Vulnerability of Dryland Agriculture over Non-dryland Agriculture toward the Changing Climate

Chapter · March 2023

DOI: 10.1007/978-981-19-9159-2_3

Shubham Singh
Central Agricultural University Imphal

Shidayaichenbi Devi
Dr. Rajendra Prasad Central Agricutural University Pusa

Vulnerability of Dryland Agriculture over Non-dryland Agriculture toward the Changing Climate

3

Shubham Singh and Shidayaichenbi Devi

Abstract

Farming in dry areas is under threat because of climate change and not utilizing the land in a sustainable way. Around 40% of the earth's surface is made up of drylands including areas with very little water. These drylands are home to approximately 2.5 billion people. It is important for the farmers of the dryland areas to understand how climate change can affect them and what are the promising ways to face it. Moreover, the utilization of this area by growing crops is also necessary for feeding the ever-increasing population. However, the sustainability of livelihoods in drylands agriculture systems is threatened by a complex range of social, economic, political, and environmental changes. These changes present significant challenges to researchers, policymakers, and rural land users. However, these areas are highly sensitive to climate variability and change. The changing climate poses an imminent challenge to dryland farmers who practice a wide range of techniques from traditional methods to advanced irrigation systems for crop production. Different process-based models can also be helpful in designing the management options for dryland cropping systems that are more resilient to climate change. These models have been used in different regions around the world to quantify the impacts of climate change at the field, regional, and national scales. Therefore, future policies for sustainable agricultural production systems should take this into account. And technology-based regional collaborative interventions among universities, growers, companies, and others are needed to support agriculture in the face of climate change. In this article, we explore the vulnerability of dryland agriculture toward

S. Singh (✉)
College of Post Graduate Studies in Agricultural Sciences, CAU-Imphal, Umiam, Meghalaya, India

S. Devi
Dr. Rajendra Prasad Central Agricultural University, Pusa, Samastipur, Bihar, India

A. Naorem, D. Machiwal (eds.), *Enhancing Resilience of Dryland Agriculture Under Changing Climate*, https://doi.org/10.1007/978-981-19-9159-2_3

the changing climate as well as its potential for adaptation through different resilience measures. Therefore, the recommendations for better productivity in these areas require water and nutrient management, ideotype designing, modification in tillage practices, application of cover crops, insects, and disease management.

Keywords

Climate change · Dryland agriculture · Crop models · Climate model

3.1 Introduction

The surrounding of the earth's surface, i.e., the atmosphere, is increasing in its temperature since industrialization. It releases various forms of solar radiation-trapping and ozone-depleting compounds such as carbon dioxide (CO_2), chlorofluorocarbons (CFC), methane (CH_4), nitrous oxide (N_2O), etc. inducing climate change. As the movement of the atmospheric air from one region to another, climate change is a global issue other than where industries exist. It is not only due to industrialization but also due to mismanagement of lands, deforestation, faulty practices of agriculture, etc. Climate change affects dryland regions more as compared with non-dryland regions. The existence of dryland regions is in elevated temperature regions, and climate change further increases the temperature of these regions (Ahmed et al. 2022). With the elevation of temperature, the mineralization of organic materials is enhanced thereby the wide spreading of the dryland regions and degrading the environment. This directly impacts the social, economic, political, and environments of livelihoods. However, the non-dryland regions are less vulnerable to climate change as the mineralized organic materials can be substituted from the vegetation as the source. The coverage of dryland regions is almost half of the earth's surface. So the spreading of dryland regions due to climate change threatens lives. The most challenging issue is the reduction of climate change and the conversion of the dryland regions into non-dryland regions. Many scientists have designed models for quantifying the impacts of climate change at local, regional, and national levels. The most agreed solution is the adoption of sustainable-based technologies to reduce climate change and increment the non-dryland regions.

3.2 Impact of Climate Change on Dryland System

The adverse impacts of global climate change on dryland agriculture are already being felt by farmers around the world. Climate change is projected to have a number of impacts on dryland agriculture, including changes in precipitation patterns, increased temperatures, and increased frequency and intensity of extreme weather events. Changes in precipitation patterns are likely to result in more frequent and acute droughts, which will have a detrimental effect on crop yields and livestock

Table 3.1 Awareness of respondents about the impact of climate change under dryland agriculture

Indicators	Percentage of respondents
Yield reduction	76.67
Pest and disease infestation	74.44
Crop failure	86.67
Net income reduction	86.67
Soil moisture evaporations	71.11
Climate change and rainfall patterns	83.33
Increase of unsuitable land for cultivation	64.44

Source: Angles et al. (2011)

productivity. Increased temperatures will also lead to higher evaporation rates, further exacerbating drought conditions. In addition, these irregular weather events are likely to become more recurrent and intense, causing damage to crops, infrastructure, and livelihoods (Challinor 2009).

Drought and erratic rains are becoming more common, and crop yields are declining as a result. In some regions, farmers are being forced to abandon their land entirely as the climate becomes too harsh to support any agriculture at all. In addition to the direct impacts of climate change on dryland agriculture, the indirect impacts are also caused for concern. As global temperatures rise, pests and diseases are able to spread to new areas, attacking crops and livestock. This puts even more pressure on farmers who are struggling to adapt to the changing climate. For this reason, farmers will need to adopt new production practices and technologies to manage the changing conditions.

Angles et al. (2011) conducted an experiment at the Dharmapuri district of Tamil Nadu to identify the issues faced by dryland farmers from the impact of climate change. For this they selected 90 respondents through the multistage random sampling design. The data revealed that nearly 87% of respondents agree that their net income is reduced over the years, 83% noticed that there is a change in climatic pattern, 77% admitted that there is a reduction in yield, and 74% are dealing with heavy pest and disease problem (Table 3.1).

The impact of climate change on dryland agriculture is not just economic – it is also social and political. Small-scale farmers in particular are struggling to adapt to the new conditions, and many are being forced into poverty or even starvation. In some parts of the world, this is leading to social unrest and even conflict. The situation is only likely to get worse in the future as the effects of climate change intensify. Dryland agriculture is vital to the global food supply, and the impact of climate change on this sector could have devastating consequences for millions of people around the world. There are three approaches used to analyze the variability in crop production (Fraser et al. 2011):

- Socio-economic framework: This approach mainly emphasizes the political and socio-economic aspects of social or individual groups which differ in terms of the resources available like level of education, the status of health, etc.

- Biophysical framework: This approach helps in identifying the level of damage due to environmental stress on biological systems as well as on social systems and is usually identified by the vulnerability assessment. For example crop simulation models which help us in analyzing the impact of changing climate on crop yields.
- Integrated framework: This will include both the principles of biophysical as well as socio-economic aspects to determine vulnerability. This will be accomplished by taking adaptive measures and policy reforms.

3.3 Need of Vulnerability Assessment

Agriculture is an essential component of any society, and it contributes to the food supply, the economy and, in some cases, the cultural identity of a country. Climate change is likely to have a severe impact on agriculture and its practices, especially in dryland areas. Research on future changes in agricultural practices is still in its embryonic stages (Eigenbrode et al. 2018). A vulnerability assessment for dryland agriculture under changing climate is an important step in the process of understanding how climate change will affect dryland agriculture.

Climate change is gradually altering the landscape of dryland agriculture. This is especially true in arid zones, where drylands provide one of the most important ecosystems for human subsistence. Dryland agriculture, however, puts extreme pressure on vulnerable ecosystems. In India, dryland covers about 68 percent of the total cultivated land which influences nearly 44 percent of the total food grain production. Geographically this area includes northwestern part of Rajasthan, Yamuna Ganga alluvial river basins, central plateau region of Madhya Pradesh, highlands of Maharashtra, Tamil Nadu and Gujarat, and Deccan Plateau of Maharashtra and Andhra Pradesh (Vijayan 2016). There is an urgent need to understand the vulnerability of dryland agriculture in the context of climate change. Vulnerability assessment helps to identify the possible risks of climate change that might affect dryland agriculture. This can help to plan for and mitigate the risks. One way that vulnerability assessment helps to plan for and mitigate the risks is by using crop insurance, which helps to reduce the risks of climate change.

Vulnerability assessment is the process of identifying opportunities and threats that an area may face in the future. Under changing climate, vulnerability assessment is becoming critical for dryland agriculture. The need for vulnerability assessment for dryland agriculture under changing climate is for the purpose of implementing appropriate adaptations to the changing climate. This assessment will include a detailed analysis of the vulnerabilities of the dryland agriculture systems and the development of appropriate adaptation strategies.

Ashalatha et al. (2012) also conducted one experiment with a similar trend to Angles et al. (2011), in Dharwad district of Karnataka with 250 respondents. The data reveals that the main reason for reduction in yield is the uncertainty in rainfall which comprises 92 percent of the total respondents. Pest and disease infestation is also increased due to climate change which also is the reason for yield and revenue reduction as shown in Table 3.2.

Table 3.2 Indicators for yield and revenue reduction due to the impact of climate change under dryland agriculture

Indicators	Percentage of respondents
Alteration in seasonal and temperature patterns	42.22
Rainfall	92.22
Pest and disease infestation	72.22
Degradation of soil fertility and erosion	46.67

Source: Ashalatha et al. (2012)

3.4 Dryland Agriculture Implications under Climate Change

The condition of the atmosphere which is beyond the normal either in temperature or the gaseous compounds is climate change. It may be due to an increase or decrease in the temperature and the addition or removal of gaseous compounds. Today's climate change is due to the addition of solar trapping compounds which rising the atmospheric temperature. The environmental components are directly and indirectly dependent on temperature. Depending on the landscape and climate of a region, the rising temperature has positive or negative impacts. The drylands occur where elevated temperature regions have less weathered soil particles due to constraints of water and less organic matter content thereby supporting less vegetation. With rising temperatures due to climate change, the drylands are prone to desertic regions. The available water in the drylands evaporates from the soil pores, and severe wildfires occur which destroy the slow-growing trees and shrubs and higher the chance of fast-growing grasses dominating the region. Moreover, the litter of the soil surface and soil organic matter are also destroyed leading to poor soil health. The soil supports for agriculture and forestry is almost negligible in this dryland region affected by climate change. However, it covers half of the earth's surface land and is settled by 38% of the world's population (Huang et al. 2017). The contribution of the dryland region to livelihood is enormous. Erroneous acts of industrialization, conventional agriculture, transport, mismanagement of land, etc. lead to climate change which affects the environment and threatens livelihood. Moreover, climate change-affected dryland regions render to loss of biodiversity. The environmental cycles, i.e., the hydrological cycle and nutrients cycle (carbon, nitrogen, phosphorous, and sulfur), are disturbed thereby the existence of the vegetation, microbes, and higher organisms. The reason for converting non-dryland to dryland and to desertic regions is human-induced climate change. A proper understanding of the cause of anthropogenic climate change and its impacts and managements is the only solution to mitigate climate change and control the increment of dryland areas.

3.5 Drylands' Vulnerability to Climate Change

The dryland regions are facing disruption of the hydrological cycle rather than rising temperatures (Thomas 2008). The erratic rainfall pattern renders the crop production system discouraged. There exists a malfunctioning ecology under climate change. Many strategies have been established for drylands to adapt to the changing climate including the following.

3.5.1 Crop Rotation

Monocropping renders poor soil health as the uptake of the same nutrients each year or cropping system exhausts the nutrients. This also imbalances the nutrient ratio into toxicity or deficiency of nutrients. The cropping system like cereal legume is the most prominent system for soil health. Cereal crops are known as nutrient-exhaustive crops, and legume crops have atmospheric N fixation potential. The cereal crops required more primary nutrients (N, P, and K) as compared with the legumes. The nutrients exhausted by cereals are regained by the legume crops and maintaining the nutrient ratio in the soil. Not only the soil's chemical properties are enhanced but also the soil's physical and biological properties. In the context of dryland soils, there is already poor soil health due to unfriendly precipitation, temperature, and soil condition of crops. The introduction of a cropping system that maintains the nutrients cycle and enhances the soil properties without compromising productivity is a promising approach in dryland regions under climate change.

3.5.2 Residue Management

The crop residue content nutrients uptake from the soils. With a lack of knowledge, residues are considered waste materials. It is either burnt or removed from the fields which reduced the soil's nutrient level and soil properties. The burning of residues induced climate change. Eastern India is facing climate change due to the burning of cereal residues. This pollutes the air, decreases soil properties, and induces global warming into climate change. A new approach is the return of crop residues after collecting the economical yields. However, different crops have different C/N ratios. The cereal residues have a wide C/N ratio as compared with legume crops. The incorporation of residues should be in a way that does not hamper any crop productivity and disturb the soil conditions (Lawrence et al. 2018). It helps the dryland regions to prevent climate change impacts as it develops the soil's physical, chemical, and biological properties in an optimum condition for plant growth and development.

3.5.3 Water Management

The erratic and irregular nature of precipitation defines dryland regions. The management of a drop of rainfall matters in this region for cultivation. Irrigation is the main source of water for crops. Engineering-based irrigation sources such as canals, tanks, and dams are constructed. Due to its high cost, farmers cannot construct whenever required instantly without government support. The site conservation of rainfall is the most effective, i.e., half-moon shape, terrace, mulching, etc. As water is the primary source of cultivation, water management in the dryland regions provides chances for cultivation which facilitates the region against climate change impacts.

3.5.4 Conservation Agriculture

Tillage in drylands is disastrous in the soil conditions. It renders soil erosion due to water and wind agents destroying the optimal soil conditions. Since the experience of soil and air disasters due to conventional farming, conservation farming is a promising approach in drylands. It includes reduced, minimum, or no tillage, incorporation of residues, and soil mulching. Conservation farming reduces soil exposure to erosions, enhances soil-water infiltration, aggregates stability, optimizes soil temperature, and reduces runoff under mulching. It also enhances the accumulation of organic matter.

3.5.5 Germplasm

The selection of crops based on climatic factors, soil types, and topography facilitates proper plant growth and development. The growing of water stress-resistant varieties is the best option for dryland regions. It depends on the availability of water at the critical stage, the duration of crops, good rooting crop varieties, and the capacity to uptake nutrients. Mainly pulses, oilseeds, and plantation crops are favorable in the drylands.

3.5.6 Participatory of Locals

Many strategies and methods have been adopted from the laboratory for farmers' dryland practices. Due to farmers' belief in their own indigenous practices, it is difficult to convince of any innovative ideas to combat climate change. The participation of each person or community, district-wise, and at state and national levels, is mandatory to succeed in dryland cultivation under the changing climate. The scientifically proven technologies and methods that possibly grow crops with minimum requirements without compromising productivity and little contribution to climate change should be followed. The support of the government based on a large project is required. In return to maintain and function properly, the localities play a role. Success to combat climate change in drylands can only be possible when giving hands to each other (Rama Rao et al. 2013).

3.5.7 Participatory Plant Breeding

Through conventional and modern plant breeding methods, an ideal plant type, i.e., ideotype can be developed for the target environment through selection for specific adaptations and involving the participation of farmers to overcome some problems with fitting crops to the wide range of target environments.

3.5.8 Changes in Cropping Patterns

In the medium term (up to 10 years), efforts should be focused on assisting the farmers in coping with and adapting to climate change rather than attempting to anticipate in greater detail how climate change will affect agriculture or how to reduce greenhouse gas emissions from agriculture. Use of early sowing, short-duration crops, and crops that are more tolerant to heat, salinity, and drought can adjust to climate change.

3.5.9 Carbon Sequestration and Increased Resilience of Soils

Climate change is induced by the anthropogenic activities that release GHGs that seal the incoming solar radiation, thereby causing global surface temperatures to increase. Land degradation is another aspect to climate change. This can be mitigated by reducing the GHGs in the atmosphere. The strategy to reduce the atmospheric CO_2 in dryland soil is to make sure first of good soil health for net plant productivity.

3.6 Conclusion

Dryland agriculture is practiced in areas that receive less than 20 inches of rain per year. These areas are generally found in the semi-arid and arid regions of the world with little or no surface water. Such areas cover almost one third of global land area and have high potential to increase food production if they are managed appropriately. The arid and semi-arid regions, where dryland agriculture is predominantly practiced, are highly sensitive to climate variability and change. The changing climate poses an imminent challenge to dryland farmers who practice a wide range of techniques from traditional methods to advanced irrigation systems for crop production. Drivers of vulnerability in dryland agriculture include limited surface water availability, inter-annual variability in rainfall and extreme rainfall events, water quality and salinity, soil degradation, and climate-sensitive diseases and pests.

Infrastructure, such as diversifying cropping patterns, investing in on-farm water harvesting, and developing multiple cropping systems, could help in enhancing the resilience of dryland agriculture. Produce using renewable resources, such as relying on indigenous water harvesting techniques and reducing emissions and increasing carbon sequestration, could also help in reducing the impacts of climate change.

References

Ahmed M, Hayat R, Ahmad M et al (2022) Impact of climate change on dryland agricultural systems: a review of current status, potentials, and further work need. Int J Plant Prod 16:341–363

Angles S, Chinnadurai M, Sundar A (2011) Awareness on the impact of climate change on dryland agriculture and coping mechanisms of dryland farmers. Indian J Agric Econ 66(3):365–372

Ashalatha KV, Gopinath M, Bhat ARS (2012) Impact of climate change on rain fed agriculture in India: a case study of Dharwad. Int J Environ Sci Dev 3(4):368–371

Challinor A (2009) Towards the development of adaptation options using climate and crop yield forecasting at seasonal to multi-decadal timescales. Environ Sci Pol 12:453–465

Eigenbrode SD, Binns WP, Huggins DR (2018) Confronting climate change challenges to dryland cereal production: a call for collaborative, transdisciplinary research, and producer engagement. Front Ecol Evol 5:164

Fraser EDG, Dougill AJ, Hubacek K, Quinn CH, Sendzimir J, Termansen M (2011) Assessing vulnerability to climate change in dryland livelihood systems: conceptual challenges and interdisciplinary solutions. Ecol Soc 16(3):3

Huang J, Li Y, Fu C, Chen F, Fu Q, Dai A et al (2017) Dryland climate change: recent progress and challenges. Rev Geophys 55(3):719–778

Lawrence PG, Maxwell BD, Rew LJ, Ellis C, Bekkerman A (2018) Vulnerability of dryland agricultural regimes to economic and climatic change. Ecol Soc 23(1):34

Rama Rao CA, Raju BMK, Subba Rao AVM, Rao KV, Rao VUM, Kausalya R, Venkateswarlu B, Sikka AK (2013) Atlas on vulnerability of Indian agriculture to climate change. Central Research Institute for Dryland Agriculture, Hyderabad, p 116

Thomas RJ (2008) Opportunities to reduce the vulnerability of dryland farmers in Central and West Asia and North Africa to climate change. Agric Ecosyst Environ 126(1–2):36–45

Vijayan R (2016) Dryland agriculture in India - problems and solutions. Asian J Environ Sci 11(2): 171–177