THE IMPACT OF CLIMATE CHANGE IN ASIA: AN ECONOMETRICS ANALYSIS ON AGRICULTURE SECTOR

Eern Yie Choo
School of Management & Marketing, Taylor University, Malaysia, yie793@gmail.com

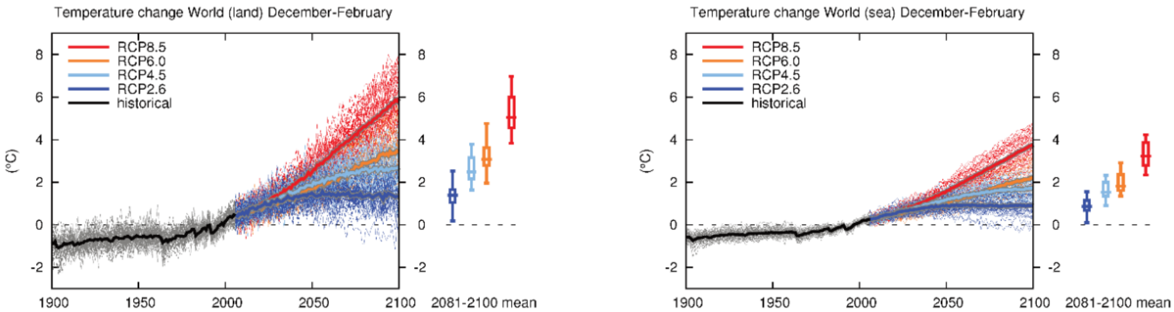
Abstract: The substantial known economic effect of changing in climate is upon on every sector especially on agriculture due to its sensitivity and size of the sector. Warming climate brings outstanding harm to agriculture in several nations because developed countries in low latitude already encounter the hot weather. This paper reviews numerous studies that evaluate the possible impact of warming climate to agriculture sector in Asia. There have been numerous studies examine how expected changes in climate are likely to effect on yield productivity in Asia. The findings in this paper is supported mainly from the fourth and fifth analysis report of Intergovernmental Panel on Climate Change (IPCC), where the latest sixth assessment report is excluded out as it is currently preparing by the panel. There are two specific objectives is needed to review the possible impacts of changing climate on agricultural. Firstly, the paper will synthesize the likely impacts of climate change on China and India's agricultural production especially for crops C3 and C4. Secondly, this paper also review the adaptive responses to change in climate that could potentially be made and promoted in the agricultural sector. Additionally, this paper discusses the overview of Asian agriculture and likely outcome if climates do warm by observing several scientific evidence on climate change. This paper done some projection by reviewing existing literatures which various research studies have been approaches to estimate the changes. The impact of climate change in agriculture sector in two countries is also describe. The countermeasure to be consider in response to warming climate will be the last section in this paper.
Keywords: Agriculture, Impacts of climate change, Asia, surface temperature

1. INTRODUCTION

Climate change can be explained with changes beyond an average condition of atmospheric which mainly possible caused by many factors such as volcanic activities, revolution of earth's orbit and somehow by artificial component of rising in the concentration of aerosol and greenhouse gases (Venkatramanan, Shah & Prasad, 2020). One study by Zhao, Luo and Huang (2021) indicates that global warming could turn into megatrend which might lead a significant future global change. Concerning with worldwide impacts, the UN Intergovernmental Panel on Climate Change (IPCC) introduced considerable scientific evidences in its fifth report on climate change. Getting proof for warming world supported from various independent indicators of climate, from the oceans' depths to high up in the atmosphere. Warming world with broader evidence collected from multiple range of independent physically consistent measurements of various interlinked elements from climate system (Bindoff et al., 2013).

However, the rising of global average surface temperature could be definite-known indicator of climate change. Although Galloway *et al* (2008) found that every year is not always warmer than the previous, the temperature of surface have warmed substantially globally since 1900. Especially, in this report, if human continues causing high present consumption level of fossil fuels, the earth's mean temperature will shoot up to 6.4°C by the end of the 21st century, followed by a rising sea level around 59cm (Sovacool, 2014). In fact, since the second half of 19^{th} century, the world annual average surface temperature has rinsed at a rate of 0.72°C/100 years. By comparison, the next century's temperature is projected to increase by 0.4 to 1.8°C (RCP8.5 scenario) and 2.7 to 4.9°C (RCP2.6 scenario) (IPCC, 2013b). Specifically, Aydinalp and Cresser (2008) stated that sea warming also dominates the rising in energy accumulated in system of climate with exceed 90% of energy stored. The global average mean ocean surface temperature had increasing 0.52°C per century. At the end of 21^{st} century, an increase of 0.7°C (RCP2.6), whereas 2.0°C in scenario of RCP8.5 (Figure 1.1).

Figure 1.1 Projected changes of global annual average surface temperature on land and wind



Sources: IPCC (2013a)

Study examined the agriculture is the most vulnerable sectors to anticipate changing in climate (Wang et al., 2017). The predicted changes in rainfall patterns and temperatures, as well as several associated effects on extreme weather events, pests and water availability are likely possible to affect potential of agriculture mass production. Some literature on the economics of weather suggests that warming climate which impact on agricultural production is unlikely to be evenly distributed across regions (Mendelsohn, 2008; McKibbin & Wilcoxen, 2002). Developing counties and low latitude are expected to suffer more from the effects, reflecting by the nation's disadvantaged geographic location. In contrast, on high latitude region, those crop production will conventionally benefit from climate change. In a recent world comprehensive study, Schreurs (2010) predicted that agricultural productivity would fall by 15.9% in the 2080s on condition that global warming continues unabated, causing developing nations encountering disproportionately huge decline of 19.7%.

2. LITERATURE REVIEW

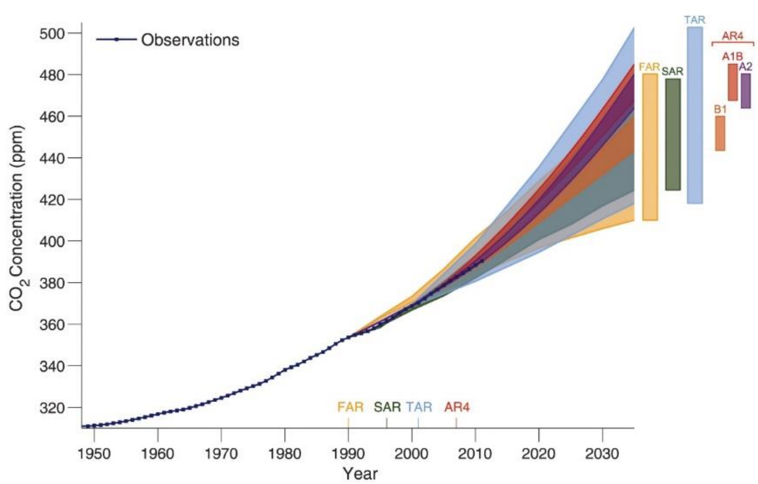
2.1 PROJECTION ACROSS ASIA: HOW THE CHANGING OF CLIMATE EFFECT THE AGRICULTURE?

The sector of agriculture plays an essential role in Asia, which contribute to more than 10% of most regional economies' gross domestic product (Aryal et al., 2019), and also provide jobs for over one third of the working population (Chanana-Nag & Aggarwal, 2020). However, will agriculture in Asia region nevertheless succumb to warming in future? As acknowledge by numerous scientists, climate change is predominately driven by letting go of greenhouse gases, where the recent annually averaged concentrations for the gases of nitrous oxide, carbon dioxide and methane is observed with increasingly constant rate (Figure 2.1). Although there have been various studies, the results for Asia are scattered (Mishra, 2017; Mo et al., 2017). So far, a comprehensive studies which cover every single agriculture sector in Asian has yet to be done.

Figure 2.1 Observed annually averaged CO_2 concentrations (parts per million)

Notes: CO_2 concentrations (dark blue line), whereas projected range of concentrations (shading).

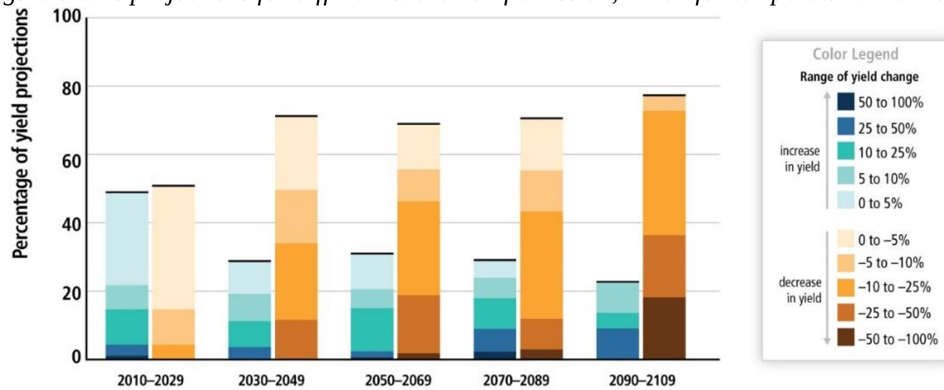
Sources: IPCC (2013a)



Concentration of CO_2, soil moisture, temperature and rainfall are all essential variables to discover the productivity of agriculture, and their correlation are simply not linear. Current analysis from major research validates the present of thresholds for above climate variables which plunged the crop yield. For instance, the recent IPCC reports with modelling studies indicate that the slightly rising in average temperature, along with related changes in rainfall, are expected to advantage the crop yields in regions of temperate. However, for the opposite, region of low-latitude are likely to obtain negative impact for major cereals yield. At last, more than 4ºC of average warming would bring negative impacts in all regions (Figure 2.2). For period 2030-2049, around 10% of projections indicates yield gains exceed than 10%, as well as compared with late 20th century, around 10% of projections indicates yield losses of exceed than 25%. In the end, the impact of risking getting more severe after 2050.

Figure 2.2 Percentage changes in crop yields projection due to changing in climate

Notes: The figure shows projections for different scenario of emission, which for temperature and tropical regions.



Sources: IPCC (2014a)

Mirroring economies studies demonstrate that increasing in atmospheric CO_2 concentration could obtain a benefit impact on crops yields by reducing plant's water loss and stimulating photosynthesis (Mulla et al., 2020). The fertilization effect of carbon is strong mainly for C3 crops which have lower photosynthetic efficiency rate, such as legumes, fine grains, soybeans, wheat and rice. However, for C4 crops like sugarcane, sorghum, millet and also maize are much smaller effects. Pan *et al* (2020) also argue some application of nitrogen also could impact on elevated CO_2 of yield production. Recent research by Hunt and Wu (2017) suggests that method of free air concentration enrichment provide a little or no stimulation of CO_2 fertilization effect for C4 yield and a much smaller effect for C3 crops. Likewise, the IPCC (2014b) reports that the yield of maize and wheat in tropics begin to fall from 1 to 2^{o}C of local warming. Yield of temperature maize and rice in tropical area are lesser clearly to be affected, yet it significantly affected during warming of 3 to 5^{o}C. Hence, the following data confirm that even a slight of climate warming will decline yields in region of low-latitude. The rice-based systems are more adaptable than maize, which projected advantages of adaptation are substantial for temperate crops then tropical.

2.2 PROSPECTIVE IMPACTS OF CLIMATE CHANGE ON THE AGRICULTURAL SECTOR

2.2.1 CLIMATE CHANGE IMPACTS ON AGRICULTURAL SECTOR IN CHINA

Changing in climate bring huge impact on Chinese agriculture has been widely study in many literature, nevertheless the negative effects tend to dominate (Mo et al., 2017; Gurgu, 2010). Since China is a large producing and international trading country, it is generally accepted that impact of changing in climate will likely also affect the rest of the world. Similarity, the IPCC assessment concluded that over the next 20-80 years, the expected effects of precipitation decreases and temperature increases could lead to a drop between 20 to 36% in China's rain fed yields of maize, wheat and rice. By contrast, Xie *et al* (2018) predicted that China's cotton yields may well increase due to climate change. However, these figures in yield changes may overestimate, as results do not account for the policy changes or new adoption of technologies in response to changing in climate.

Evidence from Chen, Chen and Xu (2016) study confirm the effect on damage of elevated tropospheric ozone (O_3) and stimulatory effects of CO_2 in most cases of crop yields. Based on the study, a medium confidence that the trends in climate have badly affected maize and wheat production for China, where there is also a medium reliance for negative effects on world aggregate production of maize and wheat. In particular, IPCC results also support and argued by Mahato (2014) states the effects on soybean and rice yields are smaller in major production regions as well as globally. Scientific proven of results shows high confidence that climate warming could benefited crop production in regions of high-latitude, such as China in northeast (IPCC, 2014a). To be specific, the discussed done by those studies indicate that climate warming brings significant impacts on world yield trends of some crops.

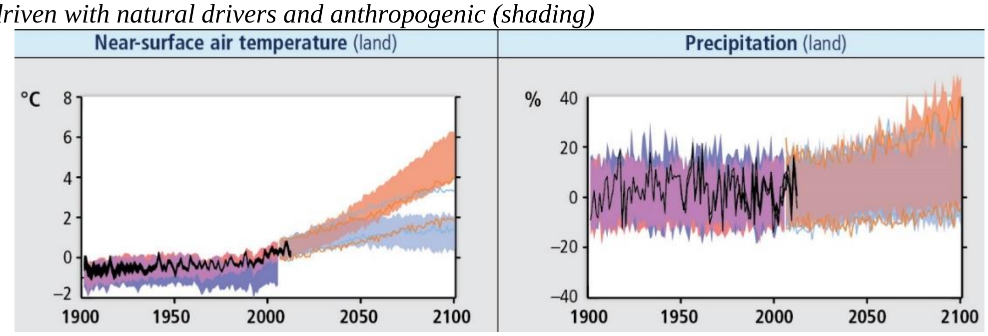
According to the Organisation for Economic Cooperation and Development (OECD) indicates that the magnitudes of the yield impacts in 2050 on China's three food crops ranged from +25.1% (irrigated wheat), and -22.8% (irrigated maize). Kim (2008) claim that the estimation of the climate impact on crop yields differ widely depending on assumptions on fertilization effect of CO_2. In some studies, accounting for the advantages of CO_2 fertilization could decreases the negative effects of climate on yields production or even projected opposite of the results (Yu et al., 2018). For instance, all analysed crop yields are projected to decline without the CO_2 fertilization effect. Throughout the study, the results summarize that wheat yields is generally benefit the most with CO_2 fertilization, while for the rice yields and rain-fed maize are adversely affected without fertilization effect. Overall, irrigated crops are projected slightly severely affected from climate change than rain-fed crops.

2.2.2 CLIMATE CHANGE IMPACTS ON AGRICULTURAL SECTOR IN INDIA

Since period of ancient, any changes in trend of monsoon drastically affects the Indian agriculture (Swami, Dave & Parthasarathy, 2018). Studies on warming's effect in India reported that rising in temperature is the biggest impact on the Indian agriculture (Arif et al., 2020). In view of the climate matter, it is known that there are less and limited data for observing impacts of changing in climate on globally food production systems, which is a true issue for Asia. Aryal *et al* (2019) observed that weather influence of global warming was projected to decline sorghum grain yield 2 to 14% by 2030, and the issue might worst in the next 20 years. In the Indo-Gangetic Plain, the pre-monsoon's changes will essentially affect the wheat crop (Porter et al., 2014), possible projected huge reduction unless adopted appropriate crop management practices. It is observed by innumerable studies that the production of rice losses during severe droughts with an estimated amount of $800 million in the states of Chhattisgarh, Odisha and Jharkhand (Kumar & Gautam, 2014; Manuta & Lebel, 2005). The IPCC (2014b) also projected that an increase mean temperature of 5^oC in time slice of 2010-2039 (Figure 2.3). Based on the analysis, wheat yields are predicted to decline by 6-10% with 1°C increase, as well as the overall crop yields might fall down to 29% in South Asia by the mid of 21^{st} century (Hijioka et al., 2014). However, the rising in temperatures will definitely affecting the wheat growing regions, which could possible placing millions of mankind on the edge of hunger.

Figure 2.3 Projected annual mean temperature and precipitation (land areas) of South Asia

Notes: Various estimates from observational measurements (black lines), climate model simulation's range percentile driven with natural drivers and anthropogenic (shading)



Sources: IPCC (2014b)

Nevertheless, an increase of 1°C in temperature might as well decreasing the yields of wheat, mustard, soybean, potato and groundnut by 3 to 7%. There are many researchers, who studied the Indian agriculture, many of them argued that most of the crops' productivity will decrease 15 to 45% by 2100 due to decrease irrigation water and variability of rainfall (Xenarios et al., 2019; Kameyama et al., 2008). One recent study by Dubash *et al* (2018) also states temperature arise by 0.5°C during winter temperature is expected to lessen India's rain-fed wheat yield by 0.45 tonnes per hectare. Agriculture sector will be worst affected at the coastal region of India, especially Maharashtra and Gujarat, as the area of fertile are vulnerable to salinization as well as inundation. Many researchers remain busy in previous decades to give theoretical answer of this issue, and therefore the best answer was the alarmist report from the IPCC assessment. If any significant effect on the country's food security, scenario will getting worsen might therefore pushed Indian agriculture into crisis.

2.3 COUNTERMEASURE FOR AGRICULTURAL SECTOR TO AGAINST CLIMATE CHANGE

Generally, it has been known that the changing of globally climatic system has resulted from the disruption of energy balance caused by the rising of aerosol and greenhouse gases in the atmosphere, as well as solar radiation and land covering. Principally, the climate issue done by deep analyses of scientific results indicates that global warming is very foreseeable to have prompt from activities of mankind (Kashyap & Agarwal, 2020). Actions taken to counteract on danger of sector in agricultural could consider in the face of challenges and risks of global warming, are predominately divide into mitigation approach that lessen the rate and scale of changing in climate by absorbing emission of greenhouse gas and the adaptation approach that acknowledge the inevitability of gradual increase of earth temperature, recognize the impacts of warming climate, and as well cut down the harm it could cause.

During global warming, some components of the climate system are initially affected by climate change and strive to adapt themselves. Still, if the impact of changing in climate is huge, the weather system could not handle the consequences just by voluntary adaptation. Hence, special measures for planned adaptation should be attempted. Even so the planned adaptation is effect, yet there is still an impact on climate system, it is presume that there is some remaining impact. As strenuous effort for systems to adjust the climate change, efforts have concentrated on bringing down the scale of changing in climate through mitigation plain such as reduction of greenhouse gas. The measurement do contributes by reducing, avoiding and postponing countless impacts of changing in climate. As climate change adaptation and mitigation are closely interrelated with each one, thus mitigation can also regarded as belonging to adaptation actions in a long-term perspective. Consequently, adaptation to warming climate is not discretionary but preferable as a compulsory countermeasure against global climate change.

For this report, measure of mitigation for agricultural sector including the advance of cultivation methods by improving fertilization and irrigation control on arable sector to suppress some greenhouse gases and carbon fixing for soil from farmland. In relation to the countermeasures against climate change for agricultural, adaptation and mitigation to changing in climate depend on availability to quality seeds, water management for crop productivity, efficient resource on crop cultivation practices, and empowering the local farmers through training and awareness.

REFERENCES

Arif, M., Jan, T., Munir, H., Rasul, F., Riaz, M., Fahad, S., & Mian, I. A. (2020). Climate-Smart Agriculture: Assessment and Adaptation Strategies in Changing Climate, In Venkatramanan, V., Shachi, S., and Prasad, R. (eds.) *Global Climate Change and Environmental Policy* (pp. 351-377). Singapore: Springer.

Aryal, J. P., Sapkota, T. B., Khurana, R., Khatri-Chhetri, A., & Jat, M. L. (2019). Climate change and agriculture in South Asia: Adaptation options in smallholder production systems. *Environment, Development and Sustainability*, 1-31.

Aryal, J. P., Sapkota, T. B., Khurana, R., Khatri-Chhetri, A., & Jat, M. L. (2019). Climate change and agriculture in South Asia: Adaptation options in smallholder production systems. *Environment, Development and Sustainability*, 1-31.

Aydinalp, C., & Cresser, M. S. (2008). The effects of global climate change on agriculture. *American-Eurasian Journal of Agricultural & Environmental Sciences*, *3*(5), 672-676.

Bindoff, N.L., Stott, P. A., AchutaRao, K. M., Allen, M. R., Gillett, N., Gutzler, D., Hansingo, K., Hegerl, G., Hu, Y., Jain, S., Mokhov, I. I., Overland, J., Perlwitz, J., Sebbari, R. & Zhang, X. (2013). *Detection and Attribution of Climate Change: from Global to Regional. In: Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*. Retrieved from https://www.ipcc.ch/site/assets/uploads/2018/02/WG1AR5_Chapter10_FINAL.pdf.

Chanana-Nag, N., & Aggarwal, P. K. (2020). Woman in agriculture, and climate risks: hotspots for development. *Climatic Change*, *158*(1), 13-27.

Chen, S., Chen, X., & Xu, J. (2016). Impacts of climate change on agriculture: Evidence from China. *Journal of Environmental Economics and Management*, *76*, 105-124.

Dubash, N. K., Khosla, R., Kelkar, U., & Lele, S. (2018). India and climate change: Evolving ideas and increasing policy engagement. *Annual Review of Environment and Resources*, *43*, 395-424.

Galloway, J. N., Dentener, F. J., Marmer, E., Cai, Z., Abrol, Y. P., Dadhwal, V. K., & Vel Murugan, A. (2008). The environmental reach of Asia. *Annual Review of Environment and Resources*, *33*, 461-481.

Gurgu, E. (2010). The impact on climate and environment change–renewable energy sector. *Annals of Spiru Haret University*, *1*(10), *41*.

Hijioka, Y., Lin, J. J., Pereira, R. T., Corlett, X. C., Insarov, G. E., Lasco, R. D., Lindgren, E. and Surjan, A. (2014). *Asia – supplementary material. In Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part B: Regional Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change.* Retrieved from https://www.ipcc.ch/site/assets/uploads/2018/07/WGIIAR5-Chap24_OLSM.pdf.

Hunt, J., & Wu, J. (2017). Asian Urban Environment and Climate Change: Preface. *Journal of Environment Science*, *59*, 1-5.

IPCC (2013a). *Annex I: Atlas of Global and Regional Climate Projections*. *In Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental*

Panel on Climate Change. Retrieved from https://www.ipcc.ch/site/assets/uploads/2018/02/WG1AR5_AnnexI_FINAL-1.pdf.

IPCC (2013b). *Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*. Retrieved from https://www.ipcc.ch/report/ar5/wg1/.

IPCC (2014a). *Summary for policymakers. In: Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change.* Retrieved from https://www.ipcc.ch/report/ar5/wg2/.

IPCC (2014b). *Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change.* Retrieved from https://www.ipcc.ch/report/ar5/syr/.

Kameyama, Y., Sari, A. P., Soejachmoen, M. H., & Kanie, N. (2008). *Climate change in Asia: perspectives on the future climate regime*. United Nations University Press.

Kashyap, D., & Agarwal, T. (2020). 'Climate Change, Water Resources, and Agriculture: Impacts and Adaptation Measures', In Venkatramanan, V., Shachi, S., and Prasad, R. (eds.) *Global Climate Change and Environmental Policy* (pp. 227-256). Singapore: Springer.

Kim, C. G. (2008). The Impact of Climate Change on the Agricultural Sector: Implications of the Agro-Industry for Low Carbon, Green Growth Strategy and Roadmap for the East Asian Region. *International Journal of Climatology*, *23*, 693-705.

Kumar, R., & Gautam, H. R. (2014). Climate change and its impact on agricultural productivity in India. *Journal of Climatology & Weather Forecasting*, *2*(1), 1-3.

Mahato, A. (2014). Climate change and its impact on agriculture. *International Journal of Scientific and Research Publications*, *4*(4), 1-6.

Manuta, J., and Lebel, L. (2005). Climate change and the risks of flood disasters in Asia: crafting adaptive and just institutions. In *International Workshop on Human Security and Climate Change* (pp. 21–23). University of Chiang Mai, Thailand.

McKibbin, W., & Wilcoxen, P. (2002). The Role of Economics in Climate Change Policy, *Journal of Economic Perspectives, 16*(2), 107-129.

Mendelsohn, R. (2008). The impact of climate change on agriculture in developing countries. *Journal of Natural Resources Policy Research*, *1*(1), 5-19.

Mishra, C. S. (2017). Changing Rainfall Climatology of North India: Implications for Rainfed Agriculture in Climate zone 4, 5 and 7 in North India. *International Journal of Civil Engineering and Technology (IJCIET,) 8*(12), 544-557.

Mo, X. G., Hu, S., Lin, Z. H., Liu, S. X., & Xia, J. (2017). Impacts of climate change on agricultural water resources and adaptation on the North China Plain. *Advances in Climate Change Research*, *8*(2), 93-98.

Mulla, S., Singh, S. K., Singh, K. K., & Praveen, B. (2020). Climate change and agriculture: a review of crop models, In Venkatramanan, V., Shachi, S., and Prasad, R. (eds.) *Global Climate Change and Environmental Policy* (pp. 423-435). Singapore: Springer.

OECD. (2021). *Organisation for Economic Cooperation and Development - Crop production (indicator)*. Retrieved from https://www.oecd-ilibrary.org/agriculture-and-food/crop-production/indicator/english_49a4e677-en.

Pan, W. L., Kidwell, K. K., McCracken, V. A., Bolton, R. P., & Allen, M. (2020). Economically optimal wheat yield, protein and nitrogen use component responses to varying N supply and genotype. *Frontiers in plant science*, *10*, 1790.

Porter, J. R., Xie, A. J., Challinor, K. C., Howden, S. M., Iqbal, M. M., Lobell, D. B., and Travasso, M. I. (2014). *Food security and food production systems. In Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*. Retrieved from https://www.ipcc.ch/site/assets/uploads/2018/02/WGIIAR5-Chap7_FINAL.pdf.

Schreurs, M. A. (2010). Multi-level governance and global climate change in East Asia. *Asian Economic Policy Review*, *5*(1), 88-105.

Sovacool, B. K. (2014). Environmental issues, climate changes, and energy security in developing Asia. *Asian Development Bank Economics Working Paper Series*, (399), 17-14.

Swami, D., Dave, P., & Parthasarathy, D. (2018). Agricultural susceptibility to monsoon variability: A district level analysis of Maharashtra, India. *Science of The Total Environment, 619*, 559-577.

Venkatramanan, V., Shah, S., & Prasad, R. (2020). *Global Climate Change and Environmental Policy*. Singapore: Springer.

Wang, Z., Chen, J., Xing, F., Han, Y., Chen, F., Zhang, L., & Li, C. (2017). Response of cotton phenology to climate change on the North China Plain from 1981 to 2012. *Scientific reports*, *7*(1), 1-10.

Xenarios, S., Gafurov, A., Schmidt-Vogt, D., Sehring, J., Manandhar, S., Hergarten, C. & Foggin, M. (2019). Climate change and adaptation of mountain societies in Central Asia: uncertainties, knowledge gaps, and data constraints. *Regional Environmental Change*, *19*(5), 1339-1352.

Xie, W., Huang, J., Wang, J., Cui, Q., Robertson, R., & Chen, K. (2018). Climate change impacts on China's agriculture: The responses from market and trade. *China Economic Review*. DOI: 10.1016/j.chieco.2018.11.007.

Yu, C., Huang, X., Chen, H., Huang, G., Ni, S., Wright, J. S. & Yu, L. (2018). Assessing the impacts of extreme agricultural droughts in China under climate and socioeconomic changes. *Earth's Future*, *6*(5), 689-703.

Zhao, Z. C., Luo, Y., & Huang, J. B. (2021). Global warming and abrupt climate change, *Climate Change Research*, *17*(1), 114-120.