Research Article

Assessing the Impact of Climate Change Adaptation Strategies on Poverty Rates of Wheat Farmers in Khyber Pakhtunkhwa, Pakistan

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Abstract | Climate change is global threat to all sectors of economy, particularly agriculture sector. Pakistan, being exposed to extreme events and low adaptation potential, is highly vulnerable to climate change. Benefits of adaptation strategies and associated impact on net farm returns, per capita income and poverty rates of wheat producers using extensive farm survey data from 150 farmers from different climatic zones of Khyber Pakhtunkhwa, Pakistan were measured in this study. TOA-MD model was used to measure the impact of climate change adaptation strategies. Adjustment in sowing time, improved fertilizer application method and increasing sowing densities were three-major adaptation practices whose benefits were analyzed. The adaptation results indicated that adopters of adaptation technology would range from 33 % to 74.47 % in Dera Ismail Khan and 62 % to 65.18 % in Peshawar. Before adaptation, poverty rates would range from 23 to 28.90 percent in D.I.Khan while from 19 to 28.62 percent in Peshawar for all GCMs. These findings concluded that proposed adaptation strategies could have significant impact to offset climate vulnerabilities in the future.

Received | November 03, 2018; **Accepted** |February 28, 2019; **Published** | April 12, 2019
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Citation | Gul, F., D. Jan and M. Ashfaq. 2019. assessing the impact of climate change adaptation strategies on poverty rates of wheat farmers in Khyber Pakhtunkhwa, Pakistan.
Sarhad Journal of Agriculture, 35(2): 442-448.
DOI | http://dx.doi.org/10.17582/journal.sja/2019/35.2.442.448
Keywords | TOA-MD model, Adaptation strategies, Poverty, Climate change

Introduction

Pakistan being part of south Asia, is in the line of fire of climate catastrophes. Pakistan's geographical location and high poverty rate, makes it extremely vulnerable to the climate change. The rise in temperature has affected all sectors, not only affecting the cropping season but also melted the Himalayan glaciers. Climate change in Pakistan exacerbated the productivity of agricultural sector, worsening food security in the country.

Change in climate is closely linked to food security and poverty alleviation, which are main challenges for agricultural sector of the country. In Pakistan agriculture is predominantly a small farm activity. Due to smallholding, low productivity and low income of agriculturalists are more susceptible to climate change. Though there is evidence of increase in food production, the nation is not self-sufficient yet. In this scenario, the proportion of change in production due to impact of climate change, and measures needed to improve farmers' adaptive capacity to climate change are important research questions.

Nowadays, the improvement of agronomical practices to combat future variation in climate has great significance (Howden et al., 2007). In addition to agronomical practices, the use of conservation practices and resource use efficiency can also be employed to mitigate climate change (Hellin et al., 2012). In many parts of the world, the cereal crop productivity is at high risk due to unexpected changes in climate events. Adoption efforts are required to counteract the vulnerabilities of climate change.

Small holder farmers have developed certain modifications to their farming systems to adapt to changing environment. Among other adaptation strategies, coping mechanisms also include adjustments to fertilizer applications, sowing dates, irrigation, increased organic matter and introduction of legumes to cropping systems.

Along adaptations, it is also important to stress on the importance of access to better weather forecasting and reliability of information (Mahoo et al., 2015). Besides challenges, the direct observable benefits of different practices allow small farmers for adoption (Kahimba et al., 2014; Tumbo et al., 2011; Shetto and Owenaya, 2007).

Wheat is a major staple food, feeding about 2.5 billion rural people around the world. Various studies show that wheat productivity is vulnerable to climate change (Oritz et al., 2008; Anwar et al.,2007). This implies the need for adoption of improved agronomic practices (Anwar et al., 2007) and adaptation strategies (Aurbacher et al., 2010).

However, the main problem of many countries is proper selection of management practices which ensure sustainable crop production in the future. For this purpose, the adaptation package might include proper water management (Kang et al., 2009), advances in agronomy and breeding (Anwar et al., 2007), alteration in sowing dates and cropping patterns (Howden et al., 2007). In addition to agronomic practices, the proper use of conservation tools and efficient use of resources can also mitigate the climate change (Hellin et al., 2012).

The failure of agriculture sector to adapt to climate change will impact global food production, especially wheat. In this paper, the adaptation options on model scenarios for measuring their efficiency in improving wheat yield and their impact on net farm returns, poverty and per capita income were assessed.

Materials and Methods

The study was conducted in various agro-ecological zones of Khyber Pakhtunkhwa, Pakistan. Multistage sampling technique was used to select 150 farmers from three districts namely Chitral, D.I. Khan and Peshawar. The selection of districts, one from each zone, was based on the presence of observatory and wheat farmers. A mixture of both primary and secondary data was used in analysis. Primary data was collected from 150 farmers (50 from each district) through well-structured questionnaire. Five Global Circulation Models (GCMs Middle, Cool wet, cool dry, hot wet, hot dry) and two Representative Concentration Pathways (RCPs 4.5 and 8.5) were used in crop modelling to assess the climate change impact on future wheat yields. Yield simulations were analysed at each GCM and each RCP. Past and future time periods used in analysis were 1981-2010 and 2040-2069. For economic impact assessment of climate change and proposed adaptation strategies, Trade off Analysis for Multidimensional Impact Assessment model (TOA-MD) was used.

Trade off analysis for multidimensional impact assessment model (TOA-MD)

The TOA-MD model is novel approach for economic, environmental and social impact assessment of agricultural systems that can be used for crops, livestock and aquaculture. (Antle and Valdivia, 2006). It depends on data from various sources like farm surveys, observed field data, simulated data and expert's judgment. The model is used as simulation technique for adoption of new technologies and environmental changes (Antle and Valdivia, 2011). The model utilizes given prices and do not solve for market equilibrium prices. TOA-MD simulates farm populations and cannot be used for individual farm as decision support tool.

As compared to other impact assessment models, this model demands less data (Claessens, 2008). TOA-MD is based on mathematical programming.

To measure the effects of climate change TOA-MD model compared base (S1) and an alternative system (S2). Data for the alternative system was generated through calibration of different biophysical simulation scenarios which measure the changes in crop yields over time. Suppose, farmers select a system to maximize a function $v(i)$ where $i = 1, 2$ indexes the production system and all attributes associated with it. Here, v(i) = expected net farm returns which based on an objective function that depends on the characteristics of the farms and the system being studied. This objective function induces an ordering δ over all farms. Where δ is defined as:

$$\delta = \text{System 1 value} - \text{System 2 value}$$
$$(P_1X_1a_1 - C_1) - (P_2X_2a_2 - C_2) \quad \ldots.(1)$$

Where;

P_1= Price in System 1; P_2=Price in System 2; X_1=Production (Yield) System 1; X_2 = Production (Yield) System 2; a_1 = land use in System 1; a_2 = land use in System 2; C_1 = Production cost in System 1; C_2 = Production cost in System 2; δ= the difference between System 1 and System 2.

$$\delta = V_1 - V_2 \quad \ldots..(2)$$

V_1= value of present climate + technology; V_2= value of future climate + technology; r=x_1/x_2; r = relative yield.

Then; $V_2 = \gamma x_1 r$

"γ" obtained from survey data and r is obtained from crop models; x_1 = actual crop yield in present climate; s_1 = simulated crop yield with present climate = b_1 x_1; s_2 = simulated crop yield with changed climate = b_2x_2; x_2 will be estimated with crop simulation models

Assume, $b_1 = b_2$

Then, $R = x_2/x_1 = s_2/s_1$ (estimated from crop models).

$$x_2 = R\,x_1$$

data for x_1 and R at a representative sample of sites, then x_2= climate perturbed yields = R x_1

The TOA-MD model incorporates the statistical correlations among environmental, economic and social impacts of technology adoption into the simulation of impacts on farm income and income-based poverty.

Results and Discussion

Climate change impacts on wheat yields

CERES-Wheat simulations of wheat yields showed yield decline in D.I. Khan and Peshawar with respect to five GCMs and baseline in mid-century (2040-2069) under RCP 4.5 emission scenario while yields in Chitral showed increasing trend. During mid-century all GCMs projected yield reduction versus baseline climate. Under RCP8.5 emission scenario, wheat yield showed further decline in D.I. Khan and Peshawar districts with respect to baseline simulations. Therefore, to offset climate vulnerabilities in affected districts, adaptations strategies were applied.

Climate change adaptation options

The failure of agriculture sector to adapt to climate change will impact global food production, especially wheat. The main problem confronted to each country is proper selection of management practices which ensure sustainable crop production in the future. For this purpose, the adaptation package might include proper water management (Kang et al., 2009), advances in agronomy and breeding (Anwar et al., 2007), alteration in sowing dates and cropping patterns (Howden et al., 2007). In addition to agronomic practices, the proper use of conservation tools and efficient use of resources can also mitigate the climate change (Hellin et al., 2012). To utilize the benefits of adaptations, the current adaptation package was formulated for wheat through continuous engagement process with researchers, farmers and policy makers to combat the current and future climatic vulnerabilities.

Wheat adaptation strategies

Optimizing the use of sustainable, natural fertilizing sources in wheat production, including nitrogen fixing crop rotations, compost and composted manure would be helpful in raising yield figures (Kassem, 2009; Alam et al., 2012; Majeed et al., 2015). No extra cost will be incurred for this adaptation. By increasing plant population, we mitigate the seed germination losses due to harsh climate as well as it can increase the production per area unit (Hussain et al., 2010; Naseri et al., 2012). Extra cost incurred for seed to increase sowing density was incorporated in the total variable cost. An early of 10 days for sowing of wheat crop as most of the people grow late in November and December (Tahir et al., 2009; Baloch et al., 2010; Mumtaz et al., 2015). No extra cost will be incurred for this adaptation.

Mean changes in projected productions after adaptations

Since, the impact of CC (climate change) is positive in Chitral, therefore, adaptation strategies were applied to D.I. Khan and Peshawar only to offset the vulnerabilities of CC in these districts.

Table 1: *Wheat adaptation package.*

Variable/Parameter	Base Value (S-1)	Units	Crop model parameter name (ID)	Describe Change	Value S-2
Improved Method of Fertilizer	Broadcast not incorporate		FEACD	applied with irrigation water	
Sowing Density (absolute or percent change in plant population on top of baseline)	330	No per m^2	Plpop	10 percent increase in plant population	363
Sowing date (10 days decrease for those farmer's whose sowing date were beyond the 20 Nov.)	20-Nov	Days	PDATE	10 days earlier	10-Nov

Table 2: *Impact of CC adaptations on the output of wheat.*

GCM and RCP District	Middle		Hot Wet		Cool Dry		Hot Dry		Cool Wet	
	4.5	8.5	4.5	8.5	4.5	8.5	4.5	8.5	4.5	8.5
D.I. Khan										
Projected Mean Output with adaptation (kg/farm)	3085.76	2862.64	3570.23	3073.81	2969	2961.97	2801.31	2793.52	2905.83	3038.47
Mean Change in Output (%)	19.21%	16.47%	32.38%	15.3%	14.20%	19.71%	13.96%	18.98%	12.69%	22.17%
Peshawar										
Projected Mean Output with adaptation (kg/farm)	3811	3870.48	3570.23	3464.95	3906.52	4030.34	3729.90	3516.02	4037.92	3957.10
Mean Change in Output (%)	23%	25.07%	23.7%	28.81%	24.32%	25.41%	26.18%	28.09%	24.41%	27.36%

Impact of CC adaptations on the production of wheat crop (kg/farm) in the study area are shown in Table 2. For district D.I. Khan, the projected average production would vary from 2801.31 to 3570.23 kg/farm in RCP 4.5 and from 2793.52 to 3073.81 for RCP 8.5. Average increase in output would be from 12.69 to 32.38 percent in RCP 4.5 and for RCP 8.5, simulations showed a change from 15.3 to 22.17 percent.

For the Peshawar district, projected average production would vary from 3570.23 to 4037.92 kg/farm in RCP 4.5 and from 3464.94 to 4030.34 in RCP 8.5. Average production increase of wheat crop in RCP4.5 would be from 23 to 26.18 while in the case of RCP 8.5, wheat showed an increase ranging between 25.07 and 28.81 percent for all five GCMs.

Assessing benefits of adaptations

For adaptation analysis in TOA-MD, system 1 was considered without adaptation strategies while System 2 was taken with adaptation strategies for wheat system based on the crop simulations of DSSAT. This analysis was basically for the future, in which adopters and non-adopter's categories were compared. After taking adaptation strategies into account, the vulnerabilities of future wheat production have been reduced to greater extent and these adaptations have positive impact on socio-economic indicators of wheat producers in KP.

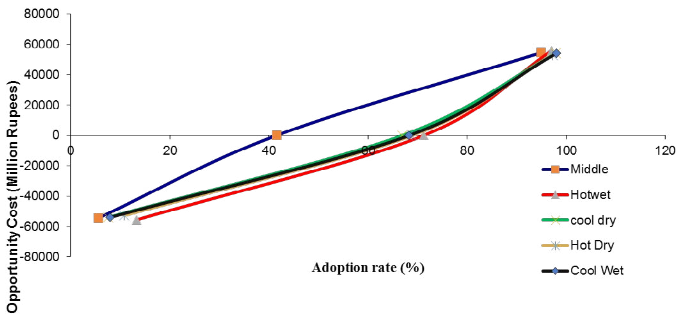

Figure 1: *Adaptation curve showing distribution of adopters and non-adopters under RCP 4.5.*

Impacts of CC adaptations for D.I. Khan district are given in Table 3. The adopters (in the form of %) for RCP 4.5 ranged from 32.99 to 74.47 percent and for RCP 8.5 from 67.77 to 74.43 percent. Adaptation curves showing the distribution of adopters and non-adopters, for all farms of district D.I. Khan are given in Figure 1. In RCP 4.5, the projected net returns without considering adaptation strategies would range from PKR 61962.98 to 78021.46/ farm/year and with adaptation it ranged from PKR 80342.02 to 93221.38/ farm /year. For RCP 8.5, the projected net returns without taking adaptation strategies into account ranged from PKR 63,606 to 68433.31/farm/year

Links Researchers

Table 3: *Benefits of climate change adaptations for District D.I. Khan.*

District	RCP	GCM	Adoption rate (%)	Projected NR without adaptation (Rs/farm/year)	Projected NR with adaptation (Rs/farm/year)	Projected PCI without adaptation (Rs/person/year)	Projected PCI with adaptation (Rs/person/year)	Projected Poverty rate without adaptation (%)	Projected Poverty rate with adaptation (%)
DIKhan	4.5	Middle	32.99	78021.46	84752.21	89852.44	91618.28	27.04	23.16
		Hot Wet	74.47	71039.03	93221.38	89298.00	96057.31	27.69	17.35
		Cool Dry	68.38	63583.64	81024.39	87814.65	92194.48	28.93	20.24
		Hot Dry	71.35	61962.98	80342.02	87842.77	94615.51	28.90	18.31
		Cool Wet	69.95	62906.27	80958.30	87679.39	91190.81	28.97	20.92
	8.5	Middle	71.76	63606.00	82369.46	94041.39	100229.61	23.50	14.44
		Hot Wet	67.77	65054.66	82757.69	88105.36	93142.53	28.62	19.56
		Cool Dry	72.88	63874.27	83426.69	94225.81	102609.60	23.56	13.34
		Hot Dry	74.43	64296.01	83601.92	94515.38	101661.21	23.15	13.61
		Cool Wet	67.79	68433.31	86903.96	94784.63	106724.53	23.40	12.40

Table 4: *Benefits of climate change adaptations for District Peshawar.*

District	RCP	GCM	Adoption rate (%)	Projected NR without adaptation (Rs/farm/year)	Projected NR with adaptation (Rs/farm/year)	Projected PCI without adaptation (Rs/person/year)	Projected PCI with adaptation (Rs/person/year)	Projected Poverty rate without adaptation (%)	Projected Poverty rate with adaptation (%)
Peshawar	4.5	Middle	62.61	72874.40	84408.10	102301.88	106306.38	18.10	16.08
		Hot Wet	63.22	80078.88	89676.28	103870.73	107242.85	17.61	15.86
		Cool Dry	62.29	74006.89	85647.20	102842.29	107547.10	17.98	15.71
		Hot Dry	63.52	79698.25	89764.86	106170.90	112416.67	17.18	14.39
		Cool Wet	62.02	72756.66	84759.93	103875.10	111336.21	17.79	14.57
	8.5	Middle	62.14	79589.05	90149.93	101079.14	106461.55	19.92	17.04
		Hot Wet	65.18	82787.59	91875.86	104018.25	110124.98	19.15	15.91
		Cool Dry	61.69	76044.55	87798.85	100218.38	106497.93	20.23	16.98
		Hot Dry	64.34	84799.73	93613.55	104096.69	109791.15	19.08	16.04
		Cool Wet	62.16	76192.74	88276.70	101424.43	109975.43	20.06	16.02

and with adaptation it ranged from 82369.46 to 86903.96/farm/year.

The projected per capita income without considering adaptation strategies would range from PKR 87.67 to 89.85 thousand/person/year, while in case of adaptation it would range from 91.19 to 96.05 thousand/person/year for RCP 4.5. In RCP 8.5, the projected per capita income without adaptation strategies would be between PKR 88.10 to 100.22 thousand/person/year and with adaptation it would range from PKR 93.14 to106.72 thousand/person/year. Without adaptation poverty rates would range from 27 to 28.90 percent for RCP 4.5 and from 23.15 to 28.62 percent for RCP 8.5. However, with adaptations the poverty rates would range from17.35 to 23.16 percent for RCP4.5 and 12.40 to 19.56 for RCP 8.5. Impacts of CC adaptations for Peshawar district are given in Table 4. The adopters (in the form of %) for RCP 4.5 ranged from 62 to 63.52 percent and for RCP 8.5 from 62.14 to 65.18 percent. Adaptation curves showing the spread of adopters and non-adopters, for all farms of district Peshawar are given in Figure 2. In RCP 4.5, the projected net returns without considering adaptation strategies would range from PKR 74006.89 to 79698.25 / farm/year and with adaptation it ranged from PKR 84408.10 to 89764.68 /farm /year. For RCP 8.5, the projected net returns without taking adaptation strategies into account ranged from PKR 76044.55 to 84799.73/farm/year while with adaptation it ranged from PKR 87798.85 to 93613.55/farm/year.

The projected per capita income without considering adaptation strategies would range from PKR 102.30 to 106.17 thousand/person/year, while in case of adaptation it would range from 106.30 to 112.41 thousand/person/year for RCP 4.5. In RCP 8.5, the projected per capita income without adaptation strategies would be between PKR 100.21 to 104.09 thousand/person/year and with adaptation it would range from PKR 106.46 to 110.12 thousand/person/year. Without adaptation poverty rates would range from 19 to 20.23 percent for RCP 4.5 and from 23.15 to 28.62 percent for RCP 8.5. However, with adaptations the poverty rates would range from17.35 to 23.16 percent for RCP4.5 and 15.91 to 17.04 for RCP 8.5.

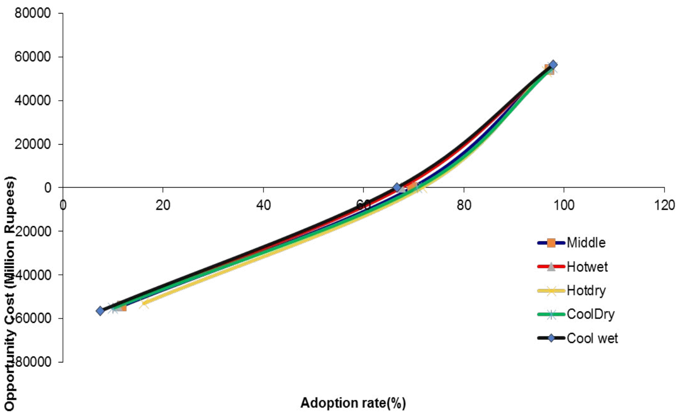

Figure 2: *Adaptation curve showing distribution of adopters and non-adopters for all farms under RCP 8.5*

Conclusions and Recommendations

Since, Climate change has negative impact on wheat crop in D.I. Khan and Peshawar, therefore, proper adaptation package was designed after thorough consultations with experts. Adaptation package was applied to measure the benefits of adaptation strategies and associated impacts on wheat producers net returns, per capita income and poverty rates in Khyber Pakhtunkhwa, Pakistan. The adaptation results indicated that adopters of adaptation technology would range from 33 percent to 74.47 percent in D.I. Khan and 62 percent to 65.18 percent in Peshawar. With adaptation strategies, the poverty rate would change from 12.40 to 23.16 in D.I. Khan and 15.91 to 23.16 in Peshawar, respectively.

Given the positive relationship between climate change adaptation strategies and net farm returns, per capita income and poverty rates, measured by TOA-MD model, there is a scope for policy makers to further promote the adoption of climate change adaptation strategies.

Author's Contribution

This paper is a part of Farhana Gul's Ph.D. research. Dawood Jan and Muhammad Ashfaq supervised her.

References

Alam. M. 2012. Climate change adaptation policy in Malaysia: Issues for agricultural sector. Africa. J. Agric. Res. 7(9):1368–1373. https://doi.org/10.5897/AJARX11.030

Anwar, M.R., G.O. Leary, D. McNeil, H. Hossain and R. Nelson. 2007. Climate change impact on rain fed wheat in south-eastern Australia. Field Crops Res. 104: 139–147. https://doi.org/10.1016/j.fcr.2007.03.020

Antle, J.M. and R.O. Valdivia. 2006. Modelling the supply of ecosystem services from agriculture: a minimum-data approach. Austr. J. Agric. Resour. Econ.50(2): 1–15. https://doi.org/10.1111/j.1467-8489.2006.00315.x

Antle, J.M. 2011a. Parsimonious multi-dimensional impact assessment. Am. J. Agric. Econ. 93(5): 1292–1311. https://doi.org/10.1093/ajae/aar052

Aurbarcher, J., C. Lippert and T. Kirmly. 2010. Assessing the impact of climate change in agriculture in Germany-a Ricardian analysis. Int. Agric. Trade Res. Consortium (IATAC).

Baloch, M.S., Shah, I.T.H., Nadim, M.A., Khan, M.I. and Khakwani, A.A. 2010. Effect of seeding density and planting time on growth and yield attributes of wheat. J. Anim. Plant Sci. 20(4): 239–240.

Claessens, L., J.J. Stoorvogel and J.M. Antle. 2008. Ex ante assessment of dual-purpose sweet potato in the crop-livestock system of western Kenya: a minimum-data approach. Agric. Syst. 99(1): 13–22. https://doi.org/10.1016/j.agsy.2008.09.002

Hussain, K., M.F. Nisar, A. Majeed, K. Nawaz, K.H. Bhatti, S. Afghan, S. and S. Zia-ul-Hussnian. 2010. What molecular mechanism is adapted by plants during salt stress tolerance? Africa. J. Biotechnol., 9(4): 416-422.

Hellin, J., B. Shiferaw, J.E. Cairns, M. Reynolds, I. Ortiz-Monasterio, M. Banzige, K. Sonder and R. La Rovere. 2012. Climate change and food security in the developing world: Potential of maize and wheat research to expand options for adaptation and mitigation. J. Dev. Agric. Econ.

4(12): 311–321.

Howden, S.M., J.F. Soussana, F.N. Tubiello, N. Chhetri, M. Dunlop and H. Meinke. 2007. Adapting agriculture to climate change. PNAS 104(50): 19691–19696. https://doi.org/10.1073/pnas.0701890104

Kahimba, F.C., K.D. Mutabazi, S.D. Tumbo, K.F. Masuki and W.B. Mbungu. 2014. Adoption and scaling-up of conservation agriculture in Tanzania: Case of Arusha and Dodoma regions. Nat. Resour. 05: 161–176. https://doi.org/10.4236/nr.2014.54016

Kang, Y., S. Khan and X. Ma. 2009. Climate change impacts on crop yield, crop water productivity and food security. Rev. Prog. Nat. Sci. 19: 1665–1674. https://doi.org/10.1016/j.pnsc.2009.08.001

Kassem, M. A. 2009. Effect of fertigation methods on productivety and nitrogen use efficiency for wheat and barley crops. Misr J. Ag. Eng. 26(2): 866–885.

Majeed, A., M.K. Abbasi, S. Hameed, A. Imran and N. Rahim. 2015. Isolation and characterization of plant growth-promoting rhizobacteria from wheat rhizosphere and their effect on plant growth promotion. Front. Microbiol. 6: 198.

Mahoo, H., W. Mbungu, I. Yonah, M. Radeny, P. Kimeli and J. Kinyangi. 2015. Integrating indigenous knowledge with scientific seasonal forecasts for climate risk management in Lushoto district in Tanzania. Copenhagen: CGIAR Res. Prog. Clim. Change, Agric. Food Secur. (CCAFS).

Mumtaz, M.Z., M. Aslam, H.M. Nasrullah, M. Akhtar and B. Ali. 2015. Effect of various sowing dates on growth, yield and yield components of different wheat genotypes. Am-Eura. J. Agric. Environ. Sci. 15(11): 2230–2234. https://doi.org/10.5829/idosi.aejaes.2015.15.11.12576

Naseri, R., A. Soleymanifard, H. Khoshkhabar, A. Mirzaei and K. Nazaralizadeh. 2012. Effect of plant spacing on grain yield and yield components and associated traits of three durum wheat cultivars in western Iran. Intl. J. Agri. Crop Sci. 4: 79-85.

Ortiz, R., K.D. Sayre, B. Govaerts, R. Gupta, G.V. Subbarao, T. Ban, D. Hodson, J.M. Dixon, J.I. Ortiz-Monasterio and M. Reynolds. 2008. Climate change: Can wheat beat the heat? Agric. Ecosyst. Environ. 126: 46–58. https://doi.org/10.1016/j.agee.2008.01.019

Shetto, R. and M. Owenya. 2007. Conservation agriculture as practised in Tanzania: Three case studies: Arumeru district, Karatu district, Mbeya district. Nairobi: ACT, FAO, Cirad, Relma.

Tahir, M., M.R. Javed, A. Tanveer, M.A. Nadeem, A. Wasaya, S.A.H. Bukhari and J. Rehman. 2009. Effect of different herbicides on weeds, growth and yield of spring planted maize (*Zea mays* L.). Pak. J. Life Soc. Sci. 7(2): 168-174.

Tumbo, S., K. Mutabazi, F. Kahimba and W. Mbungu. 2011. Conservation agriculture in Tanzania. Dar es Salaam: Sokoine Univ. Agric.