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Towards the Development of a Crop Productivity Model

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ABSTRACT

One of the keys to a country's inclusive growth is to foster the agricultural sector. However, this segment is utmostly disturbed by climate change. The farmers' yields have been affected by the changes in temperature, precipitation patterns, and season extremes. The crop productivity likewise suffers due to unavailability of resources required for adaptive strategies, especially in less developed countries. Previous studies have found the different links between climate change and crop production, negative impacts more dominant than positive. To negate the unfavorable impact, adaptive strategies are suggested. In other countries, climate change positively impacts crop productivity through the proper fitting to the cropping system. Farm size has been found to influence the adaption decision of farmers to climate change; thus, may also alter the effect of climate change on crop productivity. Past researches have established a strong positive relationship between farm size and crop productivity. However, scant literature has focused on the moderating effect of farm size in the relationship between climate change and crop productivity. This present study hoped to contribute to the farm size – crop productivity relationship by developing theories toward a crop productivity model. An intensive literature review on the subject matter was carried out. Then, recommendations for future research directions were suggested.

Keywords: (climate change, adaptive strategies, cropping system, farm size, crop productivity, Philippines).

1. INTRODUCTION

Inclusive growth has been one of the major concerns of many countries around the globe. It is an absolute requirement for a nation's sustainable development; hence, most states are harmonizing various external and internal factors to be able to achieve this. In recent years, the Philippines has exerted many efforts on inclusive growth, focusing on poverty reduction (World Bank, 2018). However, various economic issues such as high inflation rate and shortage in agricultural supply or production are now surrounding the country that may critically impact the poverty reduction objective. For instance, a high inflation rate may affect the business sector which may later increase unemployment and underemployment rates. The shortage of agricultural supply or production may likewise disturb poverty reduction objective by raising the prices of agricultural commodities, following the supply and demand curve, that may cut the disposable income of many individuals.

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The current economic turmoil destructs the prior labors of the government and hampers the desire of the country to achieve inclusive growth. Though, the World Bank (2018) pronounced a way for the Philippines to attain inclusive growth, that is, through improving its agricultural productivity (i.e., the ratio of the farm output vis-à-vis the input). Increasing agricultural productivity is viable; however, the sector is susceptible to weather conditions like drought, typhoons, and flooding. Since "*agriculture is based on crop growth*," the crop production, in particular, is most affected due to its sensitivity to weather variation (Luo, Muleta, Hu, Tang, Shao,…Lee, 2017, p.78). This sub-sector had lost about 3.4% in production in 2010, higher than the other agricultural sub-sectors such as fisheries and livestock (Escarcha, Lassa, Palacpac, & Zander, 2018). In December 2017, the typhoon Urduja had caused a 23,829 metric tons-damage to farm outputs (World Bank, 2018).

The evaluation of the impacts of climate change on agriculture attracts the interests of numerous researchers and academic scholars (e.g., Mia, Miyamoto, & Garcia, 2018). Previous studies have found that the links between climate change and crop production vary, negative impacts were more dominant than positive (Luo et al., 2017). To negate the unfavorable impact, adaptive strategies are suggested (Chalise, Narampanawa, Bandara, & Sarker, 2017; Maia et al., 2018). The extant literature reveals some adaptation patterns of Asian farmers toward climate change namely: farm management, crop management, physical infrastructure and social activities, irrigation and water management, and financial management (Shaffril, Krauss, & Samsuddin, 2018). In the Philippines, scant studies had focused on the relationship between climate change and agricultural productivity (e.g., Gomez, 2015). The study analyzed the impact of climate change on maize, banana, and durian production, and found climate change adaptations to impact farm productivity considerably.

According to International Union for Conservation of Nature, as cited in Shaffril et al. (2018), adaptation is defined as "*the ability to respond to challenges through learning, managing risk and impacts, developing new knowledge, and devising effective approaches*" (p.683). Adaptation is critical to climate change risk reduction (Luo et al., 2017) as it condensed the undesirable impacts of weather variability (see, Espeland & Kettenring, 2018; Maia et al., 2018). The changes in the weather affect the daily routine of the farmers (Shaffril et al., 2018); hence, "*agriculture needs to adapt to the climate impact*" (Luo et al., 2017, p.78). As cited in Espeland and Kettenring (2018), climate adaptation is "*the process of adjustment to actual or expected climate and its effects*" (p.316). Usually, crop productivity suffers due to the absence of resources required for adaptive strategies, especially in less developed countries.

In other countries, climate change positively impacts crop productivity through the proper fitting to the cropping system (see, Yang, Chen, Lin, Liu, Zhang…Tang, 2015). In Asia, crop diversification (also known as mixed, changed, intercropping, rotating, or multiple cropping) is practiced by many farmers since different crops react differently to the impacts of climate change (see, Shaffril et al., 2018). To properly fit with the changing climates, some farmers changed the sowing dates, harvesting timing, and fertilizer types, switched the crop varieties (e.g., drought-tolerant crops and flood-tolerant crops), and improved the cropping patterns (see, Abid, Schneider, & Scheffran, 2016; Ali & Erenstein, 2017; Rahut & Ali, 2017; Shaffril et al., 2018; Tripathi & Mishra, 2016). Intercropping, according to Temesgen, Fukai, and Rodriquez (2015), "*is a common practice in low productivity (low input-low output) small-scale*

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farming systems" (p.155). It can improve land productivity by developing its use efficiency and resource capture.

Climate change is not new; it is a global phenomenon. Changing weather and its effects have been witnessed in almost all parts of the world (Lou et al., 2017). Crop productivity, based on the previous studies, can be affected by climate change, adaptive strategies, and cropping system. The literature likewise divulged that farm size influences the adaption decision of farmers to climate change (see, Ali & Erenstein, 2017; Trinh, Rañola, Camacho, & Simelton, 2017). That small farmers, might not have the resources or capacities to adapt to climate change. Previous studies have found a strong positive relationship between farm size and agricultural productivity (see, Key, 2018). However, scant literature has focused on the moderating effect of farm size in the relationship between climate change and crop productivity. This paper hoped to contribute to the farm size – crop productivity by developing theories toward a crop productivity model. The significance of this article centers to the advancement of the country's agricultural productivity in the years to come. The rest of the paper is organized as follows. Section 2 presents the methodology, while Section 3 discusses the findings. Then, section 4 concludes with a set of recommendations for practice.

2. METHOD

An intensive review of the literature on agricultural productivity and climate change was performed by the study. Following Paulino and Castano's (2019) conduct of literature review, the review process started with the ScienceDirect database which publishes scholarly journals in the field of physical sciences and engineering, health sciences, life sciences, social sciences, and humanities. The study began its search by utilizing keywords like agricultural productivity, farm productivity, crop productivity, land productivity, and climate change. The search included only review and research articles, focused on articles published in English, and selected papers published in the database for the last five years (from 2015 to 2019).

The study obtained 4,955 results in the initial search, from which 57 related articles were considered for review. Before the actual review, there was a screening process to qualify only related studies and disregard articles not connected to the subject matter (i.e., the relationship between climate change and crop productivity). From the opening review, the paper was able to establish a connection between the main variables. An assumption that aside from climate change, other factors affect crop productivity was developed. This notion needs further framing; thus, an additional literature review was performed. The second phase of the review process revealed additional influences. From the assessment of the articles considered, the research was able to list down external and internal factors affecting the key variables. From the list, the study performed the elimination process and prioritized the eligible factors. The factors were then reflected in a conceptual model. The model was then analyzed before finalization, and a set of recommendations for practice was proposed after that. Figure 1 illustrates the entire review process.

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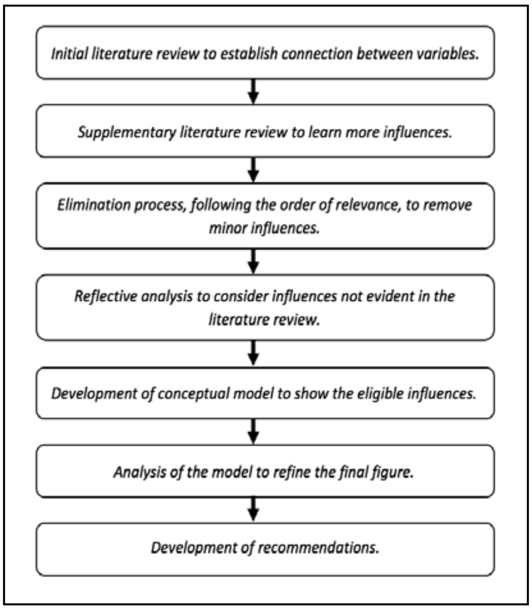

Figure 1: Methodology

3. RESULTS

The purpose of this research is to develop theories based on the results of the previous and existing studies closely related to the topic under investigation. Based on the gathered literature, the study learned that the climate change, adaptive strategies, cropping system, and farm size have direct links to agricultural productivity (e.g., Crost, Duquennois, Felter, & Rees, 2018; Mase, Gramig, & Prokopy, 2016; Triphati & Mishra, 2016). However, to narrow down the analysis and make the investigation more specific and focused, this paper concentrates only on crop productivity.

Numerous researches have examined the links between climate change and crop productivity. Many of these studies have found that climate change affects crop productivity (e.g., Chalise et al., 2017; Karimi, Karami, & Keshavarz, 2018; Luo et al., 2017; Makuvaro et al., 2018; Mase et al., 2016; Schonhart, Schauppenlehner, Kuttner, Kirchner, & Schmid, 2016; Sheng & Xu, 2018; Triphati & Mishra, 2016; Yang et al., 2015). However, the interactions are inverse, the impacts of climate change to crop productivity was found negative more dominant than positive (see, Luo et al., 2017; Sheng & Xu, 2018). To illustrate, Sheng and Xu (2018) examined the impact of an extreme weather event on productivity in the medium and long-term. The study has uncovered severe drought to contribute to the long-term slowdown of productivity in two ways: first, by reducing the outputs, and second, by cutting the profit that subsequently influences the farmers' adoption of new technologies negatively. The positive effect of climate change on crop productivity is illustrated through the relocation of the farm resources from low to high-efficiency farms.

Most of the reviewed studies have measured the effects of climate change on productivity regarding costs, for example, "*immediate loss of output or profit*" (e.g., Chalise et al., 2017; Sheng & Xu, 2018, p.1). Some studies measured the effect of climate change relative to the agricultural total factor productivity (see, Sheng & Xu, 2018). As mentioned in the earlier discussion, crop productivity is just one of the

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sub-sectors in agricultural productivity; others are fisheries and forestry. With crop productivity in mind, this study posits that climate change is directly affecting crop productivity. That weather variability like heavy rainfall and prolonged drought is directly impacting the crop yields, the impacts of which can be measured financially. The evaluation of these impacts concerning costs is imperative to accurately predict the future economic benefit derived from knowing precisely the effect of climate change to the country's crop production.

The climate change impacts agriculture through affecting the crop growth and yields; hence, farmers who adopt climate management strategies tend to have higher yields or increased productivity (Rahut & Ali, 2017; Wirehn, 2018). Predominantly, climate variability affects crop productivity negatively, but if farmers practice adaptive strategies like patterns of land use, irrigation, flood-tolerant or drought-tolerant crops, etc these adverse effects can be abridged (see, Chalise et al., 2017; Maia et al., 2018). The farmers can even achieve more significant benefits from the implementation of a combination of different adaptation strategies (Abid et al., 2016). For instance, during extreme weather events, rice yields will decline steadily unless new varieties tough to heat and water stress are adopted. Nevertheless, the impact of climate change on crop production may vary depending on the adoption of adaptive strategies. Adaptation to climate change "*is the key to avoid negative consequences and to benefit from opportunities*" (Wirehn, 2018, p.63).

Based on the systematic literature review of previous studies, this paper discovers a strong association between adaptive strategies and crop productivity (see, Abid et al., 2016). However, adaptive strategies are also factors in the relationship between climate change and crop productivity (see, Abid et al., 2016; Mase et al., 2016; Rahut & Ali, 2017). Adaptive strategies can affect the farmer's ability to cope with climate change impacts (Maia et al., 2018). During climatic changes, the level of productivity can be maintained by effective adaptation strategies (Mase et al., 2016). That is adjusting the sowing dates and harvesting timing, switching the crop varieties and fertilizer types, and the like can prevent or aggravate the impacts of climate change on crop production. On these grounds, this research theorizes that adaptive strategies are related to crop productivity in two ways: first, adaptive strategies are directly affecting the crop productivity; and second, adaptive strategies are factors in the relationship between climate change and crop productivity.

In other countries, changing climate positively impacts crop productivity through the proper fitting to the cropping system (see, Yang et al., 2015). The cropping pattern or "*the presence or absence of multi-annual crop rotations*" has been affecting crop yields regularly (Low, Biradar, Flieman, Lamers, & Conrad, 2017, p.118). Many studies have found the cropping system to affect the crop productivity (e.g., Low et al., 2017; Luo et al., 2017; Pires, Abrahao, Brumatti, Oliviera, Costa….Ladle, 2016; Yang et al., 2015). Some of these studies have found that the cropping system benefited from the adaptation strategies, though it differs on the gravity of the climate change (see, Luo et al., 2017). From this premise, this paper asserts that the cropping system is directly related to crop productivity. However, crops react inversely to the effects of climate change. By applying intercropping, rotating, or multiple cropping, the impacts of climate change to crop productivity can be mitigated. Hence, the cropping system is also a factor in the relationship between climate change and crop productivity. Based on these assertions, this paper posits that: 1) cropping system is directly affecting crop productivity, and 2) cropping system is a factor in the relationship between climate

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change and crop productivity, that cropping system can intervene in the relationship between climate change and crop productivity.

The farm size also emerged as a factor in crop productivity, though indistinct. Many studies have worked on the farm-size productivity relationship and found a strong positive correlation between farm size and agricultural productivity (see, Key, 2018; Sheng & Chancellor, 2018). If narrowed down, this result implies that there is also a secure connection between farm size and crop productivity. The literature divulged that farm size also influences the adaption decision of farmers to climate change (see, Ali & Erenstein, 2017; Trinh et al., 2017). That small farmer may not have the resources or capacities to adapt to climate change (Triphati & Mishra, 2016). Thus, theories emerged from these grounds: 1) farm size is related to crop productivity; 2) farm size is a factor in the relationship between climate change and adaptive strategies. Scant literature has focused on the role of farm size in the relationship between climate change and crop productivity. This study will contribute to this aspect of farm size-productivity relationship and climate change – productivity relationship, by investigating the role of farm size. The research posits that 3) farm size may alter the impact of climate change on crop productivity. That, farm size could have moderating roles in the relationships between climate change, adaptive strategies, cropping system, and crop productivity.

Table 1 summarizes a comprehensive literature review on the links among and between climate change, adaptive strategies, cropping system, farm size, and crop productivity.

Table 1
Links between Climate Change, Adaptive Strategies, Cropping System, Farm Size, and Crop Productivity

Links between Variables	Reference
Climate change is directly related to adaptive strategies	Chalise et al., 2017; Juhola, Klein, Kayhko, & Neset, 2017; Karimi et al., 2017; Luo et al., 2017; Mase et al., 2016; Makuvaro et al., 2018; Schonhart et l., 2016; Sheng & Xu, 2018; Triphati & Mishra, 2016; Yang et al., 2015
Climate change is directly related to adaptive strategies.	Sheng & Xu, 2018
Climate change is directly related to cropping system.	Yang et al., 2015
Adaptive strategies are directly related to crop productivity.	Abid et al., 2016; Kakraliya, Jat,H., Singh, I., Sapkota, Singh, L.,…Jat, M., 2018; Parihar, Jat, Singh, Kumar, Yadvinder-Singh,…Yadav, 2016
Adaptive Strategies are directly related to cropping system.	Luo et al., 2017
Adaptive strategies are factors in the relationship between climate change and crop productivity.	Abid et al., 2016; Ghahramani & Bowran, 2018; Mase et al., 2016; Rahut & Ali, 2017
Cropping system is directly related to crop productivity.	Andrade, Poggio, Ermacora, & Satorre, 2015; Kermah et al., 2017; Low et al., 2017; Pires et al., 2016; Yang et al., 2015
Cropping system is a factor in the relationship between climate change and crop productivity.	Luo et al., 2017
Cropping system is a factor in the relationship	Luo et al., 2017

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between adaptive strategies and crop productivity.	
Farm size is directly related to crop productivity.	Key, 2018; Sheng & Chancellor, 2018
Farm size is a factor in the relationship between climate change and adaptive strategies.	Ali & Erenstein, 2017; Trinh et al., 2017

Based on the above findings, the study theorizes that: 1) the climate change, adaptive strategies, and cropping system have direct effects on crop productivity; 2) the adaptive strategies and cropping system sequentially mediate the relationship between climate change and crop productivity; and 3) the relationship among the variables in the model are moderated by the size of the farms. These theories can be represented by a diagram, as shown below.

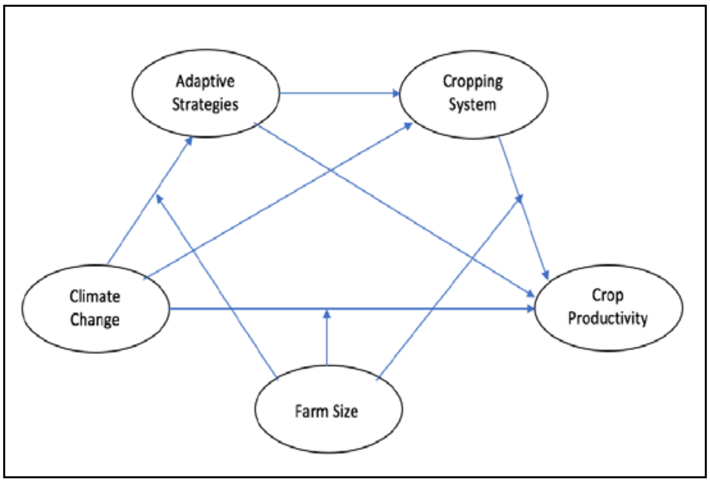

Figure 2: Proposed Crop Productivity Model

4. CONCLUSIONS AND RECOMMENDATIONS

The agricultural sector is very significant to the country's economy. It can transform such an economy into one capable of achieving inclusive growth and sustainable development. Agriculture is not just employing about 35% of the nation's workforce but also ensure food security (see, Ali & Erenstein, 2017; Crost et al., 2018). Advancing the agricultural sector is one of the keys to a country's inclusive growth. However, since this segment is utmostly disturbed by climate change, the farmers' yields and crop growth are affected. The effects though vary depending on geographical region. In some areas, climate change is beneficial; while in other areas, the impacts are not advantageous. Since its importance cannot be overstressed, this sector should be given extra attention. It has massive impacts on poverty reduction, which is critical to the nation's economic stability.

In the Philippines, almost all regions are affected by climate change due to chronic exposure to significant weather events (Chandra, Dargusch, Mcnamara, Caspe, & Dalabajan, 2017). Fuglie (2018) mentioned a noted accelerating agricultural productivity in developing countries. This proclamation should be observed in the Philippines being a developing country. However, agricultural productivity in the country nowadays is at stake due to the recurring climate change. Agriculture,

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particularly crop production, mostly rely on consistent weather patterns. Crop production needs a steady temperature and predictable precipitation, especially during plant development critical stages (e.g., flowering and grain-filling stages). In the country, fatal damages on crop production are experienced due to the recent cases of flooding brought about by a series of typhoons landed in the country. The above-average rainfall during the wet season negatively impacts agricultural production, and the above-average rainfall during the dry season positively affects agricultural production. Since weather variation is beyond the control of any organization or individual, the only way to alleviate its impacts is to adopt precautionary measures and strategies.

The need to address the issues on how to improve productivity in the agricultural sector, especially in the crop production, is imperative not just to combat poverty, reduced unemployment and underemployment, ensure food security, but foremost, for the country to achieve its goal of inclusive growth. Aoyagi and Ganelli (2015) supported this declaration. They state that one of the determinants of inclusive growth is the rise in productivity. To help improve agricultural productivity, in particular, crop productivity, this study concludes that a productivity model should be developed and then tested empirically. The model will shed light on how the farmers will manage crop productivity amidst widespread climate change. The model will be tested empirically using about 200 small-scale farmers as respondents of the study. The study will utilize structural equation modeling (SEM) in the analysis. SEM is a technique used to test the multi-relationship simultaneously, wherein some of the relationships can be moderated or mediated (Gargoum & El-Basyouny, 2016). It is also used to indicate if the observed data was adequate fit (Oruc & Tatar, 2016).

In accordance with the proposed model, the following three-fold objectives are to be carried out: 1) test if the three variables such as climate change, adaptive strategies, and cropping system have direct effect on crop productivity; 2) test if adaptive strategies and cropping system sequentially mediate the relationship between climate change and crop productivity; and 3) test if the relationships among the variables in the model are moderated by the size of the farms.

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