*Forage Res.*, **43** (3) : pp. 165-173 (2017) **http://forageresearch.in**

# CURRENT NEEDS OF SUSTAINABLE FOOD AND FORAGE PRODUCTION TO ELIMINATE FOOD AND FORAGE INSECURITY UNDER CLIMATE CHANGE ERA

**SANDEEP KUMAR[1]*, HANSA LAKHRAN[2], RAM SWAROOP MEENA[3] AND CHETAN KUMAR JANGIR[4]**

[1]Department of Agronomy
CCS Haryana Agricultural University,
Hisar-125 004 (Haryana), India
**(e-mail : sandeepsihag1992@gmail.com)*
**(Received : 3 October 2017; Accepted : 15 December 2017)**

## SUMMARY

Current trends point to continued human population growth and existing livestock population besideS climate change increase the pressure on improving the capacity of agricultural system to produce food and forage without further sacrificing the regional and natural resources. The foremost challenges, which agriculture is going to face in coming decades, will be to produce sufficient food and forage for emergent global population by keeping in mind the environmental sustainability. Climate change has immense effects on agriculture and thereafter human and livestock hunger currently and in the decades ahead. The degradation and scarcity of natural resources, pollution resulting from agricultural production, food losses and wastage, and food safety (both quantitative and qualitative), both in terms of production and post-harvest handling, are critical issues that must need to concern to attain sustainability of agricultural production. Recent agricultural technologies that have greatly increased food supply have had inadvertent, detrimental impacts on the environment and on ecosystem services, highlighting the need for more sustainable agricultural production.

**Key word :** Environment, Food and forage security, climate change, hunger, sustainable management

Food security exists when all people, at all times, have physical and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life (World Food Summit, 1996; FAO *et al.*, 2015). Simply, we can say that food security is the ability of people to secure satisfactory food (Anderson, 1990). It is the outcome of food production system processes all along the food chain (Ranuzzi and Srivastava, 2012). This definition comprises four key dimensions of food supplies (Schmidhuber and Tubiello, 2007; FAO, 2008; Ranuzzi and Srivastava, 2012; Pedercini *et al.*, 2012) : availability, access, stability and utilization. The first dimension, availability, relates towards the availability of adequate food i. e. to the overall ability of the agricultural system to meet food demand. It is threatened by reduced agricultural production locally, changes in land utilization pattern, temperature pattern and rainfall pattern. The second dimension, access, covers access by individuals to sufficient resources (entitlements) to gain proper foods. Entitlement, a key element, is the buying power of consumers and the evolution of actual incomes and food prices. However, these resources need not be exclusively monetary but may also include traditional rights. This dimension is affected by the higher food prices resulted from decreased crop yield, loss of income because of the potential increase in damage to agricultural production, etc. The third dimension, stability, covers the individuals who are at high risk of losing their access to the resources required to consume sufficient food. Climate variability is an important reason of unbalanced access i.e. landless farmers, who entirely reliant on agricultural wages in inconsistent rainfall areas and have few savings would be at high risk of losing their access to food and nutrition. Besides this, increased intensity and frequency of extreme events such as floods and drought as a result of climate change

[2]Department of Agronomy, S. K. N. Agricultural University, Jobner-303 329 (Rajasthan), India.
[3]School of Environment and Natural Resources, The Ohio State University, Columbus, OH, USA- 43 210.
[4]Department of Soil Science, CCS Haryana Agricultural University, Hisar-125 004 (Haryana), India.

would affect the crop yield, livestock, fisheries and allied sectors and ultimately largely share to instable food supplies. Fourth dimension, utilization, covers all food safety and quality aspects of nutrition; thus, its sub-dimensions are associated to health, as well as the sanitary conditions across the whole food chain. It is not sufficient that someone is getting what appears to be a suitable quantity of food if that individual is not able to make use of the food as he/she is sick. Therefore, climate variability decreases food utilization ability of individual because of increased malnutrition caused by vector borne pests/diseases and water pollution. An important consequence to this is that a nation or region may be self-sufficient but it does not guarantee food security at the individual level *vice-versa*. Like for, India is self-sufficient in agricultural production at national level but their whole population is not food secure, while on the other hand, populations of Hong Kong and Singapore are food secure even after agriculture does not exist there (Schmidhuber and Tubiello, 2007).

Several studies have revealed the sensitivity of agricultural to inter annual climatic variations (Maharjan and Joshi, 2013). During the recent decade, with the growing recognition of the possibility of climate change and clear evidence of observed changes in climate during 20$^{th}$ century, an increasing emphasis on food security and its regional impacts has come to forefront of the scientific community (Mall *et al.*, 2006).Temperature rise and rainfall variability are likely to result in reduced food production within the next couple of decades in regions already facing food insecurity. For instance, yields of major cereal crops (i. e. rice, wheat, maize and sorghum) in the tropics and sub-tropics regions are likely to drop with a temperature rise as small as 1°C, such as could occur by nearby 2030. However, adaptation strategies could balance some of the probable productivity decline, impacts from a temperature increase of 3°C or more, which may well occur by the end of the century, could upshot in a significant forfeiture of agricultural productivity in low-latitude regions and lessened adaptation measures' effectiveness (World Bank, 2009). In the coming decades, impacts of climate change on agricultural system are expected to carry on, leading in the direction of continuing problem of food insecurity.

The expected global food demand poses enormous challenges for the sustainability both of food production and of terrestrial and aquatic ecosystems and the services they provide to society (Tilman *et al.*, 2002; Meena *et al.,* 2017). Looking onwards, whole globe is facing one of the utmost challenges of this century : climate change, meeting society's growing food needs, while at the same time reducing agriculture's environmental damage (Foley *et al.*, 2011).

In line, food and fiber production is indispensable for sustaining and well-designed human welfare. The vulnerability of global food supply to climate change is a matter in two distinct ways. First, future food supply may perhaps be directly endangered by climate change. Another, food supply capacity may be changed by means of efforts towards reduction in greenhouse gases emissions as people crack to mitigate future climate change influences. To meet the world's future food security and sustainability needs, food production must grow substantially, while at the same time, agriculture's environmental footprint must shrink dramatically (Foley *et al.,* 2011; Meena *et al.,* 2015a). We define sustainable agriculture as practices that meet current and future societal needs for food and fiber, for ecosystem services, and for healthy lives, and that do so by maximizing the net benefit to society when all costs and benefits of the practices are considered (Bahadur *et al*., 2015; Tilman *et al*., 2002). Until recently, most agricultural paradigms have focused on improving production, often to the detriment of the environment (DeFries *et al*., 2004; Foley *et al.*, 2011). Likewise, many environmental conservation strategies have not sought to improve food production. However, to achieve global food security and environmental sustainability, agricultural systems must be transformed to address both the challenges. Today, we need a more resilient and sustainable food and farming systems. In order to develop truly sustainable concepts, public research has to take a much wider perspective than market-oriented private research. New ways of sustainable landscape management will be increasingly important to ensure the vitality of rural areas that provide our essential ecosystem services (SCAR, 2009). As the rice, wheat and maize are most important cropping systems to meet the global food supply, of which wheat is cultivated in about 221.26 million ha around the world, while rice and maize are each grown on over 161.03 and 179.92 million ha area, respectively (FAOSTAT, 2015; Sihag *et al*., 2015). Stagnant yield potential of important crops is one of the chief impediments to sustainable agriculture and concerted efforts are needed to increase the yield potential of the major staple food crops (Tilman *et al*., 2002).

Agriculturalists are the foremost managers of world's working lands and will shape, possibly irrevocably, the surface of the earth in the upcoming times. New policies, technologies and incentives for safeguarding the sustainability of agriculture and ecosystem services will be critical if we are to meet the demands of enhancing crop yields without doing a deal with environmental integrity, public health and food security (Tilman *et al*., 2002; Meena *et al*., 2017). From the perspective of stabilizing farmer incomes and national food supply and security, this new high-resolution information at the global scale should help direct further research and policy more effectively to those regions where climate variability poses the greatest risk and provides leverage points (West *et al*., 2014; Ray *et al*., 2015) in the most critical regions. As the climate change will impact food production very differently in different parts of the world (Parry *et al*., 2004). Consequently, trade and marketing have vital role in ensuring global food supply. Indeed global impacts on agriculture and food supply may be small, once the dynamics of economic adjustments and trade are considered (Fischer *et al*., 2002; Parry *et al*., 2005). Besides this, socio-economic drivers like increased food and feed demand and improvements in production strategies and efficiency need to be considered in order to realistically expected climate change impacts on food supply (Fischer *et al*., 2002; Ewert *et al.*, 2005; Meena *et al*., 2017).

Forage crops have served as an important source of feed of domestic animals for a long period. Animals require forage as basal food. Forage crops are plants which, when grown as a crop, have been found to produce high yields of plant material, which are also high in nutrients suitable for livestock requirements for maintenance and production. Natural pasture is a forage but is not grown as a crop, so is termed forage, not a forage crop. Forage crops produce much higher yields than natural forages and because they produce high yields, can be fed to cattle as green forage during the rains and conserved for the long dry season. Climate change exerts multiple stresses on forage production (Ziervogel *et al.*, 2006). The average yield of these crops is low due to various biotic and abiotic stresses. The major challenges faced by forage crops are extreme weather conditions in form of high as well as low temperature, drought, declining soil fertility and increasing aridity, low availability of high yielding varieties, low seed replacement rate and emergence of new pests and diseases, etc. As the planet warms, rainfall patterns shift, and extreme events such as droughts, floods, and forest fires become more frequent (Zoellick, 2009), which results in poor and unpredictable yields, thereby making farmers more vulnerable (UNFCCC, 2007). Farmers, face prospects of tragic crop failures, reduced agricultural productivity, increased hunger, malnutrition and diseases (Zoellick, 2009). Certainly, there are some opportunities like good climatic condition for good quality production, ample international demand and highly remunerative crops for the farmers. There is, therefore, the need for concerted efforts towards tackling this menace. The strategy should cover selection and breeding of high yielding and stress tolerant fodder crops and varieties, improving the yields through sustainable production practices, efficient conservation and strengthening the value chain of dairy and meat producers to provide various critical services required to optimize the income by maintaining production level with environmental security.

This chapter reviews the existing state of knowledge on the relationship between climate change and global food security. Besides, further examining sustainable measures needed to achieve improve productive base and effective management of natural resources and higher efficiency in the use of these resources and inputs for production to ensure the global food security.

**State of Food Insecurity**

Numerous reports indicate that international estimates of people experiencing chronic hunger increased dramatically over the period 1990 to 2016. Increasing population and consumption are placing unprecedented demands on agriculture and natural resources. The global human population is currently (up to 2009) about 6.6 billion, with about two billion lacking the basic needs of life, and the human population increasing at about 75 million annually (Trevors, 2010) of this approximately a billion people were chronically malnourished in 2010 (Foley *et al.*, 2011). The most vulnerable people cannot access enough of the major macronutrients (carbohydrates, fats and protein). Another one billion are thought to suffer from 'hidden hunger', in which important micronutrients (such as vitamins and minerals) are missing from their diet, with consequent risks of physical and mental impairment (Foresight, 2011). Roughly one in seven people lacks access to food or is chronically malnourished, stemming from continued poverty and mounting food prices (FAO, 2009). However, today, around 795 million people are undernourished globally, down 167 million over the last decade, and 216 million less than in 1990-92. This decline is more pronounced in developing regions (FAO *et al*., 2015). For the developing regions as a whole, the share of undernourished people in the total population has decreased from 23.3 per cent in 1990-92 to 12.9 per cent (Table 1) (FAO *et al*., 2015). Projections suggest that the number of people at risk of hunger will increase by 10-20 per cent by 2050 due to climate change, with 65 per cent of this population in Sub-Saharan Africa (WFP, 2012). Maternal and child under-nutrition is the basic reason of 3.5 million deaths each year and 35 per cent of the disease burden in children younger than five years. For all developing countries, nearly one-third or 178 million children younger than five years are stunted. There are 55 million acutely malnourished children globally (10%) and 19 million children severely acutely malnourished (3.5%) which could increase up to 21 per cent (24 million children), with the majority being in Africa (Black *et al*., 2008; Parry *et al*., 2009; Nelson *et al*., 2009).

The projected human population for 2050 is about 9.2 billion (Trevors, 2010). By keeping in mind, recent scientific researchers suggested that global food production would need to around double over the next 50 years to meet the food demand of growing population, dietary changes (especially meat consumption), and increasing bioenergy use (Tilman *et al*., 2002; Tilman *et al.*, 2009; Kearney, 2010; Cirera and Masset, 2010; Foley *et al*., 2011) including an increase from 2 billion to 4 billion tonnes of grains annually (Ranuzzi and Srivastava, 2012).

Since last few years, the agricultural food sector has been hit by a shock of huge proportions (SCAR, 2009). As of May 2006, 39 nations in the world experienced serious food emergencies and required external assistance for dealing with critical food insecurity : 25 in Africa, 11 in Asia and Near East, 2 in Latin America and 1 in Europe. Over the

TABLE 1
Undernourishment around the world during 2010-12 and 2014-16

| Particular | Number of undernourished (millions) and prevalence (%) of undernourishment | | | |
|---|---|---|---|---|
| | 2010-12 | | 2014-16* | |
| | Number | % | Number | % |
| **World** | 820.7 | 11.8 | 794.6 | 10.9 |
| Developed regions | 15.7 | <5.0 | 14.7 | <5.0 |
| Developing regions | 805.0 | 14.1 | 779.9 | 12.9 |
| Africa | 218.5 | 20.7 | 232.5 | 20.0 |
| Northern Africa | 5.1 | <5.0 | 4.3 | <5.0 |
| Sub-Saharan Africa | 205.7 | 24.1 | 220.0 | 23.2 |
| Eastern Africa | 118.7 | 33.7 | 124.2 | 31.5 |
| Middle Africa | 53.0 | 41.5 | 58.9 | 41.3 |
| Southern Africa | 3.6 | 6.1 | 3.2 | 5.2 |
| Western Africa | 30.4 | 9.7 | 33.7 | 9.6 |
| **Asia and Central Asia** | 546.9 | 13.5 | 511.7 | 12.1 |
| | 7.1 | 8.9 | 5.8 | 7.0 |
| Eastern Asia | 174.7 | 11.8 | 145.1 | 9.6 |
| South-eastern Asia | 72.5 | 12.1 | 60.5 | 9.6 |
| Southern Asia | 274.2 | 16.1 | 281.4 | 15.7 |
| Western Asia | 18.4 | 8.8 | 18.9 | 8.4 |
| **Latin America and the Caribbean** | 38.3 | 6.4 | 34.3 | 5.5 |
| Caribbean | 7.3 | 19.8 | 7.5 | 19.8 |
| Latin America | 31.0 | 5.5 | 26.8 | <5.0 |
| Central America | 11.3 | 6.9 | 11.4 | 6.6 |
| South America | Ns | <5.0 | ns | <5.0 |
| **Oceania** | 1.3 | 13.5 | 1.4 | 14.2 |

*Data for 2014-16 refer to provisional estimates.
*Source* : FAO.

past two decades, the number of food emergencies has risen from an average of 15 per year in the 1980s to more than 30 per year from 2000 onwards (FAO, 2006). Therefore, food crisis has emerged as a global agenda item and calls for action both in the short term – to mitigate the impact of the crisis – and in the mid to long term to get at the roots of the crisis, have proliferated. The food crisis has triggered an acceleration of the debate over food and has facilitated links between policies once anchored to narrow sectorial interests (SCAR, 2009; Meena *et al.*, 2015b).

According to the report, the increase in numbers of chronically hungry people was due to increased food prices worldwide as a result of lower production of staple food such as cereals because of extreme climatic threats. The price of oil also contributed to the high food prices in many parts of the world (FAO *et al*., 2015). Even in regions with comparatively lower yields, fluctuations in crop production may impact the regional food security (Ray *et al*., 2015).

### State of Forage Insecurity

The livestock production has an imperative role in Indian economy paying about 4 per cent to national gross domestic product (GDP) and also a crucial basis of human employment for nearly 70 per cent population mostly in rural expanses. India leads in terms of total livestock population worldwide accounting for 57.3 and 14.7 per cent of the world's buffalo and cattle population (Anonymous, 2013).Even though, the cultivated area under forage crops is only 4.9 per cent having an annual total forage production of 978.7 Mt (525.5 million tonnes green+453.2 million tonnes dry forage). In contrast, to support and fulfil the forage requirement of existing livestock population there is need to produce about 1325.7 million tonnes annual forage (816.8 million tonnes green+508.9 million tonnes dry forage). Therefore, right now, the country is facing a net deficit of 347 million tonnes annual forage production [291.3 million tonnes (35.6%) green+55.7 (10.95%) million tonnes dry forage)] and 44 per cent concentrate feed ingredients (Anonymous, 2013). Looking at the vast gap between demand and supply along with prevailing changed climatic era, there is an urgent need to look for scientific sustainable ways to ensure the availability of good quality forage production under current climatic conditions.

### Impacts of Climate Change on Food Security

Climate change has been described by means of the most important environmental threat of the 21st century, owing to more permanent modifications in seasonal climatic parameters are near term increases in the frequency and intensity of weather threats (Edame *et al*., 2011). Globally, agriculture is the most sensitive economic sector to the growing climate change and variability of its parameters. Climate change affects the global food production in complex ways directly and indirectly. The direct effects are through changes in agro-ecological conditions and indirectly through affecting individual's income and demand of food produce (Schmidhuber and Tubiello, 2007). Changing climate threatens to exacerbate existing threats to food security and livelihoods due to a combination of factors that include shrinking water and land resources, increasing frequency and intensity of climate hazards, increasing biodiversity losses and soil degradation, increasing the pressure from vector and food-borne diseases, decreasing or stable agricultural production, poor farmers' living status and their overall economy, particularly in the light of the uncertainties of climate change (IPCC, 2007; SCAR, 2009; FAO, 2009; NMSA, 2010). In addition, eminent higher production costs, ecosystem and food wastage and nutrient victims, poor food circulation and estrangement of consumers from produc-ers also responsible for growing food insecurity, globally (Jan Willem Erisman, 2015; Meena *et al.,* 2015c). Climate change will act as a hunger risk multiplier exacerbating current vulnerabilities, with one study projecting up to 20 per cent more people at risk of hunger (WFP, 2012).

These climatic consequences will bring greater fluctuations in crop yields and regional food supply and higher risks of food insecurity (FAO, 2009), specifically in developing poorer countries with predominantly rural economies that are already climate-vulnerable (drought, flood and cyclone) and that already face hunger and poverty. They have little flexibility to buffer potentially large shifts in their production bases (Edame *et al.*, 2011). Effects are likely to be particularly significant in specific rural locations where crops fail and yields decline. Impacts will be felt in both rural and urban locations where supply chains are disrupted, market prices increase, assets and livelihood opportunities are lost, purchasing power falls, human health is endangered, and affected people are unable to cope (FAO, 2008). The high level of yield variability owing to changing climate enhances instability of farmer's income and thus, price spikes on food markets resulting in threatening the global food security especially global poor farmers. Price spikes on food markets are also growing due to seasonal droughts which damage cultivated lands and thus quality of harvest (IPCC, 2007). Therefore, stumpy global food reserves along with instability in agricultural production can, in particular, account for global food price variability (Piesse and Thirtle, 2009; Wright and Cafiero, 2011) from market speculation, bioenergy crop expansion and climatic disturbances (Godfray *et al*., 2010; Naylor, 2011). Climate change also resulted in sea-level rise with its associated consequences, and includes fiercer weather, amplified frequency and intensity of storms, hurricanes, increased frequency of fires, poverty, malnutrition and series of health and socio-economic penalties (von Braun *et al.*, 2008).

At the global level, therefore, food system performance today depends more on climate than it did 200 years ago; the possible impacts of climate change on food security have tended to be viewed with most concern in locations where rainfed agriculture is still the primary source of food and income (FAO, 2008). These impacts include those on the water and energy used in food processing, cold storage, transport and intensive production, and those on food itself, reflecting higher market values for land and water and, possibly, payments to farmers for environmental services (FAO, 2008). The potential impacts of climate change on food security must, therefore be viewed within the larger framework of changing earth system dynamics and observable changes in multiple socio-economic and environmental variables (FAO, 2008).

**Sustainable Management of Food Security**

Twin challenges of threatening environment and agricultural production system due to current and expected future climate change along with food insecurity of fast growing global population calling for increases in cropland productivity towards ensuring the constancy of global food security and better socio-economic status of populations especially poor small and marginal farmers to variable production associated with extreme climatic risks (Ray *et al*., 2015; Meena *et al.*, 2015, 2016). These drastic challenges can be solved by means of new geospatial information and models, new approaches and technologies could be assessed that help in improving agriculture food production in cooperation with environmental sustainability (Foley *et al.*, 2011). Even if we solve these food access challenges, much more crop production will probably be needed to guarantee future food security (Foley *et al.*, 2011). Most of the increase in food production in the next decades is likely to come from sustainable intensification of existing cropping systems rather than from increasing agricultural land. Sustainable intensification of cropping systems has been a vastly prosperous way for increasing food production. Such cropping systems must consider not only boosting food production but that also go into reducing environmental impact (Ortiz-Monasterio *et al*., 2010). While improving crop yields and reducing agriculture's environmental impacts will be instrumental in meeting future needs, it is also important to remember that more food can be delivered by changing our agricultural and dietary preferences. Simply put, we can increase food availability (in terms of calories, protein and critical nutrients) by shifting crop production away from livestock feed, bioenergy crops and other non-food applications (Foley *et al.*, 2011). Besides this, animal protein gets on with it remain part of food security, we must track sustainable intensification and work out how to retain livestock in ways that work best for human population, communities, earth as well. Currently by looking in the direction of climate change, there is a need of change in cropland area, owing to enlarged multiple cropping, fewer crop failures, and less land left fallow (Foley *et al.*, 2011). A persuasive sequence of recent reports has suggested conceivable solutions to our linked food security and environmental challenges (Godfray *et al*., 2010). Closing yield gaps could substantially increase global food availability. Closing yield gaps without environmental degradation will require new approaches, including reforming conventional agriculture and adopting lessons from organic systems and precision agriculture (Verma *et al*., 2015).

So far farmer's production system is focused only on instantaneous aspects such as yield maximization, evading temporary price fluctuations and crop dis-ease. As per the today's need farmers would also con-sider sustainable crop production under climate change, floods and droughts and ecosystem services. Cropland unsuited for other food production may be used for grazing systems, and mixed crop-livestock systems which can add calories and protein and improve economic conditions and food security of individuals in many regions. However, using highly productive croplands to produce animal feed, there is no matter that how efficiently it represents a net drain on the world's potential food supply (Foley *et al.*, 2011). If climate change is expected to increase in the similar regions where climate change historically described most of the crop yield variability, approaches to stabilize or enhance sustainable crop production should be prioritized to ensure stable future crop production without food price spikes (Ray *et al*., 2015).

A vast amount of food is not ever used up but is instead discarded, degraded or consumed by pests besides the supply chain. About one-third of food is never consumed as per the reports of FAO (Gustavsson *et al.*, 2011). The food wastage is more in developing countries which accounts for over 40 per cent of total food produced; lost during processing or after harvest due to the availability of poor storage and transport facilities. On the other hand, developed countries have little food wastage as a consequence of better industrial infrastructure, but then again by the side of the retail or consumer level over 40 per cent of food may be unused (Gustavsson *et al*., 2011). Thinking about eliminating food waste and changes of the human diet is not as effective to secure the food supply as food incremental strategies. Likewise, efforts should be made for tumbling misuse of most dietary foods such as dairy and meat to minimize the impact. Dietary, bioenergy and other agricultural choices could substantially improve the delivery of calories and nutrition without supplementary environmental impairment.

Advances in storage, preservation and transport technologies have made food processing and packaging a new area of economic activity. This has allowed food distributors and retailers to develop long-distance marketing chains that move produce and packaged foods throughout the world at high speed and relatively low cost. Where supermarkets with a large variety of standard-quality produce, available year-round, compete with small shops selling high-quality but only seasonally available local produce, the supermarkets generally win out (FAO, 2008).

Innovative agricultural practices and technologies can play a role in climate mitigation and adaptation. This adaptation and mitigation potential is nowhere more pronounced than in developing countries where productivity of forage crops remains low; poverty, vulnerability and food insecurity remain high; and the direct effects of climate change are expected to be especially harsh. Creating the necessary agricultural technologies and harnessing them to enable developing countries to adapt their agricultural systems to changing climate will require innovations in forage crop production. Measures which could enhance the mitigation of climate change and encourage the crop production include; carbon sequestration, use of bio-energy and farm level mitigation approaches. The development of forage crops has been dramatically accelerated by two main factors. The first is the enormous impact of modern science and technology. Progress in plant improvement has led to the development of many new cultivars and the dramatic growth of the seed industry, and thus to the global dispersion of many new forage plants. The second is the diversification in the value of forages as livestock feed has been continuously well recognized, with their production and utilization being strengthened by industrialized agriculture. On the other hand, many other uses of forage crops have been highlighted with the rise and growth of environmental issues. This emerging diversity of functions points to the future roles of forage crops in human existence and development. The harvesting of these forage crops needs to be done at particular growth stages so as to optimize both quantity and quality of biomass.

## REFERENCES

Anderson, S. 1990 : Core indicators of nutritional state for difficult-to-sample populations. Report prepared by the Life Sciences Research Office, Federation of American Societies for Experimental Biology for the American Institute for Nutrition. *J. Nutr,* **120** : 1559-1600.

Anonymous. 2013 : *Vision 2050*. Indian Grassland and Fodder Research Institute, Jhansi (U. P.).

Bahadur, S., S. K. Verma, S. K. Prasad, A. J. Madane, S. P. Maurya, Gaurav, V. K. Verma, and S. K. Sihag. 2015 : Eco-friendly weed management for sustainable crop production–A review. *J. Crop and Weed,* **11** : 181-189.

Black, R. E., L. H. Allen, Z. A. Bhutta, L. E. Caulfield, M. de Onis, M. Ezzati, C. Mathers, and J. Rivera. 2008 : Maternal and child under nutrition: global and regional exposures and health consequences. *Lancet,* **371** : 243-260.

Cirera, X., and E. Masset. 2010 : Income distribution trends and future food demand. *Philosophical Transactions of the Royal Society B Biological Sciences,* **365** : 2821-2834.

DeFries, R., Foley, J. and Asner, G. P. 2004 : Land use choices : balancing human needs and ecosystem function. *Frontiers in Ecology and the Environment,* **2** : 249-257.

Edame, G. E., A. B. Ekpenyong, W. M. Fonta, and E. J. C. Duru. 2011 : Climate change, food security and agricultural productivity in Africa: Issues and policy directions. *Int. J. Humanities and Social Sci.* **1** : (Special issue), December, 2011.

Ewert, F., M. D. A. Rounsevell, I. Reginster, M. J. Metzger, and R. Leemans. 2005 : Future scenarios of European agricultural land use. I. Estimating changes in crop productivity. *Agric. Ecosyst. Environ.*, **107** : 101-116.

FAO. 2006 : FAO Agricultural and Development Economics Division : http://www.fao.org/es/esa/ EC-FAO Food Security Programme : http://www.foodsecinfoaction.org/.

FAO. 2008 : Climate change and food security : A framework document. Food and Agriculture Organization of the United Nations, Rome.

FAO. 2009. Insecurity in the world. Economic crises, impacts and lessons learned. Rome.

FAO, IFAD, and WFP. 2015 : The state of food insecurity in the world. Meeting the 2015 International Hunger Targets : Taking Stock of Uneven Progress. Rome, FAO.

FAOSTAT. 2015 : The state of food and agriculture. Food and Agriculture Organization of the United Nations, Rome. http://www.fao.org/docrep/012/i0680e/i0680e.pdf.

Fischer, G., M. Shah, and H. van Velthuizen. 2002 : Climate change and agricultural vulnerability. A special report prepared as a contribution to the World Summit on Sustainable Development (IIASA, Laxenburg, Austria).

Foley J. A. *et al.* 2011 : Solutions for a cultivated planet. *Nature*, **478** : 337-342.

Foresight. 2011. *The Future of Food and Farming.* London : The Government Office for Science.

Godfray, H. C. J. *et al.* 2010 : Food security : The challenge of feeding 9 billion people. *Science*, **327** : 812-818.

Gustavsson, J., C. Cederberg, U. Sonesson, R. van Otterdijk, and A. Meybeck. 2011 : Global food losses and food waste : Extent, causes and prevention. Food and Agriculture Organization (FAO) of the United Nations, Rome.

IPCC. 2007 : Climate change : Impacts, adaptation and vulnerability. Contribution of WG II to the fourth assessment report of the Intergovernmental Panel on Climate Change (Cambridge Univ Press, Cambridge, UK).

Jan Willem Erismanet 2015 : Put people at the center of global risk management. *Nature*, **519** : 151-153. MacMillan Publishers Limited.

Kearney, J. 2010. Food consumption trends and drivers. *Philosophical Transactions of the Royal Society B Biological Sciences*, **365** : 2793-2807.

Maharjan, K. L., and N. P. Joshi. 2013 : Climate change, agriculture and rural livelihoods in developing countries. Springer Tokyo Heidelberg, New York Dordrecht London. ISBN 978-4-431-54342-8. doi 10.1007/978-4-431-54343-5.

Mall, R. K., R. Singh, A. Gupta, G. Srinivasan, and L. S. Rathore. 2006 : Impact of climate change on Indian agriculture : A review. *Climatic Change*, **78** : 445-478.

Meena, R. S., J. S. Bohra, S. P. Singh, V. S. Meena, J. P. Verma, S. K. Verma, and S. K. Sihag. 2016 : Towards the prime response of manure to enhance nutrient use efficiency and soil sustainability a current need : A book review. *J. Cleaner Production*, **112** : 1258-1260.

Meena, R. S., N. Gogoi, and S. Kumar. 2017 : Alarming issues on agricultural crop production and environmental stresses. *J. Cleaner Production*, **142** : 3357-3359.

Meena, R. S., R. S. Yadav, H. Meena, S. Kumar, Y. K. Meena, and A. Singh. 2015a : Towards the current need to enhance legume productivity and soil sustainability worldwide : A book review. *J. Cleaner Production*, **104** : 513-515.

Meena, R. S., V. S. Meena, S. K. Meena and J. P. Verma. 2015 : Towards the plant stress mitigates the agricultural productivity : A book review. *J. Cleaner Production*, **102** : 552-553.

Meena, V. S., S. K. Meena, J. P. Verma, R. S. Meena, and B. N. Gosh. 2015c : The needs of nutrient use efficiency for sustainable agriculture. *J. Cleaner Production*, **102** : 562-563.

Meena, V. S., S. K. Meena, J. P. Verma, R. S. Meena, and L. K. Jat. 2015b : Current trends to mitigate climate change and sustainable agriculture : A book review. *J. Cleaner Production*, **102** : 548-549.

Naylor, R. L. 2011 : Expanding the boundaries of agricultural development. *Food Security*, **3** : 233-251.

Nelson, G. C., *et al.* 2009 : Climate change : Impact on agriculture and costs of adaptation. Washington, D. C. IFPRI.

NMSA. 2010 : National Mission for Sustainable Agriculture : Strategies for meeting the challenges of climate change. Department of Agriculture and Co-operation, Ministry of Agriculture, New Delhi, August.

Ortiz-Monasterio, I., R. Wassmann, B. Govaerts, Y. Hosen, N. Katayanagi, and N. Verhulst. 2010 : Greenhouse gas mitigation in the main cereal systems : Rice, wheat and maize. In : Climate Change and Crop Production, Reynolds, M. (ed.). Wallingford, UK : CABI Publishing. pp. 151-176.

Parry, M., A. Evans, M. W. Rosegrant, and T. Wheeler. 2009 : *Climate Change and Hunger : Responding to the Challenge.* Rome, Italy : WFP.

Parry, M., C. Rosenzweig, and M. Livermore. 2005 : Climate change, global food supply and risk of hunger. *Phil. Trans. Roy. Soc. B.* **360** : 2125-2138.

doi:10.1098/rstb. 2005.1751.

Parry, M. L., C. Rosenzweig, A. Iglesias, M. Livermore, and G. Fischer. 2004 : Effects of climate change on global food production under SRES emissions and socio-economic scenarios. *Global Environ. Change,* **14** : 53-67.

Pedercini, M., H. Kanamaru, and S. Derwisch. 2012 : Potential impacts of climate change on food security in Mali. Natural Resources Management and Environment Department, FAO, Rome.

Piesse, J., and C. Thirtle. 2009 : Three bubbles and a panic : An explanatory review of recent food commodity price events. *Food Policy,* **34** : 119-129.

Ranuzzi, A., and R. Srivastava. 2012 : Impact of climate change on agriculture and food security. ICRIER Policy Series, May.

Ray, D. K. *et al*. 2015 : Climate variation explains a third of global crop yield variability. *Nature Commun.,* **6** : 5989, doi: 10.1038/ncomms6989.

SCAR. 2009 : New challenges for agricultural research : Climate change, food security, rural development, agricultural knowledge systems. 2nd SCAR foresight exercise. Directorate-General for Research 2009-Food, Agriculture, Fisheries, and Biotechnology – EN.ISBN 978-92-79-11747-3. doi 10.2777/6185.

Schmidhuber, J., and F. Tubiello. 2007 : Global food security under climate change. *PNAS*, **104** : 19703-19708.

Sihag, S. K., M. K. Singh, R. S. Meena, S. R. Naga, S. Bahadur, Gaurav, and R. S. Yadav. 2015 : Influences of spacing on growth and yield potential of dry direct-seeded rice (*Oryza sativa* L.) cultivars. *The Ecoscan,* **9** : 517-519.

Tilman, D., G. Cassman Kenneth, A. Matson Pamela, R. Naylor, and S. Polasky. 2002 : Agricultural sustainability and intensive production practices. *Nature Publishing Group,* **418** : 671-677.

Tilman, D., R. Socolow, J. A. Foley, J. Hill, E. Larson and L. Lynd. 2009 : Beneficial biofuels–The food, energy and environment trilemma. *Science*, **325** : 270-271.

Trevors, J. T. 2010 : Climate change : Agriculture and hunger. *Water Air Soil Pollut.*, **205** (Suppl. 1) : 5105. doi 10.1007/s11270-009-0177-7.

UNFCCC (United Nations Framework Convention on Climate Change). 2007 : Climatic Change Impact, Vulnerabilities and Adaptation in Developing Countries. Secretariat, Martin-Luther-King-Straat 8 53175 Bonn, Germany. http;//www.unfccc.int.

Verma, J. P., D. K. Jaiswal, V. S. Meena, and R. S. Meena. 2015 : Current need of organic farming for enhancing sustainable agriculture. *J. Cleaner Production,* **102** : 545-547.

von Braun, J., A. Ahmed, K. Asenso-Okyere, S. Fan, A. Gulati, J. Hoddinott, R. Pandya-Lorch, M. W. Rosegrant, M. Ruel, M. Torero, T. van Rheenen, and K. von Grebmer. 2008 : High food prices : The what, who and how of proposed policy actions. Policy Brief. Washington, DC, IFPRI.

West, M., R. Eckert, K. Steward, and B. Pasmore. 2014 : Developing collective leadership for health care. London : The King's Fund/Center for Creative Leadership. Available at : *www.kingsfund.org.uk/ collectiveleadership.*

WFP. 2012. Climate impacts on food security and nutrition : A review of existing knowledge. This report was produced by the Met Office and WFP's Office for Climate Change, Environment and Disaster Risk Reduction.

World Bank. 2009 : Agricultural development under a changing climate : Opportunities and challenges for adaptation. *Internet www.worldbank.org/rural.*

World Food Summit. 1996 : Rome Declaration on World Food Security.

Wright, B., and C. Cafiero. 2011 : Grain reserves and food security in the Middle East and North Africa. *Food Security*, **3** (Suppl. 1) : S61-S76.

Ziervogel, G., A. Nyong, B. Osman, C. Conde, S. Cortes, and T. Dowing. 2006 : Climate variability and change: implications for household food security. Assessments of Impacts and Adaptations to Climate Change (AIACC) Working Paper No. 20, January 2006. The AIACC Project Office, International START Secretariat, Washington DC, USA.

Zoellick, R. B. A. 2009 : Climate Smart Future. The Nation Newspapers. Vintage Press Limited, Lagos, Nigeria. p. 18.