensor reading, which was found useful in improving the sensor and potato yield relationship (Sharma. 2017). Nitrogen use efficiency can be enhanced with applying at growth and development stage during crop season to reduce the effective use and losses. Potato used 70% of applied nitrogen within 25-30 days after planting of other crops (Lakesh K 2018). and split application is also an important technique to improve NUE (Du X. 2019). in vegetable production. Biofertilizers are also a promising technology for future sustainable farming systems to enhance the use efficiency of available nitrogen (N) and reduced stock Phosphorous in adverse climatic conditions. (Schütz L., 2018). The NUE depends on the nutrient uptake, rhizosphere, transference, absorption, storage, remobilization, and synthesis of storage compounds during plant growth and development in available climatic conditions. It can be increased with the use of other technologies, i.e., fertigation conservation agricultural practices genetic improvements with molecular markers and some agronomical changes (Jat et al. 2011; Jat et al. 2012; Kaushik, 2017).

#### **4.6. Mulching and protected cultivation**

Mulching is also beneficial as an agricultural mitigation skill against land deprivation in the wake of climate change (Abewoy 2018; Lalljee 2013 and Bhatt 2006). and it contributes to increasing in water retention, infiltration rate, maintaining soil temperature and moisture of soil and therefore lowering evaporation and weed infestations and improves water use efficiency (Steiner 1989; Li 1992; Baumhardt 2002; Kar 2004; Patil 2013). In this direction, plastic mulching increased potato yield (24.3%) and water use efficiency (28.7%) and straw mulching also increased potato yield (16.0%) and WUE (5.6%) (Qiang Li 2018). Bittergourd yield increased by 18.10% with straw mulching practices in Nepal hill station during the early spring season when there is less water available for irrigation (Subedi 2019). The black plastic mulch increases soil temperature up to 5-6°F early in the growing season, and it reduced the weed

infestation along with control outgoing radiation (Patil 2013). Pliable mulch can also be used in winter months where temperatures fall sharply.

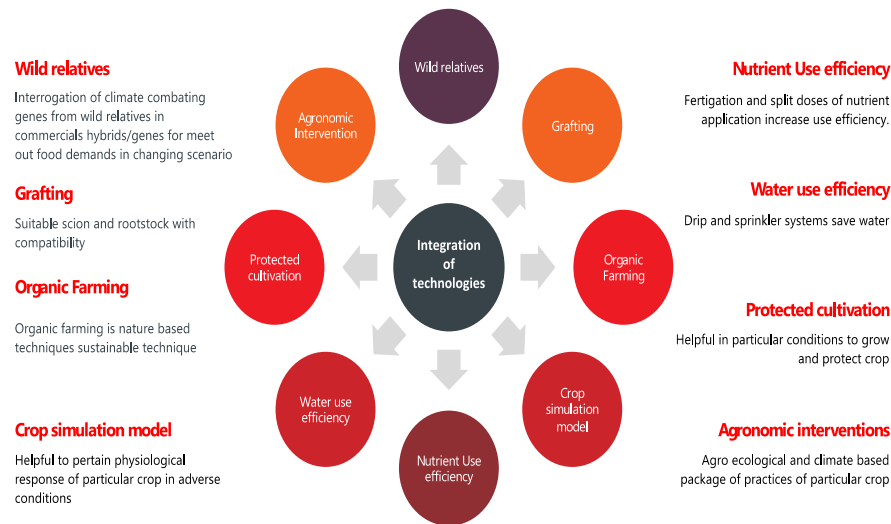
Protected cultivation is a technique where we provide optimum microclimate to the plant for its better development and growth, which can be attained in naturally ventilated poly-house or net-/polytunnel-house or low tunnels. This technique is beneficial if used based on agro-climatic regions and growing seasons. The commercial production of cucurbits in cold desert areas of higher altitude is only possible under protected conditions. A low tunnel is very helpful for getting early summer production (Capsicum, Brinjal, Cucurbits) while preventing cold waves during winter months and provides an optimum temperature for first crop establishment (Ogden 2009; Ibarra 2001). Extreme winter for growing cool-season vegetables (Carrot, Spinach, Pak-choi) can be mainly mitigated by opting for the low tunnel with a high tunnel (Shiwakoti 2018).

## **5. Conclusions and future outlook**

Improved reporting of methodological details and the results from agricultural experiments is essential to tackle climate change. The time has come to begin extreme research on climate change specific to agriculture at national and international levels. Establishment of great synergy between the public-private sector and NGOs, which are concentrating on climate change, is substantially needed. Financial incentives that inspire growers to get going with adequate carbon storage plus better WUE and FUE practices are required. Being mindful and to be able to ask about the current effects of climate change on production, and to provide information about new regulatory structures and government objectives and policies. Training programs need to be initiated to inspire and to teach farm owners to take a look at mitigation and adaptation methods. Variability, as well as climate change, has adverse effects on vegetable production productivity. The reasons for climate change are not entirely understood under these times, but as per the accessible information, anthropogenic activities as industrialization and mechanization might add a few amounts. Implications of the climate created by climate change on harvested crops would be the main among the climate change effects.

## Intervention strategies to Adoption and mitigation

Climate variation and change is an unavoidable phenomenon but some interventions directly in crop field help with combat changes and some indirectly strategies help with some modifications



**Figure 3.** A summary of the strategies used to overcome the effects of climate change.

### Keynotes:

- Need to strengthen available technologies in vegetable breeding for cultivation under changing pattern (organic or conventional; micro irrigation or conventional; open or protected)
- Need to evaluate wild species of the particular crop for desired traits. Last century's majority of the evaluation was done for only yield traits.
- On the one hand, we are investing thousands in genomics and plant biotechnology, whereas organic farming is just the opposite of this science.
- Ample opportunity and challenge for evolving countries while on the other hand, developed countries have a well-established market.
- Mulching has positive relationship under soil fertility, water-saving, weed management and fruit yield under the available set of environment.

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