Chapter 13
Decreasing the Vulnerability to Climate Change in Less Favoured Areas of Bihar: Smart Options in Agriculture

Anshuman Kohli, Sudhanshu Singh, Sheetal Sharma, S. K. Gupta, Mainak Ghosh, Y. K. Singh, B. K. Vimal, Vinay Kumar, and Sanjay Kumar Mandal

Abstract Anthropogenic climate change results from developmental activities across various sectors including agriculture. Threats resulting from these have variously been proposed to be manageable with mitigation and adaptation mechanisms by the stakeholders. The population inhabiting the less favoured environments is much more vulnerable to climate change. Despite the potential to produce under designated management, these environments have not received the due attention for development initiatives. This could partially be because of the lack of infrastructure facilities and partly also due to the tendency to concentrate in the comfort zone. Hence management adaptations that can directly influence the responsive indicators of climate change such as the concentration of green house gases in the atmosphere could be promising. System intensification is an unambiguous choice keeping in view the increasing population. Subtle climate smart technologies are also available as simple production techniques that can potentially reduce the vulnerability to climate change such as competent cultivars and cropping systems apart from time tested modifications in production practices. System diversification is a key component of disaster risk reduction and seen as a tool for reducing vulnerability to climate change. Precision nutrient management for smallholders aided by IT enabled tools helps in filling the deficit between the crop needs and indigenous nutrient

A. Kohli (✉) · Y. K. Singh · B. K. Vimal · V. Kumar
Department of Soil Science and Agricultural Chemistry, Bihar Agricultural University, Sabour, Bhagalpur 813 210, Bihar, India

S. Singh · S. Sharma
International Rice Research Institute (IRRI), New Delhi, India

S. K. Gupta · M. Ghosh
Department of Agronomy, Bihar Agricultural University, Sabour, Bhagalpur 813 210, Bihar, India

S. K. Mandal
Krishi Vigyan Kendra, Jagatpur, Banka, Bihar Agricultural University, Bhagalpur, Bihar, India

S. Sheraz Mahdi (ed.), *Climate Change and Agriculture in India: Impact and Adaptation*, https://doi.org/10.1007/978-3-319-90086-5_13

supply of the soil for rational yield targets and results in saving fertilizers, increase fertilizer use efficiency and reduce greenhouse gas emissions vis-a-vis conventional management. Sustainable biochar technology can trap atmospheric carbon dioxide in the soil for a time scale of the order of thousands of year and at the same time improve crop productivity and soil physical conditions.

Keywords Climate change · Ahar-pyne system · Biochar

13.1 Introduction

Climate change is a global environmental and humanitarian concern and with increasing awareness and scientific efforts to monitor and combat climate change, the threat of changing climate appears more real (Solomon et al. 2007). Agriculture is the precursor for economic growth and more vulnerable sector than others because of its inherent larger dependence on weather and climate. The challenge and threat from climate change in agriculture has been thought to be manageable with a host of adaptive and mitigating options (Makuvaro et al. 2018), most of which are directed by farmers themselves and not pointed out by government institutions. The mitigation options can be exercised by all consumers and producers; however, adaptive role is largely limited to the stakeholders such as the primary cultivators and others engaged in primary occupations. Masud et al. (2017) revealed that education, experience as well as access to resources and societal support systems have significant impacts on adaptation practices. However, it is pertinent to assume that the adaptation has to be in proportion with their vulnerability or their stake.

13.2 Possible Indicators of Global Climate Change

There is a general consensus among the scientific community that the threat of climate change is real on a global scale. There are indicators such as a generalised global warming characterised by a gradual increase in the mean temperature, increased atmospheric concentration of green house gases, sea level rise, erratic weather patterns, and the increased frequency of extreme weather events. Though the climate of the globe has never been constant on a geological scale, the scientific data available has confirmed beyond doubt that the climate of the globe is changing on scales far shorter than the geological scale, largely because of anthropogenic activities.

13.3 Vulnerability of the Less Favoured Areas

Communities living in the less favoured areas are more vulnerable because they have lesser access to resources. They need to adapt to a greater degree in order to decrease their vulnerability to the effects of climate change. Climate change directly affects the vulnerable by damaging physical resources through the increased frequency of extreme weather events (Garnaut 2013; Nelson and Shively 2014). Ismail et al. (2013) has commented that rural poverty and food insecurity prevail in rainfed and flood-prone ecologies and these areas are expected to increase substantially as a consequence of climate change (Coumou and Rahmstorf 2012). With complete submergence, most of the rice cultivars die within days, resulting in total crop loss (Mackill et al. 2012). Hence the vulnerability of rice farmers in such areas is much more to climate change. The flood prone areas on the banks of Ganges, Kosi, Gandak, Budhi Gandak, Mahananda and their tributaries; the rainfed ecosystems of south Bihar; the *tal* and *diara* lands; *chaur* lands; and the areas fed by the *ahar pyne* systems predominant in Bihar have characteristics of the less favoured areas. Despite their potential to produce under designated management, these areas have not received attention in terms of development initiatives, largely because these are not the ideal choice of the development professionals. Development professionals usually prefer more remunerative postings and even the private sector enterprises do not give an equitable share to these areas. This could partially be because of the lack of infrastructure facilities and partly also due to the tendency to concentrate in the comfort zone.

Another conviction in asserting that the communities in the less favoured areas are more vulnerable to climate change is that the less favoured areas are so largely neglected because of their agro-climatic locations or agro-ecological setting. These areas are less favoured simply because of the harsh agro-climatic conditions that make the agricultural enterprises in these conditions more risky than in the competing areas. Although the communities have adapted to the harsh agro-climate of these areas and there are technologies (both traditional as well as modern) for sustained productivity from these locations, this call for an extra effort and a greater risk; which weans the stakeholders from these ecologies at the very first opportunity in the comfort zone. To illustrate the vulnerability of communities in the less favoured areas to climate change, let us consider the behaviour of irrigation production function in the scenario of climate change (Fig. 13.1). If suppose the climate change scenario involves the shift from a normal to a drier regime, though the irrigation production function would show a southward shift meaning a decrease in the yield of all crops at the similar level irrigation, the maximum decrement in relative terms would be observed in case of rainfed crops. Contrastingly, if the change involves the shift from an existing to a wetter regime, the irrigation production function would show a northward shift meaning an increase in the yield of all crops at the same level of irrigation with a maximum increment in case of rainfed crops. In the first scenario, obviously the most vulnerable communities would be those inhabiting the rainfed areas. In the second scenario, the vulnerability of the rainfed communities

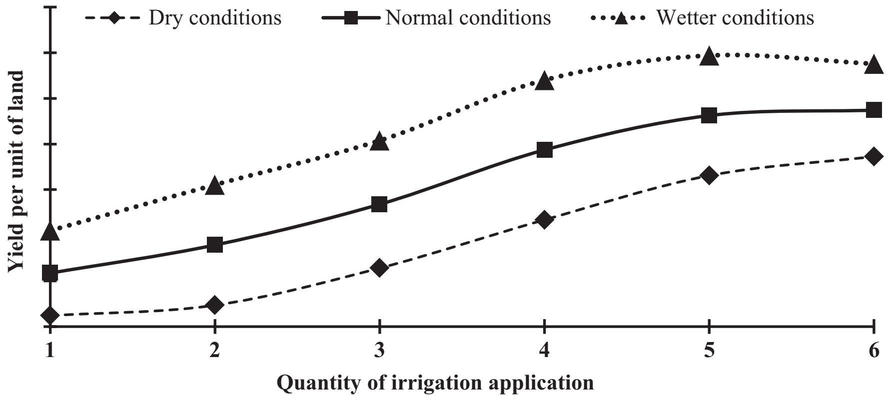

Fig. 13.1 Production function for irrigation under climate change

would be no less because they are likely to encounter an extreme of the precipitation events which would call for a greater adaptation given their original adaptation for the water scarce environments. Another community at the receiving end in a scenario of shift to a wetter regime would be those inhabiting the flood prone areas which have the increased risk of flooding. These areas, having fewer and poorer infrastructure facilities, have the danger of facing greater losses with the advent of similar inclement weather conditions.

13.4 Management Adaptations for Mitigating Climate Change

Adaptations in agronomic practices and adoption of agro-advisories at the farm level can be key components in improving the adaptation of agriculture to climate change (Byjesh et al. 2010; Naresh Kumar et al. 2014; Naresh Kumar and Aggarwal 2013). These options can significantly improve crop yields, increase input-use efficiencies and net farm incomes, and reduce greenhouse gas emissions (Smith et al. 2007). Many of these interventions have been successful in increasing production, income and building resilience among farming communities in many areas such as the Indo-Gangetic plains (Parihar et al. 2016).

Amongst the various possible indicators of global climate change discussed above, the indicator that is likely to respond directly to management adaptations in agriculture is the concentration of green house gases in the atmosphere. The management adaptations that can contribute to decreasing the emission of greenhouse gases from the agricultural soils are primarily reducing or eliminating tillage along with a host of management decisions that can increase crop intensification and plant production efficiency. To illustrate, let us consider a hypothetical case where there is a certain level of greenhouse gas emission under a traditional management regime.

These emissions will usually be far greater than those under a fallow system but fall short of those under an intensified production system. This is the scenario when we consider the emissions per unit of land area per se. With a consideration that there is a need to grow more food for the increasing demand due to increasing population as well as to meet the requirements of improved lifestyles, there is no alternative to intensification. Fallowing cannot be allowed when taking decision based on economic sense. Hence, in our analysis, if we just try to focus on emission per unit land area per unit of output or production, we can see that the emissions scenario will be the best for an intensified system followed by that of a traditional cultivation system or a fallow, which could vary with the season. So this means that the whole set of practices that characterise a system as intensive can contribute to a decreased overall load of greenhouse gases in the environment.

13.4.1 Subtle Climate Smart Technologies

Climate smart technologies are simple production techniques or apart from the techniques that can potentially reduce the vulnerability to climate change. The introduction of SUB1 gene into varieties that are already popular among farmers considerably shortened the time for further evaluation and adoption of flood tolerant varieties (Ismail et al. 2013). Another option is preferring cultivation of resilient crops. One example of such resilient crops is millets in rainfed environments during the *kharif* (rainy) season. Another is *lathyrus* during the *rabi* (dry) season. Such resilient crops are least dependent on external inputs and have a lower incidence of pests and diseases. Traditionally these crops have been grown by broadcasting the traditional seeds and can compete with the native weeds in the rainfed environments. They are generally capable of completing their life cycle from seed to seed solely on the soil moisture residual from the previous crop. The root system is robust to capture the soil moisture from the lower soil layers even when the upper soil layers become too dry to allow any vegetation. When roots transgress the lower layers of the profile for moisture, they inadvertently access the nutrients held up in these soil layers and also enrich those layers with the root exudates and associated organic carbon. During broadcasting of seeds, the traditional practice is to use slightly higher seed rates which takes care of the lower germination under rainfed environments. In case of a rainfall event during the initial stages there is an increased plant population which also gets an extra bout of nutrients from the upper profile till the time it has sufficient moisture. Research into sustainable intensification of these practices under such resilient systems has provided resilient cultivars of various crops that can compete with the water limited environments. This has been made possible by breeding of varieties that have a more robust and extensive root system, those which can be cultivated in a bigger planting window that makes them resilient across cropping systems as well as vagaries of weather. This is just another expression of a cultivar resilient to climate change. An example that is coming out of research initiatives in eastern India is that planting of medium to short duration rice varieties such as

Fig. 13.2 Drought resistant rice cultivar Sahbhagi dhan cultivated in rainfed tracts of Banka amidst traditional rice cultivars depict a distinct advantage in terms of the availability of an early window for planting rabi season crops that can utilize soil moisture residual in the rice fields for crop establishment and a substantial portion of the early growth

Sahbhagi dhan make it possible to use residual soil moisture for establishment of the subsequent dry season crop (Fig. 13.2).

Scientific research has demonstrated such practices as zero or minimum tillage to be more resilient in the unfavourable environments than the conventional practices. The traditional crop establishment practices such as *bhokha* (direct drilling) or *paira* (relay cropping) have an advantage over the conventional tillage in terms of an early crop establishment that enables the crop to complete a portion of its life cycle on the residual soil moisture. Lack of tillage further reduces the soil moisture loss during the subsequent stages of the crop. This is akin to resilience against climate change. The improved resilient crop establishment practices employ the same principles involving an early establishment of the crop and minimizing tillage so as to retain as much residual soil moisture as possible. Another subtle technology is showing respect to and following the time tested traditions. For instance, the *ahar-pyne* systems prevalent in the plains of south Bihar, present a lively example of a tradition so suited for a fragile ecosystem. An *ahaar* is a traditional water harvesting structure which is a common sight in the rainfed lowland tracts of several districts in south Bihar. Structurally, an *ahaar* is a catchment basin embanked on three sides and the fourth side consisting of a natural gradient of the topography. Substantial areas along the highways can be seen in Gaya that have evolved such systems with a thorough understanding of the local topography and agro-climatic conditions. The lifeline of *ahaars* are the *pynes* which simply are the channels leading water to or from an *ahaar*. The crops being cultivated on the pyne bed include chickpea/ lentil, vegetable peas and wheat. The conventional practice is to broadcast the seeds and then till the soil with a bullock driven plough to cover the seeds. The seedbed is usually very cloddy in case of vegetable peas and chick pea, which are being grown in the area without any supplemental irrigation; however the seed bed for wheat is comparatively smoother. Probably the indigenous communities recognize the presence of water in the profile and so the existing practice is of tilling the soil leaving a cloddy surface with much surface roughness and breaking the capillaries to restrict the movement of profile soil moisture to the surface soil. These indigenous practices are an essential part of the rainfed cultivation of rabi season crops in the ecology. The *ahaar* bed is usually flooded during the *kharif* season and so there is limited

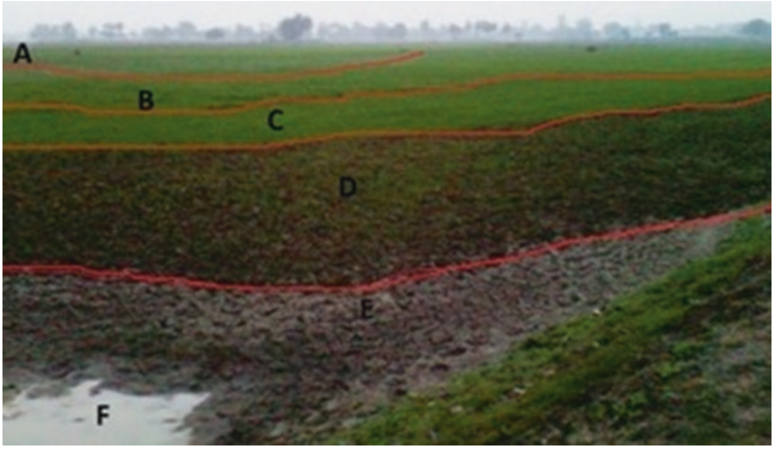

Fig. 13.3 Rabi cultivation in an *Ahaar* of Khizarsarai block of district Gaya, Bihar shows a distinct gradient in the time of planting of *rabi* season crops based on drying of the *Ahaar* bed starting from the highest point in the watershed to the lower points

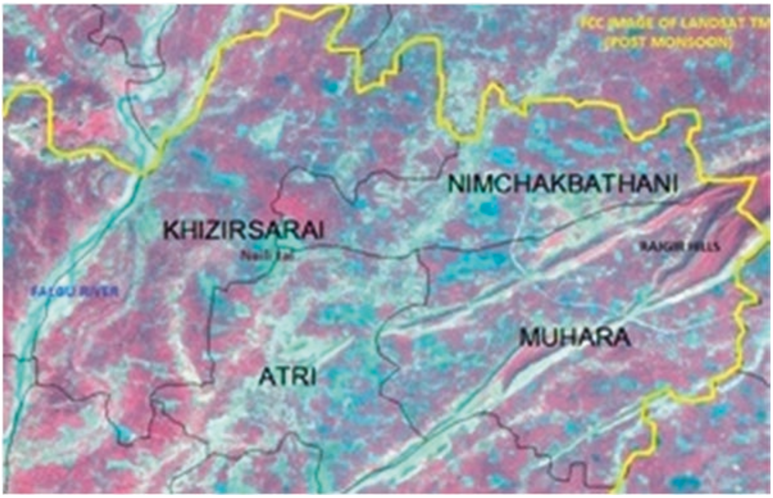

Fig. 13.4 Based on visual interpretation key, the *Ahaar-Pyne* systems can be seen densely existing in the rainfed tracts of district Gaya, Bihar

scope of cultivation. However, the advent of the *rabi* season enables cropping in phases as visible in distinct bands as the water level in the *ahaar* recedes (Fig. 13.3). The *Ahaars* can be seen very densely scattered in the area as identified in the archived post monsoon LANDSAT-TM imagery (Fig. 13.4).

13.4.2 Diversification and Intensification of Rainfed Systems Reduces Vulnerability to Climate Change

Drought is a widespread abiotic stress and drastically reduces rice yield. Technologies that reduce the production risk caused by drought will favor input use and have a major impact on system productivity in good and bad years. In addition, improved technologies that reduce labor and land requirements for crops are needed to allow these resources to be released for other income-generating activities. Several varieties of rice have been evaluated for tolerances to abiotic stresses such as drought and submergence. Drought affects rice at morphological, physiological, biochemical and molecular levels and thereby affects its yield. Good opportunities for diversification through post-rice crops are provided by the development of new drought-tolerant short-duration rice varieties/lines such as *Sahbhagi dhan* and *Susk Samrat*. Most farmers practice limited or no cropping during the *rabi* season in drought-prone areas of Bihar, thus failing to realize the full production potential of their land. New area specific systems need to be developed to improve the post-rice production. Timely and appropriate planting techniques allow earlier-maturing crops, maximizing the use of residual water for post-rice *rabi* crops. New, improved varieties of *rabi* season crops, notably pulses, allow for a greater range of options for *rabi* season cropping and land productivity. Broadcasting of seeds of pulses like lentil or lathyrus into the standing rice crop before harvest is practiced in these areas if sufficient moisture is available. There is a strong need of managing midterm and terminal droughts of 2–3 weeks to have a capacity for intensifying cropping in hitherto single crop situations; more so because of the prevailing low cropping intensity in these areas (e.g. the cropping intensity of Bihar is just 146 per cent). Besides weather, soil moisture availability in a situation also depends on land use practices. There is a need to identify agricultural practices that maximize precipitation utilization and minimize evaporation. Reduced tillage, raising the height of farm bunds, rational residue retention and reducing the time of fallow between crops can allow better utilization of precipitation. Soil incorporation of biochar like substances can improve the water holding capacity, infiltration rate, microbial ecology and nutrient relations. System diversity can be increased by introducing interventions such as growing short to medium duration legumes like chickpea, green gram, grass pea, vegetable peas and lentils or short duration oilseeds like linseed. A host of practices that aim to increase the infiltration opportunity time, minimize evaporation, decrease soil bulk density and erosion susceptibility, increase the access of the rainfed crops to the stored water and nutrient resources in the lower layers, staggered planting in conjunction with diverse crop rotations, weed management, controlling grazing and human interference and avoidance of terminal heat stress can contribute towards obtaining greater yields from rainfed agriculture on a sustainable basis. However, the effects of each of management option needs to be quantified on a uniform scale for the effects to be additive and comparable.

13.4.3 Targeting Precision Nutrient Management Using IT Enabled Tools for Smallholders in Less Favoured Areas for Mitigating Climate Change

Precision nutrient management aims at satisfying the total mineral nutrient requirements of the crop by filling the deficit between the total needs to the crop and the soils' indigenous supply by first ensuring the effective use of the indigenous nutrients and then assessing the crops additional needs based on an attainable yield target. The benefits towards mitigating climate change by adopting precision nutrient management are expected in terms of the savings in fertilizers and increased fertilizer use efficiencies that can reduce the emissions of green house gases. The conventional approach for implementing a precision nutrient management programme is through soil testing based management. There is no doubt about the validity of this approach, but still it is a fact that despite the best efforts of government agencies, agricultural universities and others, the soil testing programme has had little visibility. This is obvious considering the high cost of analysis and difficulty in availability of timely results of analysis. Of late, several organizations have made concerted efforts to develop IT enabled tools to recommend a balanced fertilizer dose for various crops considering the system as a whole. Use of SSNM-based fertilizer recommendations for rice were shown to increase yields, increase net income of farmers, and provide positive impacts on the environment when compared to existing fertilizer practices. Field experiments were conducted at Bihar Agricultural University, Sabour with tools such as Nutrient Expert™ for Hybrid Maize, Nutrient Expert™ for Rice, Rice Wheat Crop Manager, Rice Crop Manager for stressed conditions (drought) and with Crop manager for rice based systems, all of which have shown a potential for considerable fertilizer saving, improving yields and profitability.

13.4.4 Sustainable Biochar Technology for Mitigating Climate Change in Less Favoured Areas

Scientific literature is multiplying exponentially with new benefits and applications of biochar as a soil conditioner and as a carbon negative technology. No other technology has a potential to trap atmospheric carbon dioxide in the soil for a time scale greater than that offered by biochars, whose mean residence time in the soil is of the order of thousands of years. During biochar production, up to a large fraction of the carbon in the original organic residue is retained in the crystalline biochar structure. Simultaneously, there is production of energy in the process. Thus our organic residues / wastes can be used for energy production using vessels which allow pyrolysis. The byproduct of these energy production systems can be a useful material known as biochar. Biochar production can be achieved during energy production systems at household to industrial scale. For instance, electricity co-generation in several rice mills is achieved by pyrolysis of rice husk, and this simultaneously produces rice husk biochar. The communities in the less favoured areas are dependent on fuel wood or other agricultural waste biomass for cooking activities with traditional stoves. At a household scale, there are top lit up draft (TLUD) stoves that can be used for cooking with any organic residue as feedstock and result in generation of clean energy for cooking and simultaneously producing biochar as a byproduct. TLUD technology needs to be promoted as a low external input technology which can be used easily in the far flung areas and hinterlands as against the current impetus of the governments on taking LPG connections to each household. Use of biochar in soils not only increases crop productivity, but also improves soil tilth, fertility, water holding capacity, reduces risk of soil erosion and the need for fertilizer inputs.

References

Byjesh, K., Naresh Kumar, S., & Aggarwal, P. K. (2010). Simulating impacts, potential adaptation and vulnerability of maize to climate change in India. *Mitigation and Adaptation Strategies for Global Change, 15*, 413–431. https://doi.org/10.1007/s11027-010-9224-3.

Coumou, D., & Rahmstorf, S. (2012). A decade of weather extremes. *Nature Climate Change, 2*, 491–496.

Garnaut, R. (2013). Removing climate change as a barrier to economic progress: twentysecond Colin Clark Memorial Lecture November 2012. *Journal of Economic Analysis and Policy, 43*(1), 31–47. https://doi.org/10.1016/S0313-5926(13)(50002-6).

Ismail, A. M., Singh, U. S., Singh, S., Dar, M. H., & Mackill, D. J. (2013). The contribution of submergence-tolerant (Sub1) rice varieties to food security in flood-prone rainfed lowland areas in Asia. *Field Crops Research, 152*, 83–93. https://doi.org/10.1016/j.fcr.2013.01.007.

Mackill, D. J., Ismail, A. M., Singh, U. S., Labios, R. V., & Paris, T. R. (2012). Development and rapid adoption of submergence-tolerant (Sub1) rice varieties. *Advances in Agronomy, 115*, 303–356.

Makuvaro, V., Walker, S., Masere, T. P., & Dimes, J. (2018). Smallholder farmer perceived effects of climate change on agricultural productivity and adaptation strategies. *Journal of Arid Environments, 152*, 75. https://doi.org/10.1016/j.jaridenv.2018.01.016.

Masud, M. M., Azam, M. N., Mohiuddin, M., Banna, H., Akhtar, R., Alam, A. S. A. F., & Begum, H. (2017). Adaptation barriers and strategies towards climate change: Challenges in the agricultural sector. *Journal of Cleaner Production., 156*, 698. https://doi.org/10.1016/j.jclepro.2017.04.060.

Naresh Kumar, S., & Aggarwal, P. K. (2013). Climate change and coconut plantations in India. Impacts and potential adaptation gains. *Agricultural Systems, 117*, 45–54.

Naresh Kumar, S., Aggarwal, P. K., Swaroopa Rani, D. N., Saxena, R., & Chauhan, N. A. J. (2014). Vulnerability of wheat production to climate change in India. *Climate Research, 59*, 173–187. https://doi.org/10.3354/cr01212.

Nelson, G. C., & Shively, G. E. (2014). Modeling climate change and agriculture: An introduction to the special issue. *Agricultural Economics, 45*(1), 1–2. https://doi.org/10.1111/agec.12093.

Parihar, C.M., Jat, S.L., Singh, A.K., Kumar, B., Pradhan, S., Pooniya, V., Dhauja, A., Chaudhary, V., Jat,M.L., JAt, R.K. and Yadav, O.P. (2016) Conservation agriculture in irrigated intensive maize-based systemsofnorth-western India: effects on crop yields, water productivity and economic profitability. Field Crop Res., 193,104-116. https://doi.org/10.1016/j.fcr.2016.03.013

Solomon, S., Qin, D., Manning, M., Chen, Z., Marquis, M., Averyt, K. B., Tignor, M., & Miller, H. L. (2007). *Climate change: the physical science basis. In: Contribution of Working Group I to the Fourth Assessment Report (FAR) of the Intergovernmental Panel on Climate Change* (p. 996). United Kingdom/New York: Cambridge University Press, Cambridge.

Smith, P., Martino, D., Cai, Z., Gwary, D., JAnzen, H., Kumar, P., McCarl, B., Ogle, S.O'MAra, F., Rice, C. andScholes, B. (2007) Policy and technological constrints to implementation of greenhouse gas mitigation options inagriculture. Agric. Ecosyst. Environ., 118(1), 6-28. https://doi.org/10.1016/j.agee.2006.06.006