The Impact of Climate Change on Vegetable Growers in Sindh, Pakistan: A Case Study Shikarpur District

Author's Details:
[(1)]**Dr.Faiz Muhammad Shaikh-**Associate Professor SZABAC-Dokri-Email:faizs045@gmail.com
[(2)]**Muhammad Haroon Hullio-**Assistant Professor-Deptt: of Entomology, SZABAC-Dokri [(3)]**Zulfiqar Ali Abbassi-**Assistant Professor,Department of Agronomy-SZABAC-Dokri

Abstract
This research investigates the The Impact of Climate Change on Vegetable Growers in Sindh, Pakistan: A Case Study Shikarpur District. Data were collected from 150 farmers of Tomato and onion growers in different areas i.e. Madheji Taulka, and lakhi Taulka and Khan Pur Taulka, District Shikaropur. Data were analysed by using smart PLS. It was revealed that the largest known economic impact of climate change is upon agriculture because of the size and sensitivity of the sector. Warming causes, the greatest harm to agriculture in developing countries primarily because many farms in the low latitudes already endure climates that are too hot. This paper reviews several studies that measure the size of the impact of warming on farms in Shikarpur Sindh. It was further revealed that even though adaptation will blunt some of the worst predicted outcomes, warming is expected to cause large damages to agriculture in developing countries over the next century.
Key Words: *Climate Change, Vegetable Growers, Sindh, Pakistan*

Introduction: Shikarpur District historically was the hub of business before partition.Climate Change (CC)is not solely a concern for the future. It is a concern for today. Relative to recorded global history: (*a*) the last three years have successively been the warmest in recorded history; (*b*) each of the five warmest years ever seen have occurred since 2010; (*c*) 16 of the 17 warmest years have occurred since 2000; and (*d*) it has been 40 years since the global annual temperature was below the twentieth century's average (National Oceanic and Atmospheric Administration [NOAA 2017]). Additionally, according to the Intergovernmental Panel on Climate Change (IPCC 2014c), rainfall is changing in distribution and intensity, extreme events are increasing in severity and frequency, and many other changes are arising. As CC evolves, further changes are projected, with temperatures increasing by 2–4 °C by 2100, and by 1 °C over the next 25 years (see IPCC 2014c for discussion). Agricultural yields, costs, pests, and infrastructure needs are all being affected (IPCC 2014a). Historically, farming has evolved to adapt to local climates but those climates are shifting, and as CC proceeds, adaptations will require altered practices. Indeed, farmers are already adapting by adjusting planting dates, varieties planted, crop mix, and livestock populations, and agricultural economists are currently assessing the extent and value of such adaptation actions.

Climate change is being driven in large part by the accumulation of greenhouse gas (GHG) concentrations in the atmosphere. Atmospheric carbon dioxide (CO_2) concentration is up from an 1850 level of 275 parts per million (ppm) to over 406 ppm today, and considering all GHG heat forcing effects, this is equivalent to over 485 ppm (IPCC 2014c). Mitigation actions are being undertaken to reduce emissions, and agriculture is one of the larger emitting sectors. Globally, agricultural emissions make up an estimated 25% share of total emissions, and arise from cropping, livestock, and land use change (IPCC 2014b). Many have suggested that agricultural management can be altered as part of an overall effort to decrease GHGs, again raising economic issues of cost, best practices to follow, impact, and incentive design.

Literature Review

increasing evidence that greenhouse gases have already begun to warm the planet (Intergovernmental Panel on Climate Change (IPCC), 2007Intergovernmental Panel on Climate Change (IPCC). 2007. *The Physical Science Basis*, Cambridge: Cambridge University Press. If nothing is done to curb emissions, the stock of greenhouse gases is expected to grow substantially over the next century largely from burning fossil fuels but also from land use change (IPCC, 2007Intergovernmental Panel on Climate Change (IPCC). 2007. *The Physical Science Basis*, Cambridge: Cambridge University Press. This in turn will cause future climates to warm and will likely cause changes in precipitation patterns (IPCC, 2007Intergovernmental Panel on Climate Change (IPCC). 2007. *The Physical Science Basis*, Cambridge: Cambridge University Press. Although there are many impacts expected from global climate change, one of the largest impacts is expected to be on agriculture (Nordhaus, 1991Nordhaus, William D. 1991. To slow or not to slow: The economics of the greenhouse effect. *The Economic Journal*, 101: 920–937. [Crossref], ®], , Pearce, 1996Pearce, D., Cline, W., Achanta, A., Fankhauser, S., Pachauri, R., Tol, R. and Vellinga, P. 1996. "The social costs of climate change: Greenhouse damage and benefits of control". In *Climate Change 1995: Economic and Social Dimensions of Climate Change*, Edited by: Bruce, J., Lee, H. and Haites, E. 179–224. Cambridge: Cambridge University Press. Cline, 2007Cline, W. 2007. *Global Warming and Agriculture*, Washington, DC: Peterson Institute for International Economics. Quantifying these impacts provides important insights into how much to spend on mitigation. Understanding the impacts of climate change will also help direct where, when, and how adaptation should proceed.

There are many economic studies that have measured climate impacts on US agriculture. Mathematical programming has been used to capture crop switching in response to changing yields (Adams *et al.*, 1990Adams, R.

Agronomists have long warned that farms in developing countries are often more sensitive to warming than US farms (Rosenzweig & Parry, 1994Rosenzweig, C. and Parry, M. L.1994. Potential impact of climate change on world food supply. *Nature*, 367: 133–138. Reilly *et al.*, 1996Reilly, J., Baethgen, W., Chege, F., van de Geijn, S., Erda, L., Iglesias, A., Kenny, G., Patterson, D., Rogasik, J., Rotter, R., Rosenzweig, C., Somboek, W. and Westbrook, J. 1996. "Agriculture in a changing climate: Impacts and adaptations". In *Climate Change 1995: Intergovernmental Panel on Climate Change Impacts, Adaptations, and Mitigation of Climate Change*, Edited by: Watson, R., Zinyowera, M., Moss, R. and Dokken, D. 427–468. Cambridge: Cambridge University Press. Using crop simulation models, these studies revealed that the yields of grains in many developing countries would fall with warming. Economists have also worried that agriculture in many developing countries would be more sensitive to climate than in the US (Pearce, 1996Pearce, D., Cline, W., Achanta, A., Fankhauser, S., Pachauri, R., Tol, R. and Vellinga, P. 1996. "The social costs of climate change: Greenhouse damage and benefits of control". In *Climate Change 1995: Economic and Social Dimensions of Climate Change*, Edited by: Bruce, J., Lee, H. and Haites, E. 179–224. Cambridge: Cambridge University Press. Tol, 2002Tol, R. 2002. Estimates of the damage costs of climate change. Part 1: benchmark estimates. *Environmental and Resource Economics*, 21: 47–73. Mendelsohn *et al.*, 2006Mendelsohn, R., Dinar, A. and Williams, L. 2006. The distributional impact of climate change on rich and poor countries. *Environment and Development Economics*, 11: 1–20. Developing countries are more dependent on farming (a sensitive sector), many are located in places that are already too hot or dry and poor farmers are less able to adapt. Further, US results suggested that farms in the southern warmer regions of the US were more vulnerable than farms in the northern regions (Mendelsohn *et al.*, 1994Mendelsohn, R., Nordhaus, W.and Shaw, D. 1994. Measuring the impact of global warming on agriculture. *American Economic Review*, 84: 753–771. . Farms even closer to the equator were likely to be even more at risk.

Although predictions of large climate impacts to developing country agriculture have been long standing, there have been few economic studies that actually measured climate impacts in these countries. A handful of studies were conducted using existing Agricultural Census data from India and Brazil (Mendelsohn & Dinar, 1999Mendelsohn, R. and Dinar, A.1999. Climate change, agriculture, and developing countries: Does adaptation matter?. *The World Bank Research Observer*, 14: 277–293. [Crossref], ; Kumar & Parikh, 2001Kumar, K. and Parikh, J. 2001. Indian agriculture and climate sensitivity. *Global Environmental Change*, 11: 147–154. Mendelsohn *et al.*, 2001Mendelsohn, R., Dinar, A. and Sanghi, A. 2001. The effect of development on the climate sensitivity of agriculture. *Environment and Development Economics*, 6: 85–101). The main hurdle to measuring impacts in developing countries was the absence of existing data on farm performance. Existing data were often available only at the country level or in very select places. The next section of this paper reviews the first few studies done in Brazil and India, two countries with very good existing data.

The third section of the paper deals with a more recent wave of studies that have been done with economic data collected precisely to study climate change. Surveys were conducted in Africa and South America in order to obtain individual farm data across a wide range of climate zones. These continental scale studies have confirmed earlier concerns that agriculture in developing countries could well be the largest single damage from climate change.

All of the economic studies on developing countries in this paper rely on the Ricardian method. With the Ricardian method, land values or net revenues are regressed on climate, soils, geographic variables and economic variables that are independent of the farmer (not choices). The approach is a cross-sectional analysis. The method captures the locus of net revenues across each climate. It presumes that farmers adjust their inputs, outputs and farming practices to best take advantage of where the farm is located, including the climate. The Ricardian model is a comparative static analysis. It reflects all the adjustments that farmers and ecosystems have made in response to climate. It is a measure of the long-term consequences of climate change. It is not a dynamic analysis and so it does not measure the transition costs of moving from one climate to another.

One of the important advantages of the Ricardian method is that it takes into account efficient adaptation. Efficient adaptation implies that farmers will make adjustments if it makes them better off. Many early agronomic studies assumed that farmers would continue farming as they always have. This assumption has been labelled the 'dumb farmer' approach because the farmer does not make adjustments that are in his own interest. Ignoring adaptation leads to 'potential impacts' that always overestimate damages, sometimes dramatically. Including efficient adaptation is important because it provides an unbiased assessment of what will actually happen.

Subsequent analyses of adaptation reveal that farmers in Africa and South America make very many important adaptations in response to climate. They choose whether to grow crops or livestock (Mendelsohn & Seo, 2007Mendelsohn, R. and Seo, N.2007c. *An integrated farm model of crops and livestock: Modeling Latin American agricultural impacts and adaptation to climate change*, Washington, DC: World Bank. World Bank Policy Research Working Paper 4161 Seo & Mendelsohn, 2008eSeo, N. and Mendelsohn, R.2008e. *A structural Ricardian analysis of climate change impacts on African farmers*, Washington, DC: World Bank. World Bank Policy Research Working Paper 4603 They choose whether to irrigate (Mendelsohn & Seo, 2007Mendelsohn, R. and Seo, N.2007c. *An integrated farm model of crops and livestock: Modeling Latin American agricultural impacts and adaptation to climate change*, Washington, DC: World Bank. World Bank Policy Research Working PapeKurukulasuriya & Mendelsohn, 2008cKurukulasuriya, P. and Mendelsohn, R. 2008c. *Modeling endogenous irrigation: The impact of climate change on farmers in Africa*, Washington, DC: World Bank. World Bank Policy Research Working Paper 4278 They alter their crop mix (Kurukulasuriya & Mendelsohn, 2008bKurukulasuriya, P. and Mendelsohn, R. 2008b. Crop switching as an adaptation strategy to climate change. *African Journal Agriculture and Resource Economics*, 2: 105–126. Seo & Mendelsohn, 2008dSeo, N. and Mendelsohn, R.2008d. An analysis of crop choice: Adapting to climate change in Latin American farms. *Ecological Economics*, 67: 109–116. They alter which species of livestock to raise

(Seo & Mendelsohn, 2007Seo, N. and Mendelsohn, R. 2007. *An analysis of livestock choice: Adapting to climate change in Latin American farms*, Washington, DC: World Bank. World Bank Policy Research Working Paper 4164 , N. and Mendelsohn, R.2008a. Measuring impacts and adaptation to climate change: A structural Ricardian model of African livestock management. *Agricultural Economics*, 38: 150–165. ,bSeo, N. and Mendelsohn, R.2008b. Climate change impacts and adaptations on animal husbandry in Africa. *African Journal Agriculture and Resource Economics*, 2: 65–82. Seo *et al.*, forthcoming). So although the Ricardian method did not specify how farmers adjusted to climate change, subsequent research has specified and quantified the adaptations farmers actually make.

The Ricardian method makes a number of other assumptions. Because the method is a cross-sectional analysis, the method assumes that prices remain constant. The Ricardian method consequently overestimates welfare changes (both gains and losses). Several authors are concerned that the Ricardian method does not account for the farming method, especially whether or not irrigation is used (Cline, 1996Cline, W. R. 1996. The impact of global warming on agriculture: Comment. *American Economic Review*, 86(5): 1309–1311. Schlenker *et al.*, 2005Schlenker, W., Hanemann, M. and Fischer, A. 2005. Will US agriculture really benefit from global warming? Accounting for irrigation in the hedonic approach. *American Economic Review*, 95(1): 395–406. One of the problems of including irrigation is that it is a choice by farmers and a choice that is sensitive to climate (Kurukulasuriya & Mendelsohn, 2008cKurukulasuriya, P. and Mendelsohn, R. 2008c. *Modeling endogenous irrigation: The impact of climate change on farmers in Africa*, Washington, DC: World Bank. World Bank Policy Research Working Paper 4278 Several Ricardian analyses have explicitly distinguished between irrigated and rain-fed land in order to address this concern (Kurukulasuriya & Mendelsohn, 2008aKurukulasuriya, P. and Mendelsohn, R. 2008a. A Ricardian analysis of the impact of climate change on African cropland. *African Journal Agriculture and Resource Economics*, 2: 1–23.,c; Seo & Mendelsohn, 2008cSeo, N. and Mendelsohn, R.2008c. A Ricardian analysis of the impact of climate change on South American farms. *Chilean Journal Of Agricultural Research*, 68(1): 69–79. Wang *et al.*, 2008Wang, J., Mendelsohn, R., Dinar, A., Huang, J. and Rozzelle, S.2008. *Can China continue feeding itself? The impact of climate change on agriculture*, Washington, DC: World Bank. World Bank Policy Research Working Paper 44. The studies measure a different climate response from rain-fed versus irrigated cropland, but it is not clear that a model that includes all farms is consequently biased. Finally, like all empirical studies, there remains the possibility that the functional form of the model could be improved or that there are important missing variables in the regressions.

The absence of local economic data is a severe limitation to conducting climate studies in most developing countries. One way to overcome this limitation is to collect data on individual farms across a wide range of climate zones. This section describes a new wave of research that is based on samples of farms collected precisely to study climate change. The sampling was designed to examine countries in different climate zones and to select farms within each country across a wide range of climate zones. The survey instrument was designed to measure annual net revenue in places without land markets and land values when possible. The instrument collected information about the choices that farmers made: which crops to plant, which livestock to raise and which inputs to purchase. Data was collected about inputs, outputs and prices (see Dinar, *et al.*, 2008Dinar, A., Hassan, R., Mendelsohn, R. and Benhin, J., eds. 2008. *Climate Change and Agriculture in Africa: Impact Assessment and Adaptation Strategies*, London: EarthScan. [Google Scholar] for a copy of the survey instrument). This information was combined to estimate gross revenues and costs. Net revenues were calculated by subtracting costs from gross revenues. Information from other sources was collected on climate, soils and other control variables and then merged with the economic data.

The first set of impact studies with individual farm data was undertaken in Africa. The GEF and World Bank financed a study of 11 African countries (Burkina Faso, Cameroon, Egypt, Ethiopia, Ghana, Kenya, Niger, Senegal, South Africa, Zambia and Zimbabwe). A survey instrument was designed and tested for Africa. Teams from each country collected data using this instrument across a wide range of African climate zones.

A Ricardian analysis was undertaken to measure the impact of climate on current net revenues (Kurukulasuriya *et al.*, 2006Kurukulasuriya, P., Mendelsohn, R., Hassan, R., Benhin, J., Diop, M., Eid, H. M., Fosu, K. Y., Gbetibouo, G., Jain, S., Mahamadou, A., El-Marsafawy, S., Ouda, S., Ouedraogo, M., Sène, I., Seo, N., Maddison, D. and Dinar, A. 2006. Will African agriculture survive climate change?. *World Bank Economic Review*, 20: 367–388. [Crossref], Kurukulasuriya & Mendelsohn, 2008aKurukulasuriya, P. and Mendelsohn, R. 2008a. A Ricardian analysis of the impact of climate change on African cropland. *African Journal Agriculture and Resource Economics*, 2: 1–23. In many places in Africa, land markets were not sufficiently formed to provide land values. Three regressions are displayed in Table 1. The first regression shows the relationship between net revenues and climate and soils for all farms. The second regression looks at only dryland farming. The third regression looks at only irrigated farms. All three regressions reveal that both temperature and precipitation play a role in determining net revenue per hectare. All four seasons are important and the impacts of each season are different. The climate effects are nonlinear. The climate coefficients are not the same in each regression. Climate has a different impact on dryland versus irrigated farms. Other variables that are important include the flow of water into the district, the size of the farm, the elevation, availability of electricity and several soil types. Another topic that was investigated in these studies was whether farms were more responsive to climate normals or climate variance. The climate normal is the mean weather over a 30 year period. The climate variance is the interannual variation around that mean over that same period. Studies that have examined both normals and variance have found that both measures are important (Mendelsohn *et al.*, 1996Mendelsohn, R., Nordhaus, W.and Shaw, D. 1996. Climate impacts on aggregate farm values: Accounting for adaptation. *Agriculture and Forest Meteorology*, 80: 55 bMendelsohn, R., Basist, A., Dinar, A. and Kurukulasuriya, P. 2007b. What explains agricultural performance: Climate normals or climate variance?. *Climatic Change*, 81: 85–99. Increased interannual variance in spring and summers reduce land value. Increased interannual variance in the winter, however, increases land value. Whereas farmers can adapt to observed changes in winter weather by planting different crops and changing the timing of the following growing season, there are fewer adjustments that can be made during the growing season to the weather that unfolds.

Research Methodology

Empirical economic studies of agriculture in most of the South Asian Countries like Pakistan. Data were rare because of the absence of suitable data. Data were collected from 150 farmers of Tomato and onion growers in differernt areas i.e. Madheji Taulka, and lakhi Taulka and Khan Pur Taulka, District Shikaropur. Data were analysed by using smart PLS. In general, land values are easier to analyse because they reflect the long term productivity of the land. Net revenues capture the annual productivity and can be influenced by many factors that are peculiar to a given year such as the weather. In the India study, only net revenue per hectare was available and so that was used as the dependent variable. In Brazil, both net revenue and land value were available and both were tested. However, the land value data led to more consistent and significant results. One must be careful in comparing land values to net revenues to remember that land values are the present value of all future net revenue. In general, land values are about 20 times larger than annual net revenue. The coefficients on a regression with land value are consequently expected to be about 20 times larger than a similar regression using net revenues.

Results and Discussions

Climate change alters productivity, production costs, resource availability, market prices, welfare, poverty, and food security. In order to estimate economic impacts, economists generally need measures of potential CC impacts on physical productivity and input usage. These impacts have been estimated using either econometrics or process-based simulation models. Generally, the econometric approaches let us infer the future from the past by examining the impacts that climate has had across time and space. The simulation approaches can be less data-intensive, but embody strong assumptions about climate/production performance inter-relationships and model accuracy. Impact studies have examined implications for crops, livestock, land, water, labor, infrastructure, factor productivity, and environmental quality. Broadly, impacts are negative under extreme heat or cold, with lesser impacts in between and a general inverted-U shape, plus impacts can be positive in cold areas. Specific findings by broad agricultural attribute follow.

Both small and large farms reduce stock as precipitation increases but small farms have a larger percentage reduction. The larger response by small farms is because they can more readily substitute into crops in wetter places. They are both subject to reductions in income because ecosystems shift from grasslands to forests and livestock diseases become more prevalent with more rainfall.

The economic information was then matched with climate and soil data.

Variables	All Tomato and Onion farms	Irrigated Farms
Intercept	285.11*	
Temp. summer	−10.31*	
Temp. summer squared	−153.36*	
Temp. winter	0.26	
Temp. winter squared	−4.12	
Prec. summer	−0.01	
Prec. summer squared	−9.38*	
Prec. winter	1.30	
Prec. winter squared	7.28	
Temp. summer × large	−0.02*	
Temp. summer squared × large	−4.8	
Temp. winter × large	0	
Temp. winter squared × large	0.37*	
Prec. summer × large	0.63*	
Prec. summer squared × large	0	
Prec. winter × large	0.39	
Prec. winter squared × large	−3.03	
Temp. × prec. summer	12.77*	
Temp. × prec. winter	11.74*	
Temp. × prec. summer × large	27.07*	
Temp. × prec. winter × large	5.55*	
Soil Cambisols	10.66*	
Soil Ferrasols	16.01*	
Soil Phaeozems	−2.5	
Soil Luvisols	0.18	
Soil Arenosols	421.4*	
Soil Regosols	363.7*	
Soil Vertisols	−64.33	
Soil Yermosols	−361.5*	
Altitude	−6.13	
Electricity dummy	−46.18	
Computer dummy	−1423.9*	
Texture (mixed)	−2355.8*	
Texture (clay)	804.1*	
Age of the head	−236.5	
Female dummy	−2534.0*	
Argentine	−40.1	
Chile	2283	

Colombia	16.4	
Ecuador	0.776	
Uruguay	-	
Venezuela	−40.1	
N	16.4	
F-statistic	17.8	
Adjusted R-squared	0.22	

This paper describes several new studies that measure the economic impact of climate change on agriculture in developing countries. The studies confirm some earlier hypotheses and prove that other hypotheses were false. The studies generally confirm the hypothesis that tropical and subtropical agriculture in developing countries is more climate sensitive than temperate agriculture. Even marginal warming causes damages in Africa and Latin America to crops. Crops are also sensitive to changes in precipitation. In semi-arid locations, increased rainfall is beneficial. However, in very wet places, increased rainfall can be harmful. If climate scenarios turn out to be relatively hot and dry, they will cause a lot of damage to farms in low latitude countries. However, if climate scenarios turn out to be relatively mild and wet, there will be only modest damages and maybe even beneficial effects. The magnitude of the damage depends greatly on the climate scenario.
Small farmers are not necessarily more vulnerable than large commercial farmers. The livestock study in Africa found that small household incomes would rise with warming whereas commercial incomes would fall. Small livestock farmers have many options to switch crops and livestock that appear to make them less vulnerable than commercial livestock operations that are more specialized. The study in South America found that small farmers are no less sensitive to warming than large farmers. Within developing countries, small farmers may well be less vulnerable than commercial farmers.
Irrigation appears to be a very effective tool to counteract the harmful effects of either warming or drying. The incomes of irrigated farms are generally less vulnerable to warming than rain-fed farms and can even increase with warming. For example, irrigated farms in Africa and China are much less vulnerable to warming than rain-fed farms in those same countries. However, it is important to recognize that irrigation is constrained by the availability of water. If climate change reduces water supplies and increases water demand, water may become scarcer. Farmers may well find that they cannot pay for or obtain the water they would need to irrigate. Farmers may be forced to switch from irrigated to rain-fed acreage. It is very important that analyses of agriculture in regions relying upon or considering irrigation examine watershed management as part of their analysis of the agriculture sector. There have been a few pioneering studies of climate and water but they are still rare (Strzepek *et al.*, 1996>

Climate Change will be a central agricultural issue in the twenty-first century; there will be negative impacts from CC in some regions, and positive impacts in others. Over time, negative impacts will likely strengthen, while positive ones will diminish (IPCC 2014a). Crop and livestock production, water availability, and pest incidence will all be affected. These impacts not only constitute a shift in mean levels, but also shifts in variance and higher-order moments. Agricultural and applied economists can play a major role in identifying impacts and estimating economic consequences in agriculture and in other economic sectors. Furthermore, given its strong inter-disciplinary roots, the profession is well-placed to contribute to the emerging field of research into food-energy-water-climate nexus issues.

As temperatures rise, society will inevitably need to develop adaptation strategies allowing efficient operations under foreseen levels of CC. Understanding the scope, limitations, and constraints to achieving such adaptation is an important topic for applied economic research. In the absence of strong mitigation action, and given likely limits on adaptation, we may expect much more damaging climate change, with potentially dire implications. Agricultural and applied economists can play an important role in estimating this vulnerability and determining the appropriate mix of mitigation and adaptation. The future of our planet rests on making sound decisions on these issues in upcoming decades.

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