Impact of Climate Change on Rainfed Agriculture in India: A Case Study of Dharwad

Asha latha K. V., Munisamy Gopinath, and A. R. S. Bhat

***Abstract*—The impact of climate change is studied in many aspects in different locations in the country and it is concluded that there is high impact on agriculture compared to any other sector in the country. The study results revealed that the climatic variation such as occurrence of drought have high level of impact on the yield of Rainfed crops. The farmers perception on the impact of climate change on the crops grown in Rainfed condition, such as yield reduction and reduction in net revenue. The farmers already act to the changes in the climatic changes both by adopting the technological coping mechanisms on the positive side and negatively through shifting to other professions. It is concluded that the small and medium Rainfed farmers were highly vulnerable to climate change and to a larger extent the small and medium Rainfed farmers adopted coping mechanisms for climate change compared to large farmers. The study suggests that as the impact of climate change is intensifying day by day it should be addressed through policy perspective at the earliest to avoid short term effect such as yield and income loss and long-term effects such as quitting agricultural profession by the Rainfed farmers.**

***Index Terms*—Climate, net revenue, rainfed, vulnerable.**

I. Introduction

Climate is one of the main determinants of agricultural production. Through out the world there is significant concern about the effects of climate change and its variability on agricultural production. Researchers and administrators are concerned with the potential damages and benefits that may arise in future from climate change impacts on agriculture, since these will affect domestic and international policies, trading pattern, resource use and food security. The Climate change is any change in climate over time that is attributed directly or indirectly to human activity that alters the composition of the global atmosphere in addition to natural climate variability observed over comparable time periods(IPCC, 2007).Since climatic factors serve as direct inputs to agriculture, any change in climatic factors is bound to have a significant impact on crop yields and production. Studies have shown a significant effect of change in climatic factors on the average crop yield[(Dinar et al.(1998), Seo and Mendelsohn(2008), Mall et al.(2006)and Cline(2007)]. In developing countries, climate change will cuase yield declines for the most important crops and South Asia will be particularly hard hit (IFPRI, 2009). Many studies in the past have shown that India is likely to witness one of the highest agricultural productivity losses in the world in accordance with the climate change pattern observed and scenarios projected. Climate change projections made up to 2100 for India indicate an overall increase in temperature by 2-40 c with no substantial change in precipitation quantity (Kavikumar, 2010). In course of time where the industrial revolution occurred in western countries and usage of the fossil fuels increased rapidly, on the other side the natural buffering system for climate change forests, were destroyed indiscriminately for want of fuel, fodder and timbers in the developing countries. These factors were intensified by the human activities in the past 250 years, which had tremendous impact on the climate system. According to the IPPCC the green house gas emission could cause the mean global temperature to rise by another 1.4oC to 5.8oC. Already the symptoms of climate change were observed at a faster rate in the artic and under artic regions through melting of the frozen ice which have danger of submergence of the coastal zones. In the case of the inland water source, there is tremendous change in both surface as well as ground water due to erratic rainfall and occurrence of frequent droughts. Many studies (Parry et al., 1999; Darwin, 2004; Olesen and Bindi, 2002; Adams et al.,2003 and Tsvetsinskaya et al.,2003) find that region-specific analysis is required to evaluate the agronomic and economic impact of weather changes in more detail.

Manuscript received May 23, 2012; revised July 9, 2012. This work was financially supported by National Agricultural Innovation Project (NAIP), Indian Council of Agricultural Research (ICAR), New Delhi. Dr Asha Latha K V acknowledge the ICAR for selecting her for NAIP_ICAR International Training award and also for providing an opportunity to carry out this research on Modelling the Impact of Climate factors on Crop Production in a major Indian state at the Department of Agricultural and Resource Economics, Oregon State University, Corvallis, USA.

Asha Latha K. V. and A. R. S. Bhat are with University of Agricultural Sciences, Dharwad, Karnataka, India (e-mail: kvashakv@ rediffmail.com).

Munisamy Gopinath is with the Department of Agricultural and Resource Economics, Oregon State University, 213, Ballard hall, Corvallis, USA (e-mail: m.gopinath@ oregonstate.edu).

II. Scenario of Rainfed Agriculture

Globally 80 per cent of the agricultural land area is rainfed which generates 65 to 70 per cent staple foods but 70 per cent of the population inhabiting in these areas are poor due to low and variable productivity. India ranks first among the rainfed agricultural countries of the world in terms of both extent and value of produce. Rainfed agriculture is practiced in two-thirds of the total cropped area of 162 million hectares(66 per cent). Rainfed agriculture supports 40 per cent of the national food basket. The importance of rainfed agriculture is obvious from the fact that 55 per cent of rice, 91 per cent coarse grains, 90 per cent pulses, 85 per cent oilseeds and 65 per cent cotton are grown in rainfed areas. These areas receive an annual rainfall between 400 mm to 1000 mm, which is unevenly distributed, highly uncertain and erratic. In certain areas, the total annual rainfall does not exceed 500mm. As a result of low and erratic rainfall, a significant fall in food production is often noticed.

Within agriculture, it is the rainfed agriculture that will be most impacted by climate change. Temperature is an important weather parameter that will affect productivity of rainfed crops. The last three decades saw a sharp rise in all

India mean annual temperature. Though most rainfed crops tolerate high temperatures, rainfed crops grown during rabi are vulnerable to changes in minimum temperatures (Venkateswarlu and Rama Rao, 2010).As far as Karnataka state is concerned 82 per cent of the net sown area was under rainfed condition during 2009-10.

There are a number of studies which assessed the impact of climate change on Indian Agriculture and vulnerability of the small and medium rainfed farmers in different aspects. But the perceptions on the climate change and the factors which drive the farmers to adopt or to follow coping mechanisms have not been studied in detail. The present study is a modest attempt to assess the perception of the Rainfed farmers on climate change. The specific objectives of the study are to assess the impact of drought on the yield of Rainfed crops, to identify the level of awareness on the climate change and to identify the factors influencing in decision making on the coping mechanism to mitigate the impact of climate change.

III. Methodology

Dharwad district in Karnataka was selected to assess the impact of climate change, where the Rainfed farmers are highly vulnerable to frequent droughts as well as other climate factors. The normal rainfall is 769mm in the district. In order to assess the impact of climate change a multi-stage random sampling design was employed for the selection of the sample respondents. The total sample constitutes 250 sample respondents and the needed information for the study was collected using pre tested questionnaire. The analytical tools such as compound growth rate, instability index and Logit model were employed to analyse the data among Rainfed farmers.

IV. Impact of Climate Change on Agriculture

The climate is being modified at a faster rate due to mushrooming of industries and high cattle population along with exploding human population. To meet the demand of the growing population, the natural resources such as forests are also being exploited at a faster rate. In spite of the rising demand for food and fodder, the climate change will further worsen the condition by reducing in the yield of dry land crops. Most of the studies projected that the decreased yield in rainfed and dry land wheat and rice and loss in farm net revenue between 9 to 25 per cent for a temperature increase of 2 to 3.5^{O}c . Sinha and Swaminathan (1991) showed that an increase of 2 degree Celsius in temperature could decrease rice yield by about 0.75 tons/ha in the high yield areas; and a 0.5 degree Celsius increase in winter temperature would reduce wheat yield by 0.45 ton/ha. Saseendran et al. (2000) showed that for every one degree rise in temperature the decline in rice yield would be about 6 percent. Major impacts of climate change will likely be on rainfed crops (other than rice), which account for nearly 60 percent of crop land area. In India, poorest farmers often practice rainfed agriculture. For the temperature rise of 2oC in mean temperature and a 7 per cent increase in the mean precipitation would create a 12 per cent reduction in net revenues for the country as a whole (Dinar et al., 1998).

V. Growth and Instability in the Yields of Major Rainfed Crops

Compound growth rates and instability index of major rainfed crops such as sorghum, maize, tur, groundnut, wheat, onion and cotton that are grown under rainfed condition in Dharwad district were worked out. The analysis was carried out during 1990-91 to 2009-10. The results of growth and instability in yield of the crops are presented in Table I. The results revealed that for the study period all the major crops registered negative growth in spite of the technologies such as new variety, fertilizers etc., and the government to boost the Rain fed agriculture, the yield could not be increased at significant level due to the vagaries in the monsoon and temperature in the district. The major factor which influence the yield of Rain fed crop is the rainfall; the yield will vary according to rainfall level. The instability index revealed that the variation was very high for sorghum, cotton and wheat compared to other major rainfed crops.

TABLE I: Growth and Instability in the Yileds of Major Rainfed Crops

Crop (1)	Compound Growth rate (per cent) (2)	Instability Index (3)
Sorghum	-17.47	0.83
Maize	-6.00	0.56
Tur	-8.44	0.58
Groundnut	-13.06	0.61
Wheat	-16.00	0.70
Onion	-3.93	0.53
Cotton	-10.65	0.79

VI. Drought and its Impact on Rainfed Crop Yields

In Dharwad district out of the years (1994 to 2010) there were three chronic drought years which occurred during 2001 and 2003 followed by 2006 experienced severe drought. During the severe drought year, the shortfall in rainfall was 37.57 per cent as compared to normal year in the district.

TABLE II: EFFECT OF DROUGHT ON RAINFED CROP YIELD IN DHARWAD DISTRICT

(kg/ha)

Crop (1)	Per cent loss of normal yield (2)
Sorghum	43.03
Maize	14.09
Tur	28.23
Groundnut	34.09
Wheat	48.68
Onion	29.56
Cotton	59.96

The major effect of the drought reflected in the yield of the Rainfed crops due to inadequate and poorly distributed rainfall. The drought need not be a lengthier one even a dry spell during the critical growth period as short drought can cause significant damage and harm local economy. Production loss which is often used as a measure of the cost of drought is only a part of the overall economic cost. The effect of drought on Rainfed crop yield in Dharwad district is presented in Table II. In maize only 14.09 per cent of yield reduction was registered. In all other Rainfed crops yield

reduction was very high to the extent of 59.96 per cent in cotton crop since it is a sensitive crop to drought, followed by wheat, sorghum and groundnut to the extent of 48.68 per cent, 43.03 per cent, 34.09 per cent. It is evident from Table II that if there was moderate deviation in precipitation there will be high reduction in the yield of Rainfed crops.

VII. Farmers' Perception on the Impact of Climate Change

The farmers' perception on the climate change was assessed using yes or no type questions and the results are presented in Table III. Most of the farmers were not able to express their perception on climate change directly but they expressed through the effects or the changes that occurred compared to the earlier years or based on their elder's experiences. About 86.67 per cent of the sample respondents expressed that their net income was reduced over the years, 83.33 per cent of the farmers expressed that there was change in climate and rainfall patterns, 76.67 per cent farmers expressed reduction in yield, 74.44 per cent expressed that there was fast evaporation of soil moisture, 64.44 per cent farmers expressed that due to soil erosion and other factors day by day the land was degrading and it becomes unsuitable for cultivation, 54.44 per cent of the respondents expressed that the seasonal pattern is changing and 7.78 percent of the respondents expressed that they have no idea on the changes in climate. From the table it is clear that the level of farmers' perception on the climate change was good.

TABLE III: Farmer Perception on the Impact of Climate Change

(Per cent)

Factors (1)	Small Farmers (2)	Medium Farmers (3)	Large Farmers (4)	Total Farmers (5)
Reduction in yield	90.00	80.00	60.00	76.67
Reduction in net income	93.33	86.67	80.00	86.67
Pest and disease outbreak	73.33	76.67	73.33	74.44
Fast evaporation of soil moisture	86.67	73.33	53.33	71.11
Erratic rainfall	100.00	80.00	80.00	86.67
Crop failure	96.67	96.67	66.67	86.67
Shifting of seasons	60.00	50.00	53.33	54.44
Land is becoming unsuitable for cultivation	76.67	63.33	53.33	64.44
Change in climatic and rainfall patterns	86.67	83.33	80.00	83.33
Other factors/ no idea	0.00	3.33	20.00	7.78

VIII. Reason for Reduction in Yield and Net Revenue

The sample farmers were highly concerned about the reducing yield rate and net farm income since their livelihood and socio-economic status is determined by the net income. Almost 100 per cent of the small farmers and 92.22 per cent of the sample farmers reported that the reduction in the rainfall was the major reason for reduction in the yield levels over the period followed by the pest and disease to the extent of 72.22 per cent and changes in temperature and seasonal patterns were quoted as the reason for the reduction in the yield by 42.22 per cent of the sample respondents. About 46.67 per cent of the farmers expressed that the soil lost its vigour due to factors such as erosion, lack of organic manures etc., and 7.78 per cent expressed that they do not have any idea for the reduction in yield over the years. It is clear that the farmers know that the yield reduction occurring continuously and to some extent they have knowledge on the reason for yield reduction also.

TABLE IV: Reason for Reduction in Yield and Net Revenue

(Per cent)

Factors (1)	Small Farmers (2)	Medium Farmers (3)	Large Farmers (4)	Total Farmers (5)
Change in temperature and seasonal patterns	53.33	40.00	33.33	42.22
Rainfall	100.00	93.33	83.33	92.22
Soil fertility and erosion	60.00	53.33	26.67	46.67
Pest and disease	83.33	73.33	60.00	72.22
Other factors/ no idea	0.00	6.67	16.67	7.78

IX. Coping Mechanisms of Dryland Farmers to Mitigate the Impact of Climate Change

The coping mechanism was followed to mitigate the climate change through technologies as well as through the socio economic aspect and the results are presented in Table V. There are many coping mechanisms which were followed by the Rainfed farmers of Dharwad district. The mixed and intercropping was the major coping mechanism which was adopted by 75.66 per cent, followed by integrated and mixed farming which was adopted by 71.11 per cent and change in cropping pattern to the extent of 42.22 percent.

TABLE V: Major Coping Mechanism Adopted by Rainfed Farmers to Mitigate the Impact of Climate Change

(per cent)

Coping mechanism (1)	Small Farmers (2)	Medium Farmers (3)	Large Farmers (4)	Total Farmers (5)
Technological mitigation				
Change in cropping pattern	60.00	40.00	26.67	42.22
Mixed/inter cropping	93.33	76.67	56.67	75.56
Cultivating tree crops	0.00	10.00	76.67	28.89
Soil organic matter enhancement	46.67	46.67	16.67	36.67
Drought resistant/tolerant crops	13.33	43.33	20.00	25.56
Integrated/Mixed farming system	93.33	76.67	43.33	71.11
Socio-economic factors				
Reduced consumption expenditure	60.00	50.00	0.00	36.67
Shifting to other profession	80.00	50.00	20.00	50.00
Borrowing	86.67	50.00	10.00	48.89
Crop insurance	6.67	16.67	10.00	11.11
Selling of land and livestock	26.67	6.67	3.33	12.22
No response	6.67	23.33	23.33	17.78

When there is change in the climate in either rainfall or temperature from the normal condition, there would be reduction in yield and net income of the farmers. To mitigate the reduction in the net income, the farmers in the district have to adopt some socio-economic strategies to sutain their life. The major socio-economic coping is shifting the profession which is observed to the extent of 50 per cent followed by borrowing for consumption from private money lenders was 48.89 per cent, reduction in consumption expenditure was observed in small and marginal farmers and not in the case of large farmers. Nearly 12 per cent of the sample farmers sold land and livestock, where as 11.11 per cent of the respondents adopted crop insurance as a coping mechanism.

X. Conclusion

This research study revealed that the climatic variation as occurrence of drought have significant impact on the production of Rainfed crops. The small and medium Rainfed farmers were highly vulnerable to climate change and to a larger extent the small and medium Rainfed farmers adopted coping mechanisms for climate change compared to large farmers. The farmers already act to the changes in the climatic changes both by adopting the technological coping mechanisms on the positive side and negatively through shifting to other professions. The study suggests that as the impact of climate change is intensifying day by day it should be addressed through policy perspective at the earliest to avoid short term effect such as yield and income loss and long-term effects such as quitting agricultural profession by the Rainfed farmers.

References

[1] Adams, R. M., B. A. McCarl and L. O. Mearns, "The effect of spatial scale of climate scenarios on economic assessments: An example from U.S. Agriculture", *Climate Change*, vol. 60, pp.131-148, 2003.

[2] Aggarwal, P. K., "Global climate change and Indian agriculture: Impact, adaptation and mitigation", *Indian Journal of Agricultural Sciences*, vol. 78, No. 11, pp.911-919, 2008.

[3] Cline, W. R., "Global warming and agriculture: Impact estimates by country", *Peterson Institute of International Economics, NW, Washington, D.C*., U.S.A. 2007.

[4] Darwin, R., "Effect of green house gas emission on world agriculture, Food Consumption and Economic Welfare", *Climate Change*, vol. 66, pp.191-238, 2004.

[5] Olesen, J. E. and Bindi, M., "Consequences of Climate Change for European Agriculture Productiivty, Land Use and Policy", *European Journal of Agronomy*, vol. 16, pp.239-262, 2002.

[6] Parry, M., C. Rosenzweig, A., Inglesias, G. and Fischer and M. Livermore (1999), "Climate Change and World Food Security: A New Assessment", *Global Environ. Change*, vol. 9 (Suppl.), pp.S51-S67.

[7] Saseendran, S. A., L. Ma, R. W. Malone, P. Heilman, L.R. Ahuja, R.S. Kanwar, D.L. Karlen, and G. Hoogenboom., "Simulating management effects on crop production, tile drainage, and water quality using RZWQM-DSSAT". *Geoderma* 140:297–309, 2007..

[8] Seo, N. and R. Mendelsohn, "A Ricardian Analysis of the Impact of Climate Change on South American Farms", *Chilean Journal of Agricultural Research*, vol. 68, No. 1, pp.69-79, 2008.

[9] Sinha, S. K. and M. S. Swaminathan 1991. "Deforestation, Climate Change and Sustainable Nutrition Security: A Case Study of India". *Climate Change* 19: 201-209.

[10] Tsvetsinskaya, E. A., L. O., Mearns, T. Mavromatis, W., Gao, L. McDaniel and M.W. Downton, "The effect of spatial scale of climate change scenario on simulated mazie, winter, wheat and rice production in the Southeastern United States", *Climate Change*, vol. 60, pp.37-71, 2003.

[11] Anselin, L., R. J. Florax and S. J. Rey. (Editors). *Advances in Spatial Econometrics. Methodology, Tools and* Applcations. Springer-Verlag, Berlin, pp. 1-25, 2004.

[12] Dinar, A., R. Mendelsonhn, R. Evenson, J. Parikh, A.Sanghi, K.Kumar, J.McKinsey, S.Longergan (Eds.) (), *Measuring the Impact of Climate Change on Indian Agriculture*, World Bank Technical Paper 402, Washington, D.C., U.S.A.

[13] Hillel, D., and C. Rosenzweig (Editors): *Handbook of* Climate *Change and Agroecosystems: Impacts, Adaptation, and Mitigation*. ICP Series on Climate Change Impacts, Adaptation, and Mitigation, vol. 1. Imperial College Press, 2010.

[14] Venkateswarlu, B. and C. A. Rama Rao, *Rainfed Agriculture: Challenges of Climate Change*, Agriculture Today Yearbook, 2010, pp.43-45, 2010.

[15] IPCC, "Impacts, Adaptation and Vulnerabilty", the intergovernmental Panel on Climate Change, Cambridge University Press, 2007, U.K.

[16] Kavikumar, K.S., "*Climate sensitivity of Indian Agriculture: Role of Technological Development and Information Diffusion, in Lead Papers-National Symposium on Climate Change and Rainfed Agriculture, Indian Society of Dryland Agriculture*", Ceentral Research Institute for Dryland Agriculture, Hyderabad, February 18-20, 2010, pp.1-18. 2010.

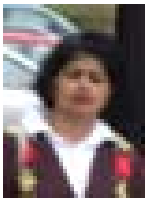
[17] Krishna Kumar, K. "Impact of Climate Change on India's Monsoon Climate and Development of High Resolution Climate Change Scenarios for India". Presentation made to Hon. Minister MOEF, on 14th October, 2009 at New Delhi, India.

[18] Dinar, A. R., Mendelsohn, R., Evenson, J. Parikh, A. Sanghi, K. Kumar, J. McKinsey and S. Lonergen , "Measuring the Impact of Climate Change on Indian Agriculture", Technical Report, The World Bank, Washington, D.C., U.S.A,1998.

[19] IFPRI, "Climate Change – Impact on Agriculture and Costs of Adaptation", Food Policy Report International Food Policy Research Institute, Washington, D.C., U.S.A., pp.30., 2009

[20] IPCC, "Summary for Policymakers", in Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor and H.L. Miller (Eds.), *Climate Change: The Physical Science Basis*. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press, Cambridge, United Kingdom and New York, NY, U.S.A, 2007.

[21] Yadav, Kiran (2009), "A Report on Recent Advances in Rainfed Agriculture", submitted to Panthnagar Agricultural University, Punjab.



Asha Latha K. V. has around 17 years of teaching and research experience. Equipped with Masters degree in Agricultural Statistics, a Doctorate in Statistics and having Post-Doc from USA on "Impact of Climate Change on Indian Agriculture", recipient of many state and national awards. She has visited USA, China and Singapore etc…and presented papers in the international conference. Additionally, her contributions have been achieved through working on different Econometric Models, strong analytical skills, experience with quantitative research methods, strong computer skills and knowledge about different statistical soft wares. She has vast experience with data collection across the country in many of the projects, completed more than 10 Projects. She has been keenly involved in organizing training programs for students and faculty members. Her training programs on different soft ware's have been instrumental in off campus interviews, and have helped the post graduate students to get recruited in IT companies. She has authored a commendable number of research papers in international/national conference/journals and also guided many research scholars. Currently she is working as Associate Professor in the department of Agricultural Statistics, University of Agricultural Sciences, Dharwad, one of the best Agricultural Universities in India.