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IMPACT OF CLIMATE CHANGE ON FORAGE AND PASTURE PRODUCTION AND STRATEGIES FOR ITS MITIGATION – A REVIEW

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SUMMARY

In recent times, the popularity of forage and livestock sector has increased at a very rapid rate throughout the country due to their important roles in employment generation and sustainable production. From last few decades, the problems associated with climate change have reached to a new height. Among these problems, the elevation in CO_2 concentration has most disastrous impacts on forage production. This elevated level of CO_2 decreases the quality as well as quantity of various fodder crops and trees. Impact of climate change varies from sector to sector depending on their inherent capacity of adaptation and vulnerability. Forage sector act as both contributor as well as source of adaptation to climate change. Generally, the crop simulation models are used at wider scale to assess the impact of climate change on crop production. With the help of these simulation models, various crop management decisions are made to provide alternative options to farmers for their farming system. Use of these models will increase in near future due to advancement in technologies and computer use. Various approaches of climate resilient agriculture have potential to mitigate the harmful impacts of climate change and thus raise the income of farm families. This paper provides an overview of impact of climate change on forage production and possible management strategies to mitigate its harmful impacts on forage crops for achieving sustainable production.

Key words : Climate change, forage, pasture, mitigation

India ranks first in the production and consumption of milk. Due to urbanization, there is a significant change in the feeding habits of various people regarding consumption of milk products, meat and eggs which resulted into an increase in demand of various livestock products (Ghosh *et al.*, 2016). But livestock productivity of India is one of the lowest in world mainly due to various problems faced by livestock and forage sector. In India, fodder requirement is mainly fulfilled by three sources: crop residues, fodder crops and pasture or grazing lands. One of the main problems incurred in meeting fodder requirement is the uneven distribution of fodder sources throughout the country. Currently India faces a net deficiency of 35.6% green fodder, 10.95% dry crop residues and 44% concentrate feed ingredients (IGFRI Vision, 2050). The main reason behind this deficiency is climate change and its adverse impacts on forage production and livestock management.

India and other developing countries are comparatively more vulnerable to climate change as compare to developed nations because of predominance of agriculture in their economies (Parry *et al.,* 2001; Kumar *et al.,* 2017). There are many adverse effects of climate change, but out of them global warming is most prominent one. Due to climate change, the average global temperature is increased to a great extent during 20th century (Jung *et al.*, 2002; Yadav *et al.*, 2016). It is assumed that the atmospheric CO_2 concentration that is continuously increasing at an alarming rate due to global warming will definitely affect the future global agricultural production by changing the rate of plant growth (Rotter and Van de Geijn, 1999) and transpiration rate. Several problems like decline in soil fertility, change in water table, increasing soil salinity, development of resistance to various chemicals and degradation in the quality of irrigation water are also associated with climate change

(CGWB, 2002). Squires and Guar (2018) reported that alteration in vegetation cover, plant community composition, hydrologic conditions, or soil properties affect various dry-land regions adversely resulting into the desertification of whole area. In India, a lot of research work has carried out to quantify the gains and losses in the crop yield under the influence of climate change (Mall *et al.*, 2004).

Gangadhar Rao *et al.* (1995) studied the impact of climate change on the productivity of sorghum crop in three different locations of India *i.e.* Hyderabad, Akola and Solapur. Results indicated a downfall in the production of sorghum at Hyderabad and Akola under influence of climate change whereas sorghum grown at Solapur with stored soil moisture showed a marginal increase in yield. Hopkins and Del Prado (2007) observed some major impacts of climate change on forage crops and grazing systems as listed below :

(1) Changes in growth and development of crop plants due to change in CO_2 concentration and temperature brought about by changes in atmospheric carbon dioxide concentrations and temperature.
(2) Changes in the constituents of pastures, like changes in the ratio of grasses to legumes.
(3) Changes in quality of forage due to change in the concentrations of water-soluble carbohydrates and nitrogen.
(4) More chances of drought cause change in dry matter yield.
(5) Climate change may cause higher intensity rainfall which results into leaching of nitrogen in the system.

Importance and Contribution of Pastures

Two third of global dry areas are covered by pasture based production systems. Nori *et al.* (2005) observed that it supports nearly 200 million pastoral households. Africa accounts nearly 40% area for pastoralism and around 70% population is dependent on dry and sub humid land for their livelihood (CBD/UNEP/IUCN, 2007). This shows that pasture is not only important for livestock production but it also have an important role in the livelihood of various small and marginal farmers. Livestock sector contributes a major portion in agricultural economy of our country. This sector is growing at a very rapid rate and to meet the feed requirement of this sector it is necessary to sustain or increase the productivity of pasture based production systems. But various obstacles such as overgrazing, salinization, alkalization and acidification (FAO LEAD, 2006) are decreasing the productivity of pasture systems to a great extent. Safriel *et al*. (2005) observed that the grasslands and rangelands of arid and semiarid or sub humid areas are mainly affected by mismanagement, habitat conversion and climate change.

Plant behavior towards climate change

Under the influence of climate change, there are several modifications in plant behavior that will affect their interactions with pathogens (Garett *et al.*, 2006). Eastburn *et al*. (2010) observed change in canopy density and leaf age of soybean due to elevation in the CO_2 and O_3 concentrations.
These modifications are listed below :

(1) Change in genetic makeup of plant species.
(2) Change in dominance of particular plant species.
(3) Increase in the incidence of various diseases and their symptoms such as wilting, leaf burn, leaf folding, abscission etc.
(4) Loss of biodiversity.
(5) Changes in the physiology and resistance of host species and alteration in the rate of development of pathogens.

Impact of climate change on forage and pasture production

Forage sector is an important part of agriculture, as it makes availability of quality feed to animals. The changes in climate cause several environmental stresses on forage crops that adversely affect the forage production (Ziervogel *et al.*, 2006). Climate change causes significant changes in composition (Polley *et al*, 2013), growth and development of pastures (Hopkins and Del Prado, 2007). Stokes *et al.* (2008) concluded that various factors such as changing precipitation pattern and rates, enhanced evaporation rate, decreased soil moisture content etc. are responsible for decreased availability of irrigation water for crop production. Cultivation of forage, legumes, perennial grasses and trees requires different climatic conditions. So a minute change in climatic conditions may cause immense variation in productivity of green fodder. The alterations in quality and quantity of crops vary from regions to regions (Polley *et al.*, 2013 and Thornton *et al.*, 2009). Both the dry matter content as well as nutritive value of forage crops is reduced to a great extent due to harmful impacts of climate change particularly due to rise in temperature and increased level of CO_2 concentration in atmosphere (Chapman *et al.*, 2012). The IPCC reported that this decrement in nutritional quality of fodder by elevated CO_2 concentration is mainly due to the increased carbon to nitrogen ratio in plants and increased dominance of palatable plant species. Craine *et al.* (2010) also observed a decline in crude protein and digestible organic matter content due to increased level of CO_2. These adverse impacts resulted into a reduction in fodder production. Several positive impacts are also associated with climate change on fodder production. Zavaleta *et al.* (2003) observed that higher temperature my increase the soil water content by accelerating the plant senescence. Climate change mainly affects the forage production by raising the concentration of CO_2, elevating the global temperature, changing the precipitation pattern, stimulating the growth of weed and enhancing the frequency of extreme events (Fig. 1). These impacts are discussed below in detail :

Impact of increased concentration of CO_2

The atmospheric concentration of CO_2 has exceeded 400 ppm in year 2013. This increased

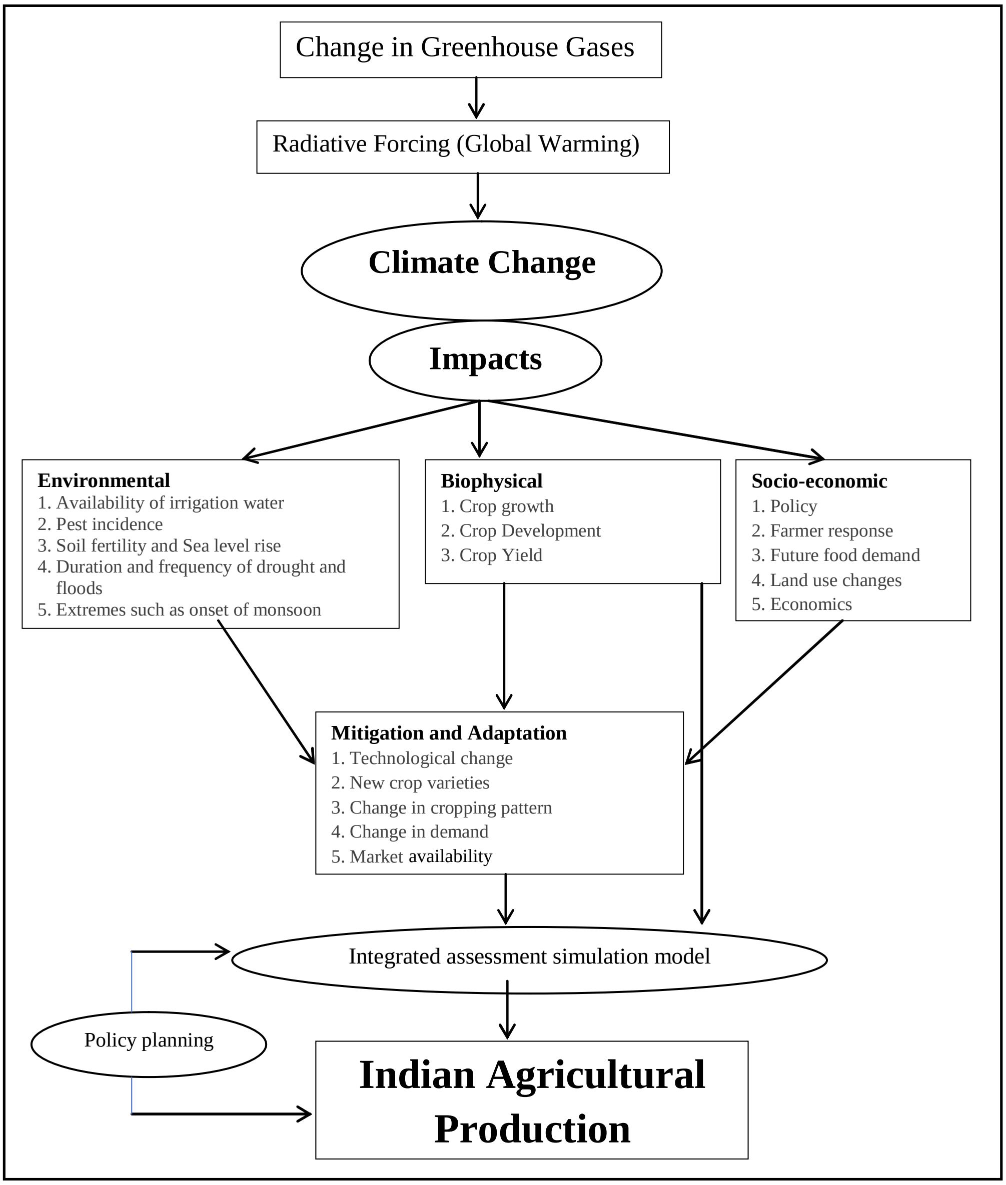

Fig. 1. Driving forces of assessment of the vulnerability of Indian agriculture production to climate change (Mall *et al.,* 2006).

concentration of CO_2 has significant effects on growth and development of plants (Ziska and Bunce, 2007). It results into partial closure of stomata which reduces transpiration and improves the water use efficiency (Rötter and van de Geijn, 1999). Thornton *et al.* (2010) reported that elevation in CO_2 concentration is helpful in improving the growth of various legume species in grasslands. Howden *et al.* (2008) reported that global warming has more beneficial impact on C_4 plants as compare to C_3 plants. The dry matter of legume is increased by 24% as compare to grasses where only 10% increment was observed under elevated CO_2 concentration (Ainsworth and Long, 2005). Increased concentration of CO_2 has also some positive impacts on temperate regions as it increases the primary production of pasture by slowing the evapotranspiration at canopy level (Baron and Belanger, 2007).

Impact of high temperature

Increasing temperature may have either positive or negative impacts on crop production depending upon present climatic conditions and soil resources availability (Hatfi eld *et al.*, 2011; Yadav *et al.*, 2016). Higher temperature may cause lengthening of crop growing season that results into a decrease in the need of accumulation of forage reserves during the winter season in the USA (Izaurralde *et al.*, 2011). Coret *et al.* (2005) reported that higher temperature may results into shortening of life cycle of various perennial grasses which cause deficit of 25 per cent at least in their production. Schlenker and Roberts (2009) reported that higher temperature may cause severe damage to soybean and corn crops leading to a greater yield loss. Minnson *et al.* (1990) reported that higher temperature cause enhanced lignification of plant tissues which results into reduction in digestibility and rate of degradation of plant tissues. It causes insufficient availability of nutrients to animals and ultimately leads to reduction in the livestock production.

Impact of precipitation pattern

Water availability has an important role in behavior of grasslands under the influence of climate change (Izaurralde *et al.*, 2011). Around 80% of our agricultural land and 100% of pasture land are rain-fed, and the modifications in precipitation pattern have potential to shape the direction as well as magnitude of overall impact (Reilly *et al.*, 2003). Extreme rainfall regimes have tendency to increase the duration and severity of soil water stress mainly in mesic ecosystems (Knapp *et al.*, 2008). It is observed that any change in growing season rainfall results into a reduction in richness of grass species (Wilkes *et al.*, 2008) and more problem of soil salinity and degradation (Howden *et al.*, 2008). (Fay *et al.*, 2003) concluded that 50% increase in duration of dry spell results into 10% reductions in the primary productivity. If there is incidence of high temperature along with precipitation deficit of up to 300 mm, then yield will be reduced to an extent of 20-36% (IPCC, 2007).

Impact of increased concentration of ozone gas

Krupa *et al.* (2001) observed a visible injury on the foliage of vegetation under ambient conditions due to the severity of ozone gas. But this foliar injury may not always an accurate detector of ozone effects on dry matter production and quality of crops (Booker *et al.*, 2009). Mills *et al.* (2007) also concluded that present concentration of ozone gas in number of countries worldwide have potential to suppress the growth and productivity of various agricultural plants. Once the ozone gas enters into leaf, it interacts with various cellular processes of plants and inhibits the photosynthesis of plants thus ultimately reduces the growth and yield crop plants. Increased level of ozone causes a yield reduction of 8.5-14% and 2.5-5% in soybean and maize, respectively (Avnery *et al.*, 2011). Cho *et al.* (2011) reported that the harmful effects of ozone are mainly due to the combination of chemical toxicity and plant mediated responses that may amplify or inhibits the injury. The present level of ozone concentration is very harmful for forage crops like lucerne and clover because it reduces the yield of these crops to a great extent in various parts of the world (Booker *et al.*, 2009). Ozone effects are more significant on feed quality in comparison to the dry matter content of feed (Muntifering *et al.*, 2000). It is reported that the increased level of CO_2 may ameliorates the harmful effects of ozone on vegetation (Booker *et al.*, 2009).

Impact of extreme events

Antle *et al.* (2004) concluded that various extreme events reduce the efficacy of farm inputs. When more than one extreme event combined together, they adversely reduce the dry matter of forage to great extent (Olesen and Bindi, 2004). Drought, a major extreme event is one of the major reasons behind the biggest shortfalls of crop production by causing severe withering of leaves, tillers and rhizomes (Briske *et al.*, 2005). The harmful impacts of these extreme events can be minimized by including these events in crop modeling approaches (Moriondo *et al.*, 2011).

Impact of climate change on weed growth

Ziska *et al*. (2001) reported that increased concentration of CO_2 causes more growth and higher biomass production of cocklebur (common weed of sorghum crop) as compare to sorghum crop. It is observed from studies that *Rumex obtusiflius*, a noxious weed of grasslands grows at a very faster rate and reduces the crop yield to a great extent (Gilgen *et al.,* 2010).

Adaptation and mitigation strategies

Nardone *et al.* (2010) reported that adaptation mainly includes maintaining balance between stocking rate and pasture production, managing diet quality, efficient use of tillage, optimum management of fire for control woody thickening, use of productive breeds or species of livestock and prevention of spreading of various pests, weeds and diseases.

Various breeding strategies, science and technologies advances and adaptive technologies also come under adaptation strategies (USDA, 2013). The ultimate goal of mitigation strategies is to reduce the emissions of various greenhouse gases which can be achieved by enhancing the capacity of various carbon sinks. The main priorities of mitigation strategies include the wide scale use of nuclear energy and more extension of the forest area.

Mitigation strategies for encouraging crop production generally include; carbon sequestration, use of bio energy, improved manure management and more efficient use of fertilizers (Thornton and Gerber, 2010). There are mainly two factors which are responsible for enhanced development of forage crops. First factor is the impact of advanced science and technology which include development of various new varieties and dramatic growth of seed industries resulting in global dispersion of plants. The second factor is the diversification in forages value as a source of livestock feed. This diversification of forage crops widens the importance of these crops in human growth and development.

Various approaches for mitigating climate change effects

Breeding strategies for forage crops : Productivity of forage crops can be increased by use of improved seeds, fertilizers and efficient agro techniques (Kumar *et al.,* 2012; Arya *et al.,* 2014; Kumar *et al*., 2016). Improved breeding strategies in forage crops helps to tolerate various biotic and abiotic stresses (Yadav *et al.,* 2011; Henry *et al*., 2012; Arya *et al.,* 2014; Ghosh *et al*., 2016; Bist *et al.,* 2019). Various breeding programs can be improved by the development of international gene banks (Thornton *et al*., 2008).

Efficient management of forage production system : Diversification of forage production systems is helpful in controlling the outbreak of various diseases and pests associated with climate change (Batima *et al*., 2005). Adjustments in various practices like crop rotation, cropping pattern and timing of cultural operations such as sowing, cutting, grazing, irrigating etc. helps plants to adapt under the situation of heat waves and precipitation variability (Batima *et al*., 2005). Similarly changes in diet composition, feeding time and inclusion of agroforestry species in animal feed reduces the heat load and animal malnutrition. Various conservation practices such as conservation tillage, crop residues and mulching, multiple cropping, soil alkalinity and salinity management also enhances the organic carbon content of cultivated soil (Ghosh *et al.,* 2017). Kumar and Tuti, 2016 suggested some of the fodder crops for different problematic soils (Table 1).

Grassland and pasture management : Rate of greenhouse gases emission generally depends upon management of grazing, climate conditions and our ecosystem. However, the rate of GHG emissions depends on the management of grazing, climate and ecosystem (Henderson *et al*., 2015). Conant *et al.* (2001) observed that carbon sequestration can be increased by various practices such as fertilization, incorporation of trees and legumes and introduction of earthworms. Adoption of rotational grazing and exclusion of degraded pasturelands is also helpful in improving the grasslands productivity. Inclusion of perennial forage species in forage production system not only provide higher yield but also reduces the harmful impacts of climate change by sequestration of carbon (Kaul *et al*., 2010).

Nutrient management approach : Hess *et al.* (2006) reported that proper nutrient management helps in the reduction of emission of various greenhouse gases. Various nutrient management strategies such as improving nutrient use efficiency, genetic modifications of plants, more use of organic sources of nutrients, use of slow release fertilizers, proper placement of fertilizers combined cultivation of legume and grasses and combined application of organic and inorganic sources (Dixit *et al*., 2014) are highly efficient in improving the forage production.

Water management approach : Integrated watershed management is well recognized and highly useful approach for conservation of natural resources enhancing farm productivity, improving livelihood of farmers and maintaining ecosystem (Palsaniya *et al*., 2010). Integrated watershed management approach is highly useful in improving quality as well as dry matter yield of forage crops.

Other important practices to mitigate the impact of climate change

(1) Shifting of livestock to the areas having better forage availability
(2) Accumulation of food grains for future use during dry seasons or drought
(3) Mutual sharing of resources among farmers of community or village
(4) Encouraging the farmers to practice more hay and silage making
(5) Diversifying the forage production systems
(6) Maintaining the livestock population on the basis of forage availability
(7) Inclusion of efficient crops and variety in forage production system for cultivation
(8) Efficient harvesting of rainwater

CONCLUSION

Balance diet including green fodder, feeds, concentrate, mineral mixture and other supplements is very essential for providing proper nutrition to livestock. Climate change is observed to be a major threat in forage production system. The interaction of climatic drivers such as CO_2 concentration, temperature and precipitation with plant and management factors is complex so the response of various forage crops, grasses and trees towards climate change is also complex. Generally the response of forage crops towards increasing CO_2 is expected to be consistent with the CO_2 response of C_3 and C_4 crop species. There is need of development of new technologies to mitigate the adverse effects of climate on forage production system. It is suggested that diversified crop production systems would provide increased resilience to conditions of higher CO_2, higher temperatures (to an uncertain degree), and uncertain precipitation changes, and therefore help ensure forage production under future climates. Risk management should be improved by an early warning system and policies so that crop insurance can be promoted. A green research fund should be established to promote research on adoption, mitigation and impact assessment. Various crop management practices

TABLE 1
Suitable crops for adverse climatic conditions

S. No.	Situation	Suitable crops
1	Water lodged	Para grass *(Brachiaria mutica)*, Dallies grass (*Paspalum dilatatum)*
2	Dry tolerant	Sudan grass (Sorghum sudanense), Signal grass (*Brachiaria decumbens*), Pearl millet (*Pennisetum glaucum*)
3	Shade condition	Guinea grass (*Panicum maximus*), Para grass (*Brachiaria mutica*)
4	Less water/hot situation	Buffel grass (*Cenchrus ciliaris*)
5	Wet soil	Dhaincha (*Sesbania bispinosa*), NB Hybrid (*Pennisetum purpureum* × *P. glaucum*), Guinea grass (*Panicum maximus*)
6	Acid soil	Deenanath grass (*Pennisetum pedicellatum*), Stylo (*Stylosanthes hamata* (L.) Taub.), Lupin (*Lupinus polyphyllus*)
7	Saline soil	Sorghum (*Sorghum bicolor*), Oat (*Avena sativa*), Cluster bean (*Cyamopsis tetragonoloba)*
8	Desert /unfertile soil	Stylo (*Stylosanthes hamata* (L.) Taub.), Deenanath grass (*Pennisetum pedicellatum*)
9	Degraded soil	Siratro (*Macroptilium atropurpureum*), Buffel grass (*Cenchrus ciliaris*), Marvell grass (*Dichanthium annulatum*)
10	Erosion prone area	Deenanath grass (*Pennisetum pedicellatum*)

(Kumar and Tuti, 2016).

should be integrated in such a way that least damage occur due to climate change. So with the help of improved research & development technologies, effective grazing and pasture management policies, government schemes and creation of fodder banks in drought prone areas, we can mitigate the impact of climate change on fodder production.

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